GEER 2008

Greater Everglades Ecosystem Restoration

Planning, Policy and Science Meeting

Everglades Restoration 2050 –
Advancing the Science to Achieve Success

Program & Abstracts

July 28-August 1, 2008

Naples, Florida

Welcome to the GEER 2008
Planning, Policy and Science Conference!

All previous GEER meetings (conferences) have provided an opportunity for you to ***confer*** with your Greater Everglades restoration colleagues towards the goal of Greater Everglades Ecosystem Restoration. The focus of GEER 2008 is ***Everglades Restoration 2050 – Advancing the Science to Achieve Success.*** Restoring the Greater Everglades *is our job*. Fortunately, the format and structure of GEER helps us do our job more effectively and efficiently by facilitating and enhancing communication, collaboration and coordination among all of us ***Everglades's restoration practitioners*** who have the opportunity to participate in GEER. We have had very successful GEER meetings in 2000 and 2003 with perhaps the most successful GEER in 2006. Building on that tradition, we welcome you to **GEER 2008**.

Restoration of degraded ecosystems has been and continues to be a high priority throughout the nation with Greater Everglades restoration being the largest project in the nation, and perhaps the world. GEER 2008 is a forum for restoration practitioners – including private, public and tribal decision makers, engineers, planners, resource managers, and scientists – to share their knowledge and challenges relevant to the enormous challenge of restoring the Greater Everglades. Only by merging *planning, policy and science* into a theme of success can we achieve our target of ***Everglades Restoration 2050!***

To make this meeting as beneficial as possible, there are several workshops, special sessions, training programs and symposia relevant to Greater Everglades restoration.

All of us involved in ecosystem restoration know that going from concept to reality is not easy. The same is true for GEER. The GEER08 Executive Steering Committee helped formulate the ***vision*** for this meeting – *"... the need for integrating planning, policy and science for* ***Everglades Restoration 2050 – Advancing the Science to Achieve Success*** *..."* – and the Executive Steering Committee played a major role in making GEER 2008 a reality (both conceptually and financially) . Plus, it took much dedication and many hours of work by those involved in planning and organizing the workshops, special sessions, training programs and the biogeochemistry/contaminants symposium. ***Many thanks*** to all who helped with GEER 2008.

Again, we welcome you to GEER 2008 and trust you will have a productive and rewarding experience. You have our

Best Wishes,

K. Ramesh Reddy, Ph.D.
Meeting Organizer and Chair
Soil and Water Science Department
University of Florida

G. Ronnie Best, Ph.D., PWS
Conference Chair – Technical Sessions
U.S. Geological Survey

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U.S. Army Corps of Engineers

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List of Exhibitiors and Contributing Partners

EDEN

Everglades Memorial

Hach Environmental

Joint Ecosystem Modeling (JEM)

National Park Service

PBS&J

South Florida Water Management District (SFWMD)

University of Florida/IFAS, Soil and Water Science Department

U.S. Army Corps of Engineers

U.S. Department of the Interior

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U.S. Geological Survey

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Program Agenda

WELCOME TO GEER 2008: The Greater Everglades Ecosystem Restoration Planning, Policy and Science Meeting

MONDAY	MONDAY — JULY 28, 2008	
8:00	Registration Opens & Exhibitors and Poster Session I Displays Move-in (Orchid Ballroom)	
8:00-9:30	MORNING REFRESHMENTS IN POSTER & EXHIBIT DISPLAY AREA	
	ATLSS Ecological Modeling Training Session - Part I	**Symposium on Biogeochemistry and Contaminants**
	Banyan I–II	*Royal Palm I-II*
	MODERATOR: Don DeAngelis	**MODERATOR: Ramesh Reddy**
9:30-9:50	**Donald DeAngelis** - Current Status of Across-Trophic-Level System Simulation (ATLSS) for the Wetland Systems of South Florida	**K. Ramesh Reddy & G. Ronnie Best** - Biogeochemistry and Water Quality of the Greater Everglades: Fate and Transport of Nutrients and Other Contaminants - Symposium Overview
9:50 -10:30	**Eric Carr** - The Role of ATLSS High Resolution Hydrology (HRH) Models in SFWMM Scenario Evaluations	**Nicholas Aumen** - Introduction and Overview of Biogeochemistry and Water Quality of the Greater Everglades
10:30-10:50	**Jon Cline** - Application of a Multi-Modeling Framework to Linking Ecosystem Pattern and Process Across Scales: Implementation of a Decision Support Tool for Adaptive Ecosystem Management in the Everglades Mangrove Zone	**Curt Pollman** - Atmospheric Deposition of Nutrients and Contaminants
10:50-11:10		**Willie Harris** - Mineral Weathering as Related to Biogeochemical Processes in the Everglades
11:10-11:30	**Eric Carr** - Next Generation ATLSS Models for Everglades Restoration: Incorporating Variable Meshes	**Paul McCormick** -The Contrasting Mineral Chemistry of the Predrainage and Managed Everglades: Hydrologic Basis and Biogeochemical Significance
11:30-11:50		**John Jones** - Progress and Prospects for Monitoring Landscape-Scale Patterns of Everglades Vegetation from Satellite and Airborne Imagery
11:50-12:10		**Evelyn Gaiser** - Landscape Patterns in Everglades Periphyton
12:10-12:30		**Todd Osborne** - Landscape Scale Patterns of Significant Nutrients and Contaminants in the Greater Everglades Ecosystem: Past, Present and Future
12:30-1:20	LUNCH ON OWN	
	ATLSS Ecological Modeling Training Session - Part II	**Symposium on Biogeochemistry and Contaminants**
	Banyan I–II	*Royal Palm I-II*
	MODERATOR: Don DeAngelis	**MODERATOR: Marguerite S. Koch**
	Introduction and Overview	**Introduction and Overview**
1:20-1:40	**Steve Hartley** - Introduction to ATLSS Data Visualization System	**K. Ramesh Reddy** - Phosphorus Biogeochemistry of the Everglades Ecosystem
1:40-2:00	**PART II** entails a short training course in the use of the ATLSS Data Viewer. This workshop will be of interest to agency staff members who are responsible for producing and evaluating model output relevant to ATLSS models and what they do.	**Patrick Inglett** - Nitrogen Cycling Across the Everglades Landscape: Processes, Patterns, and Implications for Restoration
2:00-2:20		**George Aiken** - Dissolved Organic Matter in the Everglades: Implications for Ecosystem Restoration
2:20-2:40	**NOTE:** Participants must bring their own laptop that already has ArcGIS9.2 (service pack 4) and Spatial Analyst loaded.	**William Orem** - Sulfate Contamination of the Everglades Ecosystem: Review of ACME Findings 1995-2008
2:40-3:00		**David Krabbenhoft** - A Review of Mercury Research and Monitoring Activities in the Everglades,1995 to 2008
3:00-3:20	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA	

MONDAY	MONDAY — JULY 28, 2008 (continured)	
	ATLSS Ecological Modeling Training Session - Part II (continued)	**Symposium on Biogeochemistry and Contaminants** (continued)
	Banyan I–II	*Royal Palm I-II*
	MODERATOR: Don DeAngelis	**MODERATOR: Sue Newman**
3:20-3:40	**Steve Hartley** - Introduction to ATLSS Data Visualization System **CONTINUATION OF PART II** which entails a short training course in the use of the ATLSS Data Viewer. **NOTE:** Participants must bring their own laptop that already has ArcGIS9.2 (service pack 4) and Spatial Analyst loaded.	**Tham Hoang** - Bioavaliability of Copper in Flooded Agricultural Soils and Toxicity to the Florida Apple Snail (*Pomacea Paludosa*)
3:40-4:00		**Youhei Yamashita** -Characterizing the Interactions between Trace Metal and Dissolved Organic Matter from the Florida Coastal Everglades
4:00-4:20		**John Carriger** - Aquatic Risk Assessment of Pesticides in Surface Waters in and Adjacent to Everglades and Biscayne National Parks
4:20-4:40		**Gary Rand** - Aquatic Probabilistic Ecological Risk Assessment of Endosulfan in South Florida
4:40-5:00		**Andrew Ogram** - Linking Nutrient Impacts on Microbial Community Structure and Function with Biogeochemistry in the Everglades
5:00-5:20		**Joel Trexler** - Effects of Phosphorus Availability on Aquatic Food Webs and Community Structure in the Everglades
5:30-7:00	EARLY BIRD NETWORKING SOCIAL (Vista Room – Lobby Level)	
TUESDAY	TUESDAY — JULY 29, 2008	
7:00-8:00	MORNING REFRESHMENTS IN POSTER & EXHIBIT DISPLAY AREA	
8:00-12:00	CONCURRENT WORKSHOPS	
	SFWMD Regional Hydrologic Models 101	**Symposium on Biogeochemistry and Contaminants**
	Royal Palm III	*Royal Palm I-II*
	MODERATOR: Jayantha Obeysekera	**MODERATOR: James Jawitz**
8:00-8:20	**WORKSHOP DESCRIPTION:** This workshop will provide an update on the status of and emerging plans for the South Florida Water Management Model (SFWMM, 2x2 Model) and the Regional Simulation Model (RSM).	**Laurel Larsen** - Role of Flow and Transport Processes in Ridge/Slough/Tree Island Pattern Dynamics
8:20-8:40		**Kang-Ren Jin** - Importance of Hurricane Impacts in a Shallow Lake
8:40-9:00		**Matthew Cohen** - Indirect Effects of Hydrology and Hydroperiod on Water Quality in the Greater Everglades
9:00-9:20		**Gregory Noe** - Biogeochemical Transformations and Transport Related to Flow in the Ridge and Slough Landscape
9:20-9:40		**James Jawitz** - Mechanistic Biogeochemical Model Applications in the Florida Everglades
9:40-10:00		**Joyce Zhang** - Long-term Water Quality Trends and BMPs in the Lake Okeechobee Watershed, Florida
10:00-10:20	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA	
	CERP 101	**Symposium on Biogeochemistry and Contaminants**
	Royal Palm VI-VII	*Royal Palm I-II*
	MODERATOR: Larry Gerry	**MODERATOR: Len Scinto**
10:20-10:40	**WORKSHOP DESCRIPTION:** This workshop will provide a review of the history of drainage and water management in South Florida and a review of the unintended consequences resulting from urban and agricultural development in the region. An overview of the more than 40 major projects and 68 project components will be presented. A summary of CERP implementation progress to date will be presented along with challenges and lessons learned during implementation.	**Jayantha Obeysekera** - Hydrologic and Hydrodynamic Modeling
10:40-11:00		**Carl Fitz** - Integrated Ecological Modeling and Decision Analysis within the Everglades Landscape
11:00-11:20		**R. Thomas James** - Water Quality Trends of the Kissimmee Chain of Lakes, Lake Istokpoga and Lake Okeechobee, Current and Future Management Challenges
11:20-11:40		**Samira Daroub** - Long-term Water Quality Trends and BMPs in the Everglades Agricultural Area
11:40-12:00		**Delia Ivanoff** - Biogeochemical Factors Influencing Phosphorus Retention in the Everglades Stormwater Treatment Area Wetlands

TUESDAY	TUESDAY — JULY 29, 2008 (continued)					
12:00-1:30	LUNCH ON OWN					
1:30-3:00	Opening Plenary Session (Royal Palm IV-V)					
	Moderators: K. Ramesh Reddy and G. Ronnie Best, GEER 2008 Co-Chairs Featured Keynote Presentations: **Lynn Scarlett**, Deputy Secretary of the Department of the Interior "Planning, Policy & Science for Large Scale Ecosystem Restoration: The Everglades Example" **Mark D. Myers**, Director, U.S. Geological Survey, "Facing Tomorrow's Challenges: The Everglades Living Laboratory"					
3:00-3:30	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA					
3:30-5:20	CONCURRENT WORKSHOPS					
	Information Systems	Symposium on Biogeochemistry & Contaminants	Landscape Dynamics	Predicting Restoration through Numerical Modeling	Tree Island Ecology	Coastal and Mangrove Ecosystems
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI*	*Royal Palm VII*	*Royal Palm VIII*
	Moderator: Heather Henkel	Moderator: Paul McCormick	Moderator: Todd Osborne	Moderator: Eric Swain	Moderator: Jay Jayachandran	Moderator: Kristen Hart
3:30-3:40	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview
3:40-4:00	**Robert Sobczak** Staying in Tune with South Florida's Water Cycle for Scientists, Managers, and Policy Makers in Five Minutes per Week	**Sabine Grunwald** Landscape Models for Spatial Upscaling of Biogeochemical Parameters	**Lee Florea** Stable Isotope Geochemistry of Shallow Groundwater beneath a Hardwood Hammock and Surface Water in an Adjoining Slough in Everglades National Park	**Melinda Lohmann** USGS Modeling Efforts in South Florida and Application to Regional Management	**John Volin** Release from Natural Enemies Belowground Helps Explains the Invasiveness of *Lygodium microphyllum* in Florida: A Cross-continental Comparison	**Joan Browder** Epifauna Community of Nearshore South Biscayne Bay: Past, Present, and Future
4:00-4:20	**Michele Maierhofer** Comprehensive Everglades Restoration Plan Model Management System (CERP MMS)	**Victor Rivera-Monroy** The Role of the Mangrove Ecotone Region in Regulating Nutrient Cycling and Wetland Productivity in South Florida	**Cheng-Feng Tsai** Application of HYMAN Model to Evaluate Water and Salt Budgets in Shark River Estuary	**Michael Kohler** Evaluation of CERP Restoration Scenario Simulations with Linked Regional, Coastal, Hydrodynamic, and Trophic Models	**Sharon Ewe** Ecophysiology of Tree Islands in Water Conservation Area 3	**Christopher Williams** Benthic Foraminiferal Assemblages in Biscayne Bay: Implications of Natural and Anthropogenic Change in South Florida Marine and Marine-Margin Ecosystems
4:20-4:40	**Peter Besrutschko** GIS Data Acquisition and Visualization in a 3D World for regional Water Quality and Hazardous Waste Screening	**Fred Sklar** A Review of our Understanding of the Biogeochemical Processes on Tree Islands in the Greater Everglades	**James Snyder** Restoration of Disturbed Pond-Cypress Savannas	**Dawn James** Numerical Model Optimization of Surface-Water Inflows to Achieve Restoration Salinity Performance Measures	**Christopher Bernhardt** Palynological Evidence of Anthropogenic Activity on Tree Islands	**James B. Murray** Resilience to Salinity Changes of the Non Native Freshwater Snail *Melanoides tuberculatus*
4:40-5:00	**Heather Kostura** CERPZone	**Sue Newman** Water Conservation Area 1- A Case Study of Hydrology, Nutrient and Mineral Influences on Biogeochemical Processes	**Michael Duever** Hydrologic Impacts and Restoration in the Fakahatchee Strand of Southwest Florida	**Catherine Langtimm** Integrated Manatee/ Hydrology Models: Synergistic and Predictive Advances Arising from a Charismatic Indicator Species	**Joseph Smoak** Ecological Shifts on an Everglades Tree Island Over the last 100 Years	**Edwin Brown** Estimating Nutrient Loads in the Caloosahatchee and St. Lucie Estuaries for CERP Projects
5:00-5:20	**Heather Kostura** Implementing the South Florida Gazetteer to Support Restoration Information Retrieval		**Walter Wilcox** Everglades Rainfall Driven Operations: The Evolution of a New Paradigm for Operating the South Florida System	**Eric Carr** The Role of ATLSS High Resolution Hydrology (HRH) Models in SFWMM Scenario Evaluations	**John Meeder** Ground Water Control of Tree Island Origin, Genesis and Destruction	
5:20-7:30	INTERACTIVE POSTER SESSION & NETWORKING					

WEDNESDAY	WEDNESDAY — JULY 30, 2008					
7:30-8:30	MORNING REFRESHMENTS IN POSTER & EXHIBIT DISPLAY AREA					
8:30-10:00	**Plenary Session (Royal Palm IV-V)**					
	ECOSYSTEM RESTORATION AND CLIMATE CHANGE **MODERATOR: Leonard Berry** **Amy Clement,** Associate Professor, University of Miami, "Global Climate Change, Sea Level Rise and Implications for South Florida" **Dan Kimball,** Superintendent, Everglades and Dry Tortugas National Parks, "Climate Change, Sea Level Rise and Natural Resource Challenges in South Florida" **Chuck Collins,** South Regional Director, Fish and Wildlife Conservation Commission, "Florida's Wildlife: On the Frontline of Climate Change"					
10:00-10:30	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA					
10:30-12:20	**CONCURRENT WORKSHOPS**					
	Climate Change Workshop	**Symposium on Biogeochemistry & Contaminants**	**System-wide Assessment of South Florida Ecosystems - Part I**	**Predicting Restoration through Numerical Modeling**	**A.R.M. Loxahatchee NWR Science Workshop - LILA**	**Coastal and Mangrove Ecosystems**
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI*	*Royal Palm VII*	*Royal Palm VIII*
	Moderator: Jayantha Obeysekera	**Moderator: Patrick Inglett**	**Moderator: Patti Sime**	**Moderator: Eric Swain**	**Moderator: Cindy Fury**	**Moderator: Mark Clark**
10:30-10:40	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**
10:40-11:00	**Glenn Landers** Climate Change Concerns for Everglades Restoration Planning	**Patrick Bohlen** Nutrient Storage and Transport Processes on Ranchlands in the Northern Everglades: Consequences for Greater Everglades Ecosystem Restoration	**Matt Harwell** What Managers Need to Know About System-wide Science to Improve Restoration Planning and Maximize Adaptive Management	**Jeremy Decker** Hydrologic Modeling of South Florida Environmental Parameters and Application to Ecology, Salinity, and Heat Transport	**Paul Wetzel** Restoring Tree Islands in the Everglades: Experimental Studies of Tree Seedling Survival and Growth	**James Fourqurean** Long-term Shifts in Seagrass Community Structure Follow Experimental Nutrient Enrichment in Florida Bay
11:00-11:20	**Michael Zygnerski & Chris Langevin** Effects of Sea-Level Rise on Saltwater Intrusion in Northern Broward County, Florida	**Marguerite Koch** Phosphorus Cycling in Florida Bay: A Synthesis		**Kiren Bahm** Development of an Interface Between the South Florida Water Management Model and a Fine-Resolution Hydrology Model of Everglades National Park	**Susana Stoffella** Tree Growth, Survival and Biomass in LILA Tree Islands	**Thomas Frankovich** Spatio-Temporal Dynamics of SAV Abundance and Water Quality in the Mangrove Lakes Region of Florida Bay
11:20-11:40	**Peter Harlem** Sea Level Rise in Miami-Dade County Florida, Implications for Management of Coastal Wetlands and the Everglades	**Lauren Serra** The Hole-in-the-Donut Wetland Restoration Project	**Aswani Volety** Eastern Oysters (*Crassostrea virginica*) as an Indicator for Restoration of Everglades Ecosystems	**Eric Carr** Next Generation ATLSS Models for Everglades Restoration: Incorporating Variable Meshes	**Samantha Lantz** The Effects of Vegetation and Water Depth on Wading Bird Foraging Site Selection and Foraging Success in the Everglades	**Brian Keller** Everglades Restoration and the Florida Keys National Marine Sanctuary: Monitoring for Possible Ecosystem Effects
11:40-12:00	**Lisa Beever** The Southwest Florida Feasibility Study and Climate Change	**Stuart Muller** A Spatially-Distributed Phosphorus Water-Quality Model for the Linked Surface-Water/ Groundwater Variable-Density Hydrology of the Southern Everglades	**Bjorn Tunberg** Ecological Disturbances in the St. Lucie Estuary and the Southern Indian River Lagoon, Eastern Florida, Elucidated Through Macrobenthic Monitoring	**Frank Marshall** Development of a Consensus Reconstruction of the Pre-drainage Everglades Hydrology and Florida Bay Salinity Using Paleoecological Information from Multiple Sediment Cores Coupled With Statistical Models	**Pamela Sullivan** Seasonal Variations in Tree Island Hydrology at Loxahatchee Impound Landscape Assessment (LILA)	**Tom Gallo** St. Lucie Estuary: Analysis of Annual Cycles and Integrated Water Column Productivity
12:00-12:20	**Leonard Pearlstine** Florida Bay Estuarine Habitat Suitability Assessments of Restoration and Sea-Level Rise Interactions		**Albrey Arrington** Assessing Large-Scale Spatial Distribution of Seagrasses in the Loxahatchee River	**Robert Fennema** Hydrology of the Everglades, Past and Present		**Darrell Herbert** Influences of Phosphorus and Salinity on Productivity and Demography of *Thalassia testudinum* across Florida Bay

WEDNESDAY	WEDNESDAY — JULY 30, 2008 (continued)					
12:20-1:30	LUNCH PROVIDED IN PRE-FUNCTION & POSTER DISPLAY AREA					
1:30-3:00	CONCURRENT WORKSHOPS					
	Climate Change Workshop	**Symposium on Biogeochemistry & Contaminants**	**System-wide Assessment of South Florida Ecosystems - Part II**	**Geospatial Approaches (Royal Palm VI)**	**A.R.M. Loxahatchee NWR Science Workshop - Hydrology**	**Coastal and Mangrove Ecosystems**
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI*	*Royal Palm VII*	*Royal Palm VIII*
	Moderator: Glenn Landers	**Moderator: Nick Aumen**	**Moderator: Greg Graves**	**Moderator: Carol Mitchell**	**Moderator: Matt Harwell**	**Moderator: Carlos Coronado**
1:30-1:40	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**
1:40-2:00	**Jayantha Obeysekera** Climate Change: Vulnerability Assessment and Modeling Scenarios for Water Resources Management in South Florida	**Symposium on Biogeochemistry & Contaminants:** Panel Discussion and Next Steps	**Gregory Graves** The Key to System-Wide South Florida Restoration: Lake Okeechobee	**William Labiosa** An Ecological Value Model for Use in a Land Use Planning Web Tool, Applied to Miami-Dade County	**Michael Waldon** Comparison of the South Florida Water Management Model (SFWMM) with a Simple Refuge Stage Model (SRSM) for the A.R.M. Loxahatchee National Wildlife Refuge	**Stephen Davis** Spatial and Temporal Nutrient Dynamics in the Mangrove Ecotone of Taylor River, Florida
2:00-2:20	**Frank Marshall** An Initial Evaluation of the Effect of Sea Level Rise on Salinity in Florida Bay Using Statistical Methods and Models			**Richard Bernknopf** A Spatial Hedonic Pricing Model for Miami-Dade, Florida: Using Econometrics and Geographic Information Systems for Property Valuation	**Chunfang Chen** Spatially-explicit Hydrodynamic and Water Quality Modeling of the A.R.M. Loxahatchee National Wildlife Refuge: Part I - Model Setup	**Vic Engel** Long-term Impacts of Hurricane Wilma on Land Surface-Atmosphere Exchanges
2:20-2:40	**Eric Swain** Numerical Model Development to Address the Effects of Climate Change on Coastal Hydrology and Ecology in Southern Florida		**Michael Ross** Assessing Several Vegetation Indicators of Everglades Water Management	**John Jones** Leveraging Highly Accurate Elevation, Field, and Remotely Sensed Image Data to Enhance Digital Elevation Models for Subregions of the Everglades	**Ehab Meselhe** Spatially-explicit Hydrodynamic and Water Quality Modeling of the A.R.M. Loxahatchee National Wildlife Refuge: Part II - Model Application	**Donna Devlin** Are There Local Differences in Adaptation of Rhizophora mangle Collected from the East and West Coasts of Florida?
2:40-3:00	**Thomas Doyle** Predicting the Fate of Florida's Coastal Ecosystems along the Gulf of Mexico under Rising Sea Levels and Climate Change		**Joel Trexler** Aquatic Fauna as Indicators for Everglades Restoration: Applying Dynamic Targets in Assessments for CERP-MAP	**Jay Sah** Developing a Data-driven Classification of South Florida Plant Communities	**Zhixiao Xie** Patterns of Variability in the EDEN Digital Elevation Model in the A.R.M. Loxahatchee National Wildlife Refuge	**Ed Proffitt** Survival, Growth, and Reproduction of Red Mangroves (*Rhizophora mangle*) in Restoration: Importance and Interaction of Genetic and Environmental Factors
3:00-3:30	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA					

WEDNESDAY	WEDNESDAY — JULY 30, 2008 (continued)					
3:30-5:40	CONCURRENT WORKSHOPS					
	Climate Change Workshop	**Symposium on Biogeochemistry & Contaminants**	**System-wide Assessment of South Florida Ecosystems - Part III**	**Geospatial Approaches**	**A.R.M. Loxahatchee NWR Science Workshop - Ecology**	**Coastal and Mangrove Ecosystems**
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI*	*Royal Palm VII*	*Royal Palm VIII*
	Moderator: Nicholas G. Aumen	**Moderator: Delia Ivanoff**	**Moderator: Joan Browder**	**Moderator: Sabine Grunwald**	**Moderator: Donatto Surratt**	**Moderator: Sharon Ewe**
3:30-3:40	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**
3:40-4:00	**Chris Madden and Dave Hallac** Review of Current Everglades Ecosystem, Landscape, and Hydrodynamic Models and Potential Applicability to Evaluate Climate Change Effects	**Jeffrey Wozniak** Understanding the Movement and Transformation of Nitrogen in the Southern Everglades	**Jeff Woods** Using Hydrologic Monitoring as a Tool for Synthesis of the Greater Everglades and Southern Estuaries Modules of the Monitoring and Assessment Plan	**Paul Conrads** Development of Soft Sensors for Real-time Quality Control of Water-level Data for the EDEN Network	**Xin Wang** Vegetation Cover Decreases Evaporative Loss in a Wetland Ecosystem	**Thomas Doyle** Forecasting Mangrove Forest Response to Sea-level Rise and Hydrologic Restoration of the Everglades
4:00-4:20	**Paul Souza** Species Conservation in South Florida and the Challenge of Climate Change	**Forrest Dierberg** Tracer Studies for Quantifying Transport Processes and Phosphorus Removal within the Everglades Stormwater Treatment Areas	**Greg Graves** Biscayne Bay Nearshore Continuous Salinity Monitoring	**Zhongwei Liu** Validation of EDEN Water-Surface Model and Ground Digital Elevation Model (DEM) for the Everglades, Florida	**Jim Entry** Water Quality Gradients in the Arthur R. Marshall Loxahatchee National Wildlife Refuge	**Edward Castaneda** Hurricane Impacts on Mangrove Forests in Florida Coastal Everglades: The Importance of Sediment Deposition in the Biogeochemistry and Fertility of Mangrove Soils
4:20-4:40	**Fred Sklar** Potential Water Balance Impacts of Global Climate Change on the Extant Everglades in Comparison to a Simulated Pre-Drainage Everglades	**Joffre Castro** Water Quality in Everglades National Park, Part I: Statistical Methods for Censored Data	**Christopher Kelble** Water Quality Monitoring in the Southern Estuaries	**Doug Donalson** From 2X2 to Ecological Model: Does High Resolution Water Affect Model Results?	**Tiffany Trent** Investigating Food Quality Effects on the Florida Apple Snail: Water Chemistry Effects on Periphyton Assemblages in the Northern Everglades	**Carlos Coronado** The Role of Biotic Processes on Soil Accretion and Elevation Change in Mangrove Forests in South Florida
4:40-5:00	**Marguerite Koch** The Resilience of Marine Ecosystems in the Greater Everglades in Response to Multiple Stressors and Climate Change	**Dilip Shinde** Water Quality in Everglades National Park, Part II: Statistical Summary, Trend Analysis and Influence of Water Sources	**Diego Lirman** SAV as Indicators of Ecosystem Change in South Florida Estuaries	**Paul Conrads** Hindcasting Water Levels for EDEN Gaging Stations, 2000-2006	**Ryan Lynch** Old World Climbing Fern (*Lygodium microphyllum*) Invasion in Hurricane Caused Treefalls	**Kevin Whelan** Hurricane Wilma's Sediment Deposition Impacts on Mangrove Forest Soil Elevation and Changes within Constituent Soil Zones
5:00-5:20	**Climate Change Panel:** Nick Aumen, Moderator Stu Appelbaum Chuck Collins Dan Kimball Jayantha Obeysekera Fred Sklar Paul Souza		**Joan Browder** Monitoring Fish and Invertebrates in the Southern Estuaries: Quantifying Variation and Reducing Uncertainty	**Forest Michael** Caloosahatchee Riverway: An Ecologically and Financially Sustainable Alternative for the C-43 West Reservoir	**Debra Willard** Response of Wetlands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge to Hydrologic Changes: Anthropogenic and Climate Impacts	**Thomas Smith III** A Decade of Surface Elevation Change in Wetlands of the Southwest Coastal Everglades: Sea-Level, Disturbance and Freshwater Inflow
5:20-5:40						
	EVENING ON OWN					

THURSDAY	THURSDAY — JULY 31, 2008				
7:30-8:30	**MORNING REFRESHMENTS IN POSTER & EXHIBIT DISPLAY AREA**				
8:30-10:00	**Plenary Session (Royal Palm IV-V)**				
8:30-9:00	**MODERATOR: G. Ronnie Best** **Stephanie E. Johnson**, Senior Program Officer, National Research Council "Progress Towards Restoring the Everglades: A Challenge Being Addressed by the National Academy of Sciences"				
9:00-10:00	A "Coffee House" Panel Discussion on Natural System Hydrology **PANELISTS: Robert Fennema, John Ogden, Rock Salt, Paul Souza and Tom Van Lent**				
10:00-10:30	**REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA**				
10:30-12:00	**CONCURRENT WORKSHOPS**				
	Wildlife Ecology and Modeling	**Symposium on Biogeochemistry & Contaminants**	**Regional Perspectives**	**Role of Flow in a Sustainable Everglades**	**Lake Okeechobee: Historic Assessment**
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI-VII*	*Royal Palm VIII*
	Moderator: Don Axelrad	**Moderator: Forest T. Dierberg**	**Moderator: Stephanie Romanach**	**Moderator: Fred Sklar**	**Moderators: Betty Grizzle and Rosanna Rivero**
10:30-10:40	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**	**Introduction & Overview**
10:40-11:00	**Andrea Bowling** How Habitat Degradation in the Everglades Has Affected Juvenile Snail Kite Movement	**Rudolf Jaffe** Characterizing the Dynamics of Dissolved Organic Matter in the Florida Coastal Everglades	**Erik Noonburg** Development of a Sampling Prioritization Model to Optimize the Selection of Tree Islands in the Everglades Wildlife Management Area for Surveying of *Lygodium microphyllum*	**Lynn Leonard** The Role of Flow on Ridge and Slough Landscape Dynamics in Shark River Slough, Everglades National Park	**Christopher McVoy** The Lake Okeechobee-Everglades Hydrologic Interface: 1850s to 1920s
11:00-11:20	**Christa Zweig** Habitat, Hydrology, and Reproduction: Conservation of the Florida Snail Kite and Everglades Restoration	**Piero Gardinali** Regional Distribution of Organic Contaminants in Water and Sediments from Everglades National Park, Biscayne National Park and Big Cypress National Preserve	**Roy Sonenshein** Hydrology of the Florida Panther National Wildlife Refuge	**John Meeder** Transverse Glades Karst Origins: The Everglades Water Table Control Mechanism	**Rosanna Rivero & Betty Grizzle** The Rise and Fall of Lake Okeechobee: Changes to Lake Morphology from 1913 to Present Day
11:20-11:40	**Amber Shawl** The Potential for Aquaculture to Support the Recovery of Apple Snail, *Pomacea paludosa*, Populations in Florida Wetlands and Lakes	**Ronald Jones** Periphyton Constructed Stormwater Treatment Areas (PSTA) Mesocosm Treatment Performance With Four Different Substrates	**Deborah Scerno** So Many Rules and Regulations! What's an Environmental Restoration project to do?	**Michael Zimmerman** Developing an Everglades Slough Vegetation Performance Measure	**Robert Fennema** Predrainge Hydrology of Lake Okeechobee
11:40-12:00	**Phil Darby** Ecological Windows of Opportunity for Florida Apple Snail Recruitment	**Christopher Osburn** Cost Effective Regional Phosphorus Concentration Mapping of Oligotrophic Open Water Systems	**Kiren Bahm** Application of a New MODHMS-Based Model to C-111 Detention Area Buildout	**Judson Harvey** Relative Importance of Hydro-ecological Processes Governing Self-Organization of the Everglades Ridge and Slough Landscape	**James Vearil** History of Lake Okeechobee Operating Criteria
12:00-12:20	**Nilmini Jayasena** Effects of Environmental Methylmercury Exposure on Reproduction in White Ibises (*Eudocimus albus*)	**William Walker** Modeling Phosphorus Dynamics in Everglades Wetlands and Stormwater Treatment Areas		**Christopher McVoy** 130 Years of Ecohydrological Change in the Everglades: What's Different and What's Not, and Why it Matters	
12:20-1:30	**LUNCH PROVIDED IN PRE-FUNCTION & POSTER DISPLAY AREA**				

THURSDAY	THURSDAY — JULY 31, 2008 (continued)				
1:30-3:00	CONCURRENT WORKSHOPS				
	Wildlife Ecology and Modeling	**Symposium on Biogeochemistry & Contaminants - R-EMAP**	**Adaptive Management 1**	**Role of Flow in a Sustainable Everglades**	**Lake Okeechobee: Historic Assessment**
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI-VII*	*Royal Palm VIII*
	Moderator: Todd Hopkins	**Moderator:** Peter Kalla	**Moderator:** Tom St. Clair	**Moderator:** Jud Harvey	**Moderators:** Betty Grizzle and Rosanna Rivero
1:30-1:40	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview
1:40-2:00	**James Beerens** Resource Selection of Two Wading Bird Species with Divergent Foraging Strategies	**Daniel Scheidt** Phosphorus and Sulfur in the Everglades: Landscape Patterns and Temporal Trends 1995-2005	**Steve Traxler** CERP AM Program Implementation	**Evan Variano** Measurements and Modelling of Vegetation Effects on Flow in Ridge and Slough Landscape	**Cherise Maples** Seminole Tribe Perspective on Lake Okeechobee
2:00-2:20	**Bryan Botson** The Effects of Hydrological Variation on Seasonal Wading Bird Prey Concentrations in the Everglades	**Guangliang Liu** Temporal and Spatial Characteristics of Mercury Contamination in the Everglades during the Past Three R-EMAP Phases	**Andrew LoSchiavo** System-wide Planning for CERP: Lessons Learned from Band 1 Model Run Evaluation	**Althea Hotaling** Environmental Drivers of Wet Prairie Conversion in Water Conservation Area 3A	**Panel Discussion**
2:20-2:40	**Dale Gawlik** A Spatially-explicit Simulation Model of Landscape Quality for the Wood Stork (*Mycteria americana*) in Southwestern Florida	**Leonard Scinto** Trends in Biogeochemical Processes across the Greater Everglades Landscape – Results of R-EMAP III	**Robert Doren** Ecolgical Indicators for System-wide Assessment of the Greater Everglades Ecosystem Restoration Program	**Judson Harvey** Threshold for Everglades Sediment Entrainment Determined by Flow Enhancement in a Field Flume	
2:40-3:00	**Elise Pearlstine** Wintering Bird Area Occupancy in a Mosaic of Harvested and Un-harvested Sugarcane Fields	**Marguerite Madden** Everglades Vegetation Community Analysis at the Landscape Scale	**Rachel Pawlitz** Data Communication and Decision Support Tools in Everglades Restoration	**Dianne Owen** Characterization of Tree Island Hydrology in the Central Everglades: An Application of the EDEN Water Surface Model	
3:00-3:30	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA				
	Moderator: Barry Rosen	**Moderator:** Joffre Castro	**Moderator:** Eliza Hines	**Moderator:** Leonard Pearlstine	**Moderator:** Lewis Hornung
3:30-3:40	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview
3:40-4:00	**Debra Willard** Vegetation and Hydrologic History of Everglades Marl Prairies: Paleoecological Evidence from Big Cypress National Preserve	**Pete Kalla** Characterization of Southern Florida Marsh Vegetation Using a Landscape Scale-Random Sample: R-EMAP Phase III	**Matt Harwell** AM in a Learning Environment - A Case Study of Hydrology and Water Quality at Loxahatchee NWR	**Tom Givnish** Self-assembly of Patterned Landscapes and Vegetation in the Central Everglades: Importance of Local and Landscape Drivers	**Paul McCormick** Lake Okeechobee: Current and Future Management Challenges
4:00-4:20	**Lara Drizd** A Conceptual Model for Integrating Predator-Prey Monitoring for the Everglades Landscape	**Evelyn Gaiser** Landscape Patterns in Periphyton Abundance and Composition in the South Florida R-EMAP Study.	**Lynn Wingard** Restoration and Sea-Level Rise: The Role of Paleoeologic Data in Incremental Adaptive Management Strategies	**Danielle Watts** Patterns of Peat Elevation in the Ridge-Slough Mosaic	**Thomas Teets** Lake Okeechobee Watershed Construction Project Phase II Technical Plan
4:20-4:40	**Daniel Slone** Discovery and Delineation of Seagrass Beds in the Ten Thousand Islands Using Manatee Radiotelemetry Data, Spatial Modeling, and Stratified Field Sampling	**Joel Trexler** Scaling Revealed by Spatial Cross-Correlation Analysis of Aquatic Communities and Environmental Drivers Using R-EMAP Data	**Eric Bush** CERP Project Implementation - Incremental Analysis and Justification of a Comprehensive Plan	**Laurel Larsen** A Process-Based Cellular Automata Model of Ridge and Slough Landscape Evolution	**Stuart Appelbaum** The Role of CERP in Addressing Lake Okeechobee Watershed Issues
4:40-5:00	**Kristen Hart** Hurricane Impacts on Mangrove Diamondback Terrapins (*Malaclemys terrapin*) in the Everglades	**Pete Kalla** Mercury in the Greater Everglades: Changes in Bio-magnification over Time, and Relationships to Other Contaminants, across the Landscape R-EMAP 1995 - 2005	**John Ogden** The Yellow Book Nine Years Later - Unanticipated and Unresolved Issues	**Paul Glaser** Radiocarbon Dating Sediments in the Everglades of South Florida: Sources of Error and Mass Accumulation Rates	**Frank Nearhoof** Chronology of the Florida Department of Environmental Protection's Historic Involvement in Lake O Restoration

THURSDAY	THURSDAY — JULY 31, 2008 (continued)				
3:30-5:40	CONCURRENT WORKSHOPS				
	Wildlife Ecology and Modeling	**Symposium on Biogeochemistry & Contaminants R-EMAP**	**Adaptive Management 2**	**Role of Flow in a Sustainable Everglades**	**Lake Okeechobee Watershed: Holistic Approach**
	Royal Palm IV-V	*Royal Palm I-II*	*Royal Palm III*	*Royal Palm VI-VII*	*Royal Palm VIII*
5:00-5:20	**Shawn Liston** Hydrologically-Induced Seasonal Changes in Cypress Forest Aquatic Fauna Communities	**DISCUSSION**	**DISCUSSION**	**Michael Kline** A Comparison of Adjacent Ridge and Slough Vegetative Communities	**Richard Budell** Agricultural Best Management Practices in the Okeechobee Watershed
5:20-5:40	**Jennifer Rehage** Temporal and Spatial Dynamics in the Fish Community of Marsh-Mangrove Ecotonal Habitats in the Southwest Region of Everglades National Park			**Workshop Discussion:** >How will increased flow restore the Everglades? >Is there scientific consensus? What questions remain? >Are current performance measures adequate?	**Patrick Bohlen** Securing Water Related Environmental Services at a Landscape Scale from Working Cattle Ranches in the Northern Everglades Watershed
5:40-7:30	INTERACTIVE POSTER SESSION & NETWORKING				

FRIDAY	FRIDAY — AUGUST 1, 2008			
7:30-8:30	MORNING REFRESHMENTS IN POSTER & EXHIBIT DISPLAY AREA			
8:30-10:00	CONCURRENT WORKSHOPS			
	Wildlife Ecology and Modeling	**Regional Perspectives**	**Hydrogeology and Modeling of Karst Aquifers of Southern Florida**	**Tree Islands: Conceptual Model and Performance Measures**
	Royal Palm IV-V	*Royal Palm III*	*Royal Palm VI-VII*	*Royal Palm VIII*
	Moderator: Joel Trexler	**Moderator: Jed Redwine**	**Moderator: Kevin J. Cunningham**	**Moderator: Agnes McLean**
8:30-8:40	Introduction & Overview	Introduction & Overview	Introduction & Overview	Introduction & Overview
8:40-9:00	**Jeffrey Kline** Fish Introductions into Everglades Wetlands: An Unforeseen Consequence of Restoration?	**James Beever** Growth Management Regulation, Public Investment and Restoration Resource Implications for the Estero Bay Watershed	**Kevin Cunningham** Marine High-Resolution Seismic-Reflection Data in Biscayne National Park: Indications of a Regional Seal Bypass System	**Panel Discussion:** 1. What are the best indicators for assessing and evaluating tree island change? 2. What are thee best hydrological and ecological models to predict tree island change, i.e., how are the evaluation performance measures built? 3. How are the restoration targets for tree island performance measures to be determined?
9:00-9:20	**David Ceilley** Fish Community Structure of Aquatic Refugia, Impacted and Reference Wetlands in Southwest Florida	**Nora Egan Demers** Using Stable d15N Ratios and Biological Diversity to Examine Effectiveness of Restoration Efforts within a Residential Community- Another Tool for the TMDL Toolbox	**Michael Sukop** High-Resolution X-ray Computed Tomography of Macroporous Karst for Permeability Measurement and Non-Darcian Flow via Lattice Boltzmann Models	
9:20-9:40	**Mark Miller** Estimating Effect of Precipitation on Survival of Hatchling American Crocodiles	**John Marshall** GEER Progress from a Total Ecosystem View	**Michael Sukop** and **Jeffrey Lee** Lattice Boltzmann Methods Applied to Three-Dimensional Virtual Cores Constructed from Digital Optical Borehole Images of a Karst Carbonate Aquifer	
9:40-10:00	**Peggy VanArman** Comparison of Growth Between Newly-Hatched Young of Two Species of Crayfish, *Procambarus alleni* (Faxon) and *Procambarus fallax* (Hagen), from South Florida	**Jed Redwine** Calculating Carbon Storage Performance of Three St. Johns River Water Management District Wetland Restoration Projects	**Barclay Shoemaker** Effects of Turbulence on Hydraulic Heads and Parameter Sensitivities in Preferential Groundwater Flow Layers of the Biscayne Aquifer	
10:00-10:30	REFRESHMENT BREAK IN POSTER AND EXHIBIT DISPLAY AREA			
10:30-12:00	**CLOSING PLENARY SESSION — Summaries, Discussions and Recommendations (Royal Palm IV & V)** – Session organizers will give a very brief overview of major emerging concepts, recommendations and next steps resulting from the symposium, workshops and special sessions held throughout the week.			
10:00-1:30	POSTER DISPLAY REMOVAL & EXHIBITOR MOVE-OUT			

GEER Poster Directory – Session One

1 ***Gordon Anderson***, Comparing Seasonal Salinity Variations in Shark River Estuary
28 ***Lonny Anderson***, Seagrass Restoration - Florida Keys National Marine Sanctuary
59 ***Peter Besrutschko***, Periphyton Constructed Stormwater Treatment Areas
38 ***Michelle Boudreaux***, Predicting Effects of CERP Projects on Salinity Patterns
39 ***Michelle Boudreaux***, RECOVER: Southern Estuaries Performance
37 ***Michelle Boudreaux***, RECOVER's Scientific Role in Everglades Restoration
56 ***Joan Browder***, Prevalence of Abnormal Fish as Indicator of Environmental Quality
46 ***Michael Byrne***, Measuring Nutrient Concentrations in Tributaries of Lake Okeechobee
63 ***Cory Catts***, Tilling of Biomass in Treatment Wetlands
58 ***Hongjun Chen***, Analysis of Historical Vegetation
64 ***Robert Compitello***, Prescribed Fire Effect on Phosphorus Cycling and Repopulation
48 ***Stacey Cote***, Effects of Vegetation and Soil Management Practices on Phosphorus
13 ***James Cuda***, A Model for Sustainable Management of Brazilian Peppertree
40 **Gretchen Ehlinger**, RECOVER: Northern Estuaries Performance Measure Synthesis
14 ***Edwin Everham***, Estero Bay Tributaries Riparian Vegetation Analysis
51 ***Adolfo Fernandez***, Endosulfan Sulfate in Fish Tissue
50 ***Melissa Victoria Fernandez***, Submerged Aquatic Vegetation as Contamination Indicators
15 ***Joshua Filina***, Salinity, Light and Temperature Effects on *Ruppia maritima* Germination
24 ***Andrew From***, Mapping Mangrove Migration under Altered Hydrologic Flow
52 ***Piero Gardinali***, Microconstituents in Surface Waters with Respect to Water Reuse
42 ***Andrew Gottlieb***, RECOVER: Greater Everglades Performance Measure Synthesis
41 ***Andrew Gottlieb***, RECOVER: Lake Okeechobee Performance Measure Synthesis
47 ***Kevin Grace***, Effect of Soil Phosphorus Enrichment on Release and Long-Term Removal
25 ***Marie-Theres Graf***, Geochemical Analysis of Carbonate Layers in Tree Island Peats
53 ***Erin Hanan***, Patterning of Plant-Soil-Water Interactions
2 ***Peter Harlem***, Lidar Detection of Karst Landforms
16 ***Rachel Harris***, Tidal Influence on Mangrove Community Structure
49 ***Scott Jackson***, Water and Sediment Phosphorus Gradients in STAs
17 ***Krish Jayachandran***, Potential Biological Control Agents for Invasive Plant Species
18 ***Darlene Johnson***, Development of Habitat Suitability Models for Biscayne Bay Fishes
70 ***Manohardeep Josan***, Effect of Drainage Flow on Phosphorus Concentrations
3 ***David Kaplan***, Predicting Restoration Scenarios on Floodplain of Northwest Fork
29 ***Anwar Khan***, Ecosystem Restoration Risk Analyses
4 ***Ken Krauss***, Hydrologic Fluxes, Restoration and Marsh-Mangrove Ecotone
30 ***Katie Laakkonen***, City of Naples Approach to Treating Stormwater
31 ***William Labiosa***, South Florida Ecosystem Portfolio Model
19 ***Sanjay Lamsal***, Spatial Variability of Soil Nutrients
32 ***Andrew LoSchiavo***, CERP Process to Apply Adaptive Management
33 ***Kathleen McCallion***, Southwest Florida Feasibility Study
20 ***Carole McIvor***, Biota in Mangrove-Forest Food Webs using Stable Isotopes
60 ***Kathleen McKee***, Soil Phosphorus Storage in Isolated Wetlands of Improved Pastures
5 ***Jennifer Mellein***, Hydrologic Heterogeneity and Forest Structure Dynamics on Tree Islands
54 ***Fernando Miralles-Wilhelm***, Spatial and Temporal Variation-Tree Island Phosphorous Cycling
65 ***Rajendra Paudel***, Modeling Spatio-Temporal Phosphorus Cycling
66 ***Yun Qian***, Effects of Burn Temperature on Ash Nutrients; Availability of Cattail and Sawgrass
61 ***K. Ramesh Reddy***, Phosphorus Composition of Wetlands in an Agricultural Landscape
43 ***Jed Redwine***, Predicting CERP Influences on Extreme High and Low Water Levels
44 ***Jed Redwine***, Predicting CERP Impact on Wet Prairie Vegetation Communities
6 ***Amy Renshaw***, Environmental Impacts of the Annual Agricultural Drawdown
45 ***Gregg Reynolds***, Methods for Evaluating Landscape-Scale Sheet Flow Properties
62 ***Rosanna Rivero***, Applications of Remote Sensing and Multivariate Geostatistics
21 ***Michael Robblee***, Comparison of Juvenile Pink-Shrimp Abundance
57 ***Colleen Rochelle***, Mercury Bioaccumulation in Fish
22 ***Pablo Ruiz***, Vegetation of Biscayne National Park, Homestead, FL, USA
26 ***Amartya Saha***, Water Source Utilization and Foliar Nutrient Status in Plant Communities
34 ***Mark Shafer***, Alternative Plans for CERP Biscayne Bay Coastal Wetlands Project
35 ***Brooke Shamblin***, Tree Composition, Recruitment and Mortality of Hammocks
7 ***Sanjay Shukla***, Watershed-scale Impacts of using Stormwater Impoundments
8 ***DeWitt Smith***, Freshwater Flow through Joe Bay Relative to Taylor Slough and C111
9 ***Erik Stabenau***, Hydrologic Impacts of the C-111 Canal
10 ***Peter Stone***, Climatic Changes in Rainfall Regime
68 ***W. Justin Vogel,*** Spatial and Temporal Changes in Chemical Characteristics and Distribution of Sediments
27 ***Xin Wang***, Isotopic Effects of Hydroperiod in Tree Islands
67 ***Yu Wang***, A Loss-on-Ignition Method to Assess Soil Organic Carbon
23 ***Matthew Waters***, Reconstructing Primary Producer Communities in WCA-2A
69 ***Alan Wright***, Catabolic Diversity of Periphyton and Detritus Microbial Communities
36 ***Jing-Yea Yang***, Streamgauging Planning at Stormwater Treatment Area - 1 West
11 ***Liqiong Zhang***, Flow Rating for Interior Culverts in STAs
12 ***Mark Zucker***, Temporal and Spatial Salinity Patterns in Joe Bay, ENP
SP1 ***Adam Watts***, Unmanned Aircraft Systems for Wading Bird Surveys
SP2 ***Kathy O'Reilly-Doyle***, Think Locally, Act Neighborly

Session One Posters are on display beginning at 8:30am on Monday, July 28. A formal Poster Networking Session is scheduled Tuesday, July 29 from 5:30pm-7:30pm. Presenters will stand at their posters from 6:30pm-7:30pm. Poster Session One should be removed upon conclusion of the evening session.

NOTE: Poster abstract titles in this listing are abbreviated. Consult the poster directory in the program book for full reference.

GEER Poster Directory – Session Two

38 ***Shadab Anwar***, Tracer Test Inversion to Determine Vegetative Flow Resistance
7 ***Chris Cattau***, Effects of Invasive Exotic Apple Snail on the Snail Kite
2 ***Grady Caulk***, CERP: Cultural Resources Mitigation Strategies
14 ***David Ceilley***, Rapid Wetland Assessment Method
13 ***David Ceilley***, Aquatic Macroinvertebrates of Impacted and Reference Wetlands
33 ***Kevin Chartier***, Getting Ecological Models into the Hands of the Users: JEM
8 ***Paul Conrads***, Integration of Hydrologic and Ecological Studies of the Snail Kite
47 ***Phil Darby***, Field and Lab Studies of Florida Apple Snail Predators
43 ***Mark Dickman***, Baseline Hydrologic Data Collection along the I-75/SR 29 Corridor
68 ***Marcie Dixson***, Investigating Ecological Effects of Mineral Enrichment
44 ***Robert Dorazio***, Estimation of Manatee Abundance from Aerial Surveys
17 ***Nathan Dorn***, Seasonal Succession and Annual Hydrologic Patterns
69 ***Tom Dreschel***, Implementation and Operation of a Large Everglades Physical Model
27 ***Katherine Dunlop***, Cue Recognition and Prey Responses to Non-Native African Jewelfish
53 ***Andrew Erickson***, Baseline Hydrologic Information to Monitor Downstream Effects of Picayune Strand Restoration Project
21 ***Edwin Everham***, Biological Monitoring Program for Lake Trafford Restoration Project
9 ***Zachary Fratto***, Introduction and Colonization of Non-native Apple Snails in ENP
10 ***Ikuko Fujisaki***, Risk Assessment of Potential Invasiveness of Exotic Reptiles
3 ***Natalie Garrett***, Cultural Resources Overview for CERP: A Cooperative Effort
61 ***Rebekah Gibble***, Effects of Chemistry and Hydrology on Seed Germination and Plant Community Development
22 ***Charles Goss***, Forecasting Models and Environmental Impact Assessment
46 ***Timothy Green***, Spatial and Age-Structured Population Model of the American Crocodile
39 ***Guoqing He***, Monitoring of Water Flow in ENP
15 ***Garth Herring***, Physiological Responses of Pre-breeding Adult Great Egret and White Ibis
64 ***Jeff Hutchinson***, Repeated Herbicide Treatments for Control of *Lygodium microphyllum*
34 ***Brian Jeffery***, Effects of Off-Road Vehicles on Small Mammals in Big Cypress
30 ***Darlene Johnson***, Salinity Variability and Abundance of Fishes along Mangrove Shorelines
19 ***Nicole Katin***, Quantifying Aquatic Fauna Standing Stock in South Florida Cypress Forests
40 ***Michael Laas***, Impacts of Gate Discharge and Hurricane Conditions on Water Flow in ENP
41 ***Laurel Larsen***, Transport Dynamics of Floc in Ridge and Slough Vegetation Communities
45 ***William Loftus***, Food-Web Structure in Big Cypress Swamp Wetlands
16 ***William Louda***, Pigment-Based Chemotaxonomy to Assess Periphyton Communities
65 ***Ryan Lynch***, Post Hurricane Colonization of *Lygodium microphyllum* on Pop-up Tree Islands
70 ***Angela Markovich***, Research Activities at ARM Loxahatchee NWR
1 ***John Marshall***, GEER: Progress from a Total Ecosystem View
32 ***Frank Mazzotti***, Alligators and Crocodiles as Indicators for Restoration
31 ***Frank Mazzotti***, Burmese Pythons in the Southern Everglades
28 ***Lauren McCarthy***, Segregation of Palaemonid Shrimp Species along Shark River Estuary
60 ***Paul McCormick***, Influences of Soil Chemistry on Coexistence of Sawgrass and Slough Habitats
51 ***Nelson Melo***, Understanding Florida Bay Hypersalinity and Water Exchange
55 ***Joong-Hyuk Min***, Development of a Spatially Distributed Flow Dynamics Model
54 ***Joong-Hyuk Min***, Phosphorus Dynamics Modeling of Emergent and Submerged Aquatic Vegetation
42 ***Fernando Miralles-Wilhelm***, Modeling Spatial and Temporal Patterning of Ridge and Slough System
50 ***James B. Murray***, Geographic Distribution of Non-Native Red Rimmed Melania
23 ***Adam Obaza***, Effectiveness of Drift Fences or Monitoring Fish Movement
25 ***Danielle Ogurcak***, Spatial Distribution of Wetland Vegetation Surrounding Alligator Holes
59 ***Tae-Goo Oh***, Ridge Senescence of *Cladium jamaicense* in the Florida Everglades
4 ***James Pepe***, Preliminary Archaeological Context for Everglades Restoration Study Area
29 ***Ashley Porter***, Impact of Two Introduced Cichlids on Native Fish Communities
62 ***Rosanna Rivero***, The Rise and Fall of Lake Okeechobee: 1913 to Present Day
24 ***Adam Rosenblatt***, Habitat Use and Movement Patterns of the American Alligator
66 ***William Roth***, ARM NWR Completely Mixed Flow Model
26 ***Brooke Sargeant***, Effects of Abiotic Gradients and Trophic Interactions on Food Web Structure
58 ***Reza Savabi,*** Ground Water Quality and Flow near ENP
57 ***Ray Schaffranek***, Controls on Flow Velocity and Flow Resistance
11 ***Melinda Schuman***, Biological Monitoring of Treefrogs: Picayune Strand Restoration Project
5 ***Margo Schwadron***, Shell Mounds and Middens of the Ten Thousand Islands
20 ***David Shindle***, Pre-construction Baseline Monitoring Survey of Florida Panther
6 ***Greg Smith***, CERP: Cultural Resources Overview and Survey Strategy
49 ***Lars Soderqvist***, Storm Tide of Hurricane Wilma in Southwestern Florida, October 2005
56 ***Roy Sonenshein***, Geographical and Temporal Distribution of Flows into Shark River Slough
52 ***Brad Stith***, Integration of Individual-based Manatee Model and FTLOADDS Hydrology Model to Assess Restoration Effects
63 ***Donatto Surratt***, Novel Approach to Modeling Periphyton Distributions in the ARM Loxahatchee NWR
12 ***Brandon Van Nuys***, Pilot Study to Establish Monitoring Sites for Nesting Habitat of Florida Snail Kite
35 ***Peggy VanArman***, Examination and Comparison of Mandibles and Gastric Teeth in Two Species of Crayfish
48 ***Kathryn Villazon***, Effects of Elevation, Plant Age and Planting Density on Revegetation of Freshwater Marl Prairie Ponds
67 ***Hongqing Wang***, Simplified Modeling of Surface Water Sulfate Dynamics in the ARM Loxahatchee NWR
18 ***Shona Wilson***, Small and Medium Sized Mammal Inventory of ENP and Big Cypress
36 ***Kathy Worley***, Aerial and Field Monitoring of Selective Avifauna in Aquatic Refugia
SP1 ***Adam Watts***, Unmanned Aircraft Systems for Wading Bird Surveys
SP2 ***Kathy O'Reilly-Doyle***, Think Locally, Act Neighborly

Session Two Posters are on display beginning at 7:30am on Wednesday, July 30 through 10:30am on Friday, August 1. A formal Poster Networking Session is scheduled Thursday, July 31 from 5:30pm-7:30pm. Presenters will stand at their posters from 6:30pm-7:30pm. Poster Session Two posters should be removed upon conclusion of the 10AM break on Friday.

NOTE: Poster abstract titles in this listing are abbreviated. Consult the poster directory in the program book for full reference.

Meeting Abstracts

Listed alphabetically by presenting author.
Presenting author names appear in **bold**.

Freshwater Flow Alteration Impacts Mangrove Creek Use by Juvenile Snook and Other Fishes

Aaron J. Adams
Mote Marine Laboratory, Charlotte Harbor Field Station, Pineland, FL, USA

Freshwater flow is a major ecological structuring factor in estuaries, influencing abundance and distributions of vegetation, and of invertebrates and vertebrates that use estuaries for some or all of their life cycles. Whereas some organisms can tolerate wide ranges in salinity, most species have narrow salinity tolerances or migrate to remain in a preferred salinity range. Thus, differences in freshwater flows and associated salinity patterns can influence organism abundances, influence recruitment, and shift dominant species. Freshwater flows are especially important to small tributaries that transverse the margin between uplands and estuaries.

Disturbances are also important factors influencing biological organization. Numerous, non-mutually exclusive hypotheses on the relative importance and interactions of disturbance, competition, productivity, and species life history strategies have been proposed as explanations for maintenance of species diversity in both terrestrial and marine systems. However, most of this research and formulation of disturbance ecology theory has focused on natural disturbances, such as hurricanes. Less studied are the impacts of anthropogenic disturbances.

Anthropogenic alterations of freshwater flows into estuaries are of particular concern to resource managers because of potential impacts to estuarine ecology. The increase in impervious surfaces and loss of wetland habitats associated with coastal development alter the source, timing, and velocity of freshwater flows, which influences salinity patterns. Unfortunately, despite increasing use of restoration as a tool to combat habitat degradation, there are few comparative data on restoration effects on fishes. Although freshwater flow alterations might be considered akin to a natural disturbance in management models, this approach may not be valid. This is because, in general, disturbance effects differ between natural and anthropogenic disturbances. Moreover, anthropogenic disturbances may interact with natural disturbances or alter system responses to natural disturbances.

Oligohaline creeks that are tributaries to estuaries are important habitats for many young-of-the-year marine finfish and shellfish. The recruitment success of many tropical and sub-tropical estuarine fishes, such as common snook, *Centropomus undecimalis* (part of a saltwater recreational fishery worth more than $10 billion annually in Florida) that have evolved life-histories based on a wet-dry seasonal cycle depend greatly upon access to oligohaline marshes; the recruitment of snook larvae to creeks coincides with the wet season, when they ride high tides and elevated freshwater flows into the creeks and surrounding flooded uplands. As they undergo ontogenetic shifts in diet and habitat requirements, these fishes transition downstream, and eventually to the open estuary and nearby coastal waters. These creeks also contain populations of resident fishes whose distributions are also influenced by freshwater flows and associated salinity changes. Changes to these habitats, therefore, may have significant impacts on creek-associated fishes.

Mote Marine Laboratory's Fisheries Habitat Ecology Program has been studying fish assemblages in four mangrove creeks of Charlotte Harbor, FL since 2002, to determine habitat use patterns of juvenile snook and the effect of freshwater flow alterations on juvenile snook and creek fish assemblages. The long-term goal is to develop a predictive model that associates freshwater flow alterations with fish community structure and juvenile snook habitat use. For the purposes of this study, two creeks were considered ‘less degraded’: their morphology remains largely intact except for remnant mosquito ditches (compared to 1953 aerial photos) in the upland drainages, and their immediate upland drainages are undeveloped. The mosquito ditches and water control berms are being removed as part of a restoration project. In contrast, two creeks are considered ‘more degraded’: their upland drainages and wetlands have been altered for development, creating impervious surfaces and altering freshwater flow regimes. The altered flow regimes cause short, pulsing hydroperiods limited to the immediate creek with little overland sheet flow. The uplands to the latter creeks are seeing increasing development.

The fish assemblages differed between creek types. There were fewer species and lower total abundances in the ‘more degraded’ creeks. Moreover, these fish assemblages appeared to respond differently to a hurricane disturbance. Prior to hurricane Charley, abundance and species richness were many times greater in the ‘less degraded’ creeks. After hurricane Charley, creek abundances were similar, but species richness remained higher in the ‘less degraded’ creeks. The difference between creeks in response to the hurricane may indicate that fish assemblages in the ‘more degraded’ creeks had already undergone a phase shift to due to freshwater flow alterations. A similar interaction between a natural disturbance (flooding rains) and upland habitat alteration appeared to facilitate the invasion of the exotic Mayan cichlid into the creeks.

Juvenile snook abundance was also lower in the ‘more degraded’ creeks, and juvenile snook diet was more diverse (more prey types eaten, a more even distribution of prey consumed) in the ‘less degraded’ creeks. Since juvenile snook rely on these habitats for their first year, this may have implications for the economically important fishery. That snook is a top-level predator may have wider system-level implications. Ongoing research is examining whether differences among creeks impacts the number of snook that survive and enter the adult population – the ultimate measure of connectivity between mangrove creeks and the wider estuary.

Key Findings of this work are:

- Freshwater flow alterations impact resident fish assemblages and the abundance of juvenile snook (an economically important fish species) in mangrove creeks
- Ongoing research will determine whether creek alteration impacts the number of juvenile snook that survive and enter the adult population (i.e., system-level effects)
- Natural disturbances impact fishes of ‘less’ and ‘more’ degraded habitats differently
- Upland habitat alteration also facilitates non-native fish invasions, with unknown ecological implications
- A comparative approach is essential to understanding habitat degradation effects on fishes, and for creating a predictive model for testing restoration efficacy
- Multi-year time-series are essential to discerning disturbance effects in the context of natural variation, and should be included in any restoration strategy

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Dissolved Organic Matter in the Everglades: Implications for Ecosystem Restoration

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In aquatic systems, dissolved organic matter controls a number of environmental processes important for ecosystem function including the absorption of light, mineral dissolution/precipitation, transport of hydrophobic compounds (such as pesticides), and the transport and reactivity of metals. For instance, biogeochemical processes that influence the fate, bioavailability and transport of mercury (Hg) in aquatic systems are mediated by interactions of Hg with dissolved organic matter (DOM). In addition, DOM poses problems in the production of drinking water because the amount and chemistry of DOM in source waters are key to the formation of potentially carcinogenic disinfectant byproducts. However, the pools of molecules comprising DOM in different environmental settings are not equally reactive. Chemical characteristics, such as differences in polarity, aromatic carbon content, reduced sulfur content, and carboxyl content are significant factors in controlling DOM reactivity in environmental processes. Therefore, understanding the factors that control the amount and chemistry of DOM is relevant for the successful execution of the Comprehensive Everglades Restoration Plan.

As part of our research studying the influences of DOM on Hg biogeochemistry, we have quantified and characterized DOM throughout the Everglades using a variety of chromatographic and optical approaches. DOM from different areas of the Everglades exhibits different degrees of reactivity with Hg. Areas strongly influenced by the Everglades Agricultural Area have been found to be more reactive with Hg species than DOM from more pristine areas in the Everglades. The chemistry of DOM in a given location in the Everglades is dependent on the dominant vegetation types, biogeochemical processes, hydroperiod, interactions of surface water with peat pore waters, and amounts of canal water. Most of the DOM in the Everglades originates from the degradation and leaching of organic detritus derived from the algae, bacteria and macrophytes living within the wetland environment. In addition, organic matter is also transported to the Water Conservation Areas of the Everglades in the canals that drain the Everglades Agricultural Area (EAA). Areas strongly influenced by the EAA generally have higher dissolved organic carbon (DOC) concentrations, greater amounts of reactive aquatic humic substances, and the DOM is more aromatic than samples from less impacted areas. For instance, DOC concentrations are greater and the DOM more aromatic at F1, a site in northern WCA-2A strongly influenced by EAA waters carried by the Hillsborough Canal compared to nearby sites in Loxahatchee (WCA-1) that are isolated from surrounding agricultural influences, and compared to sites in the southern Everglades that currently receive little water from the EAA.

Proposed attempts to return the Everglades to more natural flow conditions will result in changes to the current transport of DOM from the Everglades Agricultural Area and the northern conservation areas to Florida Bay. In part, the restoration plan calls for increasing water flow throughout the Everglades by removing some of the man-made barriers to flow in place today. The land and water use practices associated with the plan will likely result in changes in the quality, quantity and reactivity of DOM located throughout the greater Everglades ecosystem. Our data suggest that the long-term ecological and geochemical effects of introducing reactive organic matter to pristine areas in the Everglades and, ultimately, to Florida Bay should be assessed.

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Comparing Seasonal Salinity Variations in the Shark River Estuary and Underlying Coastal Aquifer from 1996-2007, Everglades National Park, USA

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Water movement across the underlying unconfined aquifer and the surface waters of the coastal Everglades is neither well understood nor well documented. Recharge and discharge of coastal groundwater is important in transporting dissolved nutrients and other chemical constituents. Since 1996, the National Park Service (NPS) and the U.S. Geological Survey (USGS) have monitored coastal salinity in the Shark River estuary and adjacent marsh-mangroves in Everglades National Park. During the wet season (June-Nov), the estuary salinity is substantially reduced by dilution and mixing of fresh water from increased precipitation and surface water runoff. During the dry season (Dec-May), estuary salinity increases to near marine conditions in the late spring in response to reduced rainfall and surface water runoff and high springtime evapotranspiration. The objective of this project is to compare the seasonal salinity variations observed in the Shark Slough estuary with the underlying groundwater salinity in an effort to ascertain their hydrologic connection.

Salinity data were collected from three NPS Shark River gages and three USGS surficial aquifer wells located adjacent each other. These three-paired sites were used to evaluate salinity variability between the Shark river estuary and the coastal aquifer. The upstream-paired sites: Tarpon Bay (TE, NPS) and Shark 2 (SH2, USGS) are in the freshwater marsh-coastal mangrove transitional ecotone; mid river, paired sites: Harney River (HR, NPS) and Shark 4 (SH4, USGS) in a riverine mangrove fringe forest; and the downstream-paired sites: Shark River (SR, NPS) and Shark 3 (SH3, USGS) in a mangrove river delta, near the Gulf of Mexico. Salinity data from May 1996 through April 2007 were summarized into average monthly values (132 possible months), using descriptive statistical methods. Non-parametric correlation analysis (Kendall tau) was used to determine the relationship between estuary and groundwater salinity.

The following seasonal salinity patterns and trends were observed from upstream to downstream-paired sites. At the upstream river site (TE) the average monthly salinity peaked in May (10.7 psu), decreased until August (0.9 psu), stabilized through January, then gradually rose through the dry season. At the paired-upstream SH2 site, the average monthly groundwater salinity also peaked in May (5.2 psu), but overall, the groundwater salinity was attenuated and less variable compared to the surface water. Dry season river water to groundwater salinity indicated a weak-moderate relationship (0.36, N57, $p < .01$) and little to no relationship (-.06, N55, p-value not significant) during the wet season. At the midstream river site (HR) average salinity values were high in April (18.8 psu) and May (21.1 psu), dropped to 4.5 psu in August, stabilized through January, and progressively increased through the dry season. Groundwater salinity at site SH4 also peaked in May (22.0 psu), with a salinity value similar to that of the river water, suggesting a strong connectivity between the river and the unconfined aquifer during that month. However between July and January, SH4 groundwater maintained a higher salinity (~ 4 psu) than the river water. Dry season river water and groundwater salinity were strongly correlated (0.71, N50, $p < 0.01$) at the midstream sites, and weak-moderately correlated during the wet season months (0.52, N65, $p < 0.01$). Downstream river site SR had the highest seasonal salinity, which leveled-off in April (30.2 psu) and May (30.8 psu), declined during the summer months, but with a less steep negative slope than river salinities HR or TE. Downstream river salinity did not level nor stabilize in the autumn, as observed at river sites HR and TE. After salinity ebbed in October, it sharply increased in a steep positive slope through the dry season, suggesting shortened residence time in the river caused by greater tidal mixing of marine water from the Gulf of Mexico during dry season. The groundwater salinity signature at SH3 showed little seasonal fluctuation and had a smaller and later seasonal salinity peak in October, (24.7 psu), not May, as was observed at both groundwater sites SH2 and SH4. We also observed SH3 groundwater seasonal salinity peak was coincident with the river salinity seasonal low (19.8 psu). Dry season estuary to groundwater salinity showed a weak-moderate relationship (0.53, N37, $p < 0.01$). Wet season estuary to groundwater salinity showed no relationship (0.04, N44, p-value not significant).

How is this study useful to the Everglades Restoration?

- Monitoring salinity dynamics between the estuary and groundwater can assist Everglades restoration efforts by providing an empirical baseline, useful for evaluating upstream water management practices and the influence of sea-level change on the coastal Everglades. Specifically, salinity flux and concentrations are important as they can influence the coastal marshes and mangrove forests stability and sustainability. This study supports MAP Hypothesis # 4: Sea level and freshwater flow as determinants of production, organic soil accretion and resilience of coastal mangrove forests (Recover 2005).

- Providing ancillary groundwater hydrology data to support Greater Everglades Module (GE-12), GE-12 “Greater Everglades Wetlands Coastal Gradients monitoring and assessment,” in collaboration with ongoing U.S.Geological Survey MAP “Coastal Gradient of Flow, Salinity and Nutrients” study.

- In cooperation and exchange of data and analysis with CERP and other Everglades ecosystem studies and modeling efforts, i.e., Everglades Depth Estimation Network (EDEN) and the Florida Coastal Everglades, Long-Term Ecological Research (FCE-LTER).

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Seagrass Restoration within the Florida Keys National Marine Sanctuary

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Since 2002, there has been an average of 500 reported vessel groundings per year in the Florida Keys National Marine Sanctuary (FKNMS). More than 80% of these occur in seagrass habitats. Of the five species of seagrass present in the FKNMS, *Thalassia testudinum* (turtle grass) is by far the most common species, often forming monospecific beds that dominate the seascape. However, where sufficient substrate has been removed, natural recovery of the seagrass *Thalassia* is small or nonexistent and the scars left by boat propellers and vessel groundings persist for decades or longer. In some cases, these physical disturbances become ecologically permanent features. The chronic nature of these repeated disturbances has reduced the ecological services and functions of these systems at the landscape scale.

In restoration experiments, it has been found that planting faster-growing, early-successional seagrasses, such as shoal grass (*Halodule wrightii*), can serve as a temporary substitute for the climax species, *Thalassia testudinum*. One cost-effective restoration alternative includes placing bird stakes in conjunction with seagrass transplants within the injured areas. This method has been shown to promote the natural succession of seagrass species within vessel grounding injuries. However, there is a possibility that this method by its very design could lead to delayed recovery of the natural seagrass species composition. Where possible, seagrass restoration should include replacement of all ecological functions to a level comparable to a pre-injury baseline of the adjacent submerged resources and ecological habitats as quickly as possible. That means restoring turtle grass habitats back to turtle grass.

Our experience in assessing and monitoring seagrass injuries over time throughout the FKNMS indicates that failure to replace the lost sediment in the trenches, blowholes and prop-scars will often result in a protracted natural recovery extending over a temporal scale of multiple decades or longer. The replacement of sediment into the injured site is important because it will allow for natural vegetative propagation from existing, adjacent seagrass meadows into the restoration area. The transplantation of seagrasses from local donor sites and/or nurseries can further accelerate recovery of the restored sites. In addition, understanding and establishing the natural recovery rates for a variety of habitat types, physical settings, and sediment types as well as for different levels of injury to the resource allows for the development of an ecologically-based criterion for implementing future *Thalassia* restoration projects.

It is now evident that implementing seagrass restoration programs is a viable method to stem the loss of ecologically important turtle grass. This is a valuable management tool that, when implemented in an expeditious manner, assists in the preservation of critical seagrass beds. However, it is a tool that cannot succeed without reducing the root cause – disturbances caused by vessel impacts.

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Tracer Test Inversion to Determine Vegetative Flow Resistance with Lattice Boltzmann Models

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A novel approach to understand and quantify the role of aquatic vegetation on flow at the meter to ~1 km scales in the Everglades is proposed. The approach is to invert field tracer experiment (EverTREx) SF_6 data to solve for vegetative flow resistance.

Aerial photography data are used to identify ridge and slough distributions over the tracer test area and the ridges are simulated as a resistive medium while sloughs are characterized as open channels. Lattice Boltzmann models, which are capable of inertial flow and coupled solute transport simulation, would be used to model fluid flow and tracer transport based on uniform initial estimates of vegetative resistance in ridges. A parameter optimization program would minimize the difference between observed and simulated tracer concentrations and improve estimates of aquatic vegetation resistance. The optimization might also be capable of distinguishing variations in flow resistance arising from vegetative density differences within ridges.

Successfully linking photographically-observable ridge and slough distributions and flow model resistances would allow broad application of these methods for flow and transport simulation in areas where no tracer tests were conducted. In the context of Everglades restoration, such a model would allow

- assessment of changes in flow patterns due to water management alternative effects on water depth
- estimation of changes in flow patterns due to restoration-related construction
- potential for simulation of large-scale nutrient and other dissolved constituent transport

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The Role of CERP in Addressing Lake Okeechobee Watershed Issues

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Restoration of the south Florida ecosystem, which includes the Everglades, is one of the largest ecosystem restoration efforts in the world. The south Florida ecosystem encompasses an area of 18,000 square miles and stretches south from Orlando through the Kissimmee Chain of Lakes, the Kissimmee Valley, Lake Okeechobee, the remaining Everglades, and on to the coral reefs and waters of Florida Bay.

In 1996, the Army Corps of Engineers was directed to develop a comprehensive plan to restore and preserve south Florida's natural ecosystem, while providing for other water-related needs of the region, including water supply and flood protection. The resulting plan, which was developed by the Army Corps of Engineers and the South Florida Water Management District and their interagency partners, was submitted to Congress on July 1, 1999. This plan is called the Comprehensive Everglades Restoration Plan and is commonly referred to by its acronym, CERP.

Both the problems with declining ecosystem health and the solutions to Everglades restoration start with changes to hydrological conditions. Restoring more natural hydrological conditions can be framed by four interrelated factors: quantity, quality, timing, and distribution of water. The principal goal of the effort to restore more natural hydrological conditions in the south Florida ecosystem is to deliver the right amount of water, of the right quality, to the right places and at the right time. The comprehensive plan, which is estimated to cost $10.9 billion at current price levels, involves extensive modification of the existing water management system in south Florida. The comprehensive plan contains 68 major components that involve creation of approximately 180,000 acres of reservoirs, 330 aquifer storage and recovery (ASR) wells, 36,000 acres of wetland-based water treatment areas, two wastewater reuse plants, seepage management, and removal of over 240 miles of existing levees and canals in natural areas. These components vastly increase storage and water supply for the natural system, as well as for urban and agricultural needs, while maintaining existing purposes of the Central and Southern Florida Project. The comprehensive plan is expected to restore more natural flows of water, including sheet flow; improve water quality; and establish more natural hydroperiods in the south Florida ecosystem.

When implemented, the CERP projects in the headwaters of the system, which includes the Lake Okeechobee Watershed, will provide storage areas and stormwater treatment areas to reduce phosphorus loading to Lake Okeechobee; attenuate peak flows from the watershed; provide more natural water level fluctuations in the lake; and restore wetland habitat.

This presentation will provide an overview of the Comprehensive Everglades Restoration Plan and how CERP projects in the headwaters, including the Lake Okeechobee Watershed project, will address water management and water quality issues in the Lake Okeechobee Watershed.

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Assessing Large-Scale Spatial Distribution of Seagrasses in the Loxahatchee River

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The Loxahatchee River District (LRD) has been fulfilling its mission to preserve and protect the Loxahatchee River. During 2007, LRD staff quantified the spatial distribution of seagrasses in the Loxahatchee River. Occurrence and density of seven seagrass species were assessed using large (9 m^2) quadrats deployed in a random-stratified manner throughout the Loxahatchee River, and the spatial coordinates of each quadrat were recorded. Nearly 1,100 quadrats were sampled during the summer of 2007. Seventy-eight percent of our samples (quadrats) contained at least some seagrass, while 22% of our samples completely lacked seagrass (i.e. were bare substrate). Johnson's seagrass was the most frequently encountered seagrass species within the Loxahatchee River, occurring in 71% of samples. Shoal grass was the second most abundant seagrass, and occurred in 50% of samples. Paddle grass occurred in 11% of samples, and manatee grass and turtle grass both occurred in 4% of samples. Interestingly, star grass was the only seagrass not found within the Loxahathcee River estuary, though it was present in our 2003 survey. Widgeon grass, not a true seagrass, occurred in the upstream reach between river miles 7 and 8. Spatial analysis of the quadrat data using Arcgis indicated that there were approximately 496 acres of seagrass in Loxahatchee River during the summer of 2007, while only 120 acres of seagrass were mapped by Loxahatchee River District staff in 2003.

Key messages relevant to larger-scale ecosystem restoration include:

- creating seagrass maps using GIS-based interpolation of random, stratified point samples in lieu of aerial photography interpretation;
- assessing landscape scale changes in seagrass to assess modifications to freshwater delivery schedule.

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Introduction and Overview of Biogeochemistry and Water Quality of the Greater Everglades

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Good water quality is important to restoration efforts throughout the greater Everglades ecosystem, which ranges from the Kissimmee Chain of Lakes in the north down through Florida Bay in the south, and includes coastal estuaries and the reef tract. Much of this subtropical system was oligotrophic prior to human development, and the Everglades marshes in particular are very sensitive to nutrients, especially phosphorus. Our human presence in the form of agricultural and urban development presents significant challenges to maintaining and restoring good water quality and minimizing ecosystem impacts. However, significant amounts of effort and money have been expended in south Florida to protect and restore good water quality, with much progress made over the past decade.

The assessment of water quality conditions throughout the Greater Everglades mostly focuses on nutrients, mercury, sulfur, pesticides, and other chemical constituents that may be present in increased concentrations over background conditions, and that have the potential to harm ecosystem and/or human health. The nutrients of greatest concern are phosphorus and nitrogen. Phosphorus is a limiting nutrient in Everglades marshes and other locations, and excess nitrogen is a concern particularly in estuarine ecosystems. Mercury from atmospheric and natural sources can be converted to its toxic, organic form, which can be biomagnified and result in harmful concentrations in animal tissue. In order to protect human health, much of the Everglades freshwater fishery is subject to fish consumption advisories due to high methylmercury levels in fish. Sulfur has received increased attention over the past decade because of its implications in the microbial transformation of elemental mercury to methylmercury, and its potential to mobilize phosphorus in this oligotrophic system. Pesticides, such as atrazine applied in agricultural and residential settings, can be present in surface water and in sediments. Other water chemistry concerns include the mineral composition of water, particularly in parts of the Everglades with native communities that developed under and are adapted to softwater conditions.

Efforts needed to assess and respond to water quality concerns go well beyond simple descriptive statistics. They include: long-term and project-specific water quality monitoring programs; research to assess the potential biological impacts of specific constituents at the organism, population, and community/ecosystem levels; modeling to help understand and predict water quality patterns and trends; and our responses to protect and improve water quality at the policy and regulatory levels. There are extensive water quality monitoring programs and datasets that form the foundation of water quality protection and restoration efforts. The majority of monitoring programs and data fall under auspices of the South Florida Water Management District (SFWMD) and the Florida Department of Environmental Protection (FDEP). The US Environmental Protection Agency is responsible for the Everglades Regional Environmental Monitoring and Assessment Program (R-EMAP), a probability-based, multi-media effort that has documented conditions throughout the Everglades Protection Area for over a decade. The US Department of Interior monitors water quality in federal trust resources throughout south Florida.

The SFWMD and the FDEP report on the status of water quality in the greater Everglades ecosystem annually in the South Florida Environmental Report. Research by all entities has focused on potential impacts of water quality constituents on ecosystem and human health, and substantial efforts were directed at determining the threshold level of total phosphorus, beyond which ecosystem harm could be expected. Consequently, the Everglades is the only water body in Florida, and the only wetland in the US, with a numeric water quality criterion for phosphorus. Water quality models have been developed, with more extensive and detailed models presently under development.

The eventual success of water quality protection and restoration efforts depends heavily on an effective science/policy interface. Policy-makers and regulators need high quality scientific information from which to base decisions. The extent and magnitude of water quality monitoring, research, and modeling information is both a blessing and a curse. There is far more information to support water quality decision-making in the greater Everglades ecosystem than for almost any other ecosystem in the world. However, the volume and complexity of information make it challenging to provide this information in a timely, useable, and effective way for decision-makers. This symposium will help provide a suitable framework for synthesis and interpretation, will describe new scientific approaches and techniques, and will greatly facilitate the science/policy connection.

Findings relevant to restoration:

- Good water quality is an essential component of greater Everglades protection and restoration efforts.
- The assessment of water quality conditions is focused on nutrients, mercury, sulfur, pesticides, and other chemical constituents that have the potential to harm ecosystem and/or human health.
- Water quality science centers around: water quality monitoring programs; research to assess the potential biological impacts of specific constituents; modeling to help understand and predict water quality patterns and trends; and responses to protect and improve water quality at the policy and regulatory levels. These needed approaches clearly are beyond simple descriptive statistics.
- The eventual success of water quality protection and restoration efforts depends heavily on the effective integration of science, policy, and pollution-control programs.

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Application of a New MODHMS-Based Model to C-111 Detention Area Buildout

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The USACE is currently constructing modifications to the C-111 project that provide for the restoration of hydrologic conditions in Taylor Slough and its headwaters, the Rocky Glades. These modifications entail a system of detention areas, active and passive structures, canals, and operational rules. The goals of this project are to reduce seepage losses from Everglades National Park (ENP), extend hydroperiods within the Park, and maintain flood damage reduction within the C-111 basin. The Rocky Glades Model (RGM) is a new groundwater–surfacewater interaction model that uses the MODHMS code and focuses on the C-111 project area. The model domain is located in southern Miami-Dade County along the L-31N canal and covers approximately 157 square miles of the area known as the Rocky Glades. The period of simulation is three years. The model was originally prepared for ENP to analyze the Marsh-Driven Operations Plan on the S-332B, S-332C, and S-332D pump stations and detention basins, which are part of the C-111 project.

This application of the RGM will analyze the effects of the C-111 project's configuration and operations on the hydrology of the Rocky Glades and Taylor Slough. Four simulations will be presented: base, intermediate, and full build-out conditions, and the addition of a curtain wall. These configurations will be run under three operational schemes to examine the range of expected hydrological effects: actual operations, no pumping, and continuous pumping. Analyses of hydroperiod, depth, flow across structures, and detention area overflow will provide a measure of the effects of the C-111 project on the resources of ENP.

This modeling tool will ultimately provide the ability to:

- Examine the hydrology of the Rocky Glades in Everglades National Park at a very fine resolution.
- Examine localized hydrological effects of the C-111 detention area buildout.
- Understand hydrological effects of operational rules for the C-111 detention areas.

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Development of an Interface Between the South Florida Water Management Model and a Fine-Resolution Hydrology Model of Everglades National Park

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In an ongoing effort to predict the effect of water management decisions on the hydrology of the Everglades, models have been developed to simulate various aspects of the hydrological system of South Florida. Some of these models can be used together to leverage the particular strengths of each. An interface has been created to drive a fine-resolution hydrological model of Everglades National Park (ENP) with the output of a larger-scale water management model of Southern Florida. In addition to providing more detailed effects of water management on ENP, this will provide information on the effects of management on freshwater inflows to Florida Bay.

Tides and Inflows in the Mangrove of the Everglades (TIME) is an application of the FTLOADDS numerical model to the hydrology of ENP. Created by researchers at the USGS, the TIME model has a grid resolution of 500 meters and simulates surface- and ground-water hydraulics within ENP. The model domain extends partially into Florida Bay, which allows it to simulate freshwater flows and effects on salinity in the nearshore environment.

The South Florida Water Management Model (SFWMM) is a larger-scale hydrologic model covering South Florida from Lake Okeechobee to the southern coastline. The model takes into account the canals, structures, and water management practices used within its domain. This model has a grid resolution of two miles but was not designed to predict coastal hydrology. The model has been widely used in the development of the Combined Structural and Operational Plan (CSOP) and the Comprehensive Everglades Restoration Plan (CERP) scenarios to predict and evaluate hydrologic changes caused by proposed water management alternatives.

In order to connect the water management aspect of the SFWMM with TIME's fine-resolution hydrology within the Park, code has been developed to automate the data conversion from virtually any SFWMM run to the input format required by the TIME model. This provides users the ability to predict how changes in canal levels and structure operations will effect changes in water levels, hydroperiods, and water budget within ENP and Florida Bay.

- An automated procedure has been generated to produce TIME model input and boundary conditions from virtually any SFWMM scenario.
- Linking these models allows for fine-resolution analysis of effects of water management decisions on the hydrology of ENP.
- This code provides the ability to analyze effects of water management scenarios such as those in CERP and CSOP on freshwater flows into Florida Bay.

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Resource Selection of Two Wading Bird Species with Divergent Foraging Strategies

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Seasonal variation in food availability plays an influential role in the population dynamics of many species and communities. Fluctuating resource levels are particularly pronounced in pulsed wetlands, ecosystems which dry and flood periodically. In the Everglades, wading birds depend on the process of the seasonal drying to concentrate fauna in isolated patches that are available throughout the breeding season. Identifying the key habitat characteristics of those high-quality patches for species with contrasting foraging strategies will provide a range of habitat conditions that can be used to guide Everglades restoration targets. Predicting wading bird population responses to the hydrologic and habitat changes that will result from the Comprehensive Everglades Restoration Plan will require an understanding of the effects of hydrology and habitat through intermediate pathways such as prey availability and wading bird habitat selection and movement patterns.

We quantified the habitat selection of radio-tagged Great Egrets (*Ardea alba;* n = 77) and White Ibises (*Eudocimus albus;* n = 127), two species that are representative of different foraging strategies (searchers versus exploiters), and that have dissimilar population trends. Habitat variables at foraging locations were measured and compared with habitat variables at random locations determined to be available to birds. Hydrological variables were estimated at daily time steps throughout the breeding season using the Everglades Depth Estimation Network (EDEN), a landscape level real-time hydrological model. We calculated resource selection functions using a discrete choice proportional hazards model that allows available resource units to change daily. A preliminary analysis showed that Great Egrets and White Ibises preferred sites with intermediate phosphorus concentrations, intermediate water depths and an increased number of days since a patch was last dry. Great Egrets additionally selected foraging sites with a high water recession rate. These parameters are conducive to both enhance and concentrate local prey populations. By identifying and mapping distributions of preferred environmental resources, we can predict how hydrological management will impact wading bird foraging habitat.

The significance of this study to the restoration is that it:

- Identifies key habitat preferences of several wading bird species that are used as performance measures.
- Provides probability-based parameter estimates that can be imported directly into wading bird habitat models that are used for evaluating restoration scenarios
- Provides an empirical predictive habitat model that uses EDEN water depths and that can be linked to a GIS and used for assessment of restoration progress.

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The Southwest Florida Feasibility Study and Climate Change

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The Southwest Florida Regional Planning Council (SWFRPC) has a long history of addressing issues such as hurricane surge vulnerabilities and assessing predicted sea level rise. Using methods from Titus and Narayanan (1995), the SWFRPC prepared GIS maps of sea level rise to the year 2200 based on a 95% cumulative probability or the near worst-case scenario. The US Environmental Protection Agency (EPA) has funded the development of this assessment.

The Southwest Florida Feasibility Study (SWFFS) is in the process of defining and assessing 3 alternatives plans with the expectation that a Tentatively Selected Plan (TSP) alternative will be developed. The South Florida Water Management District (SFWMD) is providing GIS services to support the SWFFS effort.

The Charlotte Harbor National Estuary Program (CHNEP) amended its Comprehensive Conservation and Management Plan (CCMP) in 2008, including adding an action to "Build capacity for communities and their local leadership to mitigate and adapt to the effects of climate change through joint efforts." EPA is providing additional funds to support this effort. As a component of assessing climate change issues, CHNEP has performed an evaluation of the SWFFS alternatives in the context of sea level change.

Depending on the SWFFS alternative, 97% to 99% of the land area proposed for restoration is located within areas that are above the predicted year 2200 sea level rise, expected to allow retreat of habitats, or are currently inundated. The remaining 1% to 3% lie in urban areas where shore protection efforts may happen. For alternative 1, 88% of this urban area is within the Belle Meade, Collier County, an area that is vulnerable and where stormwater master planning and flowway restoration are under consideration. The 15 other affected management measures are intended for acquisition and restoration of riverine and estuarine areas that will allow habitat migration. The assessment is similar for alternatives 2 and 3 at 85%, which both include 250 acres of urban area associated with the Yucca Pens in northwest Lee County.

Relevant findings to restoration include:

- Consideration of predicted sea level rise can be used to reduce risk and assess benefits of restoration investments.
- The Southwest Florida Feasibility Study includes alternatives which are predominately out of the envelope of long term (200 year) sea level rise predictions.
- Issues of climate change mitigation and adaptation are best addressed through inter-agency partnerships that the Comprehensive Everglades Restoration Plan, the Charlotte Harbor National Estuary Program, and the Southwest Florida Regional Planning Council promote.

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Palynological Evidence of Anthropogenic Activity on Tree Islands

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Tree island sediments in the Everglades wetland ecosystem are valuable archives of climate and environmental change, but they also contain a record of anthropogenic activity. Earlier research indicates that decadal-scale droughts have influenced tree island plant communities throughout the history of the Everglades. Anthropogenic alterations to the natural hydrology during the 20th century have also been shown to impact tree island plant communities. Previously, these studies focused on palynological analysis of sediment cores collected in the near tail of the tree island because they provide the clearest record of tree island development and were relatively undisturbed by native populations. This study examines sediment cores from both near tails and tree-island heads to document the formation of tree island plant communities. Archeological evidence indicates that the three study islands (Heartleaf Hammock, Duck Club Hammock, and Manatee Hammock) were occupied by Native Americans at some point in the past. This study integrates paleoecological data (pollen), biostratigraphy, radiometric dating, sedimentology, and analyses of microscopic charcoal to evaluate the development of these tree islands through periods of known climate variability and Native American occupation.

Sediment from the elevated head and near tail of Heartleaf Hammock both contain records of pre-tree island vegetation, indicated by the low percentages of fern and tree pollen and high abundance of waterlily and other marsh pollen. Pollen assemblages from the near tail appear to contain a continuous sequence of sediment deposition throughout the history of the site, capturing the initial development of tree island vegetation around 2700 calibrated years BP. This differs from sediments recovered from the tree-island head, which appear to have been disrupted by human activity. The sediment core from the elevated head of Heart Leaf, as well as the other tree islands in this study, do not appear to contain the continuous record of sedimentation that is captured in the near tail. A peak in microscopic charcoal larger than 500 μm^2 in both the head and the near tail sediments of Heart Leaf Hammock indicate a local fire event approximately 1500 calibrated years BP. This peak in charcoal is preceded by an interval barren of pollen. The barren interval also is observed sediment from heads of Duck Club and Manatee Hammock at approximately the same time. As a whole, pollen assemblages from this suite of cores document the occurrence of marsh vegetation on current sites of tree island heads from ~4.7 - 4.1 ka. Although a palynologically barren interval occurs on tree island heads directly above records of marsh vegetation, near tails indicate development of tree-island plant communities as early as 3.7 ka. The combined records from tree-island heads and near tails document the “succession” of vegetation through periods of known climate variability (i.e., Medieval Warm Period and Little Ice Age) as well as periods of human occupation.

Key Findings:

- Occurrence of marsh vegetation on current sites of tree island heads from ~4.7 - 4.1 ka
- Evidence for disturbance in palyonolgical record on elevated tree island head
- Continuous sedimentation and record of tree island formation during these intervals of disturbance

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A Spatial Hedonic Pricing Model for Miami-Dade, Florida: Using Econometrics and Geographic Information Systems for Property Valuation

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As part of the development of the Ecosystem Portfolio Model (EPM), an integrated ecological, economic, and social land use planning web tool currently applied to Miami-Dade County, we have created a spatial hedonic land pricing model, a type of econometric model that is used to explain and estimate land values. Miami-Dade County is unique in that it is the only major U.S. Metropolitan area that borders two national parks, creating a situation where land preservation near the national parks is recognized as a contentious issue. Typically, an econometric model for land values is estimated with variables that characterize a property. Here we use the hedonic pricing function both without (Model 1) and with (Model 2) spatial explanatory variables that include distances to amenities such as parks, central and secondary business districts, urban growth boundaries, and to environmentally sensitive locations. Using a geographic information system (GIS), it is possible to measure distance-related explanatory and location variables for economic applications. We demonstrate that environmental regulations and the location of amenities have a significant effect on land values. Further, we validate that the use of GIS-estimated distance variables improves model predictive accuracy in explaining the variability of the price of land.

Both models were estimated using ordinary least squares regression and both performed satisfactorily. The dependent variable for both models is the log-transformed property price/ft^2. The independent variables for Model 1 (non-spatial) include property characteristics, land zoning, and sale year. The addition of spatial explanatory variables improved the adjusted R^2 from 0.34 (Model 1) to 0.77 (Model 2). Of the twenty spatial variables evaluated, there were nine GIS variables that had a statistically significant effect on the land price. Spatial variables show that measurement of distances to the Miami Central Business District, highways, canals, inland water, and Everglades National Park can improve land value estimates. The GIS measured explanatory variables are statistically significant ($Pr < .01$) and improve the hedonic valuation of the Miami-Dade County land market.

In the application in Miami-Dade County, FL:

- the hedonic price function has been used to value vacant land that will come under pressure for development as the population of the county increases over the next several decades
- the hedonic price function can be used to assess the value of vacant land outside the Urban Development Boundary where there is considerable pressure for urban expansion allowing the quantitative analysis of locations that most likely will be considered in land preservation vs. development planning choices as specified in the Miami-Dade County Comprehensive Plan
- the hedonic price function demonstrates that inclusion of spatial explanatory variables is a significant improvement over retaining only non-spatial characteristics in the model.

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GIS Data Acquisition and Visualization in a 3D World for Regional Water Quality and Hazardous Waste Screening

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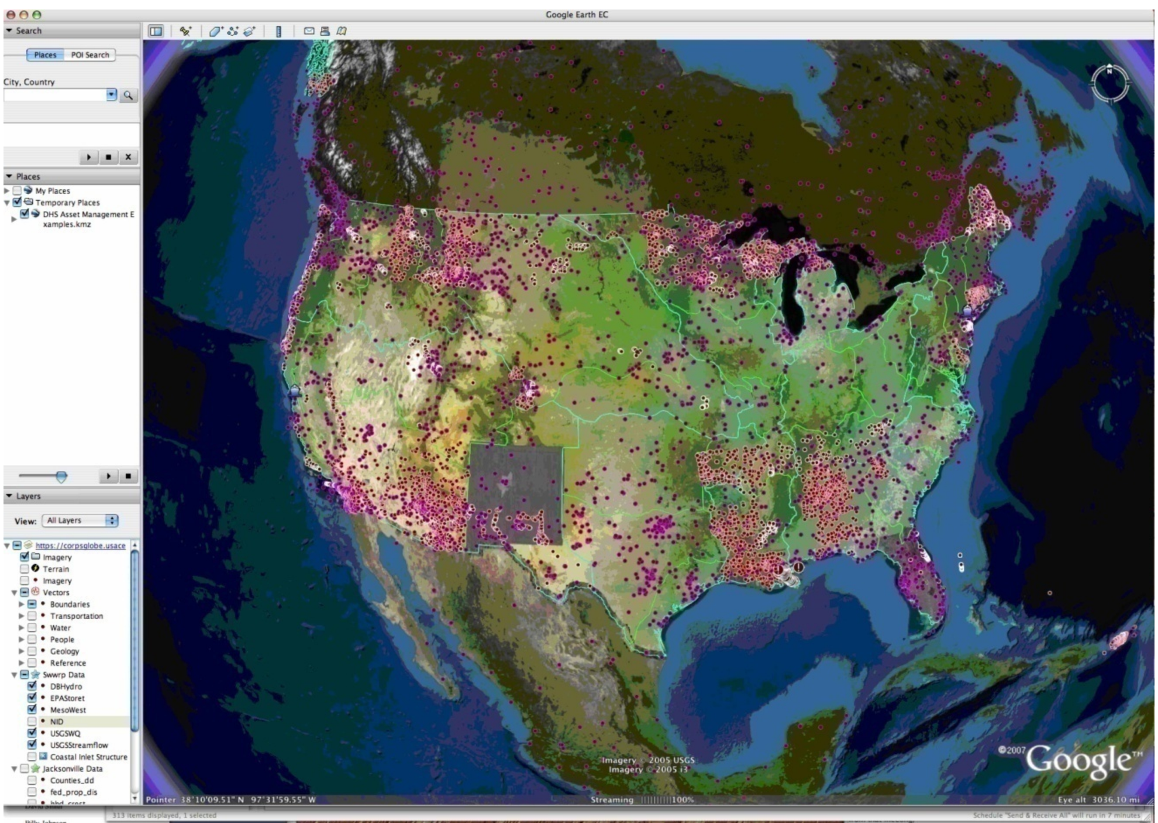
Geospatial applications increasingly require large quantities of data to be collected, assimilated, and integrated with existing and new geographical data. As a result, various geoprocessing work units throughout USACE, federal, state, and local agencies are maintaining large data repositories which locally cache geospatial data in disparate formats, resulting in redundant databases which carry high maintenance costs. The end user needs to download and visualize large quantities of data with minimal expertise and limited internet bandwidth.

CorpsGlobe (http://CorpsGlobe.usace.army.mil) is a tool that utilizes cutting-edge Google Earth technology which allows users to download and graph data from disparate source, providing a "one stop shop" visualization, rendered in a three dimensional setting with resolution up to six inches in several locations. Examples of data sources include EPA STORET, DBHYDRO water quality, USGS stream flow, NED, NID, NLCD, etc. The data resides with the data owners and technologies such as web services retrieve the data from disparate entities as the layers are clicked in demand for additional data.

Several USACE districts and Federal partners are using CorpsGlobe.



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Periphyton Constructed Stormwater Treatment Areas (PSTA): Constructed Wetlands for Achieving Water Quality for Everglades Restoration

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Restoration of the Everglades ecosystem is dependant upon restoring water quantity, quality, timing and distribution of historical patterns. The preponderance of the Comprehensive Everglades Restoration Plan (CERP) focuses on the components that collect, store and deliver water to the Everglades. Yet it has been the water quality challenges that have forestalled CERP implementation. Everglades water requires a total phosphorus (TP) concentration of 10 parts per billion (ppb). This project is offered as a solution to that challenge.

The constructed wetland will use a biological technology; a periphyton-based stormwater treatment area (PSTA) technology that was proposed in 1996 by Doren and Jones will form the wetland. This technology was based upon research in the “hole-in-the-doughnut” restoration area of Everglades National Park. As part of an exotic plant control study, portions of the former agricultural land were scraped to the limestone substrate. A natural succession of periphyton and sparse macrophytes quickly occurred. These organisms are pioneer species that occur in oligotrophic environments where the water column TP is less than 10 ppb.

This poster presentation summarizes a three (3) phase experimental approach to test the hypothesis that PSTA technology can achieve the water quality goal. The approach tests 1000 square foot PSTA cells, a 140 acre field scale demonstration and a full-scale PSTA system. The program is currently in the start-up of the 2nd phase of the field scale application . The key finding relevant to restoration is the achievement of 10 ppb TP in the water column using a green technology.

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Nutrient Storage and Transport Processes on Ranchlands in the Northern Everglades: Consequences for Greater Everglades Ecosystem Restoration

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Ranchlands have an important influence on the fate and transport of nutrients in Northern Everglades region. Improved pastures together with unimproved pasture and woodland/rangeland occupy 38% of the land area in the northern Lake Okeechobee (LO) watershed, second only to natural areas (41%). These grazing lands, which are primarily cow-calf operations, contribute to Florida's ranking 12th nationally and 3rd east of the Mississippi in beef cattle production. Cattle ranches are a low-intensity land use with much lower inputs of nutrients and agri-chemicals than more intensive agricultural land uses in the region, such as citrus, vegetable or sod farms. However, because they occupy such a huge land area ranches contribute substantially to overall storage and transport of excess nutrients in the region.

Research on the fate and transport of nutrients on cattle ranches in the LO watershed has focused on the effects of different management practices on nutrient runoff from cattle pastures, factors influencing storage of nutrients in pasture soils, and nutrient enrichment of wetland ecosystems. Much of this research has focused on phosphorus (P) due to its importance in eutrophication processes. Conversion of native range systems to improved pasture over the past several decades, along with associated fertilizer inputs has created a legacy of nutrient enrichment that contributes to higher nutrient loads in surface runoff and nutrient enrichment of wetlands and other downstream ecosystems. Most of the net P inputs on ranchlands end up being stored in pasture soils and wetland sediments. An estimated 184,000 metric tonnes (mt) of P has accumulated in the LO watershed, with 92% in uplands and 8% in wetlands. Most of this legacy P is associated with dairies or abandoned dairies. This large legacy of excess P in the watershed will contribute to eutrophication processes for many years to come, even if current net imports were reduced to zero. Recent (1997-2001) estimates indicate that current net imports of P into the watershed are 2,001 mt, with improve pastures accounting for 24% of the total. The P inputs to ranches are not distributed evenly across the landscape; P "hotspots" can be created around supplemental feed or other concentration areas.

Studies of soil nutrients on dairies and ranches in the LO watershed have elucidated the biogeochemical factors influencing soil P storage in this region. These studies have also evaluated P indices that estimate the potential risk of P release in surface and subsurface runoff. In both uplands and wetlands, the majority of soil P occurs in the surface A horizon, although the lower E, B_h and B_w horizons can store significant amounts of P in nutrient impacted sites. Organic P accounts for the majority of P in the surface horizon of both uplands wetlands. Release of Fe-bound P during flooding-drying cycles is an important source of P release from soils in this region. Mineralization and release of organic P during flooded periods is another major source of P release. Lateral transfer of P through the soil is likely to be important in the seasonally flooded soils of this region where ground water levels frequently reach near or above the soil surface during wet periods. Wetlands occupy up to 15% of the land area on ranches and are thus critical to understanding nutrient storage and transport. Nearly 50% of isolated wetlands in the region have been ditched for drainage. Removing this drainage could increase nutrient storage by building up soil organic matter in the wetlands and increasing retention time of water and nutrients.

In addition to studies of soil nutrient storage, there have also been studies of nutrient transport processes on ranches in the LO basin. Unlike many other regions where P in runoff is associated with suspended soil particles, much of the P that is lost in runoff from nutrient impacted sites in the LO watershed is dissolved reactive P (DRP). The proportion of total P in surface runoff from nutrient enriched sites is typically upwards of 70%. Extensive ditching in pastures throughout the region facilitates faster movement of water and nutrients in runoff. Slowing the rate of drainage and increasing the retention time of water in drainage ditches with water control structures can increases the uptake and retention of P and reduce P runoff. The main sources of retention are settling of solids, plant and algal uptake, deposition of detritus, and sorption/desorption interactions with bottom sediments. Although detritus accumulation can be an important storage mechanism in drainage ditches, detritus can also be a major source of P release during the first flush of nutrient that occurs when dried sediments are flooded.

Concern over eutrophication of downstream ecosystems, including Lake Okeechobee, the coastal estuaries and the Everglades has stimulated much interest in P source control and the development of best management practices (BMPs) or other activities to reduce P runoff. The Florida Cattlemen produced a document entitled “Water Quality Best Management Practices for Cow/Calf Operations in Florida” as a proactive step to encourage environmentally sensitive practices. Several research projects, funded primarily the South Florida Water Management District (SFWMD) and the Florida Department of Agriculture and Consumer Services (FDACs), have investigated the impact of different management practices on nutrient runoff. These studies have investigated: the influence of stocking rate on nutrient runoff; effects of fencing cattle out of ditches; pasture water management; wetland rehydration, and other practices. Although fencing cattle out of ditches was shown to decrease water nutrient concentrations in one study, reducing cattle stocking rates did not influence runoff nutrient loads in another 6-yr study.

Florida cattle ranches can contribute to Greater Everglades restoration by:

- Maintaining a low intensity land use on the landscape that has lower net nutrient inputs and supplies a range of other environmental services (e.g. wildlife habitat, native biodiversity) that are not provided by other agricultural land uses.
- Providing water services to the public by actively managing water to increase water storage/retention and reduce nutrient runoff in the Northern Everglades (as in the Florida Ranchlands Environmental Services Project).
- Providing refuge, foraging grounds, and breeding sites for critical Everglades species that require large unbroken parcels of habitat.

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Securing Water Related Environmental Services at a Landscape Scale from Working Cattle Ranches in the Northern Everglades Watershed

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In 2008 Florida State agencies responsible for developing the Northern Everglades Recovery Plan identified in the need for an additional 900,000 to 1.3 mil acre feet of water retention in the Lake Okeechobee watershed. This additional retention capacity is critical for not only the provision of sufficient clean water for the Comprehensive Everglades Restoration Plan (CERP) but also for restoring natural lake level fluctuations of Lake Okeechobee, reducing harmful fresh water releases to the Caloosahatchee and St. Lucie estuaries and reducing the threat of breaching the Hover Dike that surrounds Lake Okeechobee. This estimate of critical water retention capacity is in addition to the water retention/storage anticipated from implementation of regional water works projects (e.g.ASR, STAs, and RASTAs) identified in the CERP. State agencies identified numerous potential options for securing this capacity, among them the potential for paying cattle ranchers, the dominant land use in the Lake Okeechobee watershed, to retain water on private property.

Designing a program that will secure water related environmental services at a landscape scale from working cattle ranches in the Northern Everglades is the purpose of the Florida Ranchlands Environmental Services Project (FRESP). Launched in October 2005, FRESP during a 5 year pilot phase will design a program in which ranchers in the Northern Everglades' will compete to sell environmental services of water retention, phosphorus load reduction and wetland habitat enhancement to agencies of the state and other willing buyers. FRESP is being implemented through a collaboration between World Wildlife Fund (WWF), 8 participating ranchers (Wes Williamson, Jim Alderman, Joe Collins, Gene Lollis, John Payne, Chuck Syfrett, Jimmy Wohl, and Cary Lightsey), USDA's Natural Resources Conservation Service (Gregg Hendricks) and state agencies – the Florida Department of Agriculture and Consumer Services (Rich Budell), the South Florida Water Management District (Benita Whalen), and the Florida Department of Environmental Protection (Frank Nearhoof). Technical support is being provided by Resources for the Future (Len Shabman) and scientists from the MacArthur Agro-Ecology Research Center (Patrick Bohlen), the University of Florida (Mark Clark and Sanjay Shukla) and the FRESP Field Team (Steven Hollingsed, Nitin Singh and Earl Keel). Funding from Federal, state and private sources exceeds $5 mil for Phase One – pilot project implementation and program design.

FRESP's program design objective is to create new product that ranchers can produce on working agricultural landscapes in addition to food and fiber—thereby creating for the ranch enterprise a new profit center. These services would be provided on a contractual basis to the state agencies responsible for Northern Everglades restoration. An additional benefit to such an approach is that ranches can bring services on line quickly as compared to other options and can complement public investment in regional water storage and water treatment facilities. The sale of the services will be additional income for ranchers who face low profit margins and will provide an incentive against selling land for more intensive agriculture and urban development—land uses that will further aggravate water flow, pollution, and habitat problems.

Because a Pay-for-Environmental Services (PES) program on working agricultural lands is a new approach significant challenges most be addressed to bring a program to scale. Essential program design questions include: how to assure a dedicated, multiyear funding source to meet contract payment obligations; how to establish what prices that will be paid for services and how to integrate a new pay-for-services program with other state and federal programs. A key challenge for PES programs is the development of credible, transparent, cost-effective and administratable methods to document the provision of services. This is in contrast to the more common approach used in existing agricultural conservation program of paying (or more commonly cost sharing) for the installation of practices.

In its third year of implementation FRESP has accomplished the following:

- Completed the design, permitting and construction of water management alternatives (WMA) on 4 ranches and will complete the implementation on an additional 4 by August 2008. WMA implemented on ranches include rehydrating drained wetlands, pasture water table management, and pumping water from a regional public canal through existing ranch wetlands and flowing back into the canal.
- Developed procedures to compare different protocols for documenting environmental services from ranchlands (e.g. monitoring and modeling of hydrology, water and soil chemistry, vegetation change, ranch records) to document the level of environmental services provided by ranch WMAs and document the trade off between cost of data collection relative to the value of information.
- Installed the monitoring equipment needed to field test the FRESP documentation protocols on all of the ranch's WMAs (4 completed and 4 will be completed by August 2008) and have put in place a Field Team responsible for data collection, QA/QC, management and analysis.
- Working with state agencies (buyers) and ranchers (sellers) have defined the environmental services (commodities) of water retention and phosphorus load reduction.
- Developed a preliminary overview of program design.

Preliminary estimates of water retention potential on working ranches suggest that a PES program could contribute several hundred thousand acre feet of the needed water retention and compliment other regional water management projects. Based on available information the current set of 8 WMAs occupy some 8,500 acres not including service area drainage acres. A planning level estimate of the static water retention capacity of the eight projects is 8,260 acre feet of water for a single storm event with the average acre feet of storage per acre being 0.98 ft. In order to estimate the landscape scale potential of a PES program if successfully scaled we used these following assumptions. Ranchers responded to the program by contracting 20% of the roughly 1 mil acres of improved and unimproved pasture in the Lake Okeechobee watershed to provide water retention services. If each acre retained one foot, the water retained for a single storm event would be roughly 200,000 acre feet of water. The FRESP team is in the process of refining the methods to estimate the water retention potential on ranches and new estimates will be available by Sept 2008.

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The Effects of Hydrological Variation on Seasonal Wading Bird Prey Concentrations in the Everglades

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The linkage among hydrology, prey populations and wading bird populations is a core hypothesis underlying the Everglades restoration. However, a quantitative link between prey abundance and wading bird populations has not yet been established. Previous data on prey populations were collected mostly when the water was deep and wading birds were not using the habitat. We expected the hypothesized linkage would be most evident during the dry season when prey are concentrated into isolated pools and wading birds are feeding in the habitat. We quantified prey concentrations throughout the Everglades during the dry seasons of 2005, 2006, and 2007, three years with differing hydrological conditions and different levels of wading bird nesting. We collected prey using a 1-m^2 throw trap at randomly selected sites and at sites where we observed wading birds foraging.

The 2005 dry season was marked by several rain events that interrupted the natural recession causing nest abandonment by wading birds. Conversely, the 2006 dry season had few reversals, a steady recession, and strong wading bird nesting. Also the 2006 dry season was preceded by above average rainfall during the wet season so water levels system wide were high at the onset of the dry season. Limited rainfall during the 2006 wet season led to drought conditions and poor wading bird nesting in 2007.

Mean biomass of prey (mostly fish and macroinvertebrates) at random sites was significantly lower in 2007 than both 2006 and 2005, likely due to low wet season water levels which may have constrained the growth and reproduction of prey populations leading into the 2007 dry season. In contrast, the favorable hydrologic conditions preceding and continuing through the 2006 dry season produced the highest prey densities and biomass of the three years, and it was the highest of the three years in terms of wading bird nesting effort.

The contrast between prey densities at foraging sites and random sites in the landscape suggested that even in years with a low average prey density across the landscape, birds were able to find some sites with a high prey density. This was the case in 2005 and 2007 when prey density at foraging sites tended to be greater than random sites. In 2006 the prey density at foraging sites was similar to the densities at foraging sites in 2004 and 2005. However, the key difference in 2006 was that there was no discernable difference in prey density between random and foraging sites, suggesting that high quality foraging patches were simply more common in the landscape. If this pattern holds over more years, it will greatly advance our understanding of what landscape characteristics are needed to support large numbers of nesting wading birds.

The main findings of this research that are directly relevant to the Everglades Restoration are:

- The baseline means and variances of the magnitude, location, and frequency of dry season prey concentrations throughout the Everglades,
- Preliminary support for a key restoration hypothesis, which is a quantitative link among hydrologic parameters, prey availability and wading bird nesting,
- Hydrologic scenarios that produce years with good wading bird nesting effort.

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Predicting the Effects of CERP Projects on Salinity Patterns in the Estuaries of Southern Florida

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Water management activities over the last century have altered the salinity patterns of the southern Florida estuaries (south Biscayne Bay, Barnes Sound, Manatee Bay, Florida Bay, Whitewater Bay, and the riverine estuary of western Everglades National Park) by changing the quantity, timing, and spatial distribution of freshwater flows that enter the estuaries. Salinity is a key driver in the physical processes of estuarine and coastal ecosystems that affect the health, species composition, spatial distribution and lifecycles of floral and faunal communities present in a given estuary. Therefore, predicting the salinity dynamics of southern Florida's estuaries and their relationship to water management practices is an essential first step in understanding the effects of the Comprehensive Ecosystem Restoration Program (CERP) and adjusting CERP projects as necessary. In areas where water elevation data exists in upstream marshes, the Southern Estuaries (SE) sub-Team has developed empirical salinity models using Multivariate Linear Regression (MLR) in order to extend the freshwater stage (water elevation) predictions of regional hydrologic simulations into the coastal zone by enabling reasonably accurate predictions of salinity levels at a daily scale of resolution. Output from the South Florida Water Management Model (SFWMM) for each CERP alternative is post-processed using MLR statistical models to predict salinities at selected locations. Once daily salinity predictions are obtained, these values are directly compared to current target salinity values represented by the Natural System Model (NSM) and to independent estimates of historical (pre water-management) salinities based on paleoecological records in sediment cores.

The accuracy of this Performance Measure (PM) prediction is influenced by the data quality and completeness of time-series data available to describe patterns of salinity variation and the driving processes (i.e., fresh water input, stage, wind, and sea level). Thus, the SE team will continue to refine the salinity PM and target values as new assessment data, environmental data and paleoecological data become available. Additionally, the SES will consider the potential influence of climate change and sea level rise on salinity values and targets.

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RECOVER Evaluation Team: Southern Estuaries Sub-team Performance Measure Synthesis Poster

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The Comprehensive Everglades Restoration Plan (CERP) is expected to affect all of Florida's estuaries located south of Lake Okeechobee, including Florida Bay, coastal lakes inland from Florida Bay, Biscayne Bay, and estuaries within southwest Florida's mangrove zone from Whitewater Bay to Shark River Bay. Construction of the Central and Southern Flood Control District (C&SF) canals, and the urban and agricultural development that ensued altered the volume, distribution, circulation, and temporal patterns of freshwater discharges to all of these estuaries. The changes have placed severe stress upon the estuarine ecosystems by creating an increased frequency of extreme physical conditions such as greatly reduced freshwater input resulting in hyper-saline conditions. Other areas have experienced sudden drops in salinity due to large volume freshwater releases. CERP is expected to restore freshwater inflow patterns to the Southern Estuaries region, which in turn is expected to restore salinity patterns resulting in healthier Submerged Aquatic Vegetation (SAV) and mangrove communities. Restoration of salinity regimes and plant communities should provide dynamic, heterogeneous, structural habitat to support near-shore faunal communities.

The Southern Estuaries (SE) Sub-Team of the Restoration COordination and VERification (RECOVER) Evaluation Team (ET) is charged with developing Performance Measures (PM) and using them to predict the system-wide and regional performance of CERP projects and to evaluate their contribution to restoration. SE PMs are based on the CERP Conceptual Ecological Models (CEMs). CEMs are non-quantitative models that identify the major anthropogenic drivers and stressors and the ecological effects of these stressors on important indicators of system health such as native habitats and species.

The SE sub-team has developed a suite of PMs to predict the effect of CERP on the stressors and attributes of the Southern Estuaries. PMs for hydrological stressors include: (1) a performance measure that predicts salinities in Biscayne Bay and Florida Bay based on water levels at inland gages and (2) a performance measure that uses water levels at five gages in Everglades National Park to evaluate the effects of plans on Florida Bay. A Water Quality PM includes targets for nutrient loads and concentrations, water clarity/light penetration, algal blooms, toxicants, and pathogens. PMs also have been developed for the ecological/biological attributes of the Southern Estuaries including fish communities, juvenile pink shrimp, and SAV with associated epifauna. The Southern Estuaries' PMs were developed with the best available science and tools. As our understanding of the ecosystem grows and new tools are developed, PMs will be refined. At this time, not all of the SE PMs have tools to quantitatively predict CERP alternative plan performance. Future SE subteam work will focus on continued refinement of existing PMs and targets, development of the needed predictive tools, and integration of SE PMs with applicable PMs from other regions (i.e., Greater Everglades). Additionally, the subteam will consider the effect of climate change and sea level rise on CERP restoration in the Southern Estuaries region.

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RECOVER's Scientific Role in Everglades Restoration

Michelle L. Boudreaux *on behalf of the Members of the CERP RECOVER Team*

Restoration Coordination and Verification (RECOVER) is the system-wide program of the Comprehensive Everglades Restoration Plan (CERP). The Everglades restoration plan is science-based; the role of RECOVER is to ensure that the best available science continues to guide the plan's implementation and that a system-wide perspective is maintained throughout the restoration process that optimizes the design, sequencing and operations of projects. RECOVER also supports the application of adaptive management (AM) to CERP, advocating the use of a scientific process that promotes and applies learning, reduces uncertainty and increases the chances of CERP success.

RECOVER executes its mission through three technical teams: Planning Team, Evaluation Team and Assessment Team. The teams are guided by the RECOVER Leadership Group. RECOVER uses multi-governmental and interdisciplinary collaboration to foster inclusiveness, collaboration and universal access to tools and data.

RECOVER works with the CERP projects to relate systemwide goals and objectives to project design and performance and to provide the system-wide science and adaptive management perspectives during the project planning process.

RECOVER products include the publication of System Status Reports which use monitoring data to assess ecosystem health; development of an AM strategy and the AM Implementation Guidance Manual, which detail an AM program for project level implementation and system-wide application; Regional Evaluations that evaluate and account for system wide changes attributed to implementation of project alternatives and project contributions to achieving the overall restoration envisioned; and development of system performance measures that guide the evaluation of project designs and reporting of CERP performance.

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How Habitat Degradation in the Everglades Has Affected Juvenile Snail Kite Movement

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The snail kite is a federally endangered raptor that has been intensively studied for decades and whose United States population occurs only in Central and South Florida. It feeds solely on freshwater apple snails making it a wetland dependent bird. As such, the ongoing Comprehensive Everglades Restoration Plan (CERP) may use the snail kite as an indicator of wetland health. Their range is restricted due to the extreme specialization of their diet, but they show considerable movements throughout their range. It is hypothesized that the intensity of movements has changed in recent years due to habitat degradation. Based on many observations and previous studies that indicate habitat degradation in the system, Martin (2007) defined a pre-degradation time period (before and including 1998) and a post-degradation time period (after 1998). This habitat degradation has been caused by prolonged hydroperiods that induced habitat conversion to a deeper, more aquatic system overall (Kitchens, Bennetts, and DeAngelis 2002). The conversion has left apple snails inaccessible to foraging snail kites. The focus of this study is to understand how habitat degradation has affected movement patterns of juvenile snail kites. Both small- and large-scale movements of juvenile snail kites across their range have increased in the post-degradation time period versus the pre-degradation time period. We used multi-state models to estimate probabilities of movement among and within the five major wetland regions used by the snail kite. The best models include, but are not limited to, predictive variables such as the geometric features of the landscape and the level of isolation of each region, as these variables have been shown in previous studies to be important in influencing movement patterns of snail kites.

The movement estimates provided in this study are valuable for Everglades' restoration and management.

- They can be incorporated into management models to predict how management actions like water level regulations will affect the movement probabilities of juvenile snail kites. This will in turn indicate how habitat degradation and loss affects the ability of kites to survive in different wetlands
- By understanding how habitat loss and degradation in the form of vegetative community conversion affects movements, we can potentially predict movement patterns over the course of restoration efforts.
- It has also allowed us to evaluate movement differences between the sexes, which is important to the sex ratio of the population.

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Epifauna Community of Nearshore South Biscayne Bay: Past, Present, and Future

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Biscayne Bay on the lower east Florida coast is one of several coastal systems affected by changes in the quantity, quality, timing, and distribution of freshwater inflow brought about by a series of wetland drainage projects started before the end of the 19th century that culminated in the Central and Southern Florida Project. The current plan to restore, through both structural and operational changes, some of the lost or diminished ecological function of the Greater Everglades includes the Biscayne Bay Coastal Wetlands (BBCW) project, which will redirect freshwater flow from canals into coastal wetlands in an attempt to reestablish the positive salinity gradient characteristic of estuaries. Hydrologic performance measures were adopted by RECOVER with the specific objective of expanding the diversity and abundance of the faunal communities associated with oligohaline and mesohaline waters, i.e., ~0 to 20 psu. Smith's historical description of the fisheries of the bay suggests a greater diversity and abundance of fishery species belonging to the target faunal group than has been recorded recently. Thus a stated ecological objective of CERP is to restore, in shoreline and nearshore waters, the diversity and abundance of this component of the fauna. Ecological indicators and specific performance measures and targets that relate to these objectives are needed to help guide restoration planning, predict ecosystem responses to alternative designs, and monitor and assess the effects of the BBCW and other CERP projects after implementation.

A MAP Project is being conducted to characterize the epifaunal community of nearshore Biscayne Bay and relate distribution, abundance, and community characteristics to salinity, bottom vegetation, and other potential influencing factors. Other objectives are to develop perspective on the potential pool of species that might be available to Biscayne Bay if persistent oligohaline to mesohaline conditions were present and to use this information to formulate ecological performance measures and targets.

The monitoring project is spatially intensive along the mainland shoreline. Sampling is conducted twice a year, dry season and wet season. A 1-m2 throw trap is used for sampling. Three throw-trap samples were collected at each of 47 sites along the shoreline from Shoal Point to Turkey Point in 2005 and 2006. In 2007, with MAP funding, sampling was expanded to 72 sites and extended to Manatee Bay. In addition to obtaining a present view of the shoreline epifauna, this Project also is This project is coordinated with the MAP region-wide throw-trap-based Seagrass Fish and Invertebrate Network (FIAN), and the MAP Shoreline Fish Visual Survey, as well as the MAP Biscayne Bay Habitat Documentation Project.

The project study area consists of the shallow area immediately adjacent to the mainland along the southwestern shoreline of Biscayne Bay between Matheson Hammock and the south side of Turkey Point. The area from Shoal Point south to Turkey Point is the target restoration area of the Biscayne Bay Coastal Wetland Project. The quantity and timing of water flows to area and the shoreline north to Matheson Hammock also will be affected by the regional-scale CERP.

A list of fish species occurring in south Florida that are favored by oligohaline and mesohaline habitat was compiled. Gilmore's (1995) 25 most abundant species in tidal wetland habitat of the Indian River Lagoon system forms the basis of the list. Six additional species from came from Gilmore's (1995) list of 25 abundant species associated with fresh or oligohaline waters. To these we added nine species not mentioned in Gilmore (1995) that were categorized by Lorenz and Serafy (2006) as associated with oligohaline or polyhaline habitat. These include five oligohaline-associated species and four polyhaline-associated species. All mesohaline-associated species on the Lorenz and Serafy list were already included as tidal wetland species from Gilmore (1995). Thus the list consists of 40 potential past and future species of the South Biscayne Bay mainland shoreline. Other south Florida estuarine faunal literature may provide additional potential species.

From eight to 10 of the listed species were collected each season and each year in the Biscayne Bay shoreline epifaunal sampling. A total of 14 listed species were collected at these stations during the 3-yr period. The 25 additional stations in 2007 did not add any additional listed species; however, the 2007 wet season stood out for having not only the most estuarine species but also the most individuals of the estuarine species (even confining the count to only the initial 47 stations). A larger number of rainwater killifish was largely responsible for the increase in individuals, although goldspotted killifish also were caught in higher numbers during the 2007 wet season.

Cluster analyses and multidimensional scaling are being used to determine faunal similarities among stations. We found that stations near to each other were more similar than distant stations during the dry season, and stations similar to each other were scattered along the coast during the wet season (possibly reflecting freshwater outfalls). Dry seasons were more similar and wet seasons were more similar, each season differing from the other, with two exceptions.

Summary of results

- Eight to 10 of potential species of oligohaline and mesohaline habitats were found in throw-trap sampling along South Biscayne Bay mainland shoreline, 2005-2007
- Stations near to each other are more similar in faunal composition during the dry season
- Similar stations are more scattered along the shoreline during the wet season
- Dry season collections are more similar to each other in terms of total number of species.
- Wet season collections are more similar to each other in terms of total number of species.
- Exceptions are the dry season of 2005 and the wet season of 2006.

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Monitoring Fish and Invertebrates in the Southern Estuaries: Quantifying Variation and Reducing Uncertainty

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Relating the abundance of nearshore fauna to salinity and other habitat variables is a challenge. The task is confounded by the complicated life cycles and ecology of each species, with varying physiological needs and ecological responses of different age/size groups, with poorly known acclimation and compensation by individuals to prior salinity conditions, the possibility of the presence of different phenotypic or genetic types, and other concerns. The 2007 System Status Report (SSR) indicates the spatio-temporal extent, quantity, and quality of the data for four species that use the Southern Estuaries (SE) as nursery habitat: gray snapper (*Lutjanus griseus*), spotted seatrout (*Cynoscion nebulosus*), pink shrimp (*Farfantepenaeus duorarum*), and rainwater killifish (*Lucania parva*). The first three species are among the most ecologically and economically important species in the SE. The rainwater killifish, while of no direct economic importance, is one of the most abundant fish species associated with developed seagrass habitats in western and north-central Florida Bay and nearshore Biscayne Bay. In their distribution and/or abundance, the four species display responses to salinity, and therefore, to changes in freshwater flow. The monitoring efforts that collect data on these species also collect data on other species; they quantify the abundance, distribution, and size-structure for various species of mojarras, snappers, grunts, killifishes, barracuda, gobies, pipefishes, caridean shrimps, and other taxa. Data from these projects are being used to characterize species assemblages, their variation in space and time, and relationships with salinity, bottom or shoreline vegetation, and other aspects of habitat that might be changed by CERP.

Augmented by recent MAP sampling, 10 years of pre-CERP data from the shoreline fish community of Biscayne Bay indicate that gray snapper seemingly increase as a function of salinity, although gray snapper of all ages are common in the shoreline waters where salinity is often low and highly variable. Are gray snapper responding to salinity or salinity variability? It is difficult to separate the two factors because greater variability inevitably accompanies lower salinity in south Florida waters.

Spotted seatrout occurrence decreased as a function of salinity in three interior basins of Florida Bay in an analysis of MAP data combined with previously collected historical data for several years. Salinity was substantially lower in both 2005 and 2006 than in previous years in all three interior basins, Rankin, Whipray, and Crocodile Dragover. The year 2005 yielded a record high juvenile spotted seatrout density in Rankin, and 2006 resulted in a record high in Whipray. Is absence of hypersaline conditions the key to high production of juvenile spotted seatrout in interior Florida Bay? Additional years of MAP sampling are essential to answering this question.

MAP sampling with the throw-trap is providing the first comprehensive look at the abundance of pink shrimp and other seagrass-associated epifauna across the southern estuaries. Pink shrimp density is highest in Johnson Key Basin. Historic data combined with MAP data show a significant negative relationship of pink shrimp abundance to salinity in Johnson Key Basin between 1984 and present. This finding based on field data is consistent with a previous laboratory studies and an associated simulation model of pink shrimp survival and growth as a function of temperature and salinity. FIAN also is finding pink shrimp in the lower-salinity waters of Whitewater and Oyster Bays, although pink shrimp density there is less than half that in Johnson Key Basin. Rainwater killifish demonstrated a significant positive relationship with salinity in Johnson Key Basin, although this is the most abundant fish species in the shallow, often low-salinity waters of western nearshore Biscayne Bay. Are the same species responding differently to salinity in different areas?

Results obtained from initial analyses of monitoring data indicate that establishing baseline levels of abundance of estuarine species, relating abundance to salinity and other habitat variables, and detecting the impacts of CERP require substantially longer time series, concurrent with associated salinity and habitat variables, than currently on hand. The ability to interpret monitoring results to adaptively manage and guide restoration efforts will be directly proportional to the quantitative understanding developed from long-term, uninterrupted time series combined with focused short-term research. Monitoring results, in summary, are as follows:

- Gray snapper increased as a function of salinity in Biscayne Bay, but may have been responding to salinity variability.
- Juvenile spotted seatrout abundance decreased as a function of salinity in interior Florida Bay, an area of chronic hypersalinity.
- Pink shrimp abundance decreased as a function of salinity in Johnson Key Basin in western Florida Bay, an area influenced by flows from Shark River and other lower west-coast rivers.
- Abundance of rainwater killifish, a seagrass-associated species, increased as a function of salinity in Johnson Key Basin.
- More MAP data are needed to confirm or refine these relationships and establish a baseline for use in CERP assessment.

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The Prevalence of Abnormal Fish as an Indicator of Environmental Quality

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The St. Lucie estuarine system on Florida's east coast is severely impacted by a number of stressors. These include episodic massive freshwater discharges from Lake Okeechobee through the C44 canal, freshwater releases from local agricultural and urban canals, organic chemicals and heavy metals (particularly copper), deep deposits of muck sediments, which create a flocculent bottom layer and become easily suspended throughout the water column during freshwater discharges and storms. In addition, blooms of the toxic algae, *Microcystis aeruginosa*, are associated with the freshwater releases from Lake Okeechobee. These multiple stressors appear to be reflected in the health of the fish community. A 9-yr survey of fish in the St. Lucie and nearby reference systems indicated that the prevalence of fish with abnormalities varied by species, time, and location. Prevalence was greater in the St. Lucie than the reference systems and greater in the estuaries than the inlets. Prevalence was greatest upstream and lowest downstream, decreasing with decrease in freshwater influence. Abnormality prevalence reached an all-time peak in the double hurricane year, 2004, and declined thereafter, and, throughout 2007, was lower that at any other time in the survey period. In data summarized by quarter (3-month periods), the prevalence of abnormal fish was negatively related to salinity in the Estuary and negatively related to visibility throughout the system. Microscopic analysis of tissues of selected abnormal fish and outwardly normal fish selected as "controls" revealed abnormalities in gill structures suggestive of irritation from sediments or sediment-associated contaminants. These gill abnormalities were present in more than half of the fish examined. In microscopic analysis of tissues, the "affected" fish showed a greater number of microscopic changes per fish than the "control" fish, but the control fish exhibited so many changes of the same type that the affected fish may be serving as sentinels of conditions affecting the entire group.Statistical analysis indicated that abnormality prevalence

- Varies by species and is related to both species ecology and taxonomy
- Decreases downstream from freshwater inflow.
- Is greater in the St. Lucie than in the Reference Areas.
- Is higher in the estuaries than the inlets.
- Is higher when total canal inflows are high.
- Is negatively related to salinity in the Estuary.
- Is negatively related to water column visibility.

Microscopic analysis of tissue indicated that

- Digenean dermal trematodes often were associated with fin erosion and also were found at some sites of color patches in silver porgy.
- Inflammation was observed at sites of red spot and at some sites of color patches.
- Clubbing (lamellar hyperplasia and fusion) in gills, suggestive of irritation from suspended sediments, was found in both "abnormal" fish and "controls."

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Estimating Nutrient Loads in the Caloosahatchee and St. Lucie Estuaries for CERP Projects

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The magnitude, timing and distribution of freshwater inflow to the St. Lucie River Estuary (SRE) and the Caloosahatchee River Estuary (CRE) have been disrupted by a number of anthropogenic alterations of the landscape. These include over drainage of coastal watersheds and artificial connections to Lake Okeechobee (LO) for flood control purposes. Projects composing the Comprehensive Everglades Restoration Plan (CERP) are intended to achieve a more ecologically suitable pattern of freshwater inflow to these systems.

Output from the South Florida Water Management Model (SFWMM version 5.6.1), which is the primary hydrologic simulation model for CERP, is used to produce performance measure output. The SFWMM is a regional scale model that provides simulations of hydrologic conditions at a two-mile by two-mile spatial resolution. Because of the large-scale resolution of the model and the relatively small hydrologic influence of some CERP projects, performance measures may not always reveal differences in system-wide performance of project alternative plans. In these cases, additional scientific information and best professional judgment are used to evaluate the potential performance of project alternatives on the system. Relative to water quality, an interim methodology will be employed to delineate the effect of CERP on nutrient loading [Total Phosphorus (TP) and Total Nitrogen (TN)] to the CRE and the SRE. This will be limited to the large effect of LO releases.

Regulatory releases provide significant loads to the SRE and CRE. According to the South Florida Water Management District, 83 Metric Tons (MT) of TP and 881 MT of TN are contributed annually to the SRE from Lake Okeechobee. Similarly, 65 MT of TP and 1584 MT of TN are contributed annually to the CRE from Lake Okeechobee. These represent significant point source loads to these estuarine systems. For example, LO contributes over 90% of the TP load to the SRE. These are significant loads that will be influenced by the construction and operation of CERP. Moreover, they can be isolated from the effect of other non-CERP programs such as Best Management Practices (BMP's), land use changes, Total Maximum Daily Loads (TMDL), and similar basin run off controls.

Sub-regional water quality models have not been developed that can employ SFWMM output to evaluate CERP effects. For this reason, CERP regional evaluations have not employed water quality models. This poses a dilemma as the water quality effects of CERP can not be examined in a regional evaluation. To solve this dilemma, an interim methodology will be used that employs SFWMM output and uses structure nutrient data to forecast the effects of CERP on water quality. Below is the proposed methodology to estimate nutrient loads of the project alternatives.

An evaluation would involve the following: Estimate LO deliveries through the specific LO structure (S-308 for SRE, S-77 for CRE, and S-155 for LWL) for project condition and base (2000) condition.

a. This would be based upon SFWMM runs for the "without CERP 2050 condition" and the "with CERP 2050 condition".
b. This output would be water budget annual averages in ac-ft/yr
c. Estimates of Structure TP & TN concentrations (respectively). This would be the moving average of the preceding decade.
d. Multiply SFWMM volumes (ac-ft/yr) x structure concentrations (mg/l) x 1234.926 to obtain load in metric tons (1000 kg)/ year.
e. Calculate reduction in load to by comparison of the 2000 and 2050 project conditions.
f. Success would be percent reduction away from a future LO load to the estuary.

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Agricultural Best Management Practices in the Okeechobee Watershed

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The Florida legislature enacted the Lake Okeechobee Protection Act (LOPA) in the spring of 2000. This comprehensive piece of legislation pre-dates the establishment of the Lake Okeechobee TMDL and includes a multifaceted approach to control urban and agricultural non-point sources of pollutants impacting the Lake. The Lake Okeechobee Protection Act directs the Florida Department of Agriculture and Consumer Services to work cooperatively with the South Florida Water Management District, the Florida Department of Environmental Protection and other stakeholders to develop and implement Best Management Practices (BMPs) to address agricultural non-point sources of phosphorus discharge to the Lake Okeechobee watershed. Landowners who voluntarily participate in the FDACS BMP program are presumed to be in compliance with water quality standards and are also eligible to participate in cost-share programs that provide monetary assistance with the implementation of BMPs. Landowners that choose not to participate with the FDACS BMP program must conduct water quality monitoring, according to a plan approved by FDEP and the SFWMD, which demonstrates that they are in compliance with established water quality standards. The intent of the Legislature in drafting these provisions of the Lake Okeechobee Protection Act was to provide an incentive for landowners to participate in the BMP programs jointly developed by the coordinating agencies. If, despite the implementation of BMPs water quality standards are not being met, the Legislature further provided that the coordinating agencies must work cooperatively to re-evaluate the BMPs and make appropriate modifications to improve their performance. Landowners who continue to work within the BMP program maintain their presumption of compliance with water quality standards throughout this re-evaluation and modification process. By structuring the LOPA as described above, the Legislature significantly increases the likelihood that landowners will participate in the implementation of water quality based BMPs for the long-term. In April of 2007 the Florida legislature expanded LOPA to include the Caloosahatchee and St. Lucie watersheds, rivers and estuaries. The newly expanded program was re-named The Northern Everglades and Estuaries Protection Act (NEEPA). In addition, the legislature authorized funding for the implementation of the NEEPA in the amount of $100 million dollars annually through 2020. Based on the documented level of participation by agricultural landowners in the NEEPA, the coordinating agencies agree that the continuation of non-regulatory, incentive-based strategies to achieve water quality improvement is a cost-effective and sound public policy.

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CERP Project Implementation: Incremental Analysis and Justification of a Comprehensive Plan

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The Programmatic Regulations for the Comprehensive Everglades Restoration Plan (CERP) adopted by the Department of the Army in 2003 define the term "next-added increment" and require that plans selected for the individual projects comprising the CERP be justified on a "next-added increment basis." This basic economic principle (i.e., does it make sense to invest in a project based on its stand-alone outputs?) has in practice presented significant analytical and policy challenges that have affected CERP implementation. These challenges involve quantifying ecosystem restoration benefits over large spatial scales, development and application of modeling and analytical tools with enough specificity and resolution to identify potential changes, characterizing uncertainties about ecosystem response, considering ecosystem restoration benefits in a traditional economic context (i.e., cost-benefit analysis), and societal values (e.g., is restoring estuarine habitat in Biscayne Bay more important than restoring ridge-and-slough habitat in Water Conservation Area 3A?).

This presentation will describe lessons learned from applying the basic investment concept of "cost justified by benefits" to watershed-scale ecosystem restoration planning in South Florida and CERP project implementation.

- Comprehensive plans for large (watershed) scale ecosystem restoration programs are difficult to evaluate and justify incrementally;
- Investment decisions are made based on comparison of ecosystem restoration benefits to cost;
- Next-added increment analysis as presently performed is affecting CERP project implementation;
- A new approach is needed for making investment decisions about ecosystem restoration projects.

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Measuring Nutrient Concentrations in Tributaries of Lake Okeechobee

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In the fall of 2003, 17 tributaries flowing into Lake Okeechobee were instrumented for continuous monitoring of discharge, stage, as well as water-quality parameters, specifically, total phosphorous (TP), total Kjeldahl nitrogen (TKN), total suspended solids (TSS), total dissolved inorganic phosphorous (PO_4), and nitrite plus nitrate (NO_2 + NO_3). Phosphorous concentrations in the tributaries of Lake Okeechobee are among the highest in the Nation, often exceeding 1 mg/L, and these values are generally associated with eutrophication of lakes and rivers. A major source of dissolved inorganic phosphorous is agriculture runoff and it is readily assimilated by aquatic plants and organisms. Results indicate that PO_4 constitutes about 70% of the TP in 12 of the 17 tributaries. The ratio of TP to PO_4 in the remaining five tributaries is more variable possibly due to land use, tributary discharge, or remediation efforts. Additional analysis may determine why these ratios differ in the five tributaries. Monitoring of all 17 tributaries is currently planned to continue through 2013.

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Occurrence and Distribution of Trace Metals in Sediment Samples from Protected Areas in South Florida

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As part of the Contaminant Assessment and Risk Evaluation (CARE) project, the concentrations of 20 metals (Be, V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sn, Sb, Ba, Hg, Pb, Al and Fe) were measured on surface sediments/soil samples collected at 30 stations in Everglades National Park, 9 stations in the Big Cypress National Preserve and 12 stations in Biscayne National Park between 2006 and 2007. Concentrations of metals were determined by ICP-MS. Since water deliveries to these three protected areas are being extensively modified by implementation of CERP projects and the increasing of urban development, the evaluation of certain heavy metals (Cr, Ni, Cu, Zn and Pb) are important to assess environmental degradation. Typical metal sources located around these parks include: the Homestead and Imolakee agricultural areas that require the application of large quantities of chemicals containing various heavy metals; the canal systems that drain the agricultural fields, the Black Point Landfill (the largest landfill in Miami), and several large marinas along the coastline of Biscayne Bay that collectively impact these parks and their resources.

Our results showed elevated concentrations of certain metals in regions of the study area that have anthropogenic influences. For Example: Cr, Ni, Cu, Zn and Pb were above the average at some stations in the East Boundary of the Everglades National Park (E1, E3, E4, E5, E6). This area is adjacent to the Homestead Agricultural Area and also it is used for the practices of the shooting schools that contribute to the high Pb levels. Two stations within Biscayne National Park (BB1 and BB10) showed higher than average concentrations of Cu, Zn and Pb. These stations are heavily influenced by the runoff from the South Dade agricultural area and the boat traffic, since BB1 and BB10 are located inside of two Marinas. Cu and Zn were enriched in several stations of Biscayne National Park and at structure S178 in the ENP. The lowest concentrations of metals were found in sediments with high calcium carbonate content at the southern part of the Everglades National Park, at stations C111-1, C111-2 (the C111 Basin) and TS2, TS3 (Taylor Slough).

Keywords: Metals, Sediments, Everglades, South Florida.

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Next Generation ATLSS Models for Everglades Restoration: Incorporating Variable Meshes

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The Across Trophic-Level System Simulation (ATLSS) project has produced a set of Spatially Explicit Species Index (SESI) models, population demography models, and ecosystem process models. These models have been applied to provide a relative assessment of biotic responses to alternative water-management scenarios as part of the Comprehensive Everglades Restoration Plan (CERP). In the past, hydrologic data for these scenarios have been produced by the South Florida Water Management Model (SFWMM), which uses an underlying uniform spatial grid of 2-mi x 2-mi cells. Future scenarios will be produced by hydrologic models that employ variable spatial grids and meshes across the model area of southern Florida. Models that use variable mesh hydrologic input for scenario evaluation can either (a) modify the model design to incorporate variable mesh structures internally or (b) regrid hydrologic data to the familiar uniform grid format. We discuss reasons for our decision to modify ATLSS models to incorporate variable meshes. We chose to preserve information about natural boundaries and flow patterns that would be lost in the regridding process.

ATLSS has undertaken a project to enable our models to process hydrologic data from variable-mesh hydrologic models, including MODBRANCH, WASH123D, and the South Florida Regional Simulation Model (SFRSM), while maintaining compatibility with the current SFWMM grid configuration. We describe two main components of this project: (a) development of Landscape v3.0 classes to handle hydrologic input in multiple underlying shapes and spatial resolutions; and (b) modification of the ATLSS SESI models to utilize the new Landscape classes. We describe steps in the conversion process and the basic tools we developed for input conversion, formatting, and data storage.

Processing variable grids requires a mechanism for implementing geo-referencing and connectivity that is independent of cell shape and relative position. To accomplish these goals, the revised Landscape classes implement a separation of data storage, cell shape information, and interconnectivity among cells. These three components are then incorporated into a unit called a Landscape Object. The new Landscape classes provide ATLSS models with the flexibility to handle varying spatial resolutions and underlying shapes (e.g. points, triangles, squares, and rectangles). This functionality will allow hydrologic data from variable-mesh models to be stored, accessed, and processed within the Landscape v3.0 classes, enabling ATLSS models to maintain a single set of code and run a common set of algorithms for all proposed hydrology meshes. The SESI White-tailed Deer model was modified to use the new Landscape classes, and incremental steps have been taken to modify other ATLSS models. We present results of trial simulations of the mesh-based Deer model with a test set of hydrologic data from SFRSM.

This project was undertaken in support of Critical Ecosystem Studies Initiatives (CESI) restoration goals that require a defensible scientific methodology to compare and contrast impacts to biota at the spatial and temporal scales of the alternative hydrologic plans being produced.

- Biotic models used in scenario evaluations should maintain compatibility with hydrologic models used to produce scenario input data.
- Variable meshes enable models to incorporate natural landscape boundaries and flow patterns.
- The ability to use a biotic model to evaluate outputs from multiple hydrologic models enables a critical comparison of assumptions and design features.

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The Role of ATLSS High Resolution Hydrology (HRH) Models in SFWMM Scenario Evaluations

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The South Florida Water Management Model (SFWMM) produces estimates of water depth across the Greater Everglades Landscape at a 2 x 2-mile scale of resolution. This coarse scale may be adequate to model the large scale movement of water through the various Everglades basins; however, a finer resolution is needed to capture species-level dynamics for modeling biotic responses to proposed hydrologic changes. Starting with the initial RECOVER scenario runs in the late 1990's through the present, ATLSS has provided methodologies for producing finer resolution hydrologic estimates from SFWMM outputs. ATLSS High Resolution Hydrology (HRH) models provide linkage between SFWMM hydrologic models and the ATLSS species models and landscape-change models.

The ATLSS High Resolution Topography (HRT) Model utilizes information about vegetative cover and historical water levels in the Greater Everglades Landscape to build a topographic map that provides elevation estimates at a finer resolution than is available from other sources. The HRT model utilizes: (a) hydrologic outputs from Calibration/Verification (CalVer) simulations from the South Florida Water Management Hydrology Model (SFWMM) at a 2 x 2-mile resolution, (b) several inputs to the SFWMM CalVer (the SFWMM elevation and soil saturation maps), and (c) vegetative land cover information from the Florida GAP Analysis Project (FGAP) at a 30 x 30-m resolution. The HRT model is one component of the ATLSS High Resolution Multi-Data Source Topography (HMDT) model, which combines HRT data with other topographic data sources (including LIDAR and HAED data sets from USGS) to create a single topographic map. The HMDT covers the model area of the SFWMM with a uniform raster grid made up of 500 x 500-m cells. The ATLSS High Resolution Hydrology (HRH) Model interpolates hydrologic output from SFWMM simulations over the resulting HMDT topography to generate water depth estimates at the 500 m resolution that do not modify the volume of water within any 2 x 2-mile SFWMM cell.

The ATLSS HMDT model creates a composite topography that is used in conjunction with SFWMM hydrology scenario outputs to generate ATLSS hydrology (HRH) at a 500 x 500-m resolution. To create the composite topography, the HMDT model uses the ATLSS HRT, the SFWMM 2 x 2-mile topography, and the same USGS LIDAR and HAED elevation data implemented in the SFWMM by the SFWMD.

The HMDT methodology and application on the SFWMM hydrology relies on three basic principals: 1) utilization of finer scale SFWMM source input for topography where indicated by the SFWMM; 2) application of ATLSS HRT in cells where other data sources are unavailable; and 3) conservation of water in any redistribution, so that no water volume is lost or added within a 2 x 2-mile cell.

The creation of a derived ATLSS High Resolution Hydrology(HRH) from the SFWMM hydrology scenarios creates a common hydrology source for use across the ATLSS biotic models, allowing for consistent scenario comparisons. The process has been in place, utilized and applied across the previous scenario runs and been distributed for current and future needs.

- Finer resolution than 2x2 mile cells are needed for ecological modeling.
- No single resource provides a complete picture of important variation within a SFWMM 2 x 2-mi cell.
- Vegetation responds to changes in hydroperiod and can provide an indication of localized variation.
- Conservation of water should be a first principle in any redistribution methodology.

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Aquatic Risk Assessment of Pesticides in Surface Waters in and Adjacent to Everglades and Biscayne National Parks

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An aquatic risk assessment under the U.S.EPA ecological risk framework was conducted for atrazine, metolachlor, malathion, chlorpyrifos and endosulfan in the C-111 freshwater basin (east boundary of Everglades National Park), northeast Florida Bay and south Biscayne Bay in south Florida. Based on use of the hazard quotient approach, measured concentrations of chlorpyrifos and endosulfan in surface waters suggest potential hazards to aquatic organisms and were therefore considered chemicals of potential ecological concern (COPECs). Problem formulation included an overview of the physical/chemical and environmental fate characteristics and aquatic toxicology of the COPECs. Background surface water exposure concentrations of endosulfan and toxicity data from laboratory and field studies indicate that fish and invertebrate mortality may be a concern when endosulfan is applied in agricultural areas near aquatic ecosystems.

A screening level aquatic probabilistic risk assessment was also completed to determine the potential risks of the COPECs-endosulfan and chlorpyrifos in surface waters of the C-111 freshwater basin (11 sites at east boundary of Everglades National Park) and adjacent estuarine tidal zones (two sites in northeast Florida Bay, one site in south Biscayne Bay) in south Florida. It focused only on the acute and chronic risks of endosulfan and chlorpyrifos individually and jointly with atrazine, metolachlor and malathion by comparing distributions of surface water exposure concentrations with the distributions of species toxicity data. The highest risk of acute effects was associated with endosulfan exposure on freshwater arthropods at S-178/ Site C on the C-111 system, followed by endosulfan effects on estuarine arthropods at Joe Bay in northeast Florida Bay. The highest risk of acute effects from joint toxicity of pesticides was to estuarine arthropods in Joe Bay followed by freshwater arthropods in S-178/SiteC. For fish, the highest acute risk was for endosulfan at S-178/Site C. There was low potential for acute risk of endosulfan to fish at estuarine sites. Joint probability curves indicated that the majority of potential risks to arthropods and fish were due to endosulfan concentrations and not to chlorpyrifos, at S-178/Site C. In addition, the highest risk of acute effects for salt water organisms was in Joe Bay, which receives water from the C-111. The potential risk of chronic effects from pesticide exposures was minimal at fresh- and salt-water sites except at S-178/Site C, where endosulfan concentrations showed the highest exceedence of species toxicity values. In general, potential risks were higher in February than June.

Several findings with implications for the South Florida restoration effort were made and these included:

- Atrazine was the most frequently detected pesticide at low levels but it was not a COPEC in surface waters of Everglades National Park and Florida Bay;
- Freshwater and saltwater organisms may be at risk at localized sites in south Florida as a result of endosulfan exposures; and
- Future ecological risk assessments for the restoration effort should consider the effects of acute and chronic exposures to the joint action of multiple stressors at low levels

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Hurricane Impacts on Mangrove Forests in Florida Coastal Everglades: The Importance of Sediment Deposition in the Biogeochemistry and Fertility of Mangrove Soils

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Hurricanes are frequent large-scale pulsing events that shape community structure and ecosystem function of tropical and subtropical systems. Mangrove forests are more susceptible to hurricane impacts because of their position in low-lying coastal regions. In October of 2005, Hurricane Wilma, a category 3 storm directly impacted mangrove forests in the Florida Coastal Everglades (FCE), including the Long Term Ecological Research (LTER) sites. The hurricane impacts resulted in a large-scale carbonate sediment deposition (over 3 cm) and severe damage to the forest canopy. The physical damage to mangroves was variable depending on the distance from the eye-wall, which influenced the degree of defoliation, tree mortality, and sediment deposition.

We examined the immediate impact of sediment deposition in several mangrove locations in southwestern Florida (Shark River, Broad River) and Florida Bay (Taylor River). In each of these sites, transects of different lengths ranging from 150 to 700 m were established perpendicular to the edge of the water to assess the physico-chemical properties, distribution and thickness of the sediment deposited. Duplicate sediment cores were collected at different intervals along each transect in December 2005 (Shark River, Broad River) and October 2006 (Buttonwood Ridge) with a piston corer (diameter = 2.5 cm; length = 11 cm). Sediment cores were divided into two layers, upper (hurricane deposit) and lower (pre-existing sediments) layers. The thickness of the upper layer ranged from 1.2 ± 0.2 to 4.5 ± 0.5 cm across sites. The depth of the lower layer was on average 9.1 ± 0.4 cm. Soil nutrient concentrations, bulk density, and inorganic and organic pools of phosphorus (P) were determined in the soil layers.

Averaged bulk density was consistently higher in the upper layer (0.57 ± 0.1 g cm^{-3}) relative to the lower layer (0.33 ± 0.19 g cm^{-3}) in all sites. Total carbon concentrations ranged from 66.4 ± 23 to 76.5 ± 11 mg cm^{-3} for the lower and upper layers, respectively. Total nitrogen averaged 2.4 ± 0.3 mg cm^{-3} in the upper layer and 2.8 ± 0.3 mg cm^{-3} in the lower layer. Total P (TP) concentrations ranged from 0.18 ± 0.05 mg cm^{-3} (lower layer) to 0.25 ± 0.1 mg cm^{-3} (upper layer). The contribution of TP by hurricane deposition to mangrove soils accounted for 6-63% of the TP already stored in the soils, previous to the hurricane event. The Ca bound-P fraction was the largest inorganic P fraction in the carbonate deposited sediments in all sites, comprising 25-35% of total P. The labile inorganic P fraction was the second largest pool, and accounted for up to 11% of total P.

These results highlight the significance of the Ca bound-P fraction in controlling the observed productivity patterns in mangrove forests of south Florida, as has been demonstrated along the freshwater-estuarine transect of Shark River estuary. Since in estuaries of the Everglades P is supply by the Gulf of Mexico, and not the oligotrophic upstream areas, this study contributes to our understanding of how different soil P fractions, specifically the Ca bound-P fraction is tightly coupled to productivity and biomass distribution gradients in mangrove forests of the FCE. Moreover, Hurricane Wilma provided an excellent opportunity to evaluate how these pulsing events regulate productivity of mangroves in south Florida and to understand mangrove resilience response to large climatic disturbances.

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Water Quality in Everglades National Park, Part I: Statistical Methods for Censored Data

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Water quality data are best summarized by estimating means, standard deviations, correlation coefficients, and quartiles and by providing information about outliers. This relatively simple task may be challenging for censored data. Water quality data are censored to indicate that the concentrations are less-than a threshold (left censored) and can not be precisely quantified. The threshold is typically the MDL (method detection level) or other similar quantification parameter. Analytical methods and laboratory equipment have evolved and improved over time and MDLs have become smaller. Now it is not uncommon for water quality datasets to have both single and multiple-censored analytes.

Water quality practitioners, for simplicity, often opt to use simple substitution methods to incorporate the "less-than" data into the statistical analyses. The most common substitutions opted are ½-MDL and 1-MDL. The simplicity of these methods, however, comes at an unrealized hidden cost: (a) loss of valuable information from ignoring the less-than values and (b) alteration of the sample's distribution by including arbitrary substitutions. These substitution methods, in general, could potentially alter, distort, and mask the real properties and characteristics of water quality constituents. Specifically, these substitutions produce higher means, smaller standard deviations and confidence intervals, and unrealistic lower quartiles. Alternatively, statistically sound methods are now readily available to deal with single and multiple-censored water quality data. These methods have been used in the medical science (survival analysis) for many years and are now being applied to the environmental sciences. Both parametric and non-parametric methods are available with several options for different sample sizes and amount of censored data.

In Part I of this study, the most commonly adopted substitution methods (zero, ½-MDL, and 1-MDL) are compared to a battery of methods specifically designed to deal with censored data. The information used and methods applied in this analysis comes from published literature. These methods were applied to data collected at Everglades National Park's water quality monitoring stations. For the Park's data series—greater than 150 records and less than 50 percent occurrence of MDLs—the two more dependable methods are the AMLE (adjusted maximum likelihood estimator) and the MR (log-probability plot). The AMLE method is better suited for log-normal series and the MR for non log-normal series. For series with a larger number of MDLs (50 percent < MDL > 75 percent), the MR and robust ROS (regression on order statistics) are recommended. The other methods considered were KM (Kaplan-Meier) and MLE (maximum likelihood estimator). In Part II of the study, the AMLE and MR methods are applied to interior water quality stations in Everglades National Park to compute summary statistics and to estimate temporal trends.

Water quality is a key element in many of the Comprehensive Everglades Restoration Plan projects. Achieving their water quality objectives and targets could be the difference between having a successful and an unsuccessful project. Thus, objectives and targets need to be carefully estimated, using the best techniques and methods available.

- Sound statistical techniques, rather than arbitrary substitution methods, must be used to characterize and report water quality conditions in the Everglades. These methods must be reliable, accurate, and technically sound to be accepted by the scientific community and withstand the challenges of legal proceedings.

- In pristine areas of the Everglades, nutrient, pesticides, and trace metal concentrations are low and often below the MDLs. Statistical summaries, computed using simple MDL substitutions, could estimate higher means, smaller standard deviations and confidence intervals, and unrealistic quartiles. Restoration projects based on these estimates could misguidedly try to achieve higher than desired water quality targets; impose an unrealistically narrow variance on the distribution of target values; or assume these erroneous estimates to be representative of base-line conditions.

- Many water quality restoration performance measures (PM) are formulated to achieve target concentrations that are derived solely from statistical analyses of historical water quality data. Limited availability of water quality numerical models stresses the need for robust, scientifically based methods for deriving PMs, PMs targets, and for assessing project alternatives.

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Effects of The Invasive Exotic Apple Snail (*Pomacea insularum*) on the Snail Kite (*Rostrhamus sociabilis plumbeus*) in Florida

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The Snail Kite (*Rostrhamus sociabilis plumbeus*) is an endangered raptor in the U.S. that exhibits an extreme form of dietary specialization, feeding almost exclusively on one species of freshwater snail, the Florida Apple Snail (*Pomacea paludosa* Say), which is the only snail of this genus native to Florida. Lake Tohopekaliga, one of the few remaining wetland fragments utilized heavily by the snail kite in Florida, recently experienced an infestation of the invasive exotic Island Apple Snail (*Pomacea insularum*), which is relatively larger (length, x = 63.5 mm; weight, x = 56.8 g) than the native apple snail (length, x = 37.6 mm; weight, x = 15.9 g). This relative size difference raised concerns about the ability of kites (especially juveniles) to successfully forage for exotic snails, and given the sensitivity of the kite population to recruitment, we conducted a comparative observational study to elucidate the effects of the exotic apple snail on snail kite foraging behavior, energetics, nest success, and survival.

Relative to native snails, we found that, on average, exotic snails require longer handling times (for adults, 302 vs. 72 seconds; for juveniles, 496 vs. 97 seconds), lead to increased drop rates (for adults, 0.21 vs. 0.02; for juveniles, 0.33 vs. 0.06), and result in depressed capture rates (for adults, 1.09 vs. 3.30 snails/hour; for juveniles, 0.78 vs. 3.46 snails/hour); however, we also found that exotic snails provide more energy than natives (12.92 vs. 4.84 kcal/snail). Consequently, the effects of the exotic snail on foraging behavior do not have negative energetic repercussions for adult kites. In fact, we found that adult kites are attracted to Lake Tohopekaliga and that the relative contribution of the lake to the range-wide nesting effort increased from 6% to 33% after the invasion of the exotic snail. Conversely, we found that the more significant negative effects of the exotic snail on juvenile foraging behavior can lead to insufficient daily energy balances and may suppress juvenile survival. Given the critically endangered status of the snail kite and the propensity of the exotic apple snail to spread, this work suggests that serious management and conservation initiatives that address the exotic apple snail may be necessary to prevent further deleterious consequences for the kite population in Florida.

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Tilling of Biomass in Treatment Wetlands: Influence on Treatment Efficiency and Soil Phosphorus Dynamics

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High phosphorus (P) loads associated with agricultural runoff have been implicated in the eutrophication of lakes and wetlands, such as the Everglades, throughout Florida. A key technology that holds considerable promise for controlling these loads in a cost-effective manner is the use of treatment wetlands. Water hyacinth (*Eichornia crassipes*) has been studied extensively and has been shown to be highly effective at removing P from agricultural runoff; however, the vegetation must be periodically harvested to maintain favorable plant growth. Widespread implementation of *Eichornia crassipes* treatment systems has been limited because specialized equipment is required for harvesting and because the value of the harvested plant biomass (e.g. as compost or as a feed ingredient) usually does not cover the costs of harvesting and processing. We are implementing a novel approach to deal with the harvested *Eichornia crassipes* biomass. Rather than periodically harvesting the biomass, we are investigating the utility of tilling the biomass directly into the soil when the standing crop becomes too dense. This could be a cost effective method of management as conventional farm machinery can be utilized. Additionally, because soils are the ultimate storage reservoir for P within treatment wetlands, this tilling approach may accelerate the rate of transferring organic matter and its associated P into permanent storage. In this study, we investigated the effect of tilling *Eichornia crassipes* biomass on treatment efficiency and soil P dynamics through observation of water quality and soil properties. A series of 24 mesocosms were closely monitored for a period of one year to evaluate changes in water chemistry and P pools within the soil. The mesocosms were periodically tilled and soil cores were taken to evaluate the P storage pools in each mesocosm as a function of time and vertical distribution in the soil profile. Phosphorus fractions within soil cores were identified using potassium chloride (labile), sodium hydroxide (Fe- and Al-bound) and hydrochloric acid (Ca- and Mg-bound) extractions. Initial findings suggest that the mesocosms have been effective in treating total P in the system by reducing P inflow concentrations by as much as 76.3%.

If tilling *Eichornia crassipes* biomass proves to be an effective management strategy for floating aquatic plant treatment systems, this technology may be implemented to reduce the total P load leaving agricultural fields and to potentially diminish eutrophication downstream. This study has several findings relevant to Everglades restoration efforts:

- The effective removal of TP from agricultural runoff;
- A potential improvement to current wetland treatment system technology; and
- A cost effective method of reducing P loads at the source.

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Comprehensive Everglades Restoration Plan: Cultural Resources Mitigation Strategies. A Cooperative Effort between USACE, SFWMD, SHPO, New South Associates and Janus Research

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The cultural resource evaluation process follows a series of steps. The posters by Garrett, New South Associates, and Janus Research discuss the long range planning, the survey strategies, and the site evaluation criteria. This poster discusses three CERP projects which provide examples of strategies developed by the Corps of Engineers, the South Florida Water Management District, and Florida State Division of Historic Resources to mitigate adverse effects to cultural resources that have been determined eligible for listing on the National Register of Historic Places. The first example is the completed data recovery effort conducted on site 8SL1181 which was destroyed by the construction of the Ten Mile Creek Water Preserve Area Critical Project located in St. Lucie County. The second example is mitigation measures proposed for three sites that are in the C-11 Impound of the Broward County Water Preserve Area. The final example is site 8SL1646 which will be impacted by the construction of the Indian River Lagoon South C-23/24 STA. Each site is unique and the potential impacts are different. These sites, and the mitigation strategies developed for them, provide an overview of strategies that are expected to be used for future CERP projects.

Cultural resource mitigation. CERP. Archeology.

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Aquatic Macroinvertebrates of Impacted and Reference Wetlands of the Western Everglades: Picayune Strand Restoration Project

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Prior to development, Picayune Strand was characterized by seasonal flooding and slow-moving overland sheet flow that supported a variety of plant and animal communities in uplands and freshwater wetlands. Channelization of water flows by canals and road construction resulted in elimination of sheet-flow across Picayune Strand (formerly Southern Golden Gate Estates), a severely lowered surficial aquifer within Picayune, and an erratically fluctuating freshwater point-source discharge to the estuarine ecosystem through Faka-Union Canal. The inland monitoring effort was intended to establish a pre-construction baseline for aquatic fauna that will later be used to evaluate environmental changes after the Picayune Strand Restoration Project (PSRP) is complete. The monitoring protocols utilized were developed for the rapid assessment of wetland fauna including fishes, aquatic macro-invertebrates, and larval amphibians. Aquatic macroinvertebrates consist of trophic groups inhabiting a range of wetland habitats, and can be expected to serve as useful indicators for evaluating success of the restoration. This study surveyed macroinvertebrate communities from 31 impacted wetlands consisting of cypress, cypress-graminoid, wet prairie, freshwater marsh, brackish marsh and hydric pine. In addition, 11 reference sites of similar plant communities were established on nearby, relatively undisturbed public lands. Six reference sites are located in Florida Panther National Wildlife Refuge and 5 reference sites are located in Fakahatchee Strand State Preserve, including one brackish marsh that receives seasonal freshwater sheet-flow.

Aquatic macroinvertebrates were collected using a standard D-frame dip-net in all of the major and minor micro-habitats (e.g. emergent and submergent vegetation, snags, roots, algal mats, benthos, rocks etc.) available at each site. Macroinvertebrates were field sorted using forceps and eye-droppers until no new species were observed for a period of 10 minutes, which is believed to approximate the asymptote of species accumulation curve. Generally, this required one hour of dip-net sampling and field sorting and level of effort was consistent throughout the study. Three sampling events were conducted each year during the middle and late wet season and early dry season to capture seasonal variations in water levels and community composition. Eleven (11) of the 31 impacted wetlands were found to have no standing water during the any of the six sampling events between August 2005 through February 2007 and, therefore no aquatic fauna were collected. All of the 11 reference wetlands were inundated for some time period during the study and were successfully sampled for wetland fauna. A total of 83 individual samples were collected during the baseline study period. At least 7,123 individual macroinvertebrates were identified including 182 distinct species (or taxa) representing no less than 6 Classes, 20 Orders, and 57 families. Of the 182 taxa, 125 operational taxonomic units (OTUs) were considered appropriate for the statistical analysis.

Species richness and diversity was highest in the reference wetlands of Fakahatcee Strand and the Florida Panther Refuge. This baseline assessment found that the shortened hydroperiods and altered sheet-flow in impacted wetlands of PSRP have disrupted aquatic communities. Impacted wetlands had relatively low faunal diversity, low % Bray-Curtis similarity between sites within the same habitat type, and had significantly different community structure ($p<0.05$). Cluster diagrams and MDS ordination plots were useful in illustrating similarity/dissimilarity (distances) between communities from impacted and reference sites –and- significance levels when combined with random permutation tests. Reference wetlands with natural hydroperiods and surface sheet-flow showed high similarity in community structure between sites and group closely together in the ordination, especially between cypress-graminoid, wet prairie and hydric pine habitat types. Aquatic macroinvertebrate community structure was significantly different ($p<0.05$) between impacted and reference wetlands sampled in this study. Several taxa were identified that may serve as indicators of hydrologic restoration in the PSRP, including but not limited to species of crayfish, *Procambarus alleni* and *P. fallax*; apple snails, *Pomacea paludosa*; dragonflies, *Pachydiplax, Libellula* and *Coryphaeschna*; damselflies, *Ishnura* spp.; mayflies, *Caenis, Choroterpes,* and *Callibaetis;* and many taxa of water beetles. Aquatic macroinvertebrate assessments were effective for detecting significant differences between impacted and reference wetlands –and- appear to be a rapid and cost-effective method for detecting changes in wetland hydropatterns (duration and depth) across many habitat types.

This study:

1. found significant differences in macroinvertebrate community structure between impacted and reference wetlands of the Western Everglades ecosystem.
2. identified landscape-level negative impacts of drainage activities on the trophic structure of wetland habitats of the Picayune Strand Restoration Project (PSRP).
3. identified several indicator taxa that may serve as hydrologic restoration success measures for PSRP.
4. demonstrated a cost-effective and quantifiable method for the assessment of wetland macroinvertebrates communities for Everglades Restoration projects.

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Fish Community Structure of Aquatic Refugia, Impacted and Reference Wetlands in Southwest Florida

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Aquatic refugia within the southwest Florida landscape exist along an ecological continuum that is geographically complex and temporally dynamic. During seasonal dry periods (and droughts) these aquatic refugia become critical features for the survival of fishes and wetland dependent fauna, including wading birds. In this study we investigated the role of different types of aquatic refugia for sustaining fish species and community structure in altered and natural landscapes of southwest Florida, specifically Picayune Strand State Forest and Fakahatchee Strand State Preserve. We surveyed the fishes of five different long-hydroperiod or permanent aquatic biotopes over a three-year period from April 2002 through May 2005. Aquatic refugia included anthropogenic canals, artificial ponds and tram ditches, and biogenic willow ponds and popash ponds. Using Breder traps we collected 66,455 fishes representing 12 families, 19 genera and 27 species, including 7 non-native species (some which were not previously known from the region). The overall most abundant species collected was the eastern mosquitofish, *Gambusia holbrooki*, averaging 82.4% average composition of all fish samples across all habitats. Also relatively abundant were sailfin molly, *Poecilia latipinna* (4.7%), Florida flagfish, *Jordanella floridae* (2.7%), bluefin killifish, *Lucania goodei* (1.8%), golden topminnow, *Fundulus chrysotus* (1.6%), dollar sunfish, *Lepomis marginatus* (1.3%) and Everglades pygmy sunfish, *Elassoma evergladei* (1.1%).

Cluster analysis and MDS ordination based on Bray-Curtis similarity, in conjunction with similarity profile (SIMPROF) and analysis of similarity (ANOSIM) tests, identified three distinct and significantly different ($p<0.05$) fish communities including: 1) canals and artificial ponds of Picayune Strand; 2) willow ponds of Picayune Strand, and 3) tram ditches and popash ponds of Fakahatchee Strand. In the Picayune Strand refugia, canals and artificial ponds were relatively high in species richness (16-21 species, mean =18) but were dominated by exotic cichlids and large predaceous species. Willow ponds were lower in species richness (9-13 species, mean =10.75) and dominated by live-bearers, Poeciliidae. This was attributed to hydrologic isolation and drainage of willow ponds that favors tolerant livebearers. In the Fakahatchee Strand refugia, native wetland fishes were dominant in both the popash ponds (15-17 species, mean = 16.5) and tram ditches (14-16 species, mean = 15) including Florida flagfish, Everglades pygmy sunfish, warmouth, dollar sunfish, marsh killifish, and golden topminnow. Fish communities from all Fakahatchee Strand refugia biotopes shared >76% similarity and as a group were significantly different ($p<0.05$) from canals, artificial ponds and drained willow ponds in Picayune Strand. The Fakahatchee Strand hydrologic conditions and fish communities are currently considered to be reference conditions for the Picayune Strand Restoration.

Between August 2005 and February 2007, aquatic fauna assessments were conducted for the baseline assessment of Picayune Strand Restoration Project (PSRP). Wetland fish communities were surveyed at 31 impacted wetlands in Picayune Strand and 11 reference wetlands in Fakahatchee Strand and Florida Panther National Wildlife Refuge. Surveyed wetland habitats include cypress, cypress-graminoid, wet prairie, hydric pine, freshwater marsh and brackish marsh. A total of 6,381 individual fish were collected by Breder traps during 6 baseline sampling events including 25 species representing 9 families. Several impacted wetland sites did not contain fish during the study period due to the effects of drainage canals. Multivariate cluster and MDS ordination analysis identified four significantly different groupings ($p<0.05$), with one large group that includes all reference sites and several of the impacted sites that were less drained. Bray-Curtis similarity, multivariate clustering and ordination techniques were useful for describing and comparing fish communities between hydrologically impacted and reference wetlands in southwest Florida. Restoration targets for fish community structure can now be established for Picayune Strand based on the results of these studies.

Combined, these fish studies:

1. identified significantly different fish communities from various aquatic refugia in the Western Everglades, including anthropogenic habitats and impacted and reference natural systems.
2. demonstrated the landscape-level negative impacts that drainage canals and roadways have on native fish species and communities across all wetland habitats.
3. identified specific restoration targets and performance measures for fishes in the Picayune Strand Restoration Project.
4. tested and developed cost-effective, rapid and quantifiable methods for the assessment of fish communities in restoration projects for southwest Florida.

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A Rapid Wetland Assessment Method Using Macroinvertebrates as an Indicator of Wetland Condition for Assessing Everglades Restoration

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The U.S. Fish and Wildlife Service recognized a need to develop a rapid assessment tool to evaluate existing benchmark condition and future ecological changes to wetlands associated with Comprehensive Everglades Restoration Plan projects. A Habitat Evaluation Team (HET) was formed to develop a process that balances the need for a scientifically based investigation of wetland biological condition with administrative timelines and cost. Three biological groups - plants, fish, and macroinvertebrates - were considered critical ecosystem components that can be used to assess biological condition through time. Indices from each of these groups will be combined into a single Ecological Condition Index.

The HET formed working groups composed of representatives from government agencies, universities, and environmental for-profit and non-profit organizations to seek advice for each biological group to develop specific methodologies. The multi-agency Invertebrate Working Group was given two constraints in the development of an index: 1) sampling was to be completed within one hour and 2) only field identifiable taxa could be used. A list of field identifiable taxa has been generated and is in the process of being field-tested. Also, a time-limited qualitative dip-net procedure for collecting field-identifiable macroinvertebrates that will provide a rating of wetland biological condition has been developed. At present, the method requires that one biologist, with an assistant**,** will sample representative wetland habitats for one hour, and puts no constraints on spatial coverage or number of dip-net sweeps taken. Fifteen macroinvertebrate metrics are currently being tested for efficacy in discrimination between wetlands in good condition and those impacted by hydrologic alteration and/or water quality degradation.

- Provides a rapid and cost-effective method to assess and monitor Everglades Ecosystem restoration projects.
- Evaluates baseline benchmark and post restoration biological condition of wetlands to be affected by Everglades Ecosystem restoration projects.
- Macroinvertebrates included in this method (crayfish and shrimp) will be used as performance measures for modeling in the Everglades Restoration Alternatives Analysis.
- Fifteen macroinvertebrate metrics intended as indicators of habitat quality, ecological function, and hydroperiod for Everglades Restoration projects are being assessed for effectiveness.
- The macroinvertebrate results will be integrated with plants and fish to provide an overall index of wetland condition or quality.

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Getting Ecological Models into the Hands of the Users: Joint Ecosystem Modeling

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The challenge of providing useful ecological models is complex and requires a variety of skills and resources. Joint Ecosystem Modeling (JEM), a partnership of Department of the Interior agencies (USGS, FWS, NPS), universities, and others, was established to address this challenge for restoration of the Everglades.

One aspect of the modeling challenge is identifying needs and opportunities for applying modeling in restoration efforts. This aspect includes identification of the appropriate use of a model in a certain context, whether it is as a learning tool to further understanding of an organism or system, an evaluation tool to explore the possible consequences of proposed restoration alternatives, or an assessment tool to aid in the adaptive management process. This aspect also includes identifying, as precisely as possible, the users of a model, so that the model and model-exploration tools can be tailored to their skills and needs.

Another particularly daunting aspect of the modeling challenge is the realization of conceptual models in computer software. The issue of obtaining usable input datasets for modeling is not trivial; proprietary software, disparate file formats, and documentation issues often complicate this part of the process. In modeling the Everglades, this issue manifests itself most notably in the difficulties that are encountered in obtaining usable hydrology data for ecological models. Often, hydrology data are delivered at a scale inappropriate for ecological modeling, in a file format that is closed or improperly documented, and/or in an untimely manner.

A closely related difficulty is that of developing software tools that expose the full potential of models as tools for restoration and management. Efficiently managing and processing large spatial datasets requires thorough knowledge of computer systems and software development. Development of intuitive software interfaces that allow unhindered exploration of models requires thorough understanding of human-computer interaction and interface design principles. There are over 30 ecological models in various stages of development in South Florida. However, because of the technical issues involved in realizing these models and making them accessible to decision-makers, few of these are actually accessible for the decision process, and even fewer are utilized to their full potential.

Finally, when models and model-exploration tools have been produced, they must be maintained and made available in a way that continues to serve those involved in Everglades restoration and management, and also serves as a foundation for future modeling efforts. Version control, change management, and modernization for updates of operating systems and software packages must all be considered to ensure continued availability of reliable and trustworthy models.

Projects developed under the Joint Ecosystem Modeling umbrella have addressed the above challenges in a variety of ways. Collaborations over the last two years have resulted in:

- Development and implementation of models (oyster, seagrass, aquatic fauna, amphibians, white ibis, wood stork, landscape connectivity) for the Southwest Florida Feasibility Study for the alternative-evaluation process, along with a custom data-visualization solution for the model output
- Development of tools to enable Everglades researchers for use with Everglades Depth Estimation Network (EDEN)
- Development and implementation of HSI models for crocodiles, spoonbills, and crayfish for use as both learning tools and in project evaluation and assessment
- Collaboration with staff at University of Tennessee, Everglades National Park, and the National Wetlands Research Center to bring ATLSS modeling tools to the Interagency Modeling Center where they will be commonly accessible

A live demonstration of several models and tools that have been developed by JEM, including the JEM Data Viewer, will be presented.

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Spatially-explicit Hydrodynamic and Water Quality Modeling of the A.R.M. Loxahatchee National Wildlife Refuge: Part I - Model Setup

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) is a 58,275 ha remnant of the Northern Everglades. Changes in water quantity, timing and quality have resulted in different levels of impacts to the Refuge. Therefore, a priority for the Refuge is the development of water quantity and quality models to identify appropriate water management strategies that will maximize benefits for protection of fish and wildlife, while meeting flood control, water supply uses. Modeling provides a better understanding of the impacts of contaminants and nutrient loading, and quantifies benefits of management alternatives.

This presentation focuses on the setup and application of hydrodynamic and water quality models for the Refuge. The spatially-explicit MIKE FLOOD and ECO Lab modeling frameworks (DHI) was used to simulate the hydrodynamics and constituents transport and transformation within the Refuge. This MIKE FLOOD implementation dynamically links a one-dimensional model of the 100km perimeter canal with a 400m uniform grid of over 3600 two-dimensional marsh model cells. Constituent transport is driven by modeled water flows and dispersion, as constituent concentrations are transformed through reactive and settling processes modeled within the ECO Lab framework.

Currently, the model simulates concentrations of chloride (CL), total phosphorus (TP) and sulfate (SO_4) concentrations in the canal and marsh. CL is modeled as a conservative (i.e. non-reactive) constituent, and has proven to be of value in identification of flow patterns within the canal and marsh. TP is modeled using a two state variable model structure analogous to that applied in the widely-used DMSTA model. SO4 is currently modeled using a simplified net disappearance rate that is modified at low concentrations by a Monod relationship. SO4 provides a constituent for calibration that compliments CL calibration.

Key message relevant to restoration:

- The MIKE FLOOD and ECO Lab modeling software can be used to simulate hydrology and water quality constituent concentrations in the Everglades;
- New 400m resolution hydrodynamic and water quality models for the Refuge are available for restoration planning applications;
- When compared with single constituent modeling, modeling multiple water quality constituents further constrains and tests model calibration, increases model credibility, and better identifies needed improvements in models;
- This spatially-explicit model runs on a typical PC with run times of roughly four hours per year of simulation.

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Analysis of Historical Vegetation Information in the Everglades Stormwater Treatment Area

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The Everglades Stormwater Treatment Areas (STAs) remove phosphorus (P) from stormwater runoff through biotic and abiotic processes and subsequently store P in decomposing litter and soils. Vegetation, including emergent and submersed aquatic plant species, plays a key role in P removal within the STAs. Historical vegetation information in the STAs was reviewed and analyzed on a cell by cell basis. Vegetation establishment and sustainability were analyzed against previous land use, topographic condition, adverse weather impacts, water levels, and toal P loading. A relationship of vegetation percent cover and P removal performance was examined within the six STAs based on historical data. Vegetation analysis shows that STA-1W and STA-5 had the lowest ratio of emergent to submersed aquatic vegetation (SAV) cover, compared with other four STAs. These two STAs also had the lowest P load reduction rate (41% and 55%) in comparison with other four STAs, where P load reduction rates ranged from73 to 86%. A correlation analysis demonstrates a positive relationship between the ratio of emergent to SAV cover and P reduction rate ($R^2 = 0.588$, $P<0.01$) and a negative relationship between the ratio of emergent to SAV cover and outflow total P concentration ($R^2 = 0.570$, $P<0.01$). The relationship between the ratio of vegetation cover and P removal efficiency within the STAs provides valuable information for STA vegetation management. Further studies are needed for a more in-depth understanding of the linkage between vegetation dynamics and P removal performance.

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Global Climate Change and Implications for South Florida

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This presentation will consist of three parts. The first part will be a review of the main findings of the most recent report on the scientific basis of climate change by the Intergovernmental Panel on Climate Change (IPCC, 2007). A second part will focus on aspects of climate change that are relevant for South Florida that have been published since the 2007 IPCC report. Topics include new results on rates of sea level rise, regional precipitation trends, patterns of surface temperature changes in the tropics, and hurricane development in a warmer climate. The final part of the presentation will be a synthesis of climate change in South Florida in terms of best and worst case scenarios for the future, and a discussion of the associated uncertainties.

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Application of a Multi-Modeling Framework to Linking Ecosystem Pattern and Process Across Scales: Implementation of a Decision Support Tool for Adaptive Ecosystem Management in the Everglades Mangrove Zone

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We report on recent advances in the development of a generic multi-level modeling framework for ecological modeling. This modeling approach supports the linking of hydrologic models and ecologic models in a manner that facilitates modeling processes at multiple scales, from individual organisms to landscapes.

The model framework includes an XML-based metadata format, support for a model repository allowing dynamic loading of model components specified by metadata, and a simulation server that provides a DEVS (Discrete Event System Specifications) environment for assembling and running hierarchical, modular models. The model framework utilizes open source software libraries and open geospatial and scientific data standards to exchange model state information between model components and between the simulation server and a user-friendly GIS client that supports running model simulations from a desktop PC.

To demonstrate the generality of the modeling approach, we present an application of the framework to implementation of the ALFISHES model, one of a suite of Across Trophic Levels Systems Simulator (ATLSS) models designed to assess the impact of changes in hydrology on a suite of higher trophic level species of the southern Florida ecosystem. The ALFISHES model combines field data with hydrologic data from the Southern Inland and Coastal System (SICS) model to assess the impact of salinity on fish biomass. The model output is linked to Spatially-Explicit Species Index Models (SESI) that may used to assess the impact of changes in hydrology on fish biomass and its availability to the Roseate Spoonbill (*Ajaia ajaja*), a key indicator species, and the American Crocodile (*Crocodylus acutus*).

The ALFISHES model implementation includes two different desktop client applications, one based on the JEM (Joint Ecological Modeling) Data Viewer and the other based on GeoTools (http://www.geotools.org), a Java-based open source GIS library, both of which provide natural resource managers with an interactive, graphical user interface for running model scenarios and visualizing and analyzing geospatial data output from model runs.

Summary:

- A generic multi-level modeling framework is used to implement a decision support tool for adaptive ecosystem management in the Everglades Mangrove.
- The modeling framework provides a Discrete EVent System specification (DEVS) environment for assembling and running hierarchical, modular models with support for both continuous- and discrete-time models.
- The application integrates physical and ecological models to access restoration impacts on fish, Roseate Spoonbills and American Crocodiles in Northeast Florida Bay.
- The application provides natural resource managers with an interactive, graphic user interface for running model scenarios and visualizing and analyzing model output.

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Indirect Effects of Hydrology and Hydroperiod on Water Quality in the Greater Everglades

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Direct anthropogenic modification of water chemistry has had clear consequences for the Everglades ecosystem; changes in phosphorus, mercury, sulfur, salinity and conductivity are well documented. Less well documented are the indirect effects of human ecosystem modification on water quality. For example, changes in hydroperiod can affect rates of organic matter metabolism, which can have important consequences on nutrient, carbon and possibly trace metal concentrations in the water column. Similarly, changes in flow regime can affect regional nutrient dynamics by altering habitat mosaics which in turn alter self-organized nutrient gradients. This work examines the indirect effects of hydrologic modification on water quality in detail. While relatively little literature exists to verify the magnitude of such indirect effects, we conclude by posing testable hypotheses that may lead to a better understanding of coupling between water quantity and quality. Implications for management are clear: if water quality can be affected along indirect causal pathways, then management alternatives to ameliorate water quality problems can be multi-faceted.

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Prescribed Fire Effect on Phosphorus Cycling and Ensuing Plant Repopulation in *Cladium jamaicense* and *Typha latifolia* Stands of the Florida Everglades

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Fire is an important part of the natural cycle in both uplands and wetlands, whether it occurs through natural means (lightning strikes) or by anthropogenic means (prescribed burning). Although upland prescribed burning has been extensively studied, wetlands prescribed burns have not. With man building ever closer to areas where natural burns would normally occur, there comes a need to control fires in these regions for the safety of the populace. So, as a means to continue the "natural" cycle, man has instituted prescribed burning as a necessary management strategy for natural areas that have evolved with regular fire events.

A significant feature of Everglades restoration focuses on water quality; therefore we seek to study the use of prescribed burning, and its effect on water quality, both spatially and temporally, to better predict effects of fire and to account for prescribed fire events in relation to evaluating restoration efforts. A second objective of this work is to monitor subsequent recruitment of specific plant communities within the burned areas. *Cladium* being the primary vegetation of the Florida Everglades and an important concern in the restoration and preservation of this vast wetland, the study of conditions necessary to minimize or negate the proliferation of nuisance species is needed, namely *Typha* in areas opened by fire events.

The data presented at the time of the conference will be as current as possible to the conference date, but this is a work in progress.

- Preliminary data analysis shows phosphorus release to the water column, from a large prescribed burn, to be relatively low
- Preliminary data analysis appears to show no detrimental effects on water quality either spatially or temporally
- At this time, it appears that prescribed fire, in the presence of standing surface water, does not encourage recruitment of undesired species (i.e. *Typha*) in *Cladium* stands

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Development of Soft Sensors for Real-time Quality Control of Water-level Data for the EDEN Network

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The Everglades Depth Estimation Network (EDEN) is an integrated network of real-time water-level gaging stations, ground-elevation models, and water-surface models designed to provide scientists, engineers, and water-resource managers with current (2000-present) water-depth information for the entire freshwater portion of the greater Everglades. The U.S. Geological Survey Greater Everglades Priority Ecosystem Science Program provides support for EDEN with the goal of providing quality-assured monitoring data for the U.S. Army Corps of Engineers Comprehensive Everglades Restoration Plan. The generation of EDEN water-level surfaces is dependent on high quality real-time data. Data are automatically checked for outliers using minimum and maximum thresholds for each station. Smaller errors in the data, such as gradual drift of malfunctioning pressure transducers, are more difficult to immediately identify with visual inspection of time-series plots and may only be identified during on-site inspections of the gages. Correcting smaller errors in the data often is very time consuming and water-level data may not be finalized for several months. To provide daily water-level surfaces on a near real-time basis, EDEN needed an automated process to identify errors in water-level data and to provide estimates for missing or erroneous water-level data.

A technology often used for industrial applications is “soft sensors.” Rather than installing a redundant sensor to measure a process, such as an additional water-level gage, a soft sensor (virtual sensor) is developed that makes very accurate estimates of the process measured by the hard sensor. The soft sensor typically is an empirical or mechanistic model using inputs from one or more proximal gages. The advantage of a soft sensor is that it provides a redundant signal to the sensor in the field but without the environmental threats (floods or hurricanes, for example). In the event that a gage does malfunction, the soft sensor provides an accurate estimate for the period of missing data. The soft sensor also can be used in the quality assurance and quality control of the data. The virtual signal can be compared to the real-time data and if the difference between the two signals exceeds a certain tolerance, corrective action can be taken. Soft-sensors for gages in the EDEN network are currently (2008) under development. The soft sensors will be automated so that the real-time EDEN data will continuously be compared to the soft-sensor signal and digital reports of the status of the real-time data will be sent periodically to the appropriate personnel.

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Hindcasting Water Levels for EDEN Gaging Stations, 2000-2006

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The Everglades Depth Estimation Network (EDEN) is an integrated network of real-time water-level gaging stations, ground-elevation models, and water-surface models designed to provide scientists, engineers, and water-resource managers with real-time water-depth information for the entire freshwater portion of the greater Everglades. To increase the accuracy of the water-surface models, 25 real-time water-level gaging stations were added to the network of 253 established water-level gaging stations. To incorporate the data from the newly added stations to the 7-year EDEN database in the greater Everglades, the short-term water-level records (generally less than 1 year) needed to be simulated back in time (hindcasted) to be concurrent with data from the established gaging stations in the database to be used to create water-level surfaces. A three-step modeling approach using artificial neural network models was used to estimate the water levels at the new stations. The artificial neural network models used static variables that represent the gaging station location and percent vegetation in addition to dynamic variables that represent water-level data from the established EDEN gaging stations. The final step of the modeling approach was to simulate the computed error of the initial estimate to increase the accuracy of the final water-level estimate.

The three-step modeling approach for estimating water levels at the new EDEN gaging stations produced satisfactory results. The coefficients of determination (R^2) for 21 of the 25 estimates were greater than 0.95, and all of the estimates (25 of 25) were greater than 0.82. The model estimates showed good agreement with the measured data. For some new EDEN stations with limited measured data, the record extension (hindcasts) included periods beyond the range of the data used to train the artificial neural network models. The comparison of the hindcasts with long-term water-level data proximal to the new EDEN gaging stations indicated that the water-level estimates were reasonable. The percent model error (root mean square error divided by the range of the measured data) was less than 6 percent, and for the majority of stations (20 of 25), the percent model error was less than 1 percent.

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Integration of Hydrologic and Ecological Studies of the Snail Kite – Enhancements to the Snail Kite Decision Support System

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Hydrologists and ecologists have been working on integrating a long-term hydrologic data network and a short-term ecological database to support ecological models of the habitat of the snail kite, a threatened and endangered bird. Hydroperiods of water depths have a significant affect on the nesting and foraging of the snail kite. Data mining techniques, including artificial neural network (ANN) models, were applied to simulate the hydrology of snail kite habitat in the Water Conservation Area 3A of the Florida Everglades. Seventeen water-depth recorders are co-located at transects where extensive plant sampling is ongoing. These continuous recorders were established in 2002. Using inputs representing the three long-term gages, very accurate ANN models were developed to predict the water levels at the 17 short-term sites. The models were then used to hindcast water levels at the 17 short-term sites back to 1991. The result was extended water-level records to assist scientists to better understand how the snail kite's habitat is affected by changing hydrology. A Decision Support System (DSS) was developed to disseminate the hindcast models in an easily used package. The DSS is a spreadsheet application that integrates the models and database with interactive controls and streaming graphics to run long-term simulations.

At each continuous monitoring location, vegetation samples are collected twice a year. For each vegetation sampling site (over 6,000 sites), ecologists need to know the water-depth hydrograph. To better meet the needs of the plant ecologists, several enhancements have been made to the Snail Kite DSS. The DSS enhancements include the generation of water-depth hydrographs at each vegetation sampling site in addition to reading and writing vegetation data to external databases. Other enhancements include hindcasting the hydrology data to 1962, additional statistics (hydroecological indices), updating the application with retrained ANN models, generation of elevation transects at the continuous monitoring locations, and writing of a user's manual for the DSS. The application demonstrates how very accurate empirical models can be built directly from data and readily deployed to end-users to support interdisciplinary studies.

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The Role of Biotic Processes on Soil Accretion and Elevation Change in Mangrove Forests in South Florida

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Sediment surface elevation is a critical factor affecting wetland structure and function, especially in environments with tidal influence, such that of Florida Bay and adjacent mangrove wetlands. If elevation cannot keep pace with sea level rise, progressive waterlogging, plant death, erosion, and submersion results in wetland loss. Subsidence can lead to relative sea-level rise (RSLR), which is often much greater than eustatic rise. The current rate of eustatic sea-level rise worldwide is 1-2 mm yr-1, but relative sea-level rise in deltaic environments is much greater (5 to 10 mm yr-1). On another hand, plants contribute directly to soil formation through input of organic matter, but no empirical information directly links specific biotic processes to elevation change in mangrove ecosystems. This type of information is necessary to accurately predict the future responses of coastal subtropical forested wetlands to sea-level rise and their interactions with other factors affecting biological processes, such as inland expansion. In addition, little information exists on how peat formation and elevation change may be affected by changes in freshwater flow and nutrient input once the Comprehensive Everglades Restoration Plan is in place.

The objective of this study was to better understand processes controlling elevation change in mangrove systems by analyzing relationships among mangrove soil surface accretion, soil surface elevation change, and a suite of physical and biological characteristics, such as relative sea-level rise, above and belowground processes, and soil organic matter and bulk density. Study sites are located along two contrasting fertility mangrove settings that have been impacted by hurricanes in the recent past (Shark River and Taylor River Sloughs, South Florida). We tested the hypothesis that patterns elevation change and soil accretion patterns are controlled by of spatial and temporal variability of above- and belowground processes, which on turn are driven by environmental factors including sediment input, hydroperiod, soil salinity and fertility.

Results from ten-year study period (1998-2008) show that litterfall production is significantly higher in mangrove forests located in Shark River (ranging from 5 to 10 t ha^{-1} yr^{-1}) than in mangrove forests associated to Taylor River (ranging from 3 to 5 t ha^{-1} yr^{-1}). Mean belowground biomass varied significantly among sites ranging from 357 to 3117 g m^{-2}. Root productivity (<10 mm root diameter, to a depth of 90 cm) ranged from 407 to 643 g m^{-2} yr^{-1} with higher rates in Shark River compared to Taylor River sites. Similar patterns were observed for a one-year long study of root decomposition with higher rates at Shark River than at Taylor River. As for accretion and elevation change, results show that average vertical accretion was higher at Shark River than in Taylor River (6.6 mm yr^{-1} and 3.9 mm yr^{-1}, respectively. Over the ten-year long study period, elevation change has been very small, averaging 8.8 mm yr^{-1} in Shark River and 1.2 mm yr^{-1} in Taylor River. These rates of elevation gain or lost and biotic processes suggest that mangrove forests associated to sediment input from the Gulf of Mexico may be able to keep pace with the predicted accelerated sea level rise. In contrast, mangrove forests associated to Northern Florida Bay may not be able to keep pace with increase sea level rise.

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Effects of Vegetation and Soil Management Practices on Phosphorus Fluxes from Phosphorus-Enriched Sediments in WCA-2A

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A nutrient gradient has developed in the northern region of WCA-2A as a result of historically high concentrations of phosphorus (P) in drainage waters. Drainage water P inputs have resulted in vegetation changes, as well as accumulation of high P sediments: P concentrations in sediments have increased from 500 mg/kg in the non-impacted areas to 1500 mg/kg in the impacted region. Recently, much of the water entering WCA-2A is being treating by Stormwater Treatment Areas (STAs), resulting in a reduction in drainage water P concentrations. With the large differential in concentrations between the P-laden sediments and the low P in the water column, P release from the enriched sediment into the surface water is likely to occur.

A sediment core study was initiated in December 2006 to examine the effects of various management practices on the release of P from enriched sediments. Thirty large (45.5 cm diameter) "barrel cores" were collected from two sites within WCA-2A, wherein each core included at least one intact cattail plant (*Typha domingensis*). The first site is a highly impacted area in which sediment total phosphorus (TP) concentrations average 1485 mg/kg at 0-10 cm and 1330 mg/kg at 10-30 cm sediment depths. The second site is a moderately impacted area with average sediment TP concentrations of 1085 mg/kg at 0-10 cm and 596 mg/kg at 10-30 cm sediment depths. After relocating to an outdoor facility, cores from each site received the following treatments in triplicate: 1) control (no treatment); 2) herbicide (2% glyphosphate) to kill the cattails; 3) herbicide followed by a calcium (as $CaCO_3$) application of 1 cm thickness over the sediment surface; 4) herbicide followed by an iron (as $FeCl_3$) application to the sediment surface at a rate of 100 g Fe/m^2; 5) scraping (removal) of the top 40 cm of surface sediments.

All flow-through cores were supplied with STA-treated water from March 27, 2007 to March 19, 2008 with an average inflow TP concentration of 29 µg/L. To date, the "no-herbicide controls" for both the highly impacted and moderately impacted sediments had an overall outflow TP concentration of 42 µg/L. Outflows from both sediment types tended to follow the patterns of the inflow concentrations over time. All cores that received herbicide had a significant spike in TP release after the initial application and before the addition of chemical amendments. Compared to the $FeCl_3$ treatment, the $CaCO_3$ amendment consistently yielded lower outflow TP concentrations: 49 µg/L for the moderately impacted and 67 µg/L for the highly impacted sediment cores. The $FeCl_3$ treatment had the highest and longest rate of TP release, with outflow P concentrations gradually decreasing after 7-8 months of flow. The scraped treatment yielded the lowest and most consistent TP concentrations: 17 µg /L and 27 µg /L for the moderately and highly impacted sediments, respectively.

The initial results of this on-going investigation suggest that removal of the uppermost 40cm of sediment in the P impacted areas of WCA-2A will result in little to no net P release to the water column. Adding herbicide will result in a flush of P from the decomposing cattail litter for a period of months, although adding a blanket of $CaCO_3$ will mitigate the release to some extent. Adding iron after herbicide application may mobilize sediment P. Finally, leaving the existing cattail community as is (without treatment) is likely to result in a low, continual release of P to the water column.

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A Model for Sustainable Management of Brazilian peppertree, *Schinus terebinthifolius* (Anacardiaceae), in the Greater Everglades

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Brazilian peppertree, *Schinus terebinthifolius* Raddi (Anacardiaceae), is an aggressive, rapidly colonizing invasive weed of disturbed habitats, natural communities and conservation areas in peninsular Florida. Once established, Brazilian peppertree quickly displaces the native vegetation, often forming dense monocultures that reduce the biological diversity of plants and animals in the invaded area. This invasive shrub is considered an important invader of the Everglades National Park, and poses a significant threat to ongoing Greater Everglades's restoration efforts. Herbicides and mechanical or physical control practices (e.g., cutting, burning and flooding) are routinely used often in combination for controlling existing Brazilian peppertree stands, but these conventional methods are expensive, labor intensive and provide only temporary control due to the plant's regenerative capacity. Furthermore, non-selective chemical and mechanical controls are unsuitable for sensitive natural areas (e.g., coastal mangrove forests) because they can have negative effects on non-target species and increase water pollution. Minimizing the use of herbicides and other non-selective control practices is needed to maintain the integrity of the Everglades ecosystem. The objective of this research/demonstration project is to provide land managers with a predictable IPM strategy for addressing the Brazilian peppertree problem. A model system was developed that integrates natural processes such as biological control (top-down effect) with interspecific plant competition and allelopathy (bottom-up effect) to provide an environmentally acceptable, cost effective, and permanent solution to the Brazilian peppertree problem in Florida. The overall goal is to shift the successional dynamics of public and privately owned lands in the Greater Everglades currently dominated by Brazilian peppertree towards more desirable plant communities where the plant is reduced to a minor component of the flora. Adopting this IPM model will minimize herbicide use and improve wildlife habitat in plant communities of the region currently dominated by Brazilian peppertree.

- Conservation organizations and land managers in south Florida consider the management of Brazilian peppertree a high priority because it poses a significant threat to regional Everglades restoration efforts authorized by CERP.
- Critical ecological processes that direct plant community dynamics to the detriment of Brazilian peppertree are identified in the model and can be modified to produce predictable results.
- Natural regulating factors such as plant competition and allelopathy can be manipulated to increase their impact on Brazilian peppertree control, and host specific biological control agents will be introduced to restrict seed production and reduce the vigor of new seedlings and regrowth from treated stumps.
- The key elements for sustainable management of Brazilian peppertree in the Greater Everglades are designed disturbance, controlled colonization, and controlled species performance.

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Marine High-Resolution Seismic-Reflection Data in Biscayne National Park: Indications of a Regional Seal Bypass System

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In southeastern Florida during 2007, about 108 km of marine, multichannel, high-resolution, seismic-reflection data were acquired almost entirely inside Biscayne National Park at water depths ranging from about 0.9 to 100 m. Fourteen profiles were acquired between the shoreline of the Florida peninsula and a series of small keys that separate Biscayne Bay from the Atlantic Ocean. Additionally, three profiles were collected eastward of the islands with two extending seaward of the present-day shelf margin and its discontinuous reefs. The set of seismic images from the 17 profiles is providing recognition of intriguing geologic features beneath and beyond Biscayne Bay. For example, the seismic sections provide clues as to the sealing capacity of confining units above a highly permeable zone (Boulder Zone) in the lower part of the Floridan aquifer system used on the southeastern peninsula for deep well injection of treated wastewater. Many of the seismic profiles exhibit continuous vertical disturbances in parallel seismic reflections that correspond to the rocks of the karst Floridan aquifer system and overlying intermediate confining unit. These features indicate fractures that disrupt seismic reflections representative of confining units and may allow ground water to flow across confinement. Combined, the fractures could act as a regional seal bypass system. If this bypass system allows cross-stratal fluid migration, it could provide many pathways for upward directed ground-water flow with leakage to higher hydrostratigraphic levels or to the surface as submarine ground-water discharge. Future research will include acquisition of additional marine seismic profiles and the use of streaming marine resistivity profiling and radon water column mapping. These data will be used to investigate the source waters of submarine ground-water discharge to Biscayne Bay, which could be associated with the fractures imaged on the seismic sections.

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Ecological Windows of Opportunity for Florida Apple Snail Recruitment

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The Florida apple snail (*Pomacea paludosa* Say) has a life history adapted to water level fluctuations, including drying events, which occur in their 12-18 month life span. A myriad of predators consume the snail, and they have been identified as a barometer of wetland ecosystem health in the Greater Everglades Ecosystem. Through several field and lab studies, we have studied their demography with an emphasis on how water depths and the timing of water level fluctuations impact survival, reproduction and growth.

In an analysis of our data and that from other investigators, we find ~80% of annual egg cluster production occurs in April-June. During this critical period, water levels under natural conditions typically recede or remain relatively stable. Other published studies indicate that these conditions promote egg production. If a drying event occurs, no egg cluster production occurs, so in those years we expect a reduction in overall egg cluster production. In the context of the opposite hydrologic extreme, we have recently acquired data that shows high water, especially in March-May, suppresses egg production. High water (depths > 70 cm) in WCA3A resulted in egg production approximately 10% of the production where we found similar snail densities but where water depths where <40 cm. In years with relatively high water conditions, the field egg index (eggs produced per snail), falls below 1.0. When depths fall below ≈40 cm, the egg index ranges from 2 to 11. [We have additional analyses to complete.]

Through previously published size-frequency distributions and our own laboratory data on snail growth rates, we have identified a critical post-hatch growth period for hatchling snails to survive an ensuing dry down. Snails with shells <20 mm shell width exhibit higher rates of mortality in dry conditions compared to adult snails. Consequently, the timing of dry downs determines the opportunity for juvenile snail growth that has direct bearing on survival (and therefore overall annual recruitment). As with egg cluster production, we also have data (albeit limited) that indicates high water suppresses snail growth.

Water temperatures below approximately 21˚C results in significant declines in general activity and consequently reproductive behavior. By combining temperature data with information on hydrologic conditions, we have constructed a conceptual model of the ecological window of opportunity for apple snail recruitment. This model will be interpreted in the context of water management schedules and restoration activities in the Greater Everglades Ecosystem.

- Apple snail recruitment is sensitive to a number of environmental conditions
- We have developed a conceptual model to define the conditions that promote recruitment
- Our findings have direct implications for water management and Everglades restoration

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Field and Lab Studies of Less Charismatic Predators of Florida Apple Snails

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The Florida apple snail (*Pomacea paludosa*, Say) is best known as the nearly exclusive prey of the endangered snail kite (*Rostramus sociabilis*) and other relatively 'charismatic' predators (limpkins, alligators, etc.). These larger predators target the adult sized snails, but juveniles hatch out at 3-4 mm in diameter; consequently snails could be vulnerable to a wide variety of small aquatic predators. We hypothesized that relatively diminutive aquatic vertebrate and invertebrate predators of juvenile apple snails play a significant role in snail population regulation. An assessment of predation rates on juvenile snails by these less charismatic predators is paramount to understanding the demography of this ecologically important snail.

We approached our study of juvenile snail predation in three phases. First, we captured potential predators from the field and placed them in tanks to observe whether or not they would eat 3- 15 mm diameter apple snails. Second, we conducted a series of lab trials using confirmed snail predators, crayfish (*Procambarus allenii*) and mud and musk turtles (*Kinosternon bauri, Sternotherus odoratus*), to quantify predator-prey size relationships. Third, we conducted field trials of predation rates using tethered snails [the tethering approach was validated in controlled laboratory studies]. Snails ranging in size from 4-20 mm were tethered to poles placed in three study sites in WCA2B; each site had 30 tethering stations. We checked each station every three days during two 12-d trials, and we replaced tethered snails that had been preyed upon. We also set traps to collect fish and turtles in order to assess the relative abundance of predators in each of the three sites.

We observed the following species (in addition to crayfish and turtles) eat apple snails: Bluegill (*Lepomis macrochirus*), Redear sunfish (*Lepomis microlophus*), Mayan cichclid (*Cichlosoma urophthalmus*), Seminole killifish (*Fundulus seminolis*), and Greater Siren (*Siren lacertina*). Crayfish with carapace lengths of 15 to 35 mm ate snails from 4 to 12 mm in approximate diameter (regression results; R^2=0.69 n=12, P=0.0008). Musk and mud turtles with carapace lengths 35-95 mm ate snails from 8-22 mm in diameter (R^2=0.77, n=18, P=0.0008). In the field trials, predation rates averaged 8% per day per across all sites and snail size ranges. There was generally lower predation in sites with relatively fewer captured predators (statistical analyses to be completed).

Our data clearly indicate that small 'less charismatic' predators like crayfish and small turtles prey on juvenile apple snails. The field study indicated that aquatic predators consume a significant proportion of available juvenile snails. Any potential bias in using the tethering approach will be discussed, and additional detailed analyses will be presented.

- We documented several previously unidentified predators of juvenile apple snails
- Snail sizes consumed were a direct function of predator size, such that predation occurred on all size snails from hatchling to adult.
- Quantifying predation rates is critical to understanding what regulates populations of Florida apple snails, a species considered a barometer of Greater Everglades ecosystem health.

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Long-term Water Quality Trends and BMPs in the Everglades Agricultural Area

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The Best Management Practices (BMPs) program in the Everglades Agricultural Area (EAA) basin in south Florida was implemented basin wide in 1995 as mandated by the Everglades Forever Act (EFA) passed by the Florida state legislature in 1994. The EAA basin, located south of Lake Okeechobee and north of the Water Conservations Areas (WCAs), is comprised of organic soils totaling approximately 280 000 ha. The EAA is mainly farmed to sugarcane, vegetables, rice, and sod. On-farm water management in the EAA is achieved by groundwater flow through the organic soils and by surface flow in open field ditches and canals to raise or lower the field water tables. Rainfall is highly seasonal and frequently intense, requiring growers in the EAA to actively drain excess water from their fields. Drainage is accomplished through an extensive array of canals and pumps both on- and off-farm. Concerns about the quality of the drainage water, specifically elevated Phosphorus (P) content water, leaving the EAA and entering the WCAs prompted the legislature to adopt the Everglades Regulatory program, part of the EFA, with a goal to reduce EAA basin P loads by 25% compared to a pre-BMP baseline period. Growers are required to implement a suite of BMPs and conduct monitoring of daily rainfall, drainage volume, and P concentration. This is done through a BMP permit issued by the South Florida Water Management District (SFWMD). A point system is used to rate the BMPs and the suite of BMPs implemented must total 25 points as a base level of effort. The list of approved BMPs for the EAA basin includes nutrient controls, water management techniques, and particulate matter and sediment control methods. Other BMPs can be implemented and claimed on the BMP permit if shown to be effective and are approved by the SFWMD.

The EAA basin is monitored for runoff volume and P concentrations by the SFWMD to determine compliance by water year (May 1 to April 30). The SFWMD has multiple inflow and outflow monitoring stations located throughout the EAA to determine basin P load. During the 12 years since basin-wide, BMP program implementation, the EAA basin has achieved an average P load reduction of 50% relative to the baseline period from 1978 to 1988. The EAA continues to meet the required performance levels of the EFA as evidenced by an average reduction in total P loads of 46 percent over the past three years. The EAA basin is divided hydrologically into four sub-basins. The runoff volumes between the sub-basins have typically shown an even distribution of each sub-basin's contribution to the total EAA basin runoff volume, but runoff total P loads show a wide range of variation between the different sub-basins. Typically, if the S-5A sub-basin receives more rainfall than the other sub-basins, then runoff P loads from the S-5A sub-basin is correspondingly higher (30 to 50 percent of the EAA basin P load).

In addition to the data collected by the SFWMD and individual EAA landowners for compliance purposes, the University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS) conducted a BMP research project on ten EAA farms from 1992 through 2002. The project monitored BMP implementation and efficacy and related P load parameters and produced a dataset that contained detailed farm data, e.g. canal levels, flows, discharge water P concentrations, and land use maps. A recent comprehensive statistical analysis of the dataset determined factors that may be affecting BMP performance in the EAA basin. Factors examined included rainfall, soil depth, land use, farm location within the EAA, irrigation water quality, farm size, and rainfall detention amount. Drainage water P concentrations and loads from the UF/IFAS farms in S-5A and S-6 sub-basins were significantly higher than drainage water P concentrations from the S-7 and S-8 sub-basins. This mirrors what is observed in the EAA basin as a whole. It was difficult to quantify the importance of factors impacting P loads in the EAA, but the results from the analyses conducted (multivariate regression, Spearman correlation, and classification and regression tree analyses) were confirmatory. The analyses indicated that water management and cropping practices are important predictors for farm P load in the EAA. Higher P loads were predicted with higher drainage volume to rainfall ratios, and higher canal head difference. Lower P loads were associated when sugarcane was the main crop in the farm cropping rotation. The analysis also showed that irrigation water quality from Lake Okeechobee is deteriorating and has an impact on P loads from sugarcane farms. A relationship between soil depth and flooding of soils in the summer on P load was also revealed by the analysis. Trend analysis on farm data showed a decreasing trend in P loads for seven farms, while three farms had insignificant trends. Trend analysis was also conducted on irrigation water discharged from three outflow locations from Lake Okeechobee and showed increasing trends in P concentrations. The irrigation water P concentrations were highest from canals serving the S-5A sub-basin and lowest for the S-8 sub-basin.

Although the BMP program has been quite effective in reducing P loads in the EAA overall, there is still uncertainty concerning the efficacy of BMPs as evidenced by the variability of load reduction across the sub-basins in the EAA. High inflow total P concentrations from Lake Okeechobee to the EAA are often cited as cause of concern in maintaining the actual performance level of BMPs reducing total P loads because the lake is a major source of irrigation water. The relationship between the lake inflow and EAA basin P levels is worth investigating to ascertain the impact on the performance of the BMPs in the EAA. Deeper soils and higher P concentration irrigation water from the West Palm Beach Canal in the S-5A sub-basin may be important factors contributing to higher P loads and concentrations in runoff from this sub-basin. Other factors include changes in cropping and management practices.

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Spatial and Temporal Nutrient Dynamics in the Mangrove Ecotone of Taylor River, Florida

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The Southern Everglades mangrove ecotone is part of a highly oligotrophic estuarine ecosystem. The primary vegetation is composed of dwarf red mangrove (*Rhizophora mangle* L.). The hydrology of the Southern Everglades mangrove zone is micro-tidal (<5 cm tidal range) and seasonal in rainfall and discharge (wet and dry season). We conducted seasonal sampling to understand controls on nutrient dynamics in this ecotone. Water temperature, salinity, pH, and dissolved oxygen were measured hourly during each sampling period. We also sampled surface water nitrogen (total and inorganic) and phosphorus (total and inorganic) every six hours at upstream and downstream locations for 7 days during each sampling. We saw clear, seasonal differences in water quality between trips as well as between the upstream and downstream ends of this ecotone. Flows in Taylor River, wind, and tidal forces seemed to have significant influence on the surface water quality dynamics. Benthic flux data from batch core experiments showed net heterotrophy, plus negative flux of NOx and phosphate (i.e., from water column to sediment) and release of ammonium to the water column. Phosphate addition resulted in increased P uptake from water column to sediment. Continued studies will continue to focus on temporal and spatial patterns in water quality and nutrient dynamics in Taylor River and exchanges with Florida Bay. We will also continue core incubation studies to further understand the controlling factors of nutrient exchange between sediment and water column in this mangrove ecotone of Everglades National Park.

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Current Status of Across-Trophic-Level System Simulation (ATLSS) for the Wetland Systems of South Florida

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The ongoing goals in the ATLSS project have been the following: 1) As part of the ATLSS Program combine biological and physical models using multiple approaches, including trophic system components at differing spatial and temporal scales, to estimate landscape-level responses of biotic systems to environmental changes. 2) Produce models capable of using detailed behavioral and physiological data and dynamically linking these with spatially-explicit abiotic information. 3) Produce models capable of generating testable hypotheses about trophic component responses to alternative possible anthropogenic influences. ATLSS provides a mechanism to evaluate the relative impacts of alternative hydrologic scenarios on various trophic components. The methodology to integrate components involves: i) a landscape structure for dynamic communication between models; ii) a high resolution topography to estimate high resolution water depth across the landscape; and, iii) a variety of visualization tools to aid model development, validation, and comparison to field data.

The USGS's Across Trophic Level System Simulation (ATLSS) models were originally run at the University of Tennessee using 2 x 2 mile hydrology provided by the South Florida Water Management Model (SFWMM). In order to make these models more usable in South Florida the suite of models used to convert the South Florida Water Management Model's 2 x 2 meter hydrology to 500 x 500 meter hydrology has been implemented on Linux PCs in South Florida. In addition, several of the ATLSS Spatially Explicit Species Index (SESI) models for wading birds, white-tailed deer, American alligator, and Cape Sable seaside sparrow, are available for use on Linux compilers. An overview is provided of the capabilities of the above ATLSS models in performing assessments of impacts of hydrology on key animals in the Everglades.

In addition, progress is described on the individual-based snail kite model, EVERKITE, has been improved in three ways. To improve the resolution of EVERKITE a grid-based version of this model was developed, using the SFWMM 2*2 mile grid with an extension to the north to cover the northern range of the kites. To improve the ability of agencies to use EVERKITE, a user-interface to the grid-based version was developed with the specific aim to allow the agencies to independently produce grid-based output on critical parameters of the kite population for each hydrological scenario that produces grid-based water levels for the SFWMM grid and the northern wetlands/lakes. To improve the accuracy of EVERKITE, new empirical information is included in the model on the vital rates and movement rules of the kites in response to hydrological and successional changes in their habitat. A strategy will be developed for inclusion of new empirical knowledge in future versions of the model.

The dynamics of this Everglades fish community and its food base is of special importance because systematic, human-induced changes in hydrology over the last several decades have altered hydroperiods in most wetland areas, thereby diminishing this fish forage-base or changing the pattern of its availability. The ATLSS model GEFISH (based on the earlier version ALFISH) is currently being used to project the effects of variation in hydrology on the biomass of fish supported, the coexistence of a community of small fishes, and the effects on the trophic structure of the food web.

A new model for Everglades vegetation dynamics has been developed. Sharp boundaries typically separate the salinity tolerant mangroves from the salinity intolerant hardwood hammock species, which occupy the similar geographical areas of southern Florida. Previous studies indicate that a severe disturbance that significantly tilts the salinity in the vadose zone might cause a shift from one vegetation type to the other. In this study, a model based upon the feedback dynamics between vegetation and salinity of the unsatured, or vadose, zone of the soil was used to take account of storm surge events to investigate the effects of this large-scale disturbance on the spatial pattern of hardwood hammocks and mangroves. Model simulation results indicated that a heavy storm surge that completely saturated the vadose zone at 30 ppt for one day could lead to a regime shift in which there is domination by mangroves of areas previously dominated by hardwood hammocks. Lighter storm surges that saturated the vadose zone at less than 7 ppt did not cause vegetation shifts. Investigations of model sensitivity analysis indicated that the thickness of the vadose zone, coupled with precipitation, influenced the residence time of high salinity in the vadose zone and therefore determined the rate of mangrove domination.

The main progress by recent work on ATLSS has been to:

- Make possible use of the ATLSS hydrology model and several SESI models by agencies in South Florida
- Improve the resolution and empirical base of the individual based-snail kite model, EVERKITE
- Develope a model to examine the possible effects of storm surges on coastal vegetation

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Hydrologic Modeling of South Florida Environmental Parameters and Application to Ecology, Salinity, and Heat Transport

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The Picayune Strand Hydrologic Restoration Project (PSRP), which is a part of the much larger Comprehensive Everglades Restoration Plan (CERP), is an effort focused on restoring the predevelopment hydrology of an 85-mi^2 rural area in western Collier County in southwestern Florida. The study area was overdrained during the 1960s as part of an incomplete housing development that still retains the associated canals, structures and roadways. The proposed changes involve the removal or modification of these features with the ultimate goal of reestablishing predevelopment hydrologic patterns and improving downstream coastal areas by reducing freshwater drainage and elevating ground-water levels. This area contains primary habitats for West Indian manatees and other temperature and salinity sensitive species; consequently, the possibility of any adverse effects resulting from this project is a major concern.

The USGS has developed and implemented heat transport capabilities into the FTLOADDS (Flow and Transport in a Linked Overland Aquifer Density Dependant System) coupled hydrodynamic surface- and ground-water modeling code in order to study the ecological effects of the proposed restoration scenarios in southwestern Florida. The FTLOADDS modeling code already had the ability for salinity transport and with this addition, model simulations can be used to predict changes in both temperature and salinity caused by hydrologic alterations. Several methods for representing heat fluxes were evaluated and a heat budget approach was utilized in the model. This formulation was initially developed and tested within the Tides and Inflows in the Mangroves of the Everglades (TIME) application of FTLOADDS, with the required heat-flux coefficients and parameters estimated from field measured evapotranspiration and atmospheric data. The model was calibrated to several temperature monitoring stations, and simulated daily average temperatures closely matched coastal and inland measurements.

After testing and development, the modified FTLOADDS code has been applied to the Ten Thousand Islands (TTI) area in southwestern Florida where the PSRP is planned. The TTI model was initially constructed to represent existing conditions, with several north-south oriented canals that connect to the Port of the Islands marina, and the coast. Port of the Islands is an important manatee habitat and the potential changes induced by PSRP are of great ecological interest to resource managers and planners. The TTI simulation was then modified to represent the changes proposed by PSRP, which include (1) filling in and blocking off canals, (2) creating spreader canals, and (3) building levees and pump stations. Results of simulating this scenario demonstrate how freshwater flows may be redistributed as well as potential changes to seasonal inundation patterns. Comparing the simulations of existing conditions and the PSRP restoration scenario, Port of the Islands showed substantial salinity and temperature differences that could adversely affect the manatee habitat. Salinity differences are most evident in coastal areas to the west of Port of the Islands, due to the redistribution of freshwater flows.

Simulation results have also been compared to specimen tracking locations to determine how environmental changes may affect animal behavior during high thermal stress periods. These results, for both the existing and post-restoration conditions, have been integrated into ecological models, including a nodal network model that can be used to predict manatee responses to environmental changes. The values of salinity and temperature at the nodes are generated by the TTI model and allow comparison of hydrologic scenario effects on manatees.

The development of heat-transport for the FTLOADDS application to TTI has led to the following contributions to restoration efforts:

- The model can simulate structural changes proposed for restoration and be used to evaluate the effects of different CERP scenarios upon the coastal hydrology and ecology.
- The model simulates hydrologic factors that affect a variety of aquatic biota, including the West Indian manatee and American crocodile, as well as many species of oysters, fish, and wading birds. This data can then be transferred to ecological models to test species responses to restoration efforts.
- The model simulations indicate that PSRP redistributes water in the Ten Thousand Islands area, and may create salinity and temperature differences important to manatee habitats.

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Using Stable $\delta^{15}N$ Ratios and Biological Diversity to Examine Effectiveness of Restoration Efforts within a Residential Community- Another Tool for the TMDL Toolbox

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Deteriorating water quality in the Estero Bay and its tributaries, all of which are classified as Outstanding Florida Waters by the State of Florida, has occurred concurrently with the rapid urbanization of the watershed. We report on a spatial study of stable nitrogen isotope ratios in the residential community of San Carlos Park, Lee County, FL, USA. The study benchmarks the water quality and biological diversity of the storm-water drainage system in this community of nearly 8000 single-family and duplex homes with onsite septic tanks. The work is the first step in a multi-year restoration effort undertaken in partnership with local government, civic organizations and other participants. The goal of the project is to assess and monitor the effectiveness of implementing "soft" best management practices (BMP's). The methods included monitoring basic water quality standards, determining stable nitrogen isotope ratios in macro-algae and sediments, and examining biotic indicators including invertebrates and fish species. This report focuses on our effort to determine the influences of various anthropogenic nutrients, mainly septic and fertilizer, to the outstanding Florida waterway that leads to the Estero Bay. We undertook this project during the summer and fall of 2007, and early spring of 2008.

San Carlos Park is a large (approximately 2,366 acres) (Section 46, Township 25, Range 08) single-family, residential community constructed in the 1960's, prior to current storm-water treatment requirements. Most of the homes are on individual septic systems, and storm-water runoff from the San Carlos Park community is funneled to a single outflow system (Lee County monitoring site 46B-9GR), into the Mullock Creek headwaters. Lee County's long-term data set at this site dates back to 1992. Mullock Creek is on the Florida Department of Environmental Protection's impaired waters list for dissolved oxygen and Chlorophyll a. Mullock Creek flows directly into Estero Bay, an Outstanding Florida Water, west of U.S. 41. A number of sources are contributing to the excess nutrients released at the Mullock creek outfall at San Carlos Park . Currently the area's storm water is under the control of the East Mullock Drainage District, a severely under-funded entity. In addition, the apparently innate American desire for green lawns causes us to add too many nutrients and herbicides to our lawns, the excess of which is being transported into the failing storm-water system, and over 85% of the residences use OSTP's. Another confounding factor is that the local community golf course receives the treated wastewater from the wastewater treatment plant and uses that water to irrigate the golf course, a common practice in our region.

Samples of sediments, aquatic plants, water, and invertebrates and fishes were obtained from various locations within this heavily urbanized community. They were compared to water quality and samples obtained at other sampling sites in the county which exemplify agricultural drainage, relatively pristine, and residential communities with central sewer. Understanding these relationships amongst these data and using them to calibrate models used to determine Total Maximum Daily Load (TMDL) criteria are integral to chart the course for real watershed conservation, restoration and stewardship.

Some enrichment in nitrogen isotopes is apparent in the higher flows sections of canals, and appears to be increasing as the outfall is approached. This is especially evident in the flocculent layer immediately above the sediments, the sample which was most consistently obtained at all sample locations. The floating algae, and floating plant material don't appear to have as high a ratio, but at the outfall, green and brown algae are significantly higher (over $7^{0/00}$) compared to "control" areas sampled. A stormwater retention lake in the community which is surrounded by homes hooked to central sewer had $\delta^{15}N$ flock sediment levels of only 0.59, showing apparently little or no indication of human waste influence. This is in stark contrast to the known control of the Golf Course Effluent lake where the $\delta^{15}N$ ratio was over 17.80, and, even the lake adjacent to it on the golf course, which would only be receiving runoff from watering using the effluent lake, where the little flock present had $\delta^{15}N$ ratios of over 7.00. Biological diversity was severely limited with only a few species of invertebrates and fishes in the community streams.

In conclusion, stable isotope rations, and measures of biodiversity appear to be a valuable tool to help us understand the sources and fate of nutrients and their impacts on local waterways. Residential communities with septic tanks were enriched in $\delta^{15}N$ nearly 9 fold over communities on central sewer. Biological diversity in more pristine creeks was significantly higher than in the disturbed storm water drainage system creeks. These storm water drainage systems provide the only habitat for much of the wildlife in southwest Florida, and as such, restoration efforts should improve the habitat available, and the residents ability to interact with the environment in a positive way. Future work should focus on verifying and expanding this work to include other sites, other biological indicators and models that we use to determine and assess TMDL's.

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Are There Local Differences in Adaptation of *Rhizophora mangle* Collected from the East and West Coasts of Florida?

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Adaptation to local conditions may influence restoration of plant species, recovery from large scale disturbances such as hurricanes, and may influence population responses to climate change. The Indian River Lagoon differs considerably in terms of tidal exchange, sediment types, salinity patterns and other environmental factors from Charlotte Harbor. However, both are influenced by runoff from Lake Okeechobee. We are conducting a field experiment to determine whether populations of dominant plant species are adapted to these local conditions or if the species simply shows phenotypic plastic responses.

To determine if there are differences in growth and survival between some Florida populations of *Rhizophora mangle* (Red Mangrove) from the East and West Coasts, we planted four reciprocal common garden experiments, two on each coast. Each common garden contains propagules from fourteen different maternal cohorts of *R. mangle*: seven cohorts from the east coast (Indian River and St. Lucie Counties) and seven cohorts from west coast (Lee County) planted in a random array. The reciprocal common garden experiments were planted in St. Lucie County on the east coast and Lee County on the west coast.

Three previous experiments have shown that there are important differences in growth and survival among maternal families in three populations from the west coast (Rookery Bay, Ten Thousand Islands and Tampa Bay). This is the first experiment to examine differences among maternal cohorts from east and west coast populations in the same experimental array. We compare growth, leaf production, herbivory, parasitism and survival among cohorts and between east and west coast populations. Herbivores had important effects on both growth and survival at some sites.

Key words: Rhizophora mangle, Red Mangrove, Maternal Cohorts, Growth, Herbivory, Infestation

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Baseline Hydrologic Data Collection along the I-75/State Road 29 Corridor in the Big Cypress National Preserve

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Presented by: ***Mark Dickman***

This study will develop a program of surface water flow monitoring across I-75 and SR 29 in the I-75 corridor from L-28 Interceptor Canal west to SR 29 and SR 29 along the Western boundary of Big Cypress National Preserve. Quarterly discharge measurements will be accomplished along both reaches to begin to assess hydrologic flow patterns and evaluate the feasibility of creating a stage-discharge/index-velocity relationship for this area. Current water level monitoring sites in Big Cypress Preserve will be evaluated for any stage-discharge relationship with flows across both corridors. Index velocity sites along corridors will produce accurate continuous flow data for help in the evaluation process. Multi-agency personnel will be incorporated in the program to build a reliable monitoring network. Project data will be presented through an interactive web-based map on South Florida Information Access, http://sofia.usgs.gov.

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Tracer Studies for Quantifying Transport Processes and Phosphorus Removal within the Everglades Stormwater Treatment Areas

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Chemical tracers (rhodamine-WT or LiCl) were injected into large-scale (147-928 ha) surface flow wetlands (Stormwater Treatment Areas [STAs]) designed to remove phosphorus (P) from agricultural drainage waters in south Florida. Analyses of tracer response curves provided quantified parameters (effective hydraulic residence time [HRT], dispersion, residence time distribution [RTD], and tanks-in-series [TIS] numbers) that provided a means of comparing hydraulic performance among wetlands. Internal monitoring of tracer and P concentrations yielded two-dimensional time series plots that identified which areas within a wetland were receiving most of the flow, and whether P removal was impaired because of hydraulic constraints.

Uneven wetland bottom topography, differences in the density and distribution of aquatic vegetation, and the configuration of the inflow structures contributed to a wide range in the hydraulic efficiency ($\lambda = 0.07$-0.95) within the six wetland cells that received tracers. Since the effective HRT was high in all the wetlands, most of the differences in hydraulic efficiencies were attributed to dispersion (TIS number). Preferential flow paths (i.e., short circuits) developed in those wetlands (Cell 1, 2 and 4 of STA-1W) that exhibited poor to moderate (but not high) hydraulic efficiencies.

Phosphorus removal, as represented either by a volumetric rate constant or simple mass removal, was not correlated with hydraulic efficiency. There were, however, high correlations ($r = 0.91$-0.99) of P removal with HRT, velocity, and P mass loading. Although auto-correlation between P removal and these factors may have contributed to these significant correlations, our tracer data suggest that velocity is an important wetland hydraulic parameter in P removal. Higher velocities, up to an undefined boundary condition, will penetrate “dead zones” within the wetland and reduce diffusion gradients that limit biological P uptake within aquatic vegetation communities and the soil surface. However, velocity will only be a critical parameter if the P loading, vegetation density and distribution, and substrate (soils) are optimum for P removal. Excessive P loading can lead to shifts in the density, distribution and composition within the vegetation community, and saturation of substrates, which will affect the P removal efficiency as these are the “biogeochemical loci” for assimilating and immobilizing the P delivered in the faster-flowing water parcels.

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Investigating Ecological Effects of Mineral Enrichment in the Northern Everglades

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The A.R.M. Loxahatchee National Wildlife Refuge (Refuge) is a remnant of soft-water Everglades that retains a, rainfall-driven chemistry. Intrusion of mineral-rich canal water into the Refuge is associated with persistent chemical gradients in the soil and ecological changes including shifts in the composition of periphyton and macrophyte species, which can lead to effects at higher trophic levels. In 2004, the Refuge established a program to document spatial and temporal patterns of canal-water intrusion and associated mineral enrichment. This poster describes multiple ongoing studies designed to characterize the potential ecological effects of this enrichment, including:

- Characterization and modeling of relationships between water quality and periphyton composition;
- Investigating the effects of water quality/periphyton relationships on secondary production;
- Soil and vegetation sampling at water quality monitoring sites to establish chemical-ecological relationships;
- Field and laboratory experiments to further examine these water quality/vegetation relationships, including studies on the relative influence of water quality and hydrology on macrophyte germination and seedling survival.

Relationships between periphyton community composition and water quality gradients are being modeled using periphyton and associated surface water samples randomly collected from within the Refuge. Collected samples encompass representative areas of dominant water quality conditions and periphyton assemblages. Periphyton was analyzed for taxonomic composition to the genus level. Monitored water quality parameters include specific conductivity, phosphorus, calcium, and sulfate. Preliminary compartmentalized Refuge models completed for desmid populations indicate linear and log-linear relationships between desmids abundance and several of the monitored water quality parameters. Ongoing model development will allow for Refuge managers to predict periphyton composition based on sampled surface water, thereby allowing for real-time assessment of water management strategies on periphyton communities.

Populations of *Pomacea paludosa* (Florida apple snail) have been in decline in the Refuge since the 1970s. Altered population dynamics of this secondary producer has significant implications for predatory species, including the critically endangered Everglade Snail Kite. Therefore, the impact of altered periphyton assemblages on apple snails is being investigated. Mesh cages (1 m^2) are placed along water quality gradients within the Refuge and stocked with periphyton and associated submerged vegetation from each site. Lab-raised apple snails are randomly distributed and maintained in cages for approximately 2 months, during which time water chemistry (specific conductivity, total phosphorus, calcium, and sulfate), periphyton, and snail growth/survival are monitored and characterized. Periphyton characterization includes taxonomic composition, organic carbon to nitrogen ratios, total phosphorus, and nutritional value (carbohydrates, crude lipids, and protein). Snail growth is measured as percent increase in shell and aperture length, growth rates (mm growth/week), and ash free dry mass. Correlations between water-quality driven differences in periphyton assemblages and snail growth/survival at each site are described. This project provides further insight to the impact of changes in periphyton assemblages on higher trophic levels and can guide Refuge managers in developing conservation and restoration strategies by characterizing ecological effects of altered water quality and periphyton assemblages.

Differences in vegetation communities along soil and surface water chemical gradients are being documented within the Refuge. One study investigated the influence of water quality and hydrology on germination and seedling survival from a seed bank collected from the undisturbed Refuge interior. While hydrologic treatments had some influence on species composition, the chemistry treatments produced distinct plant communities indicative of the Refuge interior (unenriched treatment) and perimeter (enriched treatment). These results illustrate that while hydrology certainly is a critical factor affecting Everglades vegetation, soil and surface-water chemistry can exert strong independent effects on plant communities and that soil chemistry is a major determinant of differences in plant communities between the minimally impacted Refuge interior and enriched areas near the perimeter. In addition, observed effects of soil chemistry on plant community development can occur within a single growing season following disturbances such as droughts when vegetative cover is reduced and plant establishment from the seed bank may be important. Incorporating this knowledge into decisions regarding the timing and extent of surface water inputs that may impact the Refuge through canal water intrusion will help managers when assessing management options to best protect the trust resources of the Refuge.

Information gained from these studies will support ongoing hydrologic and ecological modeling efforts and provide a scientific basis for wetland management strategies that minimize detrimental effects on Refuge resources caused by mineral enrichment. The study findings presented here provide important tools and information for the restoration and maintenance of Refuge wetland ecology including:

- A model that is capable of predicting periphyton desmid populations based on routinely collected surface water chemistry parameters;
- Correlations between water quality-driven periphyton community composition and *Pomacea paludosa* growth and survival;
- Characterization of characterize the relative influence of soil chemistry and hydrology on vegetation patterns in the managed Everglades.

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From 2X2 to Ecological Model: Does High Resolution Water Affect Model Results?

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Most ecological evaluations for projects related to the Greater Everglades restoration begin with a simulation of potential hydrologic effects using the South Florida Water Management Model (SFWMM). This hydrologic model has a spatial resolution of four square miles, far in excess of the spatial scale that many of the Greater Everglades species utilize their environment. The concept of high resolution hydrology (HRH) was developed by USGS and the University of Tennessee, Knoxville in an attempt to create finer resolution hydrology to drive ecological models while still using the SFWMM as the initial input. The resolution chosen was 500 square meters and was obtained by adjusting the water depths in each SFWMM cell, on a daily basis, using high resolution elevation data obtained from either actual measurements, or inferred by vegetation type. Conservation of water between the SFWMM cell volume and the adjusted 500 meter depths is required. In an effort to increase code portability and speed, I developed a revised method to create HRH. As part of this development, I examined two methods for creating the HRH. Global adjustment holds the stage constant over the SFWMM cell and increases or decreases it until the volume of water within the cell using 500 meter elevations matches the original water volume. Local adjustment allows the stage to vary across the SFWMM cell by calculating a new depth/volume for each 500 meter cell contained within the SFWMM cell independently. Using the Calibration and Verification results from the SFWMM , the two methods were compared, along with the SFWMM output, to data from 14 hydrologic monitoring gauges distributed across the Greater Everglades demonstrating that the HRH was more accurate than the SFWMM. However, application of this process to ecological models and performance measures requires more than simply goodness of fit to real data. For this effort to be useful, the depth modifications must be significant enough to induce results in ecological models when compared to results driven by unmodified SFWMM output. Results from the Wading Bird and Alligator, Across Trophic Level System Simulation (ATLSS) Spatially Explicit Species Index (SESI) models, and the National Park Service developed Cape Sable Seaside Sparrow model, driven by HRH and the SFWMM sampled at 500 meter scale, are compared to determine whether the models are sensitive to the HRH changes.

- With respect to data from the 14 gauges, HRH improves the accuracy of the SFWMM output.
- The choice of HRH redistribution algorithms is important in providing the most accurate input to Ecological Models.
- The Wading Bird, Alligator, and Cape Sable Seaside Sparrow Index Models all showed sensitivity to the difference between SFWMM water depths sampled at 500 meters versus HRH.
- HRH increases the accuracy of the output of the SFWMM. These changes are large enough to alter the results of three ecological models (with respect to pure SFWMM output) presently being used to assist decision making for Greater Everglades restoration projects. This demonstrates that HRH is a useful addition to the Greater Everglades restoration toolkit.

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Estimation of Manatee Abundance from Aerial Surveys Using Dual Observers and Removal Sampling

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Predictions of manatee abundance as a function of habitat characteristics are needed for making conservation decisions for this threatened species. The spatial distribution of manatees in southwest Florida is known to vary across the landscape with access to fresh water for drinking, food availability, warm water refuge, and other factors related to habitat. The spatial distribution of abundance also changes seasonally with changes in water temperature and the threat of mortality from cold stress. Consequently, aerial surveys were developed to estimate abundance of manatees in spatially referenced sample units using a combination of sampling protocols. Groups of manatees were detected using double-observers, and the number of manatees in each group were detected by repeated circling to yield a sequence of "removal" counts. Thus, both kinds of counts (i.e., those of groups and those of manatees within groups) were spatially referenced. A hierarchical modeling framework is developed to estimate maps of manatee abundance while accounting for the imperfect detectability of groups and of individuals within groups. A critical component of these models is the functional dependence between the probability of detecting a group and the group's size, which is unknown, but estimable.

Relevance to restoration efforts:

- The ability to model spatial variation in abundance and its association with habitat factors, such as those produced by hydrologic models, gives managers a new tool for monitoring the response of manatees to changes in habitat due to restoration.
- Model-based estimates of abundance are corrected for detection bias and thus may be compared over space and time, a feature that is lacking in current manatee aerial survey programs.

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Ecological Indicators for System-wide Assessment of the Greater Everglades Ecosystem Restoration Program

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Abstract

Reliable measures of the general health and ecological integrity of ecosystems are critical for assessing the success of restoration programs. The South Florida Ecosystem Restoration Task Force (Task Force), which is helping coordinate a multi-billion dollar cooperative effort to restore the Florida Everglades, is using a small set of system-wide ecological indicators to assess the restoration efforts. A team of scientists and managers identified eleven ecological indicators from a field of several hundred through a selection process using criteria to determine their applicability as part of a system-wide suite. In addition, a report card was developed to assist in communicating the complex science inherent in ecological indicators in a common language for managers and policy makers. The processes of indicator development and selection, along with the criteria and the report card are presented in this paper.

Key Findings:

A small suite of integrative indicators is considered essential by managers and policy-makers to assist them in determining restoration success.

A straightforward, but transparent system to aggregate results of science into an easily understood language that provided “apples to apples” type comparisons was required by managers and policy-makers in order to provide information that would be used in restoration decisions.

Providing scientists with guidelines for assessment reports improves communication of science and scientific cooperation and reduces duplication of effort.

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Seasonal Succession and Annual Hydrologic Patterns Drive Aquatic Community Structure and Biomass in Forested Wetlands of the Big Cypress

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Conceptual models based on habitat permanence and discrete predator transitions can successfully explain variation in community composition (and species' traits) in temperate zone ponds and lakes. However subtropical wetlands in s. Florida have temporary and fish-dominated aspects; a combination of conditions not considered in most models of aquatic communities. I have been sampling communities of fish and large macroinvertebrates with 1 m^2 throw traps in six small (sampled areas ~0.2 ha) forested wetlands in the Big Cypress Seminole Indian Reservation of southern Florida for the past two years (2006 and 2007).

Each year the wetland surfaces, including associated alligator holes (fish refuges), dried for 3-8 months and then refilled with summer rains in July-September. After refilling, the wetlands remained fishless for a period of time, depending on fish re-colonization rates from local or regional refuges. Fish re-colonized all wetland sites in 2006, but in 2007 the drought was more severe, the wet season depths remained low, and three wetlands remained fishless for the entire wet season. Non-indigenous Brown hoplos (*Hoplosternum littorale*) and native mosquitofish (*Gambusia holbrooki*) dominated the fish fauna in both years, but the relative abundance of Brown hoplos increasing in 2007.

Everglades crayfish (*Procambarus alleni*) reproduction and recruitment commenced with the return of summer rains during the early fishless period. *P. alleni* appear to have one cohort per year in this environment, reaching adult sizes by late summer or early fall. Average crayfish biomass exceeded 4 g/m^2 in most sites at some point during 2006; this is a notably high biomass compared to other wetlands in s. Florida. In one site average crayfish biomass exceeded 30 g/m^2 in October 2006. In 2007 average crayfish biomass never exceeded 2 g/m^2. Grass shrimp (*Palaemonetes paludosus*), which are an important invertebrate throughout much of the s. Florida wetland complex were rare in these wetlands. Large predatory insects were a small component of the total aquatic animal biomass in these wetlands, but became relatively more abundant at the end of 2007 in sites that stayed fishless for the entire wet season.

Total animal standing biomass was variable within and between years in these wetlands and was greater in 2006 than in 2007; a function of weak crayfish population growth in most sites and a lack of fish colonization at three sites in 2007. Two of the sites with 8 month dry periods in 2007 colonized with fish shortly after re-flooding in September, while sites with similar and shorter droughts (5.5 months), some of which had standing water in July, remained fishless. This illustrates the importance of landscape position in re-colonization dynamics of fish and total wetland production.

- The aquatic communities in forested wetlands of the Big Cypress Seminole Indian Reservation have some of the highest crayfish standing stocks recorded for south Florida wetlands.
- Although these forested wetlands are relatively small they may provide substantial resources for wading birds and other species (e.g., otters) during the early part of the dry season (October-February).

- Landscape position is an important factor driving fish re-colonization dynamics, and can override local hydrologic conditions such that drought length and fish presence/production can be partly decoupled.
- Seasonally dry conditions that provide fishless periods for crayfish recruitment, combined with sufficiently high wet season depths allowing fish re-colonization and population expansion may be necessary to create the best conditions for secondary production.

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Forecasting Mangrove Forest Response to Sea-level Rise and Hydrologic Restoration of the Everglades

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The near sea-level elevation and flat slope of the protected Everglades ecosystem accounts for one of the largest contiguous tracts of mangrove forests found anywhere in the world and punctuates their potential vulnerability to rising sea level and changes in freshwater runoff. These forests are subject to coastal and inland processes of hydrology largely controlled by regional climate, disturbance regimes, and water management decisions. Mangroves are highly productive ecosystems and provide valued habitat for fisheries and shorebirds. Mangrove forests are universally composed of relatively few tree species and a single overstory strata. Three species of true mangroves are common to intertidal zones of the coastal margin of the Everglades, namely black mangrove, *Avicennia germinans* (L.) Stearn, white mangrove, *Laguncularia racemosa* (L.) Gaertn.f., and red mangrove, *Rhizophora mangle* L.

Mangroves are halophytes and can, therefore, tolerate the added stress of waterlogging and salinity conditions that prevail in low-lying coastal environments influenced by tides. Global warming has been projected to increase seawater temperatures and expansion that may accelerate sea level rise and further compound ecosystem stress in mangrove dominated systems. A landscape simulation model, SELVA-MANGRO, was developed for mangrove forests of south Florida to investigate the potential impacts of climate change and freshwater flow on the quality and distribution of future mangrove habitat. The SELVA-MANGRO model represents a hierarchically integrated landscape model that manages the exchange of system parameters up, down, and across scale between linked simulation models SELVA and MANGRO. SELVA is a Spatially Explicit Landscape Vegetation Analysis model that tracks predicted changes in the biotic and abiotic conditions of each land unit (1 sq ha) on an annual basis for the entire simulated landscape. The SELVA model administrates the spatial articulation of the landscape composed of land units composed of habitat classifications (forest, marsh, aquatic) and any forcing functions that predict changes in hydrology and disturbance. Intertidal forest units are then simulated with the MANGRO model based on unique sets of environmental factors and forest history. MANGRO is a spatially explicit stand simulation model constructed for mangrove forests of the neotropics. MANGRO is an individual-based model composed of a set of species-based functions predicting the growth, establishment, and death of individual trees. MANGRO predicts the tree and gap replacement process of natural forest succession as influenced by stand structure and environmental conditions.

Model applications were conducted to forecast mangrove migration under projected climate change scenarios of sea-level rise and saltwater intrusion for the Everglades coastal margin without hydrologic restoration. Sea-level rise was modeled as a function of historic sea-level conditions at Key West, Florida based on mean annual tide records (1940 to present) projected into the 21st century with the addition of curvilinear rates of eustatic sea level expected from climate change. The data record was extended into the next 100 years for sea-level rise scenarios of 15 cm to 1.1 m by year 2100 based on low, mid, and high projections obtained from global climate change models. Model results show that species and forest cover will change over space and time with increasing tidal inundation across the simulated landscape for all sea-level rise scenarios. The greater the rate of sea-level rise the faster or more extensive the encroachment of mangroves onto the Everglades slope. The model shows that freshwater marsh/swamp habitats will be displaced as the tidal prism increases over time as it moves upslope without Everglades hydrologic restoration. Under these modeling assumptions, mangrove habitat will increase over the next century under climate change and conversely, freshwater marsh/swamp is expected to decrease.

Modeling upgrades have been incorporated into the SELVA-MANGRO model to include physiological response to freshwater flooding and to assess the impact of increased freshwater runoff under various Everglades restoration alternatives. Empirical data of riverine and basin mangrove forests show that precipitation and runoff events affect short-term hydrology and salinity conditions that are relatively minor in relation to coastal influences of daily and seasonal tidal forcing. Everglades restoration alternatives will increase runoff conditions above current normal patterns but may not effectively abate any influence of sea-level rise in the near future. Model trials indicate that proposed freshwater flow rates may need to exceed current engineering design to affect stage and salinity at the coastal margin to affect potential mangrove migration and expansion into freshwater habitats.

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Predicting the Fate of Florida's Coastal Ecosystems along the Gulf of Mexico under Rising Sea Levels and Climate Change

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Changes in climate during ice ages and warming periods have affected sea-levels and coastal extent as evidenced from geologic records. Currently, global sea level is on the rise and may accelerate with continued fossil fuel consumption from modernization and population growth. Whether of mostly human or natural consequence, rising sea level will affect our coastal infrastructure including landholdings, pipelines, rails, and roads to an extent that society must deal with the problems and setbacks of coastal flooding. Coastal areas of the Florida Gulf Coast and worldwide are slowly being inundated by increasing sea level. Warming of our global environment threatens to speed the rate of current sea-level rise and perhaps further amplify the detrimental effects of tropical storms, droughts, and record rainfall. Sea-level has reportedly been rising since the last ice age (15,000B.P.) and over the last century by as much as 2 mm/year. The Intergovernmental Panel on Climate Change (1996, 2001) has projected a 48 cm rise in average global eustatic sea level by year 2100 within a probable range of 9 - 88 cm given some uncertainties. If realized, these moderate or "best estimate" projections will more than double the rate of sea-level rise over the past century. Thus, sea-level rise is expected to have a significant, sustained impact on future coastal evolution. Potential effects include coastal erosion, saltwater intrusion into ground-water aquifers, and submergence of cultural and natural resources.

The historical local rate of relative sea-level rise is a process and product of several components, including eustatic change due to deglaciation and thermal expansion, isostatic change from glacial rebound and tectonic uplift, and surficial subsidence caused by compaction and minerals/fluid extraction. These sea-level projections do not consider increases in relative sea level by region affected by local factors other than warming sea temperatures such as land subsidence. Gulf Coast wetlands, in particular, have shown high rates of land subsidence attributed to soil decomposition and compaction, deep fluid extraction, and the lack of allochthonous sediment deposition. Relative sea level is the effective change in the land/water datum relationship at a given site that includes both the eustatic sea level change condition and changes in surficial elevation by accretion. Subsidence rates across a broad region like the Gulf Coast are highly variable on a local scale even within a representative coastal landform such as the Everglades or the Mississippi River Deltaic Plain. Many factors contribute to the rate and process of subsidence at a given locale by natural compaction, dewatering, and subsurface mineral extractions.

Properly accounting for sea-level rise is a critical aspect of ecosystem restoration and management throughout the northern Gulf of Mexico coastal zone. Several ecosystem models have been developed by the USGS to address potential sea-level rise effects on shoreline and habitat retreat at the local park and regional scale. A utility model has been developed to forecast sea-level rise for specific coastal reaches based on historic tide data and IPCC general climate model projections. Sea level rise is therefore modeled as a function of historic sea-level conditions at long-term tide stations within the Florida Gulf Coast study area from Pensacola, FL, Cedar Key, FL, and Key West, FL based on mean monthly tide records projected into the 21st century with the addition of curvilinear rates of eustatic sea level expected from climate change. The historic record was retained to mimic the natural cycle of high and low tidal variation attributed to astronomical and meteorological causes. The data record was extended into the next 100 years with the addition of eustatic rates of sea-level rise based on IPCC (2001) low, mid, and high projections obtained from various global climate change models. Model simulations were achieved for each of 7 climate change models and 6 emission scenarios included in the IPCC (2001) dataset. Sea-level inundation models of coastal habitats have been constructed for all Florida counties and for specific park and refuge applications at Everglades National Park in southern Florida and St. Marks National Wildlife Refuge in northern Florida. Model predictions show the rate and extent of shoreline retreat and habitat migration upslope that will change the current configuration of land area and ecosystem cover. Understanding the long-term view of when and where sea-level rise will change existing shoreline and species persistence may impact restoration priorities and planning efforts. Hydrological restoration of freshwater flow and pathways may ameliorate or delay some impacts from saltwater intrusion and encroachment during years of high sea-level anomalies and incremental sea-level rise.

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Implementation and Operation of a Large Everglades Physical Model: The Loxahatchee Impoundment Landscape Assessment (LILA)

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The Loxahatchee Impoundment Landscape Assessment (LILA) project is a large scale physical model of the Everglades constructed in 2003. As a controlled research platform, LILA allows scientist to devise experiments that investigate the impacts of hydrology on the Everglades landscape. Landscape features of the Everglades constructed in each of the four 20-acre cells or macrocosms are tree islands, ridges and sloughs. Each macrocosm contains two tree islands, one with a peat core and the other with a limestone core, to simulate two basic types of tree islands found in the Everglades. Found within each macrocosm are also a series of ridges, deep and shallow sloughs and “gator holes”. These features allow the study of the impacts of flow on vegetation and wildlife as well as the morphology of these landscape features.

LILA was built to be a rain driven, closed-loop system to control water quality within the macrocosms. Using a large electric pump and a series of water control structures, flow rate through the macrocosms can be controlled and the water depth adjusted and maintained according to a predetermined hydrograph. Limitations to maintaining flow velocities and water depth are the availability of water and the volume of water that the pump can move to the macrocosms.

Since its construction, LILA has hosted a number of studies which include wading bird feeding success, crayfish migratory behavior, tree survival, growth and morphology, and ground water/surface water hydrology and chemistry.

The success of research at LILA depends on proper design within the LILA framework. All research proposed must be approved by the LILA Science and Coordination committee. This committee is made up of multi-disciplinary researchers from the South Florida Water Management District, ARM Loxahatchee National Wildlife Refuge, Florida International University and Florida Atlantic University. Another key to the success of research at LILA is the coordination and integration of concurrent projects on the site. This presentation will elaborate on the ongoing and completed research at LILA and how site operations influenced the outcome of that research.

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A Conceptual Model for Integrating Predator-Prey Monitoring for the Everglades Landscape

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The Florida snail kite (*Rostrhamus sociabilis plumbeu*) is a critically endangered species that, through its movement and reproduction, integrates the entire Everglades watershed. The kite's primary prey, the Florida apple snail, has an approximately annual life cycle and a life history highly sensitive to hydrologic alterations. Apple snail densities in important kite breeding wetland units have experienced significant reductions in recent years due to water management issues, and this low food availability has likely contributed to declining kite populations. Comprehensive monitoring data for both species have been collected separately for the past 15+ years, but due to a spatial and temporal disconnect between research projects, conclusions reached using the data have limited inference.

We have developed a conceptual model to integrate monitoring for the snail kite and apple snail and their habitats across the Everglades watershed. We address both immediate and long term research questions, with emphasis on critical issues. A pilot program has been initiated in the Kissimmee chain of lakes, the area with highest kite reproduction potential for the 2008 breeding season, and we propose to expand this effort throughout the historic kite habitat network. This integrated approach is essential for providing the best science in support of management decisions being made on behalf of the snail kite.

The results of this study will include:

- A habitat-based conceptual model that will be used in making water management decisions.
- A database of information useful for water management decision-makers.
- The development of a prototype model database for wetland-dependant vertebrate/invertebrates.

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Hydrologic Impacts and Restoration in the Fakahatchee Strand of Southwest Florida

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Fakahatchee Strand is the largest forested freshwater wetland in South Florida. It's large size and subtropical character supports a diverse temperate and tropical plant community. The canopy of large cypress, *Taxodium distichum*, was logged in the 1940's, but is steadily recovering. The natural hydrologic and fire regimes of Fakahatchee Strand have been influenced by drainage in the surrounding landscape, particularly Southern Golden Gate Estates, which is located along its western boundary. However, these impacts have been buffered by the large size of the Strand, which has left the forest interior reasonably intact.

Monthly hydrologic monitoring of 25 wells along two transects that extend across the main flowway of Fakahatchee Strand has been conducted since 1987. These data have documented seasonal water table drawdowns of almost 2 m in the vicinity of a large canal that borders the Strand's western edge. The water table in this area has been measurably lowered to over 1.5 km from the canal during the wet season when water levels are above ground in the Strand, and to almost 5 km from the canal during dry periods when the water table is naturally below ground. Drawdowns associated with a smaller road-side canal to the east can be as much as 0.7 m, and can extend to over 1 km from the canal. While periodic fires occur naturally in this ecosystem, their increased severity in the drained lands near the larger canal has converted large areas of wetland to upland communities and facilitated invasion of exotic plant species. Filling of the upper 3 km of the larger canal bordering Fakahatchee was completed in early 2004, and the remaining 8 km were filled in late 2006. During normal wet seasons, we have seen the restoration of overland flows in the vicinity of the canal section filled in 2004. Since filling the remaining section of the canal in 2006, we have been in a severe drought. However, we have still seen higher groundwater levels in the vicinity of the canal section filled in 2006 because of reduced drainage of dry season baseflows that enter the area from the upstream watershed.

Due to the abundance of native seed sources adjacent to the long, narrow footprint of the canal, we have not planted native vegetation on the restored site, but are controlling the invasion of both native and exotic nuisance plant species to facilitate recovery of the native plant community.

- Canal drainage effects extend 1.5 – 5 km into an adjacent wetland landscape
- Hydrologic restoration of canal drainage requires more than occasional short plugs
- Controlling exotic vegetation was the main mechanism for restoring native plant communities on the restored canal footprint

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Cue Recognition and Prey Responses to Non-Native African Jewelfish, *Hemichromis letourneuxi*, in Everglades Habitats

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Throughout the past century, anthropogenic disturbance in natural ecosystems has led to multiple invasions by non-native species, as has been the case in the Greater Everglades ecosystem. The arrival of non-native species often leads to negative effects on native taxa and losses in ecosystem services, which ultimately results in the deterioration of native habitats. While a great deal of research has been done on these final stages of an invasion (i.e., the impact phase), few studies have examined the initial response of native taxa to invaders, which often pose novel threats.

In ENP, fourteen predominantly predatory fishes have invaded and proliferated within the past forty years. Because of the threats posed by these species to the native biota, there is a need to better understand how non-native predators interact with native Everglades prey, and to examine the role behavior may play in mediating these interactions. Behavioral plasticity may allow naïve prey to respond adaptively to novel non-native predators. Thus, behavior may play a key role in promoting the survivorship of prey under a novel predation threat. In a series of aquaria experiments, we examined the anti-predator response of three abundant prey species (eastern mosquitofish *Gambusia holbrooki*, flagfish *Jordanella floridae*, and riverine grass shrimp *Palaemonetes paludosus)* to a native predator (warmouth *Lepomis gulosus)* and to a recently introduced predator, African jewelfish *Hemichromis letourneuxi*. We examined activity, schooling behavior, and refuge use by the prey in the presence of each predator, as well as prey mortality rates and their use of chemical and visual cues to detect these predators. Cues used by prey to detect predators may be either general or specific, and affect the ability of the prey to detect novel predators with which they ha no coevolutionary historyve. Results showed variation in the responses by prey to native and non-native predators, which had important fitness consequences (i.e., it resulted in higher mortality rates). Fish prey tended to increase schooling and to use certain microhabitats when predators were present. Prey also varied in their use of cues to detect predators.

Invasive species are a major conservation concern in the restoration of the Everglades and may be affected in a number of ways by CERP actions. Restoration should improve the habitat and enhance the functional quality of the ecosystem, which research has shown to benefit native species to the detriment of non-natives. Implications for restoration of our findings include:

- Predation by non-native fishes may represent a major impact on native aquatic biota.
- The predatory effects of non-native fishes may be functionally equivalent to that of native predators, but the effect on individual prey species varies. This has important implications for shifts in aquatic-prey community structure and fuctioning.
- Native taxa have the potential to respond appropriately to non-native predation, and thus increase their probability of survivorship, even if predators are novel, when they rely on rather general predation cues.

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RECOVER Evaluation Team: Northern Estuaries Sub-team Performance Measure Synthesis Poster

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The Comprehensive Everglades Restoration Plan (CERP) is the framework and guide for the restoration and preservation of the South Florida ecosystem. The RECOVER Northern Estuaries module includes the Caloosahatchee River and Estuary, San Carlos Bay and Estero Bay on the west coast and St. Lucie Estuary, the Southern Indian River Lagoon, the Loxahatchee River estuary and Lake Worth Lagoon on the east coast. Historically, natural freshwater discharges into these water bodies sustained an ecologically appropriate range of salinity conditions to facilitate the presence of healthy flora and faunal communities. Increased demand for water and flood protection has led to frequent high and low salinity extreme's within the coastal water bodies which has resulted in a shift in the ecological community to species that are less desirable.

Conceptual Ecological Models (CEMs) were developed for each of the estuaries and identify key stressors and attributes and describe the cause and effect relationships of flora and fauna to human induced and natural conditions. The CEMs provide a suite of testable hypotheses that will convert the broad policy-level objectives established for CERP into specific, measurable indicators of health of the natural and human systems, and predict regional responses to implementation of the restoration program. Performance measures (PMs) were developed for each of the indicators identified in the CEMs and are used as the standards for both evaluating and assessing restoration program success. Performance measures are used as planning tools to select the alternative plan that will best meet restoration goals and objectives. The PMs for the Northern Estuaries include salinity, water quality, oyster habitat, submerged aquatic vegetation (SAV), benthic macroinvertebrates and fish communities.

Output from the South Florida Water Management Model (SFWMM version 5.6.1), which is the primary hydrologic simulation model for CERP, is used to produce performance measure output. Predictive salinity envelope PMs have been established in the Northern Estuaries for CERP. Predictive targets are based on optimization of model outputs, natural variation that would occur during the period 1965-2000, and desirable salinity conditions for existing and potential aquatic resources within the Northern Estuaries. The restoration goal for the Northern Estuaries is to re-establish salinity regimes suitable for the maintenance of naturally-diverse, well-balanced estuarine ecosystems. Habitat suitability and water quality can be derived from SFWMM or other computer model hydrologic output even if they were not modeled explicitly. Post-processing methodologies of data may allow estimations of ecological attributes to assist in selection of plans. Water quality PMs have been established for the Northern Estuaries using an interim methodology to delineate the effect of CERP on nutrient loading (Total Phosphorus and Total Nitrogen). The oyster PM is currently based on the salinity envelopes from the SFWMM, however, in the future a variety of ecological and physiological responses of oysters will be used to determine the health of oysters and oyster reefs including density of living oysters, condition index, reproductive activity, larval recruitment, disease prevalence and intensity of *Perkinsus marinus* (and MSX in east coast estuaries). A Habitat Suitability Index (HSI) model is currently under optimization and will be used to predict numbers of live oyster reef acreage increase and suitable locations for reef development. The SAV PM is currently based on the salinity envelopes from the SFWMM for each species of SAV. The benthic macroinvertebrate PM uses a multivariate approach to elucidate changes/improvements within the benthic communities, and identify the major causes for those observed changes (salinity, oxygen, sediment, nutrients). The fish community PM is also based on the salinity envelopes from the SFWMM until better predictive tools are available. The ability to evaluate PMs is constrained by availability of simulation or computer modeling tools, their spatial and temporal scales, and their associated uncertainty. As more data is collected and models are created, all PMs will be updated.

Conclusions produced during the development of the performance measure include:

1. Flow metrics provide a theoretical basis for judging the ecological effects of CERP on estuarine ecosystems. Keystone species (such as oysters and seagrass) that have defined lethal salinity thresholds and their recovery can be related to salinity regime management.
2. Performance measure flow metrics can be applied to period of record model results to discern CERP effects and provide periods of recovery against future base conditions.
3. Performance measures can be used to leverage model data to discern effects of nutrient loads on Northern Estuaries ecosystems. Comparisons of CERP and future base conditions indicate significant reductions of Total Nitrogen and Total Phosphorus based upon CERP mediation of Lake Okeechobee Regulatory releases.

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Long-term Impacts of Hurricane Wilma on Land Surface-Atmosphere Exchanges

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In October 2005, Hurricane Wilma made landfall along the mangrove forests of western Everglades National Park, Florida, USA. Damage from the storm varied with distance from landfall and included widespread mortality and extensive defoliation. Large sediment deposition events were recorded in the interior marshes, with erosion taking place along the coastal margins. Wilma made landfall near a 30 m flux tower where eddy-covariance measurements of ecosystem-level carbon and energy fluxes started in 2003. Repairs to the structure were completed in 2006, enabling comparisons of surface fluxes before and after the storm. One year after the hurricane, both the average and daily integrated CO_2 fluxes are consistently lower than the pre-storm values. The storm's impact on standing live biomass and the slow recovery of leaf area appear to have resulted in decreased photosynthetic uptake capacity. Nighttime respiratory CO_2 fluxes above the canopy are unchanged from pre-storm values. During some periods, daily integrated fluxes show the forest as a net source of CO_2 to the atmosphere. Soil CO_2 fluxes are not measured directly, but daytime soil temperatures and vertical heat fluxes have shown consistently higher values after the storm. Nighttime soil temperatures values have been slightly lower. These stronger diurnal soil temperature fluctuations indicate enhanced radiative fluxes at the soil surface, possibly as a result of the reduced leaf area. The increases in daytime soil temperatures are presumably leading to higher below-ground respiration rates and, along with the reduced photosynthetic capacity, contributing to the lower net CO_2 assimilation rates. This hypothesis is supported by nearby measurements of declining surface elevations of the organic soils which have been correlated with mangrove mortality in impacted areas. Both sensible and latent heat fluxes above the canopy are found to be reduced following the hurricane, and soil heat storage is higher. Together, these results hold implications for the sustainability of these forests during a period of increased hurricane activity in the eastern Atlantic and sea level rise.

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Water Quality Gradients in the Arthur R. Marshall Loxahatchee National Wildlife Refuge

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) is the last soft water remnant of the northern Everglades ecosystem. The Refuge developed as a rainfall-driven system with surface waters low in nutrients and inorganic ions, and is characterized as a low-conductivity oligotrophic ecosystem. Water discharged into perimeter canals consists of both treated and untreated water with nutrient and mineral concentrations that have increased over the past several decades. Areas of its pristine marsh have been impacted by canal water intrusion containing elevated concentrations of nutrients and minerals. Stormwater originates in the 280,000 ha^{-1} Everglades Agricultural Area in the west and urban and horticultural sources in the east, and is treated in large constructed wetlands called stormwater treatment areas (STAs). Treated water is pumped into the Refuge from STA-1E into the eastern canal and from STA-1W into the western canal, both of which form a perimeter inside the Refuge levee. Untreated water also is discharged to the canals through STA bypass structures. We examined Refuge water quality relative to zones based on distance from the canal into the Refuge marsh on a north-to-south gradient. The Refuge was divided into four zones: canal, perimeter, transition, and interior, based on conductivity patterns from the canal to the interior. The canal zone includes the canals surrounding the Refuge. The perimeter zone is from the canal to 2.5 km into the interior; the transition zone is from 2.5 to 4.5 km into the interior; and the interior zone is > 4.5 km into the Refuge interior. The Refuge was further divided into northern, central, and southern areas.

Surface water grab samples were collected monthly by South Florida Water Management District and Refuge staff at 48 marsh and 5 canal sites from November, 2004 through August, 2007. Marsh sites were accessed by float helicopter and sampled by wading to collect 3 L of undisturbed water, and to measure temperature (T), specific conductivity (SpC), dissolved oxygen (DO), and pH. Samples were not collected when water levels dropped below 10 cm and only 500 mL of water were collected when water levels were between 10 and 20 cm to avoid sediment introduction. Samples were stored on ice at 4 C^o, filtered within 4 hr of collection, and then sent to the laboratory for analysis. Alkalinity (ALK), total organic carbon (TOC), dissolved organic carbon (DOC), total dissolved solids (TDS), total dissolved nitrogen (TDN), turbidity (TB), total suspended solids (TSS), $NO_3 + NO_2$ (NO_x), total phosphorus (TP), total nitrogen (TN), SO_4, Cl, Ca and Si were measured using standard methods described in the Standard Methods for the Examination of Water and Wastewater.

Alkalinity, pH, TOC, TDS, TSS, TB, SpC, T, and Ca, Cl, NO_x, Si, SO_4 and TP concentrations were greater in the canal than in perimeter, transition and interior zones. Alkalinity, DOC, TOC, TDS, SpC, Ca, Cl, Si and SO_4, were greater in the perimeter zone than in the transition or interior zone. Alkalinity, SpC and SO_4 were greater in the transition than in the interior zone. Alkalinity, SpC and TDS correlated in curvilinear relationships with distance from the canal toward the Refuge interior (r^2 = 0.73, 0.64 and 0.64, respectively). Calcium, Cl, and SO_4 concentrations correlated in curvilinear relationships with distance from the canal toward the Refuge interior (r^2 = 0.77, 0.57 and 0.62 respectively). In the perimeter and transition zones, ALK, DOC, TOC, TDS, TB, Ca, Cl, NO_x, Si, SO_4, TP and TDN concentrations decreased in a north-to-south direction. In the canal, TSS, TB and TDN were higher in the north than in the central area. In the perimeter zone, ALK, pH, TOC, TDS, TSS, TB, Ca and SO_4 concentrations were higher in the northern and central areas than the southern area. In the perimeter zone, the TP concentration was greater in the northern than the southern area. In the transition zone, DOC, TOC, TDS, Ca, SO_4 and TDN were greater in the northern and central areas than the southern area.

Important findings relevant to Refuge management are:

- mineral and nutrient concentrations generally decrease with increasing distance from the canal toward the Refuge marsh;
- in the perimeter and transition zones, mineral and nutrient concentrations in Refuge water generally decrease in a north-to-south latitudinal direction;
- classifying the Refuge into zones relative to latitudinal gradients provides additional insight into how stormwater intrusion affects Refuge water quality.

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Baseline Hydrologic Information of the Western Tamiami Trail and the Ten Thousand Islands to Monitor Downstream Effects of the Picayune Strand Restoration Project

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In 2006, the U.S. Geological Survey (USGS) initiated studies to describe hydrologic conditions along the western reach of Tamiami Trail (US-41) between County Road 92 and State Road 29, and at tidal rivers and estuaries of the Ten Thousand Islands area. Through this effort, the USGS has established a network of monitoring stations at selected bridges along Tamiami Trail and along coastal rivers that discharge into the bays downstream. These stations provide water-level, flow, salinity, and temperature data that can be used to develop and calibrate hydrodynamic and water-quality models of the area. The studies are being conducted as part of the USGS Greater Everglades Priority Ecosystems Science (GEPES) initiative, National Park Service (NPS) Critical Ecosystem Studies Initiative (CESI), and in cooperation with the South Florida Water Management District (SFWMD). All data generated by these studies will be available through the USGS South Florida Information Access (SOFIA) web page at http://sofia.er.usgs.gov/. Real-time water-data for Florida is available from the USGS National Water Information System at http://waterdata.usgs.gov/fl/nwis/rt.

Assuming that (1) the completion of the Picayune Strand Restoration Project will extend the hydroperiods of areas north of US-41, and that (2) the addition of culverts under the road and plugs in Tamiami Canal have changed the spatial distribution of freshwater to marshes and estuaries to the south, the data collected from these studies will provide insight about ecosystem responses to these restoration projects by providing:

- Baseline hydrologic information describing the magnitude of pre-restoration freshwater flow and distribution along US-41 to marshes and estuaries to the south.
- Long-term flow monitoring method for bridges and culverts under US-41 between County Road 92 and State Road 29.
- Baseline hydrologic information describing flow and salinity characteristics of tidal rivers and estuaries of the Ten Thousand Islands.

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A Biological Monitoring Program for the Lake Trafford Restoration Project in Collier County, Florida

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Lake Trafford is a shallow, subtropical lake subjected to increasing anthropogenic nutrient loading over the last several decades, resulting in a shift away from a clear, macrophyte-dominated system state to a turbid plankton-dominated one, resulting in algal blooms and fish kills. The Big Cypress Basin has implemented a restoration project that involves hydraulic dredging of sediment from the lake. The removal of over 4 million cubic yards of sediments should be completed in the summer/fall of 2008. This should improve the water quality and facilitate recovery of biotic communities in the lake through stabilizing sediments and reducing the available phosphorus and nitrogen.

We developed and initiated a post-dredging biological monitoring plan to supplement the current on-going monitoring efforts to adequately characterize the recovering floral and faunal communities within Lake Trafford, including the littoral zone and open water areas. This plan includes assessing submerged vegetation, algal communities, macroinvertebrate indicators, and small forage fishes of the littoral zone. Initially, monitoring will serve the purpose of establishing a benchmark of post-restoration lake conditions, and long-term, the data can help guide lake management decisions.

Currently, after sediment removal from the deeper portions of the lake, but before the littoral zone restoration has been completed, no submerged aquatic vegetation is present as sampled by dredge and an Echo-Sounder. Florida Lake Vegetation Index (LVI), a measure of the quality of aquatic vegetation, scored zero (0) based on our observations in 2007. The complete absence of native vegetation on the lake bottom is a concern for restoration since SAV tends to stabilize sediments, improve water quality, and provides fish and invertebrate habitat. Perhaps more importantly, the absence of any desirable native SAV may allow the rapid re-invasion of non-native aquatic plants like *Hydrilla verticillata.*

Preliminary fish sampling along the littoral zone indicates a paucity of small fishes and dominance by tolerant eastern mosquitofish, *Gambusia holbrooki*. Macroinvertebrate communities collected in November 2007 from the 24 Petite Ponar grab samples indicated large differences between the north side of the lake where clay, shell and mud sediments predominate and the south side of the lake where many sites were dominated by fine sand. Benthic samples from the north side of Lake Trafford contained only two species (72 individuals) of diptera larvae, *Chaoborus punctipennis* and *Coelotanypus tricolor* with Shannon diversity (H’) of 0.65 and Lake Condition Index (LCI) score of 3.56. Ponar samples from the south half of the lake contained a total of nine species (190 individuals) including crustaceans, (*Hyalella azteca* and unidentified ostracods), several diptera larvae (including *Chaoborus* and *Coelotanypus*), and oligochaete worms. The Shannon diversity for the south side was nearly three times higher than the north side (H’ = 1.82) and the LCI score was 16.64 but still in the very poor category. Based on this sampling, Lake Trafford fell into the “very poor” category (<18). This is not unexpected due the large disturbance created by the recent dredging activities as well as the lack of SAV, emergent, and floating vegetation. Currently a SAV restoration feasibility study is being implemented using tape grass (*Vallisneria americana*), in cooperation with the South Florida Water Management District and Florida Fish and Wildlife Conservation Commission. Long-term restoration plans also include planting of emergent and SAV and monitoring of biological conditions over time

This study:

- establishes a quantifiable baseline of biological conditions (LCI, LVI) to track the post-dredging recovery of the lake;
- identified the need for post-dredging replanting of native submerged aquatic vegetation;
- indicates the value and importance of building partnerships between researchers, resource managers and policy makers for the benefit of Everglades Restoration.

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Estero Bay Tributaries Riparian Vegetation Analysis

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We examined the riparian vegetation along the five main tributaries to Estero Bay. Riparian vegetation serves as a non-motile integrator of salinity conditions over time, and can prove useful for detecting shifting salinity gradients associated with altered freshwater flow. The objective of this project is to refine our understanding of the freshwater/estuarine interface in the Estero Bay tributaries, utilizing riparian vegetation as ecosystem indicators, toward more ecologically sound definitions of minimum flows. We analyzed historical aerial photography for trends in land use change over the last 40 year, and we established three, long-term vegetation transects along each tributary across the gradient of tidal influence.

Historical patterns of land use show a loss of agricultural land followed by impacts on upland communities. Earlier development showed a loss of riparian buffers, but later development, under new rules, appears to maintain riparian buffers. Measures of biodiversity were not significantly different among position along the tributary (upstream, middle, or downstream) or among the five estuaries. The proportion of exotics was surprisingly consistent across several measures: percent of species richness (22.1%), percent of vegetative cover (22.5%), or percent of woody stem richness (21.4%). To investigate influence of altered freshwater flow, we focused on specific indicator species and the percent coverage of these species by transect along each tributary, and documented the decreasing cover of freshwater indicators and the corresponding increase in saltwater species for downstream transects.

This study:

- documents the changing dynamics of land use conversion in the western Everglades;
- quantifies the extent of exotic infestation in riparian buffer of tributaries to Estero Bay;
- demonstrates the potential of riparian vegetation as an indicator of hydrologic change in tidally influenced streams;
- establishes transects for monitoring of long-term trends in vegetation, particularly shifts in indicator species resulting from altered freshwater flow and changes in competitive advantage of invasive exotic species.

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Ecophysiology of Tree Islands in Water Conservation Area 3

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Tree islands are critical habitats within the larger Everglades wetland matrix as these unique elevated environments support high faunal and floral diversity relative to the surrounding marsh. In the last century, tree islands in the Everglades have been dramatically altered due to hydrologic management practices and it is anticipated that proposed hydrologic restoration will further influence the current structure and function of tree islands. Many studies have examined long-term vegetation responses to hydrology within the Water Conservation Areas (WCAs); however, little work has been conducted on the instantaneous plant responses to differing hydrologic conditions.

The objective of this study was to examine the differences in both instantaneous and seasonal ecophysiological responses of the dominant species on tree islands across the hydrologically managed landscape of WCA 3A and 3B. By quantifying ecophysiological responses of dominant species to seasonal hydrologic changes, we will better understand how short-term responses of tree island species contribute to long-term changes in the structure and function of these islands, and provide insight into the trajectory of tree islands under current hydrologic conditions.

Four islands with differing hydrologic conditions, two within each WCA, were selected for comparison. The two islands in WCA 3A (3AS3 and 3AS5) had longer hydroperiods compared to the islands in WCA 3B (3BS2 and 3BS10). On the head and neartail of each island, we measured the dominant species' instantaneous and integrated plant gas exchange patterns, seasonal water uptake sources, and predawn water potentials (as a proxy of plant water stress).

At the end of the wet season, gas exchange rates were significantly different between the heads and neartails for some of the woody species sampled in WCA 3A. For example, *Annona glabra* and *Salix caroliana* at the head of the tree islands had higher assimilation and stomatal conductance rates relative to conspecifics at the neartail of the same island. Across both WCAs, fern (*Acrostichum aureum* and *Blechnum serrulatum*) gas exchange rates were generally lower than values observed for the woody species at the head; interspecific differences were however not observed between the ferns and woody species in the neartail. At sites where *Persea palustris* occurred, this species had the lowest water potential rates among the species compared; *P. palustris* also had the lowest water potentials at the site with the longest hydroperiod (i.e. neartail of 3AS5). Intraspecific differences in water potentials were however not observed in WCA 3B.

These findings indicate that the neartail regions of tree islands in WCA 3A are affected by hydroperiod to a greater extent compared to WCA 3B. Most woody species also appear to be influenced by hydroperiod to a greater extent compared to the ferns. In WCA 3A measurements of gas exchange and water potentials of plants in the neartails of the islands and of certain species such as *P. palustris*, which appear to be sensitive to hydroperiod, may be used as indicators of community responses to hydrologic stress.

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Hydrology of the Everglades, Past and Present

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The natural hydrology, the water depths and flows, of the pre-drainage Everglades system has been significantly changed through alterations in vegetation, surface elevations and compartmentalization of the system. Recent attempts to stabilize the current, remnant system rely on comparison of post- and pre-drainage hydrological models. Water depths and flows are compared between the models and based on the results ecological inferences are drawn. The interpretation of the model data has assumed a dominant role in the decision making process, with little attention paid to present and historical field data.

The pre-drainage model used in the analysis, the Natural System Model (NSM) and the South Florida Water Management Model (SFWMM) have undergone many input data changes since their inception. The lack of sufficient quantitative historical data to calibrate and verify the NSM allow for a range of possible solutions within established parameters. A range of possible values for model flows across transects within the Everglades will be presented, along with historical field data. The alteration of topography since pre-drainage will be discussed, along with NSM solutions using current elevation data.

The importance of developing engineering solutions to stabilize the Everglades ecosystem should be investigated as part of a more comprehensive system analysis that not includes information from model runs, but includes field data of the current system.

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Pre-drainage Hydrology of Lake Okeechobee

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Quantitative information on the hydrology of the pre-drainage Everglades is very limited. Initial information on topography, water levels, and flows were not documented until drainage efforts were well underway. The earliest records are generally qualitative descriptions of field conditions, making reconstruction of early hydrology an inexact science. However, post-drainage measured data combined with descriptive accounts provide current researchers with the ability to provide input for model scenarios that mimic pre-drainage conditions.

Information related to pre-drainage Lake Okeechobee stages and flows can thus be estimated within reasonable ranges and used to analyze the relationship of the Lake with the downstream Everglades. Based on the earliest records of Lake Okeechobee stages, the point of general overflow over the southern shore line was at elevation 20.1 feet. Widespread overflow was recorded in 1876 and 1910 and probably occurred in years of similar rainfall. The discharge may have been as little as 500,000 acre-feet per year (AF/yr) during some dry years, but averaged 1,300,000 AF/yr, based on a 1970 analysis of outflow data for the time period 1940 to 1951. These outflows correspond well with 1913 outflow measurements through the first drainage canals. Average annual outflow across the southern shoreline in versions of the Natural System Model range from 732,000 AF/yr (NSMv4.6.2) to 1,250,000 AF/yr (NSMv5.1).

In sum, the historical high stages in the lake provided the hydraulic head to maintain a persistent flow of water throughout the downstream wetlands of the Everglades. The importance of returning the Lake to its historical function as the driving force and storage reservoir for the Greater Everglades ecosystem should be investigated as part of a more comprehensive system analysis.

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Endosulfan Sulfate in Fish Tissue from Everglades National Park: Tale of an Unregulated Pesticide Metabolite

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The Contaminant Assessment & Risk Evaluation (CARE) project was established to monitor the presence and assess potential transport of contaminants, other than nutrients and mercury, within areas of Everglades National Park, Biscayne National Park, and Big Cypress National Preserve that will be affected by changes through implementation of CERP projects. The first steps of CARE involved a comprehensive survey in three major conduits for pollutant transport: water, sediment/soils and biological tissues. Although previous studies did identify Endosulfan (I and II), Endosulfan sulfate and p,p'-DDE as the chlorinated pesticides of concern in the lower C-111 basin (S-178) the associations between these findings and other areas within ENP were not clearly established. Expansion of the sampling areas to include sites as far north as Chekika and the opportunity to use small fish as biological integrators gave us the chance to assess the geographical extent of endosulfan sulfate contamination beyond S-178.

Tissue samples of mosquito fish (*Gambusia holbrooki*), marsh killi fish (*Fundulus confluentus*), flag fish (*Jordanella floridae*), mayan cichlid (*Cichlasoma urophthalmus*), diamond killifish (*Adinia xenica*), jewel cichlid (*Hemichromis* spp.), pike killi fish (*Belanesox belizanus*), and sunfish (*Lepomis* spp.) were collected between 2004 and 2007 from 27 stations located within ENP. Composite samples from each station were homogenized and analyzed for organochlorine pesticides, their major metabolites, PCB congeners, and polynuclear aromatic hydrocarbons (PAHs). The results of these analyses revealed elevated concentrations of endosulfan sulfate (ES) in whole fish tissue of up to 350 ng/g (dry wt.) with a median of 34 ng/g (n=84). Other frequently detected pesticides included the parent endosulfan I and II and the metabolite of DDT; 4,4' DDE. Concentrations, however, are much smaller than those observed for ES.

Distribution of ES in fish seems to be localized in areas influenced by the system of canals and structures along the C-111/L-31N canals between structures S332B to S-197. ES residues were detected in areas inside ENP as far as the Taylor Slough Bridge at SR 9336. Based on the water concentrations available at limited stations, BCF's from 173 to 2337 were calculated for ES. The only value reported in the literature for similar species; 1622 is in good agreement with our observations. Since there is no environmental criterion to evaluate the potential risk for ES exposure to fish, only indirect assessments based on EI and EII could be produced at this time. Based on these numbers, to achieve a body burden of 350 ng/g d.w., a fish should have been exposed to more than the 56 ng/L water quality criterion for Endosulfan II and II. However, until reliable toxicological data based on ES become available, the question of risk associated to the observed body burdens remains unanswered.

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Assessment of Submerged Aquatic Vegetation as Indicators of Antifoulant Contamination in Southeast Florida Coastal Environments

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Irgarol 1051 (2-methythiol-4-tert-butylamino-6-cyclopropylamino-s-triazine) is a common antifouling herbicide effective on preventing algal growth. It is added to marine paints, on watercrafts, to prevent fouling. Irgarol leaches from these paints and enters the surrounding waters, chronically exposing submerged vegetation to small but measurable concentrations of a PSII inhibitor.

Based on boat usage, water depths, and submerged aquatic vegetation (SAV) coverage, two locations were selected for the study: Coconut Grove Marina (CG) in Biscayne Bay and Key Largo Harbor (KLH) outside of Port Largo. Water, sediment, macroalgae, and sea grasses were collected from both sites and analyzed. The following sea grasses are abundant in South-East Florida: Manatee Grass *(Syringodium filiforme),* Turtle Grass (*Thalassia tetudinum*), and Shoal-grass (*Halodule wrightii*). Among the macroalgae, *Halimeda opuntia* is the most prevalent organism available at these sites.

The goal of this project was to determine which specie of SAVs can serve as a biological indicators of Irgarol contamination in marine environments based on their capability to accumulate the antifoulant over time. Since water contamination is subject to large temporal and geographically changes, a sentinel organism was a better choice.

SAV samples were collected by hand, extracted by Accelerated Solvent Extraction (90:10 Methanol:Water) and purified using automated Solid Phase Extraction using Oasis HLB cartridges on multiple Zymark Rapid Trace Workstations. All sample extracts were then analyzed by GC/MS-SIM for both Irgarol and two of the most common metabolites (M1 and M3).

Irgarol water concentrations were between 5.70 ng/L to 241 ng/L at Key Largo Harbor (KLH), and between 28.4 ng/L to 86.3 ng/L at Coconut Grove Marina (CG). M1, the most stable metabolite of Irgarol, was present in waters at concentrations ranging <1 to 50.0 ng/L and 8.37 ng/L to 29.0 ng/L for KLH and CG respectively. Concentrations in sediments were negligible thus accumulation in mineral matrices is not an environmental issue All SAVs accumulated Irgarol and M1 to a lesser extent. The Irgarol ranges were 17.1 ng/g to 990 ng/g and M1 ranged from <2 to 104 ng/g. Of all species, Shoal grass (*Halodule wrightii*) had the highest capacity to bioaccumulate Irgarol and M1.

This work provides a simple way to use SAV as sentinel organisms to assess potential contamination of coastal environments with this increasingly popular antifouling agent. As the need for new in-water storage of boats continue to increase in Southeast Florida, monitoring of marina-derived contaminants has become an issue of concern for areas like Biscayne Bay where important protected environments coexists with large, densely populated marinas.

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Salinity, Light, and Temperature Effects on *Ruppia maritima* Germination in Florida Bay: Mesocosm and Field Studies

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Ruppia maritima is a submerged aquatic vegetation (SAV) species that provides excellent waterfowl and fisheries habitat along the freshwater Everglades-mangrove ecotone in Florida Bay. This species has been identified as a keystone indicator of seagrass community health and a target species for salinity optimization in Florida Bay with Everglades' restoration. Although *Ruppia* is known to dominate in the oligo- to meso-haline region of the bay, it can survive as an adult in hypersaline conditions (>60 psu). To provide data for mechanistic models to forecast seagrass species shifts in the bay under changes in fresh water flows and in response to climate change scenarios, we investigated salinity (0-45 psu), light (water column [~500 µmol m^{-2} s^{-1}] and sediment [dark]) and temperature (25 and 31^{o}C) effects on *Ruppia* germination and seedling success. We are also monitoring *Ruppia* reproductive potential and germination, and will be implementing seed transplant experiments, in order to further our mechanistic understanding of conditions which promote *Ruppia* dominance in low salinity regions of the bay. In mesocosm experiments, *Ruppia* germination predominantly occurred in the 3 low salinity treatments (0, 5, 15 psu) with few to no germinations at upper salinities (25, 35, 45 psu). However, after 5 mths at treatment salinity, salinities were lowered to ~0-1 psu, at which time the highest number of experimental germinations occurred. The majority of these subsequent germinations were in tanks that were previously at marine and hypersaline conditions (35 and 45 psu). These data provide a mechanistic understanding of field observations that *Ruppia* shows greater dominance at sites with highly variable salinities. In addition, although this species is not a true seagrass with strict fidelity to the marine environment, our results provide a better understanding of the role salinity can play in the distribution of this species at marine-freshwater ecotones. Whether the seeds were placed in the water column under high light or in the sediment in the dark, or variable temperatures, did not have significant effects on seedling germination and/or seedling survival. These results are now being field validated using long-term data sets, new reproduction monitoring studies, and manipulation experiments in the field.

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Integrated Ecological Modeling and Decision Analysis within the Everglades Landscape

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Models can help organize and synthesize our understanding of the ecology of a system, and this understanding may be applied in making relative comparisons of ecological responses to alternative restoration scenarios. In this paper, we consider the dynamic physical, biogeochemical, and biological interactions that are hypothesized to be important to the function and structure of relatively simple model ecosystems in a heterogeneous landscape. Depending on the objectives for a particular application, this ecological landscape model is applied at a range of spatio-temporal scales, from subregional to regional, and decadal to century. The scales chosen for an application typically depend on the ecosystem variable(s) of interest, and are integral with the relative degree of uncertainty that may be "acceptable" for the application's objectives, in light of the state of knowledge (data) of the system. Even in a simply-designed system model, integrating the interactions among multiple variables leads to complex dynamics, and to complex decisions in assessing the relative benefits of one simulation scenario over another. Invariably, there are trade-offs that must be considered in selecting a scenario or management alternative with the most favorable overall probability towards restoration, particularly when considering the different behaviors of multiple variables across spatial gradients. We demonstrate a simple application of an existing multi-criteria decision analysis tool coupled with the Everglades Landscape Model to provide an efficient framework to evaluate the several criteria posed by the integrated simulation model. While applied here using primarily hydrologic and water quality criteria, additional social and economic factors could be mapped to the decision support system to iteratively broaden the assessment of relative benefits among Everglades restoration scenarios.

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Long-term Shifts in Seagrass Community Structure Follow Experimental Nutrient Enrichment in Florida Bay

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Restoration of the greater Everglades ecosystem may increase freshwater input to Florida Bay. Increased freshwater flow, as envisioned by the Comprehensive Everglades Restoration Plan, may increase loadings of both nitrogen and phosphorus into the Bay. We investigated the regional and temporal effects of these increased loadings on benthic communities. Community responses to anthropogenic nutrient enrichment are often evaluated with experimental manipulations, but real-world effects of enrichment usually occur over long time scales. We used a multi-year experimental approach to assess the long-term (six years) effects of nutrient enrichment on the benthic community in Florida Bay. We examined the spatial extent and temporal patterns of nitrogen (N) and phosphorus (P) limitation of each of the major benthic primary producer groups in Florida Bay: seagrass, epiphytes, macroalgae, and benthic microalgae, and characterized the shifts in primary producer community composition following nutrient enrichment. We also evaluated epifaunal assemblage responses to nutrient enrichment. We established study plots at each of six sites across Florida Bay and added N and P to the sediments in a factorial design for six years. Tissue nutrient content of the turtlegrass *Thalassia testudinum* revealed a spatial pattern in P limitation, from severe limitation in the eastern bay (N:P > 96:1), moderate limitation at two intermediate sites (~63:1), and balanced with N availability in the western bay (~31:1).

Florida Bay is primarily phosphorus-limited; nitrogen addition did not consistently affect any benthic primary producers. After three years of phosphorus addition, shoalgrass (*Halodule wrightii*) began a gradual replacement of the dominant turtlegrass (*Thalassia*). After six years of enrichment, *Halodule* dominated most P-addition plots in the eastern bay. In the western bay, where ambient *Thalassia* tissue N:P ratios indicated that N and P availability was balanced (~31:1), seagrass was not affected by nutrient addition but was strongly influenced by disturbance (currents, erosion). Macroalgal and epiphytic and benthic microalgal biomass were variable between sites and treatments. In general, there was no algal overgrowth of the seagrass in enriched conditions, possibly due to temporal stochasticity or regulation by grazers. However, within the epiphytic microalgal community, encrusting green and red algae increased following P addition at most sites, whereas diatom biomass, though highly variable among sites, did not respond to nutrient treatments. N addition had little effect on any benthic primary producers throughout the bay. There was no evidence of more than ephemeral algal overgrowth in enriched plots; epiphytes and macroalgae may have been seasonal or controlled by higher grazer densities in those treatments.

In the severely P-limited eastern bay, caridean shrimp, grazing isopod, and gammarid amphipod densities were higher in enriched than in unenriched plots. In the less P-limited western bay, epifaunal density was not affected by nutrient addition. At both sites, some variation in epifaunal density was explained by features of the macrophyte canopy, such as *Thalassia* and *Halodule* percent cover, suggesting that enrichment may change the refuge value of the macrophyte canopy for epifauna. Additional variation in epifaunal density was explained by epiphyte pigment concentrations, suggesting that enrichment may change microalgal food resources.

Stable isotopic signatures ($\delta^{15}N$) revealed increased importance of *Halodule* in the diet of benthic consumers, primarily benthic grazing snails at the P-limited site. The diet of epiphyte grazers did not change in enriched plots, but increased density suggests that grazers may be able to control epiphytic algal proliferation following moderate nutrient input to Florida Bay.

Key findings relevant to restoration:

- Increased nutrient input to Florida Bay may cause long-term shifts in benthic primary producer assemblages. Specifically, increased P loading causes a shift from a *Thalassia*-dominated seagrass community to a *Halodule*-dominated one.
- Epifaunal densities and diets may change after short-term nutrient enrichment, suggesting that changes in nutrient loading will cause changes in abundance and trophic structure of higher trophic levels in Florida Bay.
- Epifauna may control epiphytic algal overgrowth on seagrasses even at relatively high nutrient loading rates in Florida Bay.

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Spatio-Temporal Dynamics of SAV Abundance and Water Quality in the Mangrove Lakes Region of Florida Bay

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The Florida Bay coastal embayments from Terrapin Bay to Garfield Bight and the mangrove zone lakes hydrologically connected to these embayments (e.g., Seven Palms Lake, West Lake, and The Lungs) are a focus of the Comprehensive Everglades Restoration Plan (CERP) activities (CERP 2002). This area, including the mangrove dominated wetlands, is important nursery habitat for recreational and commercially valuable fishery species (Tilmant 1989; Ley and McIvor 2002); designated critical for the endangered American crocodile (Mazzotti 1989); and, is important foraging and nesting habitat for wading birds, including the endangered wood stork and the roseate spoonbill (state species of special concern), and waterfowl (Kushlan et al 1982; Ogden 1994). These species and others depend on oligohaline to mesohaline spatial and temporal salinity patterns CERP 2004a). Altered freshwater inflow patterns (quantity, duration, and distribution) from water management practices have likely had adverse ecological effects in this area (McIvor et al 1994; CERP 2004a).

Historically, under oligohaline to mesohaline conditions, these coastal lakes and embayments had extensive benthic macrophyte or submerged aquatic vegetation (SAV) beds. These macrophytes supported fishery species and waterfowl and helped maintain good water quality (Tabb and Manning 1961; Tabb et al 1962; Kushlan et al 1982; Tilmant 1989; CERP 2004a). These SAV communities experience more direct and rapid effects of changes in freshwater inputs than those in Florida Bay proper. It is hypothesized that prolonged periods of elevated salinity in the coastal lakes and basins, caused by diminished freshwater inflow volume and duration due to water management practices, have reduced the seasonal duration and spatial extent of benthic macrophytes (CERP 2004a). The decline in waterfowl abundance in the mangrove zone lakes is thought to be at least partially due to this reduction in SAV (CERP 2004a). During recent high rainfall years, and thus increased freshwater inputs, macrophyte and waterfowl abundances increased in the mangrove zone lakes (Morrison and Bean 1997; Montague et al 1998; CERP 2004a). Restoring more natural freshwater water inflow and salinity patterns in this area should have diverse ecological benefits, affecting benthic macrophytes, fishery species, waterfowl, water quality, the American crocodile, resident small fishes, and wading birds (CERP 2004a). Designing and implementing successful ecosystem restoration actions depend on developing realistic restoration targets and effective methods of assessing potential alternative restoration actions and evaluating performance of implemented actions.

The objectives of the present investigation are to describe the spatial and seasonal dynamics of SAV abundance and water quality in the Mangrove Lakes. From April 2006 to February 2008, water temperature, salinity, nutrients (total nitrogen and total phosphorus), and phytoplankton density (chlorophyll-a) were measured during monthly water quality surveys at 41 sites in the 7 Palms Lake system (7 Palms Lake, Middle lake, Monroe Lake and Terrapin Bay) and the West Lake system (West Lake, Long Lake, The Lungs, and Garfield Bight). SAV species composition and percent cover were also measured on a quarterly basis during this period. Univariate and multivariate analyses were employed to detect spatial and seasonal patterns and to describe relationships between water quality parameters and SAV community structure.

Key findings relevant to restoration:

1) Spatial SAV distribution patterns are consistent with mean salinities, with *Chara hornemanni* occupying upstream oligohaline "lakes" and *Halodule wrightii* occupying the more marine coastal embayments.

2) Seasonal abundance patterns differ between *Chara* and *Halodule*, with *Chara* following hydrologic patterns and *Halodule* following typical solar seasonality.

3) *Chara hornemanni* is the dominant aquatic macrophyte in the oligohaline regions of the Mangrove Lakes and should be a restoration target species.

4) *Ruppia maritima*, a current restoration target species, occurs only sporadically throughout the Mangrove Lakes.

5) Total phosphorus concentrations are ≈3X greater in the West Lake system than in the 7 Palms system fueling ≈6X greater phytoplankton densities. Increased water clarities in the 7 Palms System coincide with ≈3X greater *Chara* abundances.

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Introduction and Colonization of Non-native Apple Snails in Everglades National Park

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In May of 2005, the non-native island apple snail *Pomacea insularum* and spiketop apple snail *P. diffusa*, were detected at the northern boundary of Everglades National Park (ENP). After initial observations, ENP staff began to monitor the distribution and abundance of these two species. *P. diffusa* appears to have a limited distribution in northern Northeast Shark Slough but more monitoring is necessary. *P. insularum* have spread between S-12B and S-12C water control structures on the Old Tamiami canal, were detected upstream in the L-29 canal, and downstream in the Shark Valley Canal and associated marshes. Field biologist surveyed and removed egg masses in the Old Tamiami Canal every 10-14 days. During the months of May to December of 2005, 512 *P. insularum* egg masses and 19 live adults were removed. In 2006, 2,687 egg masses and 31 adult snails were removed. In 2007, 1,024 egg masses and 17 snails were removed. Effects of the colonization of *P. insularum* and *P. diffusa* in ENP are still unknown. Previous studies of introduced *Pomacea* spp. suggest that they have the ability to consume large amounts of aquatic vegetation and may cause detrimental impacts to aquatic ecosystems. Further monitoring, management, and research on non-native apple snails is needed to determine effects on native fauna and flora of Everglades marshes and possible control or eradication strategies.

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Mapping Mangrove Migration under Altered Hydrologic Flow and Changing Sea-level in Ten Thousand Islands NWR

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The Ten Thousand Islands National Wildlife Refuge (TTINWR) is a major feeding and resting destination for wintering migratory birds in southwestern Florida. Many species of wading and shore birds rely specifically on marshes as foraging habitat, making mangrove encroachment a concern for wildlife managers. With the alteration of freshwater flow to the region and global sea level rise, mangroves have migrated upstream into traditionally brackish marshes on the refuge. Aside from localized freezes in some years, very little seems to be preventing mangrove encroachment with the current hydrologic balance incident to TTINWR.

Using historic topographic sheets, south Florida Gap Analysis Program (GAP) data, 2005 Collier County aerial photography, and field verifications, we mapped mangrove stands in TTINWR from the Gulf of Mexico inland to the Tamiami Trail (US Highway 41). Extracting mangrove classes from historic imagery, we compared the area encompassing TTINWR from the 1930s era to the GAP data collected in 1995 and to aerial photographs from 2005.

We determined the area of mangroves within TTINWR to be approximately 7281 hectares in 2005, which represents an 1845 hectare increase since the 1930's. This time frame also included the construction of the Faka Union Canal in 1968, which is likely to have added considerably to mangrove encroachment as tidal signatures were vectored inland. Overall change represents an approximately 34% increase in mangrove coverage on TTINWR since the 1930's, with mangroves currently occupying 70-80% of emergent land within TTINWR.

An on-going hydrologic monitoring and modeling project on TTINWR will help determine how water management may mediate transitions of mangrove to marsh during future restoration activities, and will assist wildlife managers in making water management decisions to maintain a more favorable balance of marsh to mangrove as critical wading and shore bird habitat.

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Risk Assessment of Potential Invasiveness of Exotic Reptiles to South Florida Based on Import Pathway

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Global trade of live reptiles has facilitated introduction and establishment of exotic reptiles in many locations around the world. In south Florida, a subtropical climate and frequent import of exotic reptiles as pets have contributed to successful establishment of numerous taxa of reptiles. In this risk assessment project, we developed quantitative models to predict the successful establishment of exotic reptiles in south Florida. To identify which biotic, abiotic, and human-induced factors may be the best predictors of successful establishment for exotic reptiles, we used discriminant analysis, logistic regression, and recursive partition and regression trees.

Significant variables in the models included taxonomic group, maximum temperature match between native range and Florida, animal price, and manageability. We applied the models to predict establishment success of the 33 reptiles that were most frequently imported through Miami and St. Petersburg ports in Florida from 2000-2005. Among the assessed reptiles, we identified eight lizards and two snakes as potentially successful invaders. We further assessed risks associated with potential invaders should they become established by identifying species that are (1) dangerous to humans; (2) upper trophic-level predators in an ecosystem; (3) have the potential to spread rapidly; and (4) particularly difficult to manage or control.

Once exotic reptiles become established, managing them is expensive and labor intensive, thus prevention of establishment is the ideal management goal. Our study provides a foundation to develop screening tools that identify potentially problematic species among imported reptiles.

Relevance to Everglades restoration:

- If Everglades restoration alters microhabitat features of the landscape to be more favorable for exotic reptiles, the probability of establishment may increase.
- Restoration of native and endangered species habitats may be negated by release and establishment of exotic reptiles in south Florida. Management tools that screen potential invaders and assess risk of establishment must be integrated into restoration goals and future modeling scenarios.

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Landscape Patterns in Everglades Periphyton

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The distribution of periphyton in the Everglades is being examined through several large landscape-scale programs, including the Regional Environmental Monitoring and Assessment Program of the United States Environmental Protection Agency (R-EMAP), the Monitoring and Assessment Plan for the Comprehensive Ecosystem Restoration Plan (MAP, sponsored here by the South Florida Water Management District) and several assessments sponsored through Everglades National Park (ENP). All programs are integrative, including periphyton monitoring as one part of a larger assessment of ecosystem response to restoration. As such, periphyton is part of several conceptual models that link its productivity and composition to soil formation, nutrient chemistry, plant communities and food web structure so that patterns revealed in assessment might be used to make predictions of cascading influences of alterations in hydrology and water quality on ecosystem-scale structures and processes. Hydrology and water quality are the primary drivers in these models not only because they are regulated by management but also because periphyton has been shown to react quickly and predictably to both.

Analysis and synthesis of large-scale pattern in periphyton distribution include (1) mapping to visualize spatial pattern, (2) exploration of environmental drivers of pattern, (3) assessment of ecosystem status based on expected baseline values and (4) modelling to predict cascading effects and long-term expectations under varied operational scenarios. Parts 1-3 are fairly well-developed while part 4 (modelling) is under development. Spatial pattern assessments have revealed large-scale pattern in periphyton production, quality (nutrient content) and composition. Trends in relatively unimpacted areas of the Greater Everglades include high levels of biomass in the marl prairie and rocky glades habitats of ENP, low nutrient content in short-hydroperiod wetlands (with values naturally increasing toward coastal estuaries) and compositional patterns that correspond to underlying pattern in pH and conductivity. Increased hydroperiod and nutrient supply result in a decline in biomass of calcareous periphyton mat, increased periphyton nutrient content and increased abundance of non-endemic periphyton species. Mechanisms driving these relationships and their consequences to ecosystem structure and function are being examined in complementary experimental studies in the field and laboratory.

Findings to date can be summarized by the following:

- Periphyton biomass in short-hydroperiod wetlands will decline if water levels and flows are increased; correspondingly, it will increase in long-hydroperiod wetlands if water levels and hydroperiod continue to decline.
- Periphyton nutrient content is one of the most stable and reliable indicators of water quality degradation; interpretation of pattern and trends MUST be based on comparisons to expectations for ‘unimpacted’ conditions because of strong underlying trends in natural distributions.
- Disturbances in water quality and quantity (outside natural ranges) encourages cosmopolitan algal species that differ from native communities in their ‘engineering’ role in Everglades habitat; widespread loss of taxa endemic to calcareous subtropical wetlands has not been fully evaluated.

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Landscape Patterns in Periphyton Abundance and Composition in the South Florida R-EMAP Study

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The distribution of periphyton in the Everglades is being examined through several large landscape-scale programs, including the Regional Environmental Monitoring and Assessment Program of the United States Environmental Protection Agency (R-EMAP). In this study, periphyton attributes comprise one part of a larger assessment of the status of the Everglades ecosystem. As such, periphyton is part of several conceptual models that link its productivity and composition to soil formation, nutrient chemistry, plant communities and food web structure so that patterns revealed in assessment might be used to make predictions of cascading influences of alterations in hydrology and water quality on ecosystem-scale structures and processes. Hydrology and water quality are the primary drivers in these models not only because they are regulated by management but also because periphyton has been shown to react quickly and predictably to both.

Analysis and synthesis of large-scale pattern in periphyton distribution include (1) mapping to visualize spatial pattern, (2) exploration of environmental drivers of pattern, (3) assessment of ecosystem status based on expected baseline values and (4) modelling to predict cascading effects and long-term expectations under varied operational scenarios. Parts 1-3 are fairly well-developed while part 4 (modelling) is under development. Spatial pattern assessments have revealed large-scale pattern in periphyton production, quality (nutrient content) and composition. Trends in relatively unimpacted areas of the Greater Everglades include high levels of biomass in the marl prairie and rocky glades habitats of ENP, low nutrient content in short-hydroperiod wetlands (with values naturally increasing toward coastal estuaries) and compositional patterns that correspond to underlying pattern in pH and conductivity. Increased hydroperiod and nutrient supply result in a decline in biomass of calcareous periphyton mat, increased periphyton nutrient content and increased abundance of non-endemic periphyton species. Mechanisms driving these relationships and their consequences to ecosystem structure and function are being examined in complementary experimental studies in the field and laboratory.

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St. Lucie Estuary: Analysis of Annual Cycles and Integrated Water Column Productivity

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The St. Lucie Estuary is located on the southeast Florida coast, in an area heavily influenced by anthropogenic activities. These activities have altered inputs to the estuary including freshwater, nutrients, sediments and organic matter. The current body of knowledge in estuarine science shows that alterations in estuarine inputs increase the likelihood of eutrophication and declines in water quality. The negative effects of estuarine eutrophication include altered food webs, harmful algal blooms, hypoxia, and fish kills. The St. Lucie Estuary has periodically experienced symptoms of eutrophication including fish lesions, phytoplankton blooms, and periods of bottom water hypoxia.

Prior to 2000 there was limited quantitative information available on the nutrient dynamics of the estuary. Data were needed to support the development of pollutant load reduction goals and guide other efforts to improve water quality. In 2000-2001, the South Florida Water Management District (SFWMD) initiated the St. Lucie Estuary Productivity Study (SLEP) in concert with the Harbor Branch Oceanographic Institute. The SLEP study included the collection of data on water quality data and primary productivity of the estuary. These data were collected over a period of 15 months at various water column depths on eight stations representing the four different regions of the estuary.

In 2006-2007, the SFWMD retained Malcolm Pirnie to perform the SLEP Data Analysis Project. This project explored the SLEP data to improve understanding of the factors that control water quality and integrated water column primary productivity in the St Lucie Estuary. The analysis was performed using various graphical and statistical techniques including scatterplots, non-parametric correlation, and principal components analysis. This was followed by non-parametric hypothesis testing to identify seasonal differences, compare water quality at different stations and depths, and examine unusual or 'outlier' events in the SLEP data set. Primary productivity controls were investigated via least-squares linear regression models developed to predict depth-integrated primary productivity as a function of water quality and light-related variables. The resulting models were compared with similar models from other estuarine systems.

The results of the water quality control factor investigation demonstrated the importance of freshwater inflow and salinity to the water quality of the St. Lucie Estuary. Differences between freshwater inputs and ocean water inputs set up seasonal, hydrologic and spatial water quality gradients in the estuary. Salinity can be thought of as a 'master' variable because it had moderate to strong correlations with most other key variables, including nutrient concentrations, light availability, algal biomass, and primary productivity. The South Fork and North Fork of the estuary had similar water quality in many respects, although water clarity was significantly lower in the South Fork which receives discharge from Lake Okeechobee and the St. Lucie Canal Basin. Nutrient concentrations and chlorophyll-*a* decreased down-estuary, as water clarity increased. The data exploration revealed a complex interplay between nitrogen, phosphorus and light limitations in the estuary. Nutrient ratios were indicative of co-limitation by nitrogen and phosphorus, but primary productivity correlated more closely with phosphorus. Primary productivity varied temporally with salinity, and was generally high during periods of low salinity; however, most of the time, primary productivity was not markedly different in different parts of the estuary. The lack of spatial variations in primary productivity may be explained by the counteracting effects of nutrient and light limitations. The upper estuary is more likely to experience light limitations due to the lower water clarity. As clarity improves down-estuary, nutrient concentrations are reduced. Thus the improvement in clarity is counterbalanced by lower nutrient availability.

The results of the integrated water column primary productivity investigation confirmed the utility of a composite variable for modeling primary productivity. The composite variable comprised of chlorophyll-*a,* photic depth, and surface irradiance can explain about half of the variability in either net or gross primary productivity. Model coefficients were within the range of other estuarine models reported in peer-reviewed literature. However, regression models on shallow station data were found to have significantly lower model slopes than models using deep station data. This effect is also observed in the literature, and may be due differences in the carbon-to-chlorophyll-*a* ratios between areas of high and lower water clarity. Although phosphorus species and ammonia were found to be significant variables in selected subsets of the data, they did not greatly improve the explanatory ability of the regression models.

The results of the SLEP Data Analysis Project highlight the utility of coupling monitoring with modeling in estuarine ecosystem management. The findings not only document the status of the estuary, but can now be used to evaluate estuary ecosystem responses to proposed watershed management actions and long term environmental trends.

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Microconstituents in Surface Waters from South Florida: Occurrence, Persistence and Relevance with Respect to Water Reuse

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The term **"micro-constituents"** is often related to chemicals with a large variety of functionalities and effects that could not be grouped with traditional contaminants such as pesticides, herbicides, industrial chemicals etc. Although largely unregulated and sometimes relatively non-toxic, their presence in environmental compartments is a symbol of degraded quality of surface waters since they are broadly related to human-derived wastewaters.

In recent years, numerous pharmaceuticals, personal care products, steroids and hormones have been routinely detected not only in municipal wastewater but also in receiving surface waters not directly affected by wastewater discharges. All these compounds, commonly referred also as EPOCs, have been suggested as potential stressors in natural systems at very low concentrations. Their occurrence in aquatic environments is particularly troublesome because pharmaceuticals are deliberately designed to cause a physiological effect, thus they could potentially affect non-target organisms either as the parent compounds or as any of their stable metabolites. Hormones are a particularly relevant case since they are directly involved in controlling the endocrine system of many organism living in protected environments. However, the question of effects is often blind sighted by the issue of source identification and tracking. If we do not know where the micro constituents are coming from or how long they persist in the environment is difficult to implement changes or establish protection goals. In addition, with the increasing pressure from urban development and the expanding demand for drinking water the need for water reclamation and water reuse has hit a new high. This study reports the routine monitoring of a selected group of "micro constituents" in surface waters from freshwater canals, rivers, lakes, and coastal areas in South and Central Florida for the last 4 years and their potential use to assess water quality problems. Five (5) pharmaceuticals and personal care products and a group of fourteen (15) natural and synthetic hormones and steroids were used to compare coastal environments affected by the presence of wastewater intrusions. The compounds more frequently detected were: **Coprostanol, Estrone, Caffeine, Triclosan** and **DEET**. However, micro constituents such as Estrone and Caffeine, proved to be more useful as markers for impacted places due to their persistence while coprostanol and estrone provided the best overall correlations for human-derived intrusions.

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Regional Distribution of Organic Contaminants in Water and Sediments of Everglades National Park, Biscayne National Park and Big Cypress National Preserve

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As part of the Contaminant Assessment and Risk Evaluation (CARE) project, the concentrations of a wide variety of organic pollutants are routinely measured in selected stations along Everglades National Park, Biscayne National Park and Big Cypress National Preserve. Many stations, targeted to gain information of potential CERP project implementation and changes in water deliveries, are located along areas where anthropogenic inputs are likely (ENP Eastern Boundary, canals entering BNP, along Tamiami Trail, etc). In contrast, several stations were placed in areas not likely to be affected by any CERP transformation thus giving an indication of background activity (Florida Bay, Shark River, Whitewater Bay etc). Water and sediment samples are collected from 30 stations within ENP, 11 samples within BNP, and 9 stations within BICY. Samples from each station are analyzed for organochlorine pesticides and pesticide metabolites, PCB congeners, Nitrogen pesticides, Organophosphorous pesticides, Phenoxy acid herbicides, polynuclear aromatic hydrocarbons (PAHs), and pharmaceutical products and by-products. Although no widespread contamination is observed on a wide regional basis, anthropogenic influences and their chemical signatures are present in specific localized areas such as the C-111 basin, the canals leading to Biscayne Bay (Mowry, Military) and stations located in or nearby marinas. The results of the analyses reveal that the most frequently detected contaminants include endosulfan sulfate, endosulfan I and II, 4,4' DDE, chlorpyrifos, atrazine, metalochlor, and PAHs. For example, Endosulfan sulfate was detected in 15% of water samples analyzed, with most detections occurring near the boundary of ENP adjacent to the Homestead Agricultural Area (HAA). 4,4'-DDE, however is more prevalent in sediments along the lower C-111 in particular at structure S-178. In contrast, low levels of Atrazine (<30 ppt) are almost ubiquitous along canals leading to BNP and rather prevalent along the system. The highest concentrations of total PAHs were detected in BNP at stations located at or near marinas where boat traffic is heaviest and water circulation is low, and in areas of ENP near roadways (US-1 and Tamiami Trail) indicating that PAH contribution is predominantly of pyrogenic origin from motor vehicle and vessel exhaust.

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Cultural Resources Overview for the Comprehensive Everglades Restoration Plan: A Cooperative Effort by USACE, SFWMD, SHPO, New South and Janus

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The large scale and impact of the CERP projects, including the Acceler8 projects, has the potential to affect many known and unknown archeological sites in South Florida. Meeting the Section 106 requirements of the National Historic Preservation Act for all of CERP affords archeologists with a unique opportunity to expand the knowledge of cultural resources in South Florida.

Approved in the Water Resources Development Act of 2000, many components of CERP are already active projects, resulting in frequent and ongoing consultation with the Miccosukee Tribe of Florida and the Seminole Tribe of Florida. In response to the ongoing consultation requests for CERP and Acceler8 projects, the Miccosukee Tribe issued a statement to clarify the Tribe's position on common questions encountered in the cultural resource consultation process. The position statement charged the USACE and the SFWMD to make every attempt to avoid impacting archeological sites, particularly those containing human remains. It also offers brief guidelines for handling such sites should avoidance become impossible.

In an effort to meet this request, the combined Cultural Resources team of the USACE, the SFWMD, and their contractors: New South Associates and Janus, the State Historic Preservation Officer (SHPO) and the State Archeologist, proposed to develop a comprehensive plan for studying the cultural resources of the CERP project area as a whole rather than on a project specific basis. Examining the CERP Cultural Resources Study Area as a cultural landscape allows us a greater opportunity to utilize the known historical context to create a more focused survey strategy of the area.

As appropriate methods for addressing the policy were discussed, all parties agreed that it would be beneficial to clarify the actual archaeological procedures utilized in the field, to create a survey strategy for the CERP area, and to also update the historic context for the CERP area. Three separate documents emerged from the collaboration of the Cultural Resources team.

The first document, the Policy Statement and Guidelines Regarding Human Remains and the Comprehensive Everglades Restoration Plan (CERP) and Acceler8 Projects, reflects a joint effort by the USACE, Jacksonville District and the SFWMD to address the concerns of consulting tribes regarding the inundation of Human Remains in the CERP area. All applicable laws and regulations are discussed to emphasize the responsibility of both agencies to address the tribes' concerns, and guidelines are introduced to implement the plan of action when human remains are discovered.

The second document is an updated archeological and historic context for the CERP area. This document is intended to synthesize existing knowledge of cultural resources in the CERP area, paying particular attention to knowledge gained in recent years.

The third document is a survey strategy for cultural resources in the CERP area. Developed in conjunction with the updated context, this survey strategy examines the known cultural resource sites in the CERP project areas with respect to the physiographic region in which they are found.

It is intended to guide Cultural Resources Team members in decisions on probability zones in individual project areas to maximize the location of sites during archeological surveys.

All three documents represent the commitment of the Cultural Resources Team to identifying and protecting cultural resources in the CERP area. The Comprehensive Everglades Restoration Plan was developed as a method to restore and protect the unique environment of South Florida and the Everglades. The Cultural Resources Overview was developed as a method to identify and protect the unique cultural legacy of the people who have occupied South Florida and the Everglades.

- Coordination between state and federal agencies to maximize identification and protection of cultural resources in the CERP project areas.
- CERP projects can foster good working relationships with the Miccosukee and Seminole tribes while ensuring that tribal interests are considered and protected.
- CERP cultural resource studies provide an opportunity to better understand human settlement over hundreds of thousands of acres in southern Florida.

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A Spatially-explicit Simulation Model of Landscape Quality for the Wood Stork (*Mycteria americana*) in Southwestern Florida

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Long term declines in populations of the endangered Wood Stork in southern Florida have been attributed to declines in the quality of foraging habitat resulting from altered hydrologic patterns and a loss of wetland area. Large scale restoration efforts for southwestern Florida are mostly in the planning phases, and the ability to forecast the biological effects of different restoration scenarios will be vital to successful restoration. This area is important to the U.S. population of the Wood Stork because it includes the Corkscrew Swamp, which is home to the largest traditional Wood Stork breeding colony in North America.

A model was developed using hydrologic and other inputs to estimate the quality of foraging habitat for the Wood Stork on a landscape of ~219,000 ha of southwestern Florida. The model provides a quality estimate for each 457 m x 457 m grid cell every five days for eight breeding seasons. Results are aggregated to generate a final quality score for the landscape for each breeding year. Hydrologic characteristics of each cell were based on output from the MIKE SHE hydrologic model, which has a 5-day time step. Variables in the cell model include water depth at the start of the dry season, days since last drying, water depth, change in water depth, distance from the colony, and dominant vegetation type.

Model quality estimates correlate with log-transformed fledgling numbers for the Corkscrew Swamp colony ($r = 0.71$, $n = 8$, $P = 0.05$) suggesting the model is reflecting environmental conditions that are related to productivity. In addition, model output indicates that successful breeding years are characterized by both a greater area of high quality habitat (median = 179,485 ha) and more high quality habitat in cells with shorter hydroperiods (median = 297.5 days) than unsuccessful years (median = 156,607 ha and 314.9 days, respectively).

The significance of this study to restoration of southwestern Florida is that:

- The model is correlated with Wood Stork productivity at Corkscrew Swamp and therefore could be used to assess the effects of restoration scenarios on the Endangered Wood Stork
- There is a minimum area of foraging habitat that must be in a high quality state to produce successful breeding
- Shorter hydroperiod foraging areas are important for producing successful breeding years.

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Effects of Chemistry and Hydrology on Seed Germination and Plant Community Development in a Northern Everglades Wetland

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The effects of soil chemistry and hydrology on seed germination and plant community development were experimentally investigated using a seed bank collected from a relatively unimpacted area of the northern Everglades. The objective of this study was to characterize the relative magnitude of influence of these two environmental drivers on vegetation patterns in the managed Everglades.

The A.R.M. Loxahatchee National Wildlife Refuge (Refuge) historically was an oligotrophic, rainfall-driven wetland with minimal nutrient and mineral inputs. Regional water management and land-use changes have altered the hydrology and chemistry of the Refuge in a manner similar to other parts of the Everglades. Canal waters entering the Refuge contain elevated concentrations of nutrients such as phosphorus (P) and minerals such as calcium (Ca) that can impact wetland vegetation. While the unique topography of the Refuge has limited canal-water intrusion into the Refuge interior, water and soil chemistry around the perimeter has been affected by canal-water intrusion.

Soil was collected from the Refuge interior, homogenized, and distributed to 24 tubs (30 cm x 60 cm) that were maintained outdoors under full sunlight and protected from rainfall. Soils in half of the tubs were enriched by adding P and Ca to achieve concentrations of 1.46 g P/kg and 32.6 g Ca/kg, which were similar to canal-impacted soils near the Refuge perimeter, while the other half received no enrichment. Four tubs of each chemistry treatment were subjected to one of three water-depth treatments (flooded, saturated, or drained). Surface soils were collected from different plant communities across the interior and combined to provide a mixed seed bank for germination. This seed bank was evenly apportioned and spread over the soil in each tub. Enriched and unenriched treatments were initially hydrated with surface water collected from the L-40 canal and from the Refuge interior, respectively. Additional tubs containing commercial potting soil also were flooded with canal water to confirm that this water was not a source of seeds or other propagules. Soil specific conductance was measured weekly to monitor the effect of evaporation on soil-water mineral concentrations. Rainwater was used to hydrate treatments after enriched soil conductance exceeded 1000 μS/cm and unenriched soil conductance exceeded 100 μS/cm in order to maintain conductance levels representative of Refuge perimeter and interior conditions, respectively. Seed germination and seedling survival were non-destructively recorded on a weekly basis. Relative species abundance and above-ground biomass were documented when the experiment was terminated after 10 weeks.

Weekly germination patterns were similar between chemistry treatments, but the amount of germination and seedling mortality were higher in the unenriched treatment. More seedlings germinated in dry and saturated treatments than in the flooded treatment. However, germination in flooded tubs may have been inhibited by the unconsolidated nature of soils in this treatment. Interactive effects of chemistry and hydrology on seed germination and seedling survival were not detected.

A total of 20 species were identified across all treatments. Species richness was not significantly different among treatments, except for flooded treatments which had lower richness compared to drained and saturated treatments. However, community composition (measured as relative abundance and biomass per plant) of some species differed significantly among chemistry and hydrology treatments. *Rhynchospora* spp., *Utricularia* spp., and *Xyris* spp. were relatively more abundant in unenriched tubs. Other species, including *Nyphaea odorata, Cyperus* spp.*, Typha domingensis, Ludwigia* spp.*, Mikania scandens,* and *Juncus megacephalus* were more abundant in enriched tubs. *Xyris* spp. had greater biomass per plant in unenriched treatments, while *Cyperus* spp., *Typha domingensis, Ludwigia* spp., *Pluchea* spp., *Eleocharis* spp., and *Juncus megacephalus* had greater biomass per plant in enriched treatments. Significant interactions between enrichment and hydrology treatments were also indicated for *Typha domingensis, Utricularia* spp., and *Eleocharis* spp.

Treatment effects on germination and seedling growth and survival influenced the final composition of the plant community. While hydrologic treatments had some influence on species composition, the chemistry treatments produced distinct plant communities indicative of the Refuge interior (unenriched treatment) and perimeter (enriched treatment). Species such as *Xyris* spp. and *Utricularia* spp. failed to germinate in enriched treatments, while *Cyperus* spp., *Pluchea* spp., and *Ludwigia* spp. did not germinate in unenriched treatments. Other species such as *Mikania scandens* and *Typha domingensis* germinated in both treatments, but died off in the unenriched treatment during the course of the experiment.

Our findings have important implications for efforts to restore and maintain native Everglades plant communities. Specifically, our results show that:

- While hydrology certainly is a critical factor affecting Everglades vegetation, soil and surface-water chemistry can exert strong independent effects on plant communities;
- Soil chemistry is a major determinant of differences in plant communities between the minimally impacted Refuge interior and enriched areas near the perimeter;
- Effects of soil chemistry on plant community development can occur within a single growing season after disturbances such as droughts, when vegetative cover is reduced and plant establishment from the seed bank may be important.

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Self-assembly of Patterned Landscapes and Vegetation in the Central Everglades: Importance of Local and Landscape Drivers

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We present a conceptual model for self-assembly of the slough-ridge-tree island patterned landscape of the Central Everglades in southern Florida via local and landscape-scale feedbacks among landforms, hydrology, vegetation, and biogeochemistry. We test aspects of this model by analyzing vegetation composition in relation to local and landscape-level drivers, focusing on central WCA-3A, southern WCA-3A, and southern WCA-3B and the differences in water management and flow regimes they have experienced over the past 50 years. For 562 quadrats, we estimated species coverages and quantified maximum, minimum, and average water depth, soil depth to bedrock, NDVI, and proximity to the nearest tree island. We used non-metric multi-dimensional scaling (NMS) to relate compositional variation to local and landscape-level factors, and evaluated environmental differences among eight *a priori* vegetation types via ANOVA.

Water depth and hydroperiod decreased significantly from sloughs to ridges to tree islands, but all three regions also differed in the abundance of several community-types and the hydroregimes that characterize them. NMS revealed two significant axes of compositional variation, tied to local gradients of water depth and other correlated factors, and to a landscape-scale gradient of proximity to tall tree islands. Sawgrass height and soil thickness increased toward higher ridges, and NDVI was greatest on tree islands.

This study supports four components of our model, involving positive feedback of local substrate height on itself; woody plant invasion and subsequent P transport and concentration by top predators nesting on taller tree islands; compositional shifts in sites close to tree islands due to nutrient leakage; and flow-induced feedback against total raised area. Regional divergence in the relationship of community-types to current hydroregimes appears to reflect a lag of a few years behind shifts in water management; a longer lag would be expected for shifts in landscape patterning. Both local- and landscape-level drivers appear to shape vegetation composition and soil thickness in the Central Everglades.

Key findings include:

- Theoretical and empirical importance of flow *per se* in maintaining slough-ridge-tree island patterning;
- Vegetation gradients in the central Everglades are inherently two-dimensional, reflecting both the traditional gradient in local water depth AND a novel landscape gradient in proximity to tree islands and attendant nutrient fluxes, independent of water depth – most previous studies had assumed that ecological gradients in this area are mostly one-dimensional, tied to water depth and its correlates;
- Importance of understanding both the *absolute rates* of key processes (i.e., production, decomposition, nutrient transport, hydrology, periphyton deposition) and their *nonlinear relationships to water depth and island proximity* for quantitative predictions of the tempo and magnitude of responses of the patterned landscape;

- Central empirical contribution of the EDEN network for precisely tieing hydroregimes to vegetation samples scattered over hundreds of square kilometers of wetlands; and
- Existence of a lag of a few years between shifts in water management and equilibration of vegetation to new conditions.

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Radiocarbon Dating Sediments in the Everglades of South Florida: Sources of Error and Mass Accumulation Rates

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Paleoenvironmental investigations in lakes and wetlands are largely based on radiocarbon dated profiles that are subject to different types of dating errors. In order to assess the magnitude of these errors for one of the largest wetlands in North America, we used Accelerator Mass Spectrometry radiocarbon dating (AMS-14C) to date different sediment fractions in a core from the Northeast Shark River Slough in Everglades National Park, Florida. Very fine rootlets had modern dates down to a depth of 60 cm indicating that living roots translocate modern carbon down to the middle of this 99 cm deep sedimentary profile. This process probably accounts for the wide scatter in ^{14}C dates of coarse plant detritus throughout the core. In contrast, a gastropod shell from the top of the core had an average date of 840 yrs B.P. indicating significant contamination by old carbon since pollen data shows that the sampling depth was located just below the World War II horizon. However, the 8 shell dates fit a coherent linear progression with depth indicating that they can be used to construct a reliable age model once they are corrected for the hard water effect. This age model and bulk density data indicate a constant rate of mass accumulation of 2 gm m^{-2} y^{-1}, which is approximately 20 times slower than that reported for northern peatlands.

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Forecasting Models and Environmental Impact Assessment: The Implications of ISOP/IOP for Everglades Fish Communities

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Forecasting models are important predictive tools in environmental sciences and can be useful for assessing the effects of management actions and the success of restoration. We focus on assessing the impact of water management actions on wetlands in the Everglades. As is often the case, there are multiple confounding factors affecting the environment at a given time, making assessment difficult. In our study the effect of water management on hydrology is confounded with variation in rainfall. To control for the effects of rainfall on hydrology, we built models to using rainfall to predict hydrology prior to management action, and used these relationships to predict hydrology in the ensuing period. We use a cross-validation forecasting methodology to fit models, which allow us to assess the effect of changes in water management on Everglades fish communities.

Everglades fish communities are composed of fish that exhibit a variety of life history strategies to cope with hydrologically dynamic environments, making them good indicators of hydrological impacts. We use several species of fish as our performance measures (PM) to indicate the effects of changing hydrological management. To set targets for assessment, we examined two time periods: target period (prior to management change) and the assessment period (after management change). We predicted hydrology from rainfall by fitting linear models using cross-validation to assess model fits and to estimate hydrological parameters in the target period, and then used these parameters to project hydrology into the assessment period (hydrological model). We then estimated the relationship between observed hydrology and our PMs (ecological model). Finally, we used the parameter estimates from the ecological model and our projected hydrology, to get the predicted PM if the relationship between rainfall and hydrology had remained the same throughout the study (synthesis model). We found that our predicted depths matched closely to the observed depths in the target period. When our model predicted depths in the assessment period using rainfall, we predicted longer hydroperiods had operations been unchanged than were actually observed. Our predicted PMs matched closely matched with the observed data in the target period but not the assessment period, suggesting an impact of changing water management on fish communities at several of our long-term monitoring sites. We found that impacts were most pronounced in Shark River Slough and Taylor Slough, with mixed results in Water Conservation Areas 3A and 3B.

Our results yield several findings relevant to restoration:

- Collection of data prior to management action is necessary to set dynamic targets for assessment;
- Controlling for environmental variation (i.e. rainfall) is essential for assessing management impacts;
- Cross-validation is a useful tool for building forecasting models for assessment;
- Use of biotic indicators, in our case fish, with different life history strategies can translate changes in hydrology to the changes in aquatic community structure.

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RECOVER Evaluation Team: Greater Everglades Sub-team Performance Measure Synthesis Poster

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The RECOVER Evaluation Team, Greater Everglades (GE) sub-team is responsible for developing performance measures to forecast the effects of implementation of specific project alternatives on progress toward achieving Comprehensive Everglades Restoration Plan (CERP) goals. The domain of the Greater Everglades sub-team runs from just south of Lake Okeechobee to the Coastal gradients abutting Florida Bay and Biscayne Bay. Similar to the other RECOVER regional sub-teams, Greater Everglades developed a suite of hydrologic, water quality, and ecological/biological performance measures (PMs) to evaluate the contribution of specific project alternatives to the system-wide goals of the Plan. The following synthesis poster provides an overview of the existing suite of PMs used to evaluate the GE; and provides an overview of the team's proposed updates, and identifies existing needs and gaps.

The GE sub-team currently utilizes the following evaluation metrics: 1) four hydrologic performance measures based on South Florida Water Management Model (SFWMM) output, 2) loading and dry down as proxies for existing total phosphorus and total nitrogen water quality metrics, and 3) the team recently accepted the first biologically based performance metric developed for wet prairie plant communities. The GE sub-team is working on further development of hydrologic and biological metrics that address specific restoration concerns in the system, including barriers to flow, topographic pattern distortion, and vegetation mosaics. The GE sub-team expects that additional biological metrics will become available (including metrics for wading birds, fish and alligators) as methods to provide a more spatially refined/spatially explicit hydrology are reviewed and accepted. Over time, new metrics will be developed and existing metrics may be refined to address the planning and operational needs of projects and the CERP. Development and refinement of PMs will also help address potential needed shifts in long-term monitoring.

The Greater Everglades synthesis poster provides an overview of existing RECOVER: CERP system-wide PMs and how the suite of PMs is used to evaluate the goals of projects and the goals of CERP, and to evaluate the contributions of projects to restoring impacted parts of the system. The following bulleted list identifies the existing suite of accepted PMs for the GE region that are currently (or will) be applied to regional evaluations.

- Hydrology (Dry down duration, Inundation duration, Extreme high and low water depths, and Sheetflow)
- Water Quality (Total Phosphorus and Total Nitrogen concentration and loading)
- Ecology (Vegetation mosaics/Wet Prairie Vegetation)

Details of newly accepted or newly proposed metrics for the Greater Everglades are highlighted in the remaining GE posters in this session.

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RECOVER Evaluation Team: Lake Okeechobee Sub-team Performance Measure Synthesis Poster

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The Lake Okeechobee (LO) sub-team of the Restoration Coordination and Verification (RECOVER) Evaluation Team has developed performance measures (PMs) to forecast how well specific project alternatives achieve Comprehensive Everglades Restoration Plan (CERP) goals. LO PMs are focused on the Lake's offshore, nearshore and littoral zones. LO evaluations also provide insight into linkages between the Lake, its upstream basins and tributaries and its downstream receiving bodies; especially the east and west coast estuaries (St. Lucie and Caloosahatchee) and the Greater Everglades. Similar to the other RECOVER regional sub-teams, Lake Okeechobee developed a suite of hydrologic, water quality, and ecological/biological performance measures (PMs) to evaluate the contribution of specific project alternatives to the system-wide goals of the Plan. The following synthesis poster provides an overview of the existing suite of PMs used to evaluate LO, provides an overview of the team's proposed PM updates, and identifies existing needs and gaps.

The LO sub-team developed the following evaluation metrics: 1) A series of hydrologic metrics based on lake stages, 2) water quality metrics focused on TP, TP:TN mass ratios, and chlorophyll *a* concentrations, 3) and biological/ecological metrics for phytoplankton, submerged and emergent vegetation, fish and macroinvertebrates. Although assessment components exist for each of the three types of metrics, the LO stage envelope and extreme high and extreme low PMs are the only metrics currently applied to forecasting and evaluation.

Over time, new metrics will be developed and existing metrics may be refined to address the planning and operational needs of projects and the CERP. Development and refinement of PMs also will help address potential needed shifts in long-term monitoring. To apply the current water quality and ecology metrics for alternative evaluation, the LO sub-team is developing and refining the needed predictive tools.

Proposed changes include the elimination of the diatom:cyanobaceria ratio listed below in response to non-restoration related increases in this ratio over the last 5 years and the inclusion of a predictive tool that relates lake stage and water quality to colonizable submerged aquatic vegetation habitat. In addition, recent quantitative experimental data on bulrush (*Scirpus californicus*) growth and reproductive responses to lake stage and water quality may lead to the development of a predictive tool that links bulrush spatial extent to these parameters.

CERP projects that directly affect LO include reservoirs and stormwater treatment areas in the Lake's watershed. These projects are expected to reduce water level extremes and reduce nutrient concentrations in the Lake, as shown in the PMs. Improved water level conditions will likely improve aquatic vegetation, which will increase fish habitat and improve water quality conditions. Reduced nutrient concentrations will reduce algal bloom outbreaks, enhance water quality and in general improve the lake environment.

The Lake Okeechobee synthesis poster provides an overview of existing RECOVER: CERP system-wide PMs and how the suite of PMs is used to evaluate the goals of projects and the goals of CERP, and to evaluate the contributions of projects to restoring impacted parts of the system. The following bulleted list identifies the existing suite of accepted PMs for the LO region.

- Hydrology (Lake stage envelope and extreme high and extreme low lake stage)
- Water Quality (TP, TP:TN mass ratios, and Chlorophyll *a* concentrations)
- Ecology (1) Diatom: Cyanobacteria ratios, 2) Emergent and submerged vegetation mosaics, 3) Fish population density, age structure and condition and 4) Macroinvertebrate community diversity and distribution)

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Effect of Soil Phosphorus Enrichment on Soil-P Release and Long-Term P Removal by Wetland Mesocosms

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Phosphorus (P)-enriched soils accumulate within Stormwater Treatment Areas (STAs) over time, and soil P release has been linked to total and labile soil P contents in south Florida marshes. However, the differences in soil P release and P removal efficiency for treatment wetlands with accrued P-rich soils, relative to the native muck soils, are unclear.

Using soils from STA-1W Cell 4, an outdoor mesocosm study was conducted to determine the effects of soil P-enrichment on short-term P release after flooding, and long-term outflow quality (total P concentrations (TP)). Separate wetland mesocosms were established with accrued sediments from inflow (606 mg P/kg) and outflow regions (636 mg P/kg), and native muck (334 mg P/kg). *Najas guadalupensis*, one of several species of submerged aquatic vegetation (SAV) in STA-1W Cell 4, was established as a monoculture on these soils under flow-through conditions with STA-treated waters.

Prior to SAV inoculation and under stagnant conditions, the unvegetated soils released between 0.04 and 1.8 mg P/m^2/day when reflood water TP was 32 µg/L and between -1.5 and 1.5 mg P/m^2/day when reflood water was 85 µg/L. Significantly greater soil P release rates were observed in the wetland mesocosms that contained inflow region soils than outflow region soils or muck soils. After SAV was established under flowing conditions, mesocosms with inflow-region soils exhibited greater long-term outflow TP (25 µg/L) and lower P removal efficiency (32%) than the native muck (20 µg/L and 46%).

The differences in short-term soil-P release rates corresponded with observed labile soil-P and porewater P concentrations among the three soils. Porewater soluble reactive P concentrations (SRP) were highly correlated to the water column TP after 14 days of stagnant conditions in the absence of vegetation ($r^2 = 0.95$), largely due to the influence of the inflow region soil, which contained high porewater SRP (595-860 µg/L) relative to outflow soils (54-59 µg/L) and muck soils (47-86 µg/L).

However, the strongest correlation to long-term (2-year) P removal performance was initial soil TP ($r^2 = 0.715$), followed by porewater Fe ($r^2 = 0.712$) and soil bulk density ($r^2 = 0.711$). These data suggest that soil TP is an appropriate indicator of long-term P removal potential, while porewater SRP was the best indicator of short-term P flux potential into the water column during stagnant periods after reflooding.

Mitigating the impacts from phosphorus enrichment on Everglades marshes has been a major focus of the Greater Everglades Ecosystem Restoration project. Key findings of our study have several direct implications to restoration:

1. Phosphorus enrichment of the surficial soils can decrease the P removal potential in wetlands.
2. Porewater P enrichment can increase the short-term soil-P release rate.
3. Porewater concentrations can vary through time, suggesting with #2 above that short-term P release rates from the soil may also change temporally.

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Geochemical Analysis of Carbonate Layers in Tree Island Peats

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We are investigating the origin of cemented carbonate layers recently discovered in sediments on the heads of several large tree islands in Everglades National Park. The carbonate layers have been fully excavated on Poincianna and Sour Orange hammocks in Shark River Slough. The layers occur ~25-50 cm below the ground surface and range in thickness from ~50-75 cm. They are sufficiently hard to require a concrete saw for penetration and are underlain by ~50 cm of additional unconsolidated sediments that contain abundant archaeological artifacts. Dates from artifacts above and below the layers indicate that sediments in the layers were deposited after ~ 4400 cal yrs BP and possibly ending by 2700 cal yrs BP.

There are multiple mechanisms by which such layers can form, and different mechanisms have different palaeohydrological implications. Two mechanisms in particular are plausible in the South Florida environment. The layers may be a palustrine limestone, a type of periphyton-precipitated marl laid down in shallow surface water (common today in the southern Everglades marl prairies) and lithified upon emergence as water levels fell. The presence of artifacts below the carbonate-rich layer suggest that tree island heads were dry enough for human use prior to its formation. In order for calcareous marl to accumulate atop the human occupation layer, water would have had to shallowly flood the tree island heads for at least several months each year. The amount of carbonate in the layers suggests that such conditions would have had to persist for an extended period of time, at minimum centuries or longer. Alternatively, the layer may be a "pedogenic calcrete", formed within the soil from pre-existing calcium carbonate dissolved then reprecipitated. The calcium carbonate of pedogenic calcretes can be delivered from above by percolating soil water or from below by groundwater. Potential sources of calcium carbonate include periphyton, shallow bedrock (in this case Pleistocene Miami Limestone) and archaeological debris such as dissolving shells. Where there is a dense vegetation cover and strongly seasonal precipitation, plants and especially trees often play a major role in pedogenic calcrete formation. High evapotranspiration rates increase upward ground water movement through the soil and processes at the root-soil interface lead to mineral precipitation in the rooting zone. Calcrete formation does not require changing hydrological conditions; but it may be triggered, or be especially effective, during times of drought.

It is difficult to distinguish a palustrine limestone from a pedogenic calcrete because they may have very similar properties such as hardness, degree of cementation, mineral composition and structure, cement types, shells, plant remains, and petrological features caused by microbial activity around roots. Although palustrine limestones originate as soft subaqueously-deposited marls, their emergence and the associated influences of fluctuating water tables and vegetation impart strong pedogenic characteristics to the sediments. Geological studies document that palustrine limestone deposits often grade into calcretes, and infer from this relationship changes in hydrological conditions that shaped past landscapes. Therefore, a mixed palustrine/pedogenic origin of the carbonate in the tree islands is also possible.

We will report on elemental analyses determined by electron microroprobe from the carbonate cements of the layer. If the layer has a pedogenic calcrete origin it may contain cements derived from the dissolution and reprecipitation of the underlying Pleistocene-aged marine Miami Limestone. Unaltered marine limestone has much higher concentrations (thousands of ppm) of magnesium and strontium, and low concentrations (tens of ppm) of manganese, than periphyton-precipitated freshwater marl. As marine carbonate sediment is exposed to freshwater conditions, its most soluble components are dissolved and reprecipitated. The sediment becomes cemented and the carbonate mineral composition changes over time – strontium and magnesium levels decrease and, in the presence of decaying organic matter, manganese levels increase. Therefore, if the Miami Limestone is a source of the carbonate in the layers, then a marine limestone trace element signature may still be detectable in the oldest cements. Individual cement layers coating grains or cavities represent successive episodes of cementation that can be subsampled during electron probe microanalysis.

Carbonate layers on tree islands have been reported elsewhere in the Everglades; probing rod surveys on islands in Everglades National Park suggest that such layers exist on other large teardrop-shaped tree islands. Future work pertinent to Everglades restoration and management should include looking for, and studying, carbonate layers on islands currently experiencing different hydrological regimes. For example, islands in southern Water Conservation Area (WCA) 3A are exposed to higher water levels than islands in Everglades National Park or in WCA 3B. Comparing carbonate layers among these islands may shed light on layer formation processes, as well as layer response to higher groundwater tables on tree island heads. It is probable that tree islands with a hard shallowly buried cemented carbonate layer on their heads are more resilient to certain changing environmental conditions than those without. In terms of restoration and management, islands with the layer may experience the following benefits:

- Reduced peat destruction during episodic fires.
- Reduced peat subsidence under drainage or episodes of drought.
- Increased resilience to rapidly changing hydrological conditions (i.e., water levels, flow rates; natural or anthropogenic).
- Enhanced ability to maintain size and elevation.

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Spatial and Habitat Variations of Total Mercury in Largemouth Bass (*Micropterus salmoides*) in the Everglades Ecosystem

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Monitoring aquatic pollution and the interpretation of fish data is a crucial step in controlling water quality and in the management of aquatic wildlife. A regional mercury assessment was conducted to examine total mercury concentrations in largemouth bass (*Micropterus salmoides*) from the Everglades ecosystem. The geographic extent and size of this data set is valuable in understanding the endogenous factors (i.e., length, weight, and age) that influence the bioaccumulation of mercury to largemouth bass. Featured are differences found among tissues, major aquatic habitats and sampling locations. Total mercury concentrations in tissues were ranked from highest to lowest in the following order: muscle (0.73±0.3 µg/g) > liver (0.56±0.3 µg/g) > brain (0.21±0.2 µg/g). Mean total mercury concentrations were used to calculate muscle:liver and muscle:brain ratios, the results obtained were 0.72 and 0.68, respectively indicating muscle as a good predictor of mercury in liver and brain tissues. Age also moderately influences mercury bioaccumulation, particularly for individuals where mercury uptake exceeds elimination. Accumulated mercury varied substantially across the 24 sampling locations. Site mean total mercury concentrations in the muscle ranged between 0.036 and 4.0 µg/g wet wt. (0.97±0.037 µg/g) with 83% of the samples containing concentrations above the federal 0.3 µg mercury/g concentration recognized as unsafe for human consumption.

Total mercury levels in largemouth bass muscle tissue

- Vary across aquatic ecosystem habitats and sampling locations; and
- Increased from storm water treatment areas, to canal systems, and were greatest in water conservation area habitats; and
- Along with the species endogenous factors can serve as key predictors enhancing a mercury monitoring program; and
- Provide an effective basis for choice of habitats for mercury assessment studies.

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Biscayne Bay Nearshore Continuous Salinity Monitoring

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Biscayne Bay is the largest estuary on the southeast coast of Florida, comprising 428 square miles. Altered Everglades drainage patterns and intense urban development in the Miami area has contributed to a loss of estuarine conditions and a transition to a marine lagoon. The Biscayne Bay Coastal Wetlands restoration project aims to re-hydrate coastal wetlands that are currently drained or bypassed by the canal system, and redistribute those freshwater flows to benefit the Bay's faunal communities especially in nearshore habitats along the mainland coast.

A network comprised of over 30 continuous monitoring stations has been in operation since 2004, taking salinity readings every 15 minutes. This network consists of a series of east-west transects that radiate outward from canals or other prominent hydrological features. Most of the sites are located moored to the bottom to document salinity conditions relevant to benthos, although a few sites are located on buoys to measure surface salinities. Besides documentation of the pre-restoration condition, of great importance in its own right toward understanding and operating the constructed features to maximize their intended benefit, a better understanding of the heretofore generally lesser-known and unexpected seasonal salinity patterns has emerged. Principal among these findings is both the dominant role that groundwater flow through the coastal aquifer plays in the Bay's salinity regime. The degree to which groundwater flows are delayed in the wet season and sustained well into the dry season was unanticipated.

Key Findings

- Documentation of pre-restoration condition.
- Extended wet-season flows into mid dry-season, and delay of onset of wet-season flows.
- Importance of groundwater contribution to nearshore salinity environ.

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The Key to System-Wide South Florida Restoration: Lake Okeechobee

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Lake Okeechobee (LO) serves a variety of ecosystem and water management functions. The lake is the center of the interconnected Kissimmee River-Lake Okeechobee-Everglades ecosystem and the largest single source of freshwater for the South Florida environment. During the last 60 years the lake has been the recipient of excessive nutrient loading which has resulted in accelerated eutrophication. As a result, initiatives to restore the health of Lake Okeechobee will play a significant role in the success of the greater Everglades ecosystem restoration initiative. Failure to implement effective measures to reduce nutrients and increase water storage capacity for LO will adversely affect or significantly delay efforts to restore downstream wetland systems and estuaries that either rely on or are affected by water deliveries from the lake. Therefore, both water quantity and water quality issues will have to be addressed for LO as a prerequisite to successful regional-scale ecosystem restoration.

Key Findings

- Improvements in hydrology are frequently stated goals of environmental restoration. Lake Okeechobee is the largest potential single source of freshwater to the downstream ecosystems.
- Numerous large and small watershed restoration efforts which address water storage and water quality are ongoing to improve the ecological health of the Lake. The success of these restoration projects is critical to overall South Florida environmental restoration goals.
- Restoration efforts which focus solely on regional issues and which do not incorporate a system-wide view, necessarily including the Lake, may not succeed because they fail to account for comprehensive natural systems water supply issues.

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Spatial and Age-Structured Population Model of the American Crocodile for Comparison of CERP Restoration Alternatives

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As part of the U.S. Geological Survey's Priority Ecosystems Science (PES) initiative to provide the ecological science required during Everglades restoration, we are integrating regional hydrology models with American Crocodile (*Crocodylus acutus)* research and monitoring data. The result will be a model of the impact of various CERP restoration scenarios on the American crocodile.

A list of indicators was created by the Restoration Coordination and Verification (RECOVER) component of the Comprehensive Everglades Restoration Plan (CERP) to help determine the success of interim restoration goals. The American crocodile was established as an indicator of the ecological condition of mangrove estuaries due to its reliance upon estuarine environments characterized by low salinity and adequate freshwater inflow.

The spatial and age-structured population model for the American crocodile is based on code from the recently developed landscape-level CERP Alligator Population Model. The model couples local age-structured models into a spatial dispersal model incorporating crocodile movement behavior. A crocodile habitat suitability index and spatial parameter maps that reflect salinity, water depth, habitat, and nesting locations are used as driving functions to construct crocodile finite rate of increase maps under different management scenarios.

The crocodile simulation model makes use of the new application of FTLOADDS (Flow and Transport in a Linked Overland/Aquifer Density Dependent System) to TIME (Tides and Inflows in the Mangroves of the Everglades). TIME has the capability to link to the SFWMM (South Florida Water Management Model), which is the primary regional tool used to assess CERP restoration scenarios. By applying the crocodile model to proposed restoration alternatives and predicting population responses, we can choose alternatives that approximate historical conditions, enhance habitat for multiple species, and identify future research needs. Future modeling efforts include the incorporation of the Biscayne and Florida Bay model to assess climate change scenarios throughout the entire range of crocodiles in south Florida.

Restoration efforts will likely cause changes to salinity levels throughout the habitat of the American crocodile. The response of the crocodile to restoration efforts will provide a quantifiable measure of restoration success. This modeling effort will examine how CERP restoration alternatives that allow greater freshwater flow into Florida Bay during the critical post-hatching period (Sept-Dec) will affect:

- growth and survival rates of hatchling and juvenile crocodiles
- hatchling dispersal distance to suitable nursery habitat
- survival rates of hatchlings originating from nests within Florida Bay
- overall crocodile density and distribution

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Landscape Models for Spatial Upscaling of Biogeochemical Parameters

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Wetland ecosystems and other aquatic ecosystems are sensitive to natural and anthropogenic forcing functions that alter their hydo-, pedo-, and biodiversity as well as environmental health. An intricate and complex interplay between carbon, phosphorus, nitrogen, sulfur and other cycles generates complex ecosystem patterns that co-evolve in space and time. These emerging biogeochemical signatures are often anisotropic and diverse. To gain a better understanding, and develop recommendations to restore an ecosystem, it is critical to assess biogeochemical parameters and their dependencies to controlling environmental landscape variables using a holistic landscape modeling approach. Ecological indicators that are sensitive to anthropogenic impact and provide an integrative response are well suited to assess change trajectories within an aquatic ecosystem using a spatially and temporally explicit framework. Commonly, biogeochemical parameters tend to behave scale-dependent, meaning that their magnitude, spatial and temporal variability and functional relationships with environmental landscape properties differ across micro, meso and macro spatial scales and slow, medium and fast response scales. Several critical questions emerge: (i) Which biogeochemical parameter may serve as an indicator in a given aquatic ecosystem providing sensitive response to key ecological drivers? (ii) How do functional relationships between biogeochemical parameters and environmental landscape properties behave in space and through time? (iii) How can we best scale-up biogeochemical parameters to the landscape scale?

Observations to capture the temporal and spatial variability of parameters range from site (point)-specific measurements of biogeochemical soil characteristics; water flow and quality parameters; grid or polygon-based environmental landscape data (e.g. spectral data, vegetation, water depth) derived using geospatial and remote sensing techniques. Strategic sampling designs that capture the underlying variability of biogeochemical parameters are critical for the upscaling process. Various statistical and geostatistical methods have been used to scale biogeochemical parameters across multiple spatial scales including multivariate statistical, geostatistical and hybrid (mixed) methods, which account for spatial autocorrelation and co-variations.

Various examples on upscaling of biogeochemical parameters to landscape scales are provided for the Greater Everglades ecosystem and subsystems. Special attention is given to (i) Identify key parameters to model anthropogenic impact within a spatially-explicit framework; (ii) Characterize spatial variability and distribution of biogeochemical parameters in dependence of controlling environmental landscape variables; (iii) Describe behavior of biogeochemical parameters across multiple spatial scales; (iv) Model spatio-temporal trajectories of biogeochemical parameters; (v) Link biogeochemical parameters to ecosystem processes; (vi) Assess the accuracy and prediction quality of labor-intensive, costly, and sparsely measured biogeochemical parameters using cheap, rapid and dense sets of auxiliary environmental variables (e.g. derived using satellite imagery); and (vii) Address transferability of findings to comparable wetland and aquatic ecosystems. Synergizing environmental properties into holistic landscape models are paramount to support the ongoing restoration efforts in the Everglades.

Based on research findings the following knowledge gaps were identified: (i) Since various biogeochemical parameters behave differently in space and time more research is necessary to reveal an appropriate scale for monitoring; (ii) Integration of cheap-to-measure spectral data and costly precise analytical measurements to improve predictive models of biogeochemical parameters; (iii) Development of a comprehensive geospatial biogeochemistry grid (database) for the Everglades that facilitates trend analysis to better document restoration efforts; and (iv) Transfer of advanced geostatistical and hybrid methods (e.g. regression kriging) from terrestrial systems into the Everglades to better capture spatial biogeochemical patterns.

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Review of Current Everglades Ecosystem, Landscape and Hydrodynamic Models and Potential Applicability to Evaluate Climate Change Effects

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Restoration of the ecology of the south Florida ecosystems is based on integrated, whole-system design. The Comprehensive Everglades Restoration Plan (CERP) for the Everglades and Florida Bay is an ecosystem-based management (EBM) strategy that relies on simulation modeling at multiple levels for evaluating restoration strategies, predicting component responses to ecosystem changes and setting restoration targets. Biogeochemical and habitat relationships within subsystems of the Greater Everglades ecosystem are dependent on hydrologic timing, water quantity and quality, inundation schedules and hydraulic connectivity. Ecosystem restoration for these hydrologically altered areas rests on the repair of hydrological function and thus, it is fundamental to include models of water movement, both hydrologic and circulation, in the restoration modeling "toolkit."

Major models characterizing aspects of the hydrology of the Everglades wetland surface and subsurface flows across different domains and at spatial scales include the South Florida Water Management Model (SFWMM), the TIME (Tides and Inflows in the Mangrove Ecotone) and SICS (Southern Inland and Coastal Systems) model. These wetland runoff models provide boundary condition inputs for physical models of Florida Bay. Hydrologic transport, water and salt balance in Florida Bay are calculated within the FATHOM (Flux Accounting and Tidal Hydrology Ocean Model) modeling framework at a coarse spatial and temporal scale. The EFDC (Environmental Fluid Dynamics Code) model is a major 3-D hydrodynamic model recently adapted for Florida Bay that provides water circulation and salinity distribution at extremely fine spatial and temporal scales, including in the vertical dimension. The SoFLA-HYCOM (South Florida Hybrid Coordinate Ocean Model) simulates ocean hydrodynamics in the southern Florida coastal Atlantic Ocean, Florida Straits and Gulf of Mexico waters and provides the boundary condition for Florida Bay internal model hydrodynamics. These physical models of water and salt movement can be coupled to other models that simulate aspects of the biogeochemistry and plant/animal ecology of the freshwater and saltwater wetland ecosystems. In some cases models of hydrology contain ecological components themselves. The Everglades Landscape Model (ELM) simulates Everglades wetland hydrology, nutrient dynamics as well as periphyton and macrophyte vegetation composition and distribution throughout the Everglades.

The Everglades watershed includes ecological subsystems of Lake Okeechobee, Everglades Ridge and Slough, Cypress Wetland, Marl Prairie, Rocky Glades, Transverse Glades and Mangrove Swamp. Interconnections among the subsystems are primarily made by fresh water flow moving through the watershed and discharging into the receiving waters of multiple estuary subsystems, or tidal fluxing of estuarine waters between the estuaries and wetlands. The receiving systems in the Everglades and adjacent ecosystems include Florida Bay, Biscayne Bay, Whitewater Bay, Ten Thousand Islands and Estero Bay. Conceptual models have been developed for many of the wetland and estuarine components of the Everglades ecosystem and these conceptual models form the basis for complex ecological and biogeochemical simulation models. For example, a series of Ribbon models describes the biogeochemistry of phosphorus traversing through the wetland landscape. The Ribbon model synthesizes major P stocks and fluxes for sawgrass and wet prairie habitats in Shark River Slough to generate a simple dynamic budget model of phosphorus. The CE-QUAL ICM water quality model is being integrated with the fine-scale EFDC hydrodynamic model to simulate nutrient, plankton and benthic vegetation dynamics for Florida Bay. A mechanistic unit model of benthic-pelagic interactions has been developed for the Florida Bay seagrass and phytoplankton community that describes daily and annual biomass, production, species composition and distribution potential for three SAV species: *Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritima*. This model will be adapted to form part of the Florida Bay water quality model. In turn, both FATHOM and EFDC model outputs are used in the SAV unit model to drive water and salinity inputs. Model output of seagrass habitat is being used in predictive General Additive Models (GAM) of upper trophic levels, focusing on density and composition of the forage fish community, pink shrimp and top consumers. Habitat suitability models are also being developed for Florida Bay using a variety of data and modeled inputs to predict the probabilities of habitat suitability for several upper trophic level species under a variety of water flow and nutrient scenarios.

Conceptual, hydrological, hydrodynamic, statistical probability and numerical ecological models are aiding the design of the restoration of the Everglades and Florida Bay and are used to predict likely outcomes of climate conditions and management strategies. With water management projects being implemented on an ecosystem-wide scale, it is important to have capability for predicting consequences of restoration for the whole ecosystem, including secondary or cascading responses, as well as predicting the likelihood of success. This requires multiple models across trophic and spatial domains. The linkage of simulation models of geochemical and biological processes to hydrologic and hydrodynamic transport platforms permits the creation of geospatial, landscape-based frameworks that integrate, from the bottom-up, ecosystem drivers and stressors through biogeochemistry to upper level consumers. These integrated models will allow prediction and hypothesis testing about ecosystem components and relationships.

Many of the models described specifically have the capability to incorporate the effects of altered temperature regimes, changes in precipitation and evaporation rates and the effects of increasing rates of sea level rise. Models that are not designed with these capabilities can be adapted to do so either by incorporating additional variables, functions and regression relationships or through input files. This presentation discusses the capabilities and limitations of this complex simulation environment of interlinked models. It will focus on how such suites of models can be adapted to interact with global climate models to predict ecosystem responses in the Florida Everglades to potential climate change and sea level rise.

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Multi-Scaled Patterning of Plant-Soil-Water Interactions across Tree Islands and Marshes within The Prairie and Slough Landscapes of Everglades National Park

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Everglades heterogeneity is primarily shaped by vegetative, edaphic and hydrologic interactions nested within multiple hierarchical scales. Hydrologic compartmentalization compounded over the past century has altered the scale of tree island and marsh patches within the system's freshwater mosaic. Restoring Everglades communities and landscapes requires a more inclusive understanding of factors that interact with hydrology to shape and maintain system structure. Interactions between several environmental and soil variables including topography, hydrology, organic matter, carbonate, and total and inorganic nutrient concentrations were quantified across two important spatial scales (i.e. tree island and marsh communities nested within the marl prairie and slough landscapes). TC, TN and TP patterns were evaluated for flow-related anisotropy, and tree island woody species composition was analyzed alongside important environmental metrics. Results were scale-dependent and complexly interrelated. Total carbon and nitrogen patterning were directly related to organic matter accumulation, driven by vascular plant patterning at the community level and prolonged flooding at the landscape level. Total phosphorus was most strongly correlated with woody plant patterning across both landscapes. Bioavailable nutrient concentrations were extremely low due to several varying immobilization mechanisms. Species assemblages formed tight groups primarily defined by landscape characteristics. Analyses suggest water management changes can be compounded within variables and their interactions, and are often magnified through the Everglades nested scales.

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Lidar Detection of Karst Landforms in Miami-Dade County, Florida: A Tool for Environmental Management

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Lidar elevation data (July 2006) available from the FIU/IHRC (2004) was used to locate karst landforms in Dade County. Landforms are developed in the Miami Limestone Formation, a Pleistocene rock unit which is at the surface or is covered by thin unconsolidated deposits. Karst landforms include large solution valleys (transverse glades), solution collapse zones and dolines. Dolines include isolated dolines as small as 2m in diameter, coalescing dolines, and doline chains. In addition, numerous types of microkarst surfaces exist such as those characteristic of typical pinelands. Comparison of historic aerial photography and Lidar elevation data with confirmation by field observation have led to detailed Lidar interpretation of karst landforms.

Analysis of the Lidar data set, more than 500 tiles ($1m^2$ each), shows a strong relationship between medium sized karst features and hardwood tree canopy patterns. Dolines are common locations of hardwoods and many are associated with known hardwood hammocks. Many dolines form breaks in the canopies creating forest gaps. One of the unique aspects of Lidar technology is its ability (after filtering) to show the details of the karst topography under these canopies. These details can make resource inventory, analysis and management of these important habitats more effective. Interpretations of historic aerial photographs are used to identify and locate additional karst areas that have been anthropogenically lost.

Karst terrains have received little attention in South Florida. The Lidar data clearly shows the karst topography and can be used to map the major zones of karstification, in addition to plant communities. The largest features are usually found along or just east of the coastal ridge axis of the Miami Limestone. However, many large karst features are found in the western portion of the ridge, for example: Owaissa-Bauer Park in south Miami-Dade. This ridge has been interpreted as an oolite shoal system (Hoffmeister, 1967) and more recently as a barrier bar system (Halley, et al, 1977). Karst terrains near the coast are strongly associated with known distribution of springs and extinct spring fed coastal creeks observed in historical aerial photographs. Doline lines are believed to be the surface expression of underground water courses and these can be found in many areas of the county regardless of limestone facies. Mapping of the patterns of doline lines could yield a much better understanding of high-volume flow areas in the groundwater.

Interpretations of historic aerial imagery document that most transverse glades were lined by long, narrow hardwood hammocks. Hammocks were typically located on the outside of bends and along reaches where surface water was able to enter the rock banks. In at least two examples the eastern terminus of a TG is a karst sink which swallowed the entire surface water discharge that fed coastal springs, seeps and creeks further to the east. This observation supports the idea that the transverse glades are features of karst origin.

Karstification processes that produced the present topography occurred in at least two major episodes. Several examples of the cross-cutting of elevated karst features by a transverse glade demonstrate that some of the large scale karst is older than the transverse glades. We conclude, therefore, that the glades have little relation to the original morphology of the oolite sand body comprising the ridge.

Micro karst textures are observed in Pinelands by Lidar where soil cover or urban modification is not limiting. Medium scale surface karst patterns are frequently associated with hardwood hammocks. Most hardwood hammocks are associated with breaks in slope and areas of intense surface karst creating more moist conditions. Hammocks are almost always associated with increased karstification in areas of large sinks or swallows.

With this ability to see much of the surface of the limestone we conclude that most of the landforms in Miami-Dade are produced and controlled by dissolution of the limestone; that karst pathways are poorly understood by local hydrologists in spite of their obvious influence on all flows to the coast; and are severely understudied by area geologists. With the high likelihood these pathways will become flooded with marine water as sea level rises, in turn strongly impacting freshwater drinking supplies; this lack of understanding should be corrected quickly.

The major contributions of this work in respect to the Greater Everglades Ecosystem Restoration Project includes:

- demonstration of a use for Lidar elevation data.
- at small resolutions, Lidar data will reveal karst terrains.
- Lidar elevation data is usable in both topographic and vegetative spatial mapping.
- detailed interpretations of karst patterns and their implications to surface and groundwater movement patterns are possible.

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Sea Level Rise in Miami-Dade County, Florida: Implications for Management of Coastal Wetlands and the Everglades

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By 2100 sea level will have: 1) inundated much of coastal and interior Miami-Dade County, 2) seriously degraded freshwater availability county wide, and 3) changed the climate from a terrestrial to an oceanic process dominated system. Projected sea level rise will also result in ecological problems as anthropogenic altered areas are inundated. The IPCC (2007) has made global sea level rise projections to provide guidance for the next 100yrs but no detailed local information.

In order to better understand the meaning of various sea level scenarios, LIDAR data collected by the FIU/IHRC (2004) was used to map the physical impact of rising sea level on the coastal zone of Miami-Dade County. Because the data set overlaps the eastern edge of the historical Everglades, it is also possible to examine the effect there and to understand how the transverse glades will facilitate a change from a freshwater dominated system to a marine one.

The LIDAR data is used to generate a detailed topographic map with 0.3m contour intervals. ArcGIS software was used to create images representing each contour up to 3.3m. Impacts expected to occur at the different stages are discussed:

Early onset rise (below 0.3-1m) will produce dramatic inundation of the coastal plain, the “Southeast Saline Everglades” (Egler, 1950), to the L-31E levee and coastal water management structures. The structures and levee maintain a freshwater stage between 1.7 and 2.3 ft above msl now and therefore restrict sea encroachment. Without these manmade structures the effects of the first 0.5m rise would be considerably more causing salt water encroachment to the toe of the break in slope at the coastal ridge. Each 0.3m rise in the unprotected southern Everglades is expected to produce a considerable acreage loss due to the low /shallow slope.

At 1 m stage major erosion of the coastal organic sediments will begin causing carbon export, nutrient loading and perhaps anoxic conditions, especially in northern Florida Bay. Most of the area in front of the coastal ridge is inundated or experiencing salt water encroachment and contamination of the ground water supply. The Miami River basin begins to flood inland threatening the valley up to the original fall line (about 27th Ave) and adversely affecting the county water quality. Coastal islands including Miami Beach, Virginia Key, and Key Biscayne and low lying coastal residential areas are at risk, as is the Turkey Point Power plant and South Dade Landfill.

Between 1 and 2 m the Dade County shoreline turns into a rocky coastline with only a incomplete, narrow mangrove fringe. Anthropogenic structures create natural habitat migration barriers and totally new habitats (asphalt hardgrounds, rubble mounds) at this stage. Some high karst areas along the coast will facilitate landward penetration of the coastal ridge by subterranean means. Caves and large scale karst pathways under the ridge would be expected to reverse flows particularly at flood tides which would introduce saltwater to underground freshwater systems in unknown ways. At plus 1.2m the Miami River basin and the northern rivers, Little River, Arch Creek, Oleta River will effectively be tidal channels allowing marine flow to low inland urban areas. This includes Miami Springs, the international airport including its important canal network, as well as many areas in northern-most Miami-Dade.

At 2m in stage the entire area in front of the coastal ridge is inundated. In addition the Everglades to the west is inundated with the transverse glades south of the Miami River becoming tidal passes. Arch Creek (Snapper) and the Oleta River open up to become major tidal passes to the new northern portion of an expanded Florida Bay. At this point, the processes controlling climate will change from terrestrial to ocean dominated which will result in drier conditions much like what is seen in Key Largo presently. After 2m of rise the available dry land will shrink rapidly until such time as the entire county is submerged.

At 3.3m stage the highest parts of Cutler Ridge and Silver Bluff along the Coconut Grove coastline, form a very narrow barrier island east of a loose collection of thirteen island groups, and are all that remain above sea level in Miami-Dade County. The biggest percentage of the remaining land would be less than five feet in elevation. Therefore most of the remaining exposed land would be subject to total submergence during storm events. We personally feel that a prediction of 2m rise during the next century is not unreasonable especially since the rise may not follow a steady state increase, and we are aware of credible predictions of 7m or more in this same time period. At these levels management of the Everglades turns into the management of a major estuary with extensive shelf ecosystems.

Coastal managers must pay attention to the effect of sea level rise and management strategies should be converted to adaptive management where possible. Difficulties will arise because of human modifications to the environment and a desire to save valuable properties such as landfills and power stations. As long as sea level continues to rise dramatically, ecosystem retreat is in order. Proper management of the GEER region will buy time and make the transition more economically and ecologically sound.

The implications of this potential anthropogenic perturbation result are both obvious and subtle for both coastal and Everglades restoration:

- damage to anthropogenic structures including those used to manage coastal ecosystems.
- loss of freshwater storage capacity with significant effect on habitability.
- loss of present coastal wetlands with resulting change in dependant biological systems.
- expansion of Biscayne Bay westward and Florida Bay northward.

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Tidal Influence and Its Effects on Mangrove Community Structure and Recovery Post-Hurricane Disturbance: Revisiting Hurricane Charley (2004) Effects on Sanibel-Captiva, FL

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Mangroves are key resources to tropical coastal environments because of their ability to buffer hurricane effects such as severe winds, surge flooding and heavy erosion. Because of their critical role in protecting the shoreline, maintaining ecosystem functions, and providing habitat, mangrove community recovery post-hurricane disturbance is a concern to tropical coastal areas. We examined the combined of hurricane disturbance and anthropogenic disturbance on mangrove community hurricane recovery in both tidally restricted and unrestricted locations. Our data suggest significantly lower seedling densities in tidally restricted locations (11 seedlings m^{-2}) compared to unrestricted locations (33 seedlings m^{-2}) and significantly lower seedling densities in regions of higher severity (CT, 6 seedlings m^{-2}< NS, 9 seedlings m^{-2}< CS, 30 seedlings m^{-2}< ES, 43 seedlings m^{-2}). These results provide insight into the ecosystem recovery process, and this information is useful in both restoration and land use planning which are essential in the sustainable management practices of barrier island systems.

The findings indicate:

- Post-hurricane mangrove seedling densities reflect hurricane wind severity.
- Tidal influence effects post-hurricane mangrove seedling recovery.
- Considerations of local hydrology and tidal influence are essential to restoration efforts.

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Mineral Weathering as Related to Biogeochemical Processes in the Everglades

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Mineral weathering in the Everglades is closely tied to biogeochemical processes and tends to be reversible in response to seasonal and diurnal ecological shifts. Life and P-induced eutrophication is intertwined with calcite formation and dissolution. Biota have adapted to hydrologic and microclimatic niches on a wet limestone platform with a veneer of quartz sand that thins from north to south. Calcite weathering is promoted at the limestone interface by biological acidification, while microbial photosynthetic uptake of CO_2 induces secondary $CaCO_3$ precipitation at the soil surface. The resultant solar-driven diffusion gradient promotes surface accumulation of calcite as benthic (marl), periphytic, and epiphytic forms that are themselves subject to localized weathering from acidity associated with biota. Sorption, co-precipitation and periphytic microbial growth are prospective mechanisms whereby calcite may foster P retention. The ephemeral nature of calcite in a dynamic biological system complicates assessment of its potential to mitigate P-induced eutrophication. Formation of a discrete and stable calcium phosphate (e.g., apatite) would have favorable implications for recovery from P-induced eutrophication, but has not yet been documented except in heavily-fertilized abandoned homesteads. Bird-guano-enriched tree islands are sites of prospective apatite formation.

Other minerals that occur less abundantly in Everglades soils range in stability and ecological significance. They include other carbonates, smectite, kaolinite, illite, sepiolite, palygorskite, cristobalite, hydroxyl-interlayered phyllosilicates, iron sulfides, and iron oxides. Their provenance is varied and in some cases poorly documented with respect to natural versus anthropogenic source. Lake Okeechobee mud sediment is the likely source of sepiolite and palygorskite; these fibrous minerals are stable in the Everglades environment and constitute a potential abiotic source of turbidity in canals extending from the lake. Stability of some Everglades minerals can be influenced by hydroperiod and associated microbially-driven sediment redox changes. For example, sulfide minerals and organic S play a major role in Hg methylation via natural dry/rewet cycles in the Everglades. Sulfides oxidize to sulfates during drought. Upon rewetting, sulfate is available to stimulate microbial sulfate reduction and Hg methylation. Hence, influx of agricultural sulfate can have an indirect effect on Hg biomagnification. Mineral formation and dissolution are also influenced by eutrophication-enhanced biological byproducts, as exemplified by calcite crystal dissolution and growth rate inhibition by natural organic acids.

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Hurricane Impacts on Mangrove Diamondback Terrapins (*Malaclemys terrapin*) in the Everglades

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Diamondback terrapins (*Malaclemys terrapin*) are long-lived turtles that exist as continuously distributed geographic populations along North America's Atlantic and Gulf coasts. Residing in tidal tributaries lined by salt marshes or mangroves, the terrapin is the only North American turtle that lives exclusively in brackish water. One of the top predators of benthic macrofauna in the estuarine food chain, terrapins may play an important ecological role, and may thus be particularly suitable for monitoring as an indicator species.

The mangrove Diamondback terrapin (*M. t. rhizophorarum*) inhabits the subtropical waters of the southeastern United States, where hurricanes are a regular occurrence. In October 2005, Category 2 Hurricane Wilma made landfall on the southwest Florida coast: the eyewall passed directly over the Big Sable Creek complex, a remote wilderness area of Everglades National Park where human impact is very low. As it came ashore, Hurricane Wilma denuded mangrove trees, deposited marl sediments into mangrove forests, and scoured new tidal cuts between existing drainages. We used population models to determine whether Hurricane Wilma had observable effects on demographic parameters of terrapins (i.e., apparent survival, capture probability). We explicitly tested the hypothesis that survival and capture probability for mangrove terrapins were similar before and after the storm.

Initial results indicate that mean survival probability before Wilma (2001-2005, years with no or low intensity storms in the study site) was 0.79 (95% confidence interval = 0.60-0.91). In March 2006, we conducted our first full sampling trip after Wilma. Six months later (11 months post-Wilma), we conducted another full sampling trip. We examine data from March to September 2006 to determine trends in mean survival and capture probabilities almost a year after the storm. We will examine whether there were significant drops in terrapin survival and capture probabilities and quantify the magnitude of the change. We will use of state-of-the-art statistical techniques and high quality data for these analyses.

Because individuals of this small population do not move large distances, it is possible to resolve storm effects on a population or site-specific scale. This is the first empirical examination of storm effects on terrapin survival. Any decreases in survival could be due to direct mortality, indirect mortality, and/or emigration from the region as a consequence of storms. We will shed light on whether future impacts to the population by a single catastrophic hurricane, or series of smaller hurricanes, may increase the probability of extinction for this endemic species.

Relevance to restoration:

- Until recently, little was known about the abundance and ecology of mangrove Diamondback terrapins in the Everglades. Our study represents important baseline data on and an examination of a Category 2 hurricane disturbance to this sentinel species.

- Separate restoration activities that may also affect the habitat or ecology of Everglades *M. terrapin* include hydrological alterations that affect the salinity of tidal creeks where *M. terrapin* and their invertebrate prey items (i.e., snails, mollusks, crabs) are present, changes to sandy upland habitats that serve as nesting areas, and modifications to structured habitats within tidal creeks (i.e., submerged coarse woody debris) that may serve as refuge sites.

- Capture-recapture techniques such as those used in this study to explore hurricane effects on a sampled population can also be used to clarify and quantify the effects of on-the-ground restoration activities on Everglades terrapins, and help to project future impacts on the persistence and survival of the species in the Everglades.

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Relative Importance of Hydro-Ecological Processes Governing Self-Organization of the Everglades Ridge and Slough Landscape

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The flow-parallel ridges and sloughs of the central Everglades formed centuries ago and remained relatively stable until relatively recently. Although degradation of a large area of ridge and slough during the past century is well documented – the actual processes responsible for degradation are much less certain. The origin of the ridge and slough landscape is hypothesized to involve complex feedbacks between hydrologic and ecological processes, including flow and vegetative flow resistance and its role in redistributing sediment from topographically lower to higher areas, influences on differential rates of peat accretion, and corresponding adjustments of the plant communities. The National Research Council recently highlighted the need to incorporate measurements of flow and suspended sediment in the performance measures being used to judge restoration progress. Two of the key uncertainties are the velocity threshold for entraining organic sediment in sloughs, and the net exchange of suspended sediment between sloughs and ridges. USGS measurements are focused on quantifying these and other uncertainties in field measurements and experiments, and also modeling the connections between flow and transport and ecological processes on longer timescales ranging to centuries. Our ridge and slough simulation model is being used to identify the key factors responsible for both origin and degradation of ridge and slough pattern that will help prioritize the most fruitful restoration strategies. What follows is a synthesis of the USGS team's recent research and its implications for restoration.

- Average ambient velocities measured in the Everglades are typically on the order of 0.3 cm s^{-1} in central WCA-3A and 0.7 cm s^{-1} in Shark Slough.

- Flow was primarily through sloughs at our study location in central WCA-3A. The average flow velocity was 30% higher and the flow discharge per unit-width was more than 100% higher in sloughs compared with ridges over the 3-year measurement period. The ridge-slough difference in flow velocity was small relative to 2 - 3 times greater velocities associated with gravity waves that propagate through WCA-3A as a result of sudden pulses of water released from WCA-2A through water control structures. Severe storms such as Hurricane Wilma also locally increased flow velocity for short periods of time (by as much as 10 times).

- In general the most effective management actions that increase flow velocity will be the ones that increase water-surface slope rather than those that simply increase water depth. Pulsed flow operations at water control structures are potentially an effective means to increase water-surface slope and flow velocity, although the high velocities needed for floc entrainment possibly can only be restored for short periods of time and only in small areas of the Everglades, i.e. similar to what can be expected from severe storms.

- Our field flume experiment with enhanced flow determined that relatively fine particles associated with plant stems are entrained at a flow velocity between 0.38 and 1.73 cm s^{-1}, in other words, at relatively high velocities but not untypical conditions in the present-day Everglades. Fine suspended particles are important in transporting carbon and phosphorus (P) downgradient, although their ultimate role in ridge and slough landscape processes remains uncertain.

- Entrainment of the larger floc particles from the sediment bed occurred at substantially higher velocities (between 3.3 and 6.4 cm s^{-1}) that are rare in the present-day Everglades. The critical bed shear stress threshold for floc entrainment in the Everglades is 1.0 x 10^{-2} Pa, with the greatest increase in entrainment flux occurring between this threshold and bed shear stresses of 2.0 x 10^{-2} Pa. Depth-averaged velocities at which these bed shear stresses are obtained vary with vegetation community, flow depth, and water surface slope. Under current water-surface slopes in the Everglades, floc entrainment by flow will never occur in densely vegetated *Eleocharis* sloughs and will rarely occur in sparser deep-water sloughs. However, redistribution of floc from sloughs to ridges by flow can be restored by a combination of reducing *Eleocharis* abundance and releasing pulses of water from impounded areas that temporarily increase water surface slope. Above surface-water depths of approximately 45 cm, bed shear stresses vary little with water level but remain highly sensitive to water surface slope.

- Feedback between two distinct mechanisms is needed to explain the evolution of the ridge and slough landscape. First is the differential peat accretion mechanism that introduces topographic heterogeneity through an autogenic peat accumulation process, and second is a feedback caused by interactions between topographic heterogeneity, vegetation, and flow that reinforce landscape morphology through redistribution of sediment from sloughs to ridges. Individually these mechanisms are not sufficient to explain the origin of the ridge and slough landscape. In addition, episodic events such as hurricanes are not a necessary precursor for the sediment redistribution that supports landscape formation and maintenance.

- Topographic and vegetative heterogeneity of the landscape can be preserved by water level management alone, but flows that induce sediment transport are necessary for interconnected sloughs to persist. However, if sufficient in magnitude, these flows can be intermittent, of a total duration less than 3 weeks/year. At a bed shear stress of 2.0 x 10^{-2} Pa, two weeks of flows that induce sediment transport will result in an annual scour rate in sloughs equivalent to the spatially averaged rate of peat accumulation throughout the ridge and slough landscape.

- Water management has decreased surface water levels across large areas of the Everglades, and vegetation patterns in many of those areas responded with expansion of *Cladium* and *Eleocharis.* Although the feasibility of promoting dieback of *Cladium* just by increasing water level has been demonstrated, we predict that it will not be feasible to restore a ridge and slough pattern just by increasing water level. Increasing surface water slope and water depth are necessary to restore and maintain sediment redistribution patterns, but may not be sufficient without reducing vegetation frontal areas in remnant sloughs with at least a “one-time” mechanical removal of *Cladium* and *Eleocharis*. Once vegetation frontal area is removed from remnant sloughs, our modeling suggests that surface-water slope and depth can be successfully managed to maintain a topographically and vegetatively heterogeneous ridge and slough landscape with high habitat connectivity.

- Suspended sediment holds an important proportion of surface water total P, in relatively labile forms, despite its low abundance. Higher discharge results in greater downstream transport of labile particulate P with sloughs transporting more material than ridges. Everglades water quality models should more routinely consider the transport and fate of dissolved and particulate forms of P.

- Our measured concentrations and other characteristics of suspended sediment and associated nutrients were similar in adjacent ridge and slough under the current hydrologic regime. This finding was not predicted by our modeling of a stable ridge and slough system, which suggests that the present-day ridge and slough system is not sustainable with present velocities.
- Restoration of greater water flow through the Everglades likely will result in faster spread of P from the phosphorus hotspot in northern WCa-2A through increased particulate and dissolved P transport to down-gradient areas. Our modeling indicates that along with diminished flows, increased P is also a primary factor promoting loss of Everglades ridge and slough landscape structure. As a result, the goal to contain excess P may interfere with the goal of restoring increased flows.

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Threshold for Everglades Sediment Entrainment Determined by Flow Enhancement in a Field Flume

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Conditions for mobilizing organic Everglades sediment were determined in an experimental flume facility constructed by the USGS at a site in the central Everglades (Water Conservation Area 3A, 26° 03′ 23.7″ N, 80° 42′ 19.2″ W). The experimental flume is 7.3 meters long and 1 meter wide with boundary walls constructed of PVC sheets inserted into peat and supported by vertical and horizontal sections of angle iron on the exterior, which protected the interior vegetation, peat, and flocculent organic sediment from disturbance. The flume was aligned parallel to the dominant flow direction in a Nymphaea odorata slough with the upstream end left open. At the time of the experiment the average water depth in the flume was 31.7 cm. To enhance flow the downstream end of the flume was sealed and water was pumped water from three withdrawal wells just upstream of the end wall. After monitoring for entrainment of suspended sediment at the ambient flow speed (0.38 cm s^{-1}) the end wall was emplaced and flow speed was elevated in four steps (each lasting approximately 50 minutes) to the four higher speeds (1.73, 3.32, 6.37, and 6.05 cm s^{-1}). Flow speeds are based on duplicate velocity profiles acquired at a distance of 4.4 m downstream using two acoustic Doppler velocimeters (ADV) deployed side-by side (to the left and right of the centerline of the flume).

During each of the sequential flume runs at a different velocity the entrainment of sediment was monitored with two instruments, the first being a laser diffraction particle size analyzer (LISST-100a) deployed vertically such that a measurement was made in the middle of the water column (16 cm above the flocculent detrital sediment bed) that quantifies particles between the sizes of 1.25 and 250 µm. The second instrument was a digital floc camera viewing at 8 cm above the bed that quantifies particles larger than 14.50 µm. We also sampled suspended sediment by pumping water from three depths in the water column, followed by 0.2 µm pore size filtering and gravimetric analysis.

Under ambient Everglades flow (prior to flow enhancement) the mass-weighted and volume-weighted concentrations of suspended sediment were very low (0.51 mg L^{-1} and 0.43 µL L^{-1}, respectively), and the mean particle size of suspended sediment was 24 µm. Enhancement of flow velocity had the effect of increasing the volume concentration of suspended sediment by approximately a factor of five and the mean particle size by approximately a factor of three by the end of the experiment. Two distinct periods of elevated suspended sediment concentration were apparent: an early entrainment pulse during the first and second elevated flows and a late pulse during step four. The LISST detected an increase in the mean diameter of smaller particles from 24 µm at ambient flow to 66 µm at the first elevated flow velocity, and ultimately to 75 µm at the highest elevated flow velocity. The digital floc camera detected an increase in mass-weighted mean diameter for larger particles from 160 µm at ambient flow to 305 µm at the third elevated flow velocity, and ultimately to 279 µm at the highest elevated velocity. Suspended particle size differences and suspended particle concentration frequency differences between the pulses indicated that suspended sediment was entrained on the first elevated velocity step was from a source of relatively small organic particles associated with epiphyton on plant stems. The relatively large particles of flocculent detrital matter from the bed were not entrained until the third elevated velocity step. The smaller size class of particles detected by the LISST was the dominant contributor to total suspended sediment concentrations at ambient and higher flows. The pool of stored particles in the smaller size-class also is apparently very large because there is only limited evidence of depletion during the experiment. Entrainment of the class of larger floc particles from the bed becomes significant to total volume-weighted concentrations between a threshold velocity of 3.3 and 6.4 cm s^{-1}. Our field flume experimental data were consistent with recent numerical modeling of bed shear stress (predicted threshold = 1.0 x 10^{-2} Pa bed shear stress at a velocity of 5.2 cm s^{-1} in water 32 cm deep) and was also consistent with laboratory flume entrainment experiments.

A summary of experimental finding and implications for restoration include:

- Average ambient velocities in the Everglades are typically on the order of 0.3 cm s^{-1} at our site in WCA-3A and 0.7 cm s^{-1} in Shark Slough with a few locations averaging over 1 cm s^{-1}. Our field flume experiment with enhanced flow determined that relatively fine particles associated with plant stems begin to be entrained at a flow velocity between 0.38 and 1.73 cm s^{-1}, in other words, at flow velocities that are characteristic of the present-day Everglades. Fine suspended particles are important in carbon and phosphorus transport and cycling, although their role in ridge and slough landscape processes remains uncertain.
- Entrainment of the larger particles of floc from the sediment bed began at substantially higher velocities (between 3.3 and 6.4 cm s^{-1}) that are rarely measured in the present-day Everglades. Although a detailed assessment of velocities expected in a restored Everglades may not yet be available, we suspect that the relatively high velocities for floc entrainment reported above are likely only be reintroduced for short periods of time and possibly only in small areas of a restored Everglades, i.e. similar to the velocity increases expected from severe storms.

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Adaptive Management in a Learning Environment – A Case Study of Hydrology and Water Quality in the A.R.M. Loxahatchee National Wildlife Refuge

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A solid science foundation, including monitoring, modeling, and experimentation, is required for successful adaptive management. Linking modeling, monitoring, and research results to future management is difficult; however, these linkages are important to drive efforts to restore the health of the South Florida ecosystem. An important concept of adaptive management is that learning occurs and is incorporated into the decision process. An additional concept is that learning actually increases management decision flexibility. As directed knowledge is gained, it can be used to better assess consequences and risks of decisions thereby grounding decisions in information rather than speculation. Here, we present a case-study examining these theoretical concepts where incorporating modeling, monitoring, and experimentation contributes to increased flexibility in decision making.

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) is a 58,275 ha wetland having that protects wildlife habitat while meeting uses for flood protection and water supply. An interdisciplinary technical foundation is necessary for making sound management decisions for protection and restoration of this area. An important management question is: What impacts do water management operations have on Refuge ecology? To address this broad question it needs to be stated in the form of questions that can be examined using models, monitoring, or experimentation. Working from the premise that a combination of focused monitoring, modeling, and experimentation leads to successful adaptive management, the Refuge established an enhanced water quality monitoring and modeling program in 2004 to address key questions under the above broad management question.

Data from monthly surface water quality samples and hourly recording of conductivity (a tracer of canal water) were collected to better understand the marsh's response to water management. In addition, water quality monitoring data were coupled to development and refinement of hydrodynamic and water quality models for the Refuge. Preliminary relationships between water management strategies and the magnitude of canal-water penetration were established. From this baseline information, specific management recommendations were identified which could be applied to the water management decision processes.

Availability of the above information provides the foundation for exploring consequences of water management actions based on knowledge rather than speculation. In this case study, an adaptive approach was taken in the form of a water management dialogue about how to manage a short-term increase in inflows to the Refuge from one particular source to minimize environmental impacts. Predictions were made based on modeling and synthesis of existing monitoring data. Those predictions were examined in the context of evaluating acceptable risk to the Refuge and a subsequent water management decision was agreed upon. Subsequent monitoring proved valuable in interpreting the results of this adaptive management decision on establishing operational linkages between structures. Incorporation of the additional knowledge into the decision process added flexibility and provided an opportunity for additional learning.

Key messages relevant to larger-scale ecosystem restoration include:

- using a science-based approach allows expert knowledge to play an integral role in better assessing consequences and risks thereby increasing management decision flexibility;
- increased management decision flexibility provides additional opportunities for learning.

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What Managers Need to Know About System-wide Science to Improve Restoration Planning and Maximize Adaptive Management

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One valuable outcome of this workshop, as well as GEER 2008, is for scientists to clearly outline for managers how science, through the adaptive management (AM) framework, can guide the Comprehensive Everglades Restoration Plan (CERP) decision-making process. AM is a structured, iterative process of optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time via ecosystem monitoring. The GEER workshop entitled *System-wide Assessment of South Florida Ecosystems – Where Are We Today and Where Are We Going Tomorrow* touches upon many components of the REstoration COordination and VERification (RECOVER) program. These include the state of scientific knowledge, the health of the South Florida system, and how scientific information generated from system-wide monitoring and assessment will be used to compare ecological conditions both from a pre- and post-CERP project implementation context.

The concluding session (Session 5) of this workshop builds upon the information presented by the RECOVER Monitoring and Assessment Plan (MAP) Modules (Sessions 1-4). The following specific thematic areas will be explored both individually and in a holistic manner:

- Description and evolution of the RECOVER MAP from 2004 to 2008;
- Integration of AM and system-wide monitoring and assessment;
- Application of the RECOVER MAP as it relates to CERP project planning and implementation;
- Application of lessons-learned to better aid managers' efforts to maximize restoration;
- Long-term monitoring for enhancing restoration benefits; and
- Future of the RECOVER MAP (developing MAP 2008).

Key messages for managers relevant to restoration include:

- A clear synopsis of the evolution of the RECOVER MAP-this evolution spans from results of early implementation to current status of ecosystem health, and finally to next steps in development of linkages between science and the CERP AM program;
- Managers and decision-makers are provided with a clear understanding of how science (system-wide) is being directed to provide output relevant for managers/decision-makers;
- Understanding the environmental restoration benefits of CERP is directly coupled to regional and system-wide science-based ecosystem monitoring and assessment;
- Current and future scientific efforts are focused drawing linkages between traditional ecosystem monitoring and the CERP AM program; and

- The information presented is directly coupled to information requested by in reports to Congress, Programmatic Regulation requirements such as Interim Goals, reports to the National Academy of Science, as well as CERP Report Cards to the public.

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An Assessment of Organochlorine Pesticides and Polycyclic Aromatic Hydrocarbons and the Potential Impact to Water Quality in Florida Bay

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Agricultural discharges and urban non-point source runoff from adjacent areas have the potential to impact the ecology of Florida Bay, the largest estuary linked to the Everglades. To examine the potential exposure risk of organochlorine pesticides (OCP), polycyclic aromatic hydrocarbon (PAH), and PAH quinones exposure to the Florida Bay, eight 30-day time-integrated semipermeable membrane devices (SPMD) were collected in February 2000 at restoration sites C-11/station-9 and C-111/station-177 upstream from the Bay. Chlorinated pesticides and PAHs sequestered in SPMD triolein lipid were retrieved and analyzed by a graph chromatograph and PAH quinones were measured with high performance liquid chromatography and ultraviolet radiation detection. A laboratory static renewal uptake study of moderately hydrophobic quinones from water by SPMD results showed that the SPMD can be used to monitor the levels of the targeted PAH quinones in environmental water bodies. Mean endosulfan I concentration in SPMD at C-11 was two magnitudes lower than concentration at C-111, where OCP were similar to those reported for fish of the Everglades National Park and Florida Bay. Differences between dieldrin levels as well as benzene hexachloride (BHC-ά, β, and δ) levels found in SPMDs at C-11 and C-111 were minimal. Concentrations of these (dieldrin and BHC) contaminants varied in ranges 1.5-1.6 and 1.0-1.6 ng/SPMD, wet wt., respectively. Average total dichloro-dipenyl-trichloroethane (DDT) concentration in C-11 SPMD was comparable with DDT levels found in C-111. Among compounds of DDT family, *p,p'*-DDT isomer prevailed in all SPMD samples indicating a possible local "fresh" DDT source. Among the OCPs and their isomers, trans-chlordane and cis-chlordane were the two common predominant pesticides in detectable concentrations in SPMD (11.5-12.2 ng/SPMD) and (8.9-9.8 ng/SPMD, wet wt.), respectively.

The estimated pesticides time-weighted mean concentrations were

- Below the Environmental Protection Agency water quality criterion for freshwater at both sites; however,
- Estimated endosulfan concentrations at C-111 were at levels that could reduce the health of biota in Florida Bay downstream.

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Monitoring of Water Flow in Everglades National Park

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This study is part of a larger study which focuses on evaluating the importance of water flow in the formation and preservation of tree islands in the Florida Everglades. The specific objectives of the study described herein were to quantify water flow characteristics in the Shark River Slough in Everglades National Park (ENP). Water flow was characterized at five sites, Gumbo Limbo (GL), Black Hammock (BH), Satin Leaf (SL), Chekika (CH), and Frog City (FC), primarily through temporally intensive measurements of water velocity using fixed acoustical Doppler velocity units, and continuous measurements of water surface elevation using pressure water level loggers. By the end of 2007, the collected data have covered a period from July 9, 2003 to December 18, 2007 for water velocity and from August 5, 2003 to December 18, 2007 for water level. Raw data for water velocity were screened to filter out erroneous data due to too low signal-noise ratio, low battery voltage, entanglement of vegetation on probes, and other disturbances that have led to values not representing the actual velocity. The filtered data were compared with rainfall and gate discharge downloaded from the SFWMD's DBHYDRO database. Water flow was also compared with stage gradients obtained from the EDEN network. Results showed that water flowed southwestward (around 200^{o} clockwise from magnetic north) except at CH where water flowed southeastwards (157^{o}) most of the time. Water speeds normally were below 3 cm/s with higher values (0.03 to 1.89 cm/s) during wet seasons and lower values (0.07 to 0.94 cm/s) during dry seasons. The higher water speed during wet seasons was strongly associated with higher discharge from gates (S12C, S12D, and S333) during the same period. However, correlation between the gate discharge and the water speed weakened as stations moved from west to east of the slough. Particularly, on the east side of L67 extension levee, the slough did not receive discharge from the gates directly and thus received less influence from these gates. Stage gradient (water surface slope) in the slough was 0 to 10 cm/km with an average varying from 0.5 to 5 cm/km. A simple relationship between stage gradient and water speed could not be established. This lack of relationship was attributed to variable water resistance due to vegetation. The role of vegetative resistance should be further evaluated if efforts are to focus on utilizing EDEN derived gradients for estimating water flows on a larger scale.

Data show that the water level tracked discharge very well at GL, which has the longest period of record. A comparison between the water surface elevation measured in the current study and that from EDEN network showed that the two sets of data matched well. Gate discharges were strongly correlated with stage at the five sites, indicating that discharge was the main controlling factor for water depth in the slough. The influence of rainfall was indirect and less significant than gate discharge. High rainfall periods preceded high gate discharge periods by 11 weeks. The correlation between rainfall and water speed or stage was very weak. Water flows in the slough dropped significantly after January 2006 due to reduced rainfall in south Florida and decreased discharge from the gates. Water level data at FC and CH showed that these sites were mostly dry during the 2007 dry season.

In summary, water surface elevation in the Shark River Slough correlated well with discharge at gates located at the northern boundary of ENP. Water flow was characterized by slow and seasonally varied water speed likely driven by the interplay between small water surface slopes and vegetative resistance. Sufficient gate discharge is essential to ensure water flow in the slough. Construction of the planned Tamiami Trail Bridge would benefit this area of the East Everglades by providing much needed water to this relatively stagnant and dry area.

The following findings are from this study on water flow in Shark River Slough:

- The main controlling factor on water flow in the slough is gate discharge being strongly correlated with water surface elevation and to a less extent with water speed.
- Water speed records (2003 to 2007) at five study sites show seasonal variation with maximum hourly averaged speed less than 3 cm/s.
- Flow directions at five study sites are more diversified at low speeds but tend to be stabilized at around 200^{o} clockwise from magnetic north when the speed is greater than 0.5 cm/s.
- Reduced gate discharge during 2006 and 2007 have resulted in lower water depth during the wet season and significantly reduced water speed at five sites.

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Influences of Phosphorus and Salinity on Productivity and Demography of *Thalassia Testudinum* across Florida Bay

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Biomass, net primary productivity (NPP), foliar elemental content, and demography of *Thalassia testudinum* was monitored in populations from five sites across Florida Bay beginning in January 2001. Sites were selected to represent the gradient in phosphorus (P) availability and salinity fluctuations across the bay. On the western, open boundary between Florida Bay and the Gulf of Mexico, Sprigger Bank has the most stable salinity and highest foliar P concentration. To the northeast, Bob Allen Keys and Duck Key have low foliar P content and somewhat variable salinity. Little Madiera Bay and Trout Cove, close to the mangrove shoreline in the northernmost reaches of the Bay, have intermediate foliar P content and highly variable salinity. Phosphorus availability in this region may be influenced by elevated P in groundwater discharges.

Aboveground components of *T. testudinum* biomass and NPP were determined 5 - 6 times annually. Short shoot demography, belowground biomass, and NPP were assessed from a single destructive harvest at each site. Short shoot ages were estimated from the number of leaf scars, scaled by site-specific annual leaf production rates. Belowground productivity was estimated from excavated biomass and population mortality rates, as determined by short shoot age distributions. Biomass, relative growth rate (RGR), and overall NPP were strongly increased by P availability. Additionally, there was a positive relationship between P availability and the ratio of photosynthetic to non photosynthetic biomass suggesting that *T. testudinum* invests in belowground biomass when P is limiting. Mortality rates were weakly but positively correlated with P availability, and current year recruitment was strongly correlated with P availability. Departures from seasonally modeled estimates of RGR were found to be influenced by salinity, which depressed RGR when below 20 psu.

Freshwater management in the headwaters of Florida Bay will alter salinity and nutrient climates. It is becoming clear that such changes will affect *T. testudinum*, with likely feedbacks on ecosystem function and habitat quality.

Key findings relevant to restoration:

- Phosphorus gradients in Florida Bay affect biomass, productivity, and the population recruitment and mortality rates of *Thalassia testudinum*.
- Low and high salinity events depress productivity of *T. testudinum*.
- Very close to the mangrove shoreline in the northernmost reaches of Florida Bay *T. testudinum* has elevated foliar phosphorus concentrations and therefore higher relative growth rates compared to more P-limited parts of the system, presumably because of elevated P concentration in groundwater discharges.
- If increased hydrological head increases groundwater flow then the resulting salinity and nutrient climates may alter the role of *T. testudinum* in the functioning of Florida Bay ecosystems.

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Physiological Responses of Pre-breeding Adult Great Egret and White Ibis to Contrasting Prey Availability Conditions

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One of the key conceptual models underlying the Everglades restoration is that hydrologic changes affect prey availability, and wading bird nesting. The mechanism by which prey availability affects wading birds and produces species-specific nesting patterns has not been identified. We examined the physiological responses of pre-breeding great egrets and white ibises, two species with contrasting foraging strategies, in relation to foraging and habitat conditions in the Everglades. Both species were in good physiological condition (low levels of stress proteins and fecal corticosterone) during a year with above average habitat conditions (2006) with egrets and ibis using endogenous and exogenous mass strategies respectively. During a year with below average habitat conditions (2007) ibis physiological condition was lower; stress protein 60 and fecal corticosterone increased throughout the pre-breeding period in ibis while remaining stable in egrets. Differences in foraging strategies may explain why egret stress levels remained similar between years, and in the case of males were able to increase mass even under lower quality habitat conditions. Egrets appear to minimize energy expenditure associated with foraging, and are known to forage in diverse habitat conditions relative to ibis. During the below average year, male and female egrets and ibises used exogenous and endogenous mass strategies respectively. By using endogenous mass reserves, females likely minimized the cost of reproduction, which may be an important strategy in poor years for both species, possibly increasing the likelihood of future reproductive success. Model results confirmed the role of prey biomass and short-term hydrologic factors as the primary habitat variables that varied between years and were associated with physiological differences. Different physiological responses between species likely plays an important role in nest initiation, nest success, and chick physiology, and could be linked to the stability or decline of other species in the Everglades with similar foraging strategies.

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Bioavaliability of Copper in Flooded Agricultural Soils and Toxicity to the Florida Apple Snail (*Pomacea Paludosa*)

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Agricultural sites are being acquired under the Comprehensive Everglades Restoration Plan (CERP) for maintaining hydrological buffer areas and little is known about the potential for Cu desorption and toxicity from contaminated soils. Soils were collected from 11 agricultural sites, single or multiple times flooded, and held for 28 d under static conditions to monitor soil and overlying water concentrations of Cu. Juvenile apple snails (*Pomacea paludosa*) were also exposed for 28 d to flooded soils from three selected sites to study the effects of Cu on growth, survival and tissue uptake. In the desorption study, Cu concentrations in soils ranged from 5 to 234 mg/kg (day 0) to a range of 6.2 to 204 mg/kg (steady-state concentration) (day 28). The steady-state dissolved Cu concentration in overlying water from each of four flooding events ranged from 9.1 to 308.2 µg/L and was up to 24-fold higher than the U.S.EPA numerical freshwater quality criterion. In the 28-d growth study, high mortality occurred within 9 to 16 d in two of the three soil treatments as a result of Cu concentrations in soil and overlying water. Growth (i.e., length, weight) of apple snails over 28 d was also affected by Cu exposures in these treatments. Tissue concentrations of Cu by day 14 were 12 to 23–fold higher in snails exposed to the three soil treatments compared to controls. The present study indicates that if Cu-contaminated agricultural sites become inundated, Cu will desorb from agricultural soils resulting in soil and water exposures that will produce adverse biological effects in Florida apple snails. The endangered Florida snail kite and its main food source, the Florida apple snail, may be at risk from Cu exposure in these managed agricultural soil-water ecosystems.

Keywords: Copper Toxicity, Florida apple snail, *Pomacea paludosa*, Everglades, Comprehensive Everglades Restoration Plan (CERP)

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A Holistic Approach to Addressing Water Management and Water Quality Issues in the Lake Okeechobee Watershed

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Since the late 1970's, there has been a growing recognition that eutrophication of Lake Okeechobee was a serious threat to the lakes environmental health. This concern was one of the important factors that led to the initial push to restore the Kissimmee River. Additionally, the South Florida Water Management District and the Florida Department of Environmental Protection collaborated in the development and implementation of the Lake Okeechobee Temporary Operating Permit and later, the Interim Action Plan. These operational changes resulted in substantial reductions in backpumping from the Everglades Agricultural Area to Lake Okeechobee.

In spite of these important initial efforts and many other major initiatives that have been undertaken since, water quality and water management problems persist in Lake Okeechobee. However, what has changed is the level of recognition of the importance and the magnitude of the problems. Never before has there been a collaboration of federal, state, and private organizations and individuals that are all taking actions to address the lake's needs in accordance with a comprehensive plan.

The nature and magnitude of the water resources problems in the Lake Okeechobee Watershed require solutions that span all spatial scales from watershed to field or parcel level. Similarly, responsibilities for solutions span the full range of public and private entities, including federal, state, and local agencies as well as individual land owners. A holistic approach to planning and implementing water resources measures in the Lake Okeechobee Watershed has been developed and adopted. A comprehensive plan was developed by the SFWMD in collaboration with FDEP and FDACS and has been adopted by the state legislature.

This plan involves the application of essentially every tool in the toolbox by a multitude of public and private entities at an unprecedented scale. This workshop will consist of presentations of the following topics:

- existing water resources problems in Lake Okeechobee (Paul McCormick, Chief Scientist, SFWMD),
- development and content of the Lake Okeechobee Construction Project Phase II Technical Plan that lays out the multitude of measures that will be implemented (Tom Teets, Program Implementation Manager, SFWMD),
- the role of CERP (Stuart Applebaum, Deputy District Engineer for Everglades Restoration, US Corps of Engineers),
- development of the Lake Okeechobee phosphorus Total Maximum Daily Load (TMDL) and DEP initiatives (Frank Nearhoof, Science Coordinator, FDEP),
- implementation of agricultural measures that are required by the plan (Rich Budell, Director of Agricultural Water Resource Protection and Conservation, FDACS), and
- an example of a public/private partnership approach to "water farming" (Patrick Bohlen, Director of MacArthur Agro-ecology Research Center).

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Environmental Drivers of Wet Prairie Conversion in Water Conservation Area 3A

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Over 50% of the Florida Everglades has been lost to agriculture and urban development in the last century. The remaining wetlands have experienced compartmentalization for flood control and water delivery purposes. Unnatural hydrology due to management regimes has caused the remaining ecosystem to degrade, and now efforts are being made to restore it. Our project is an ongoing vegetative monitoring study in Water Conservation Area 3A (WCA3A) in South Florida. The main habitat of interest is wet prairie, comprised mainly of *Eleocharis* spp, *Panicum* spp., and *Paspalidium* spp., because of its structural importance to the foraging ecology of the endangered snail kite, which is considered an indicator of Everglades' health because of its dependence on the south Florida freshwater wetlands for the entirety of its life cycle. We suspect that the spatial extent of wet prairie is decreasing due to impoundment and the increased hydroperiods in WCA3A under the current water management regime. Cluster and indicator species analysis were used to determine the communities in WCA3A. These communities were input into a multistate model to predict the probability of wet prairie conversion. Using 17 water monitoring wells and vegetation collected from 20 plots in the area, we constructed and tested a model to determine where wet prairie is being lost and the hydrologic variables that are correlated with this loss. Restoration of the Everglades will be aided by increased knowledge of the habitats necessary for a healthy, proliferating snail kite population.

The estimates provided in this study are valuable for Everglades' restoration and management.

- They can be incorporated into management models to predict how management actions like water level regulations will affect the proportion of habitat occupied by wet prairie or slough communities.
- This study provides the first estimates of the transition probabilities between slough and wet prairie communities in the Everglades ecosystems based on statistical multistate models.
- It has also allowed us to evaluate several hypotheses about the factors governing the shifts from one community type to another.

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Evaluation of Repeated Herbicide Treatments for Control of *Lygodium microphyllum* using Glyphosate and Metsulfuron Methyl in the A.R.M. Loxahatchee National Wildlife Refuge

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We conducted pre-treatment evaluations on ground cover (≤ 1 m), canopy cover (> 1m), and shrubs and trees on 50 tree islands infested with *Lygodium microphyllum* in the A.R.M. Loxahatchee NWR during Dec. 2005. This was followed by aerial herbicide treatment with either glyphosate (1.8 or 3.6 liters / 75.7 liter diluent / 0.4 ha) or metsulfuron methyl (56.7 or 113.4 grams / 75.7 liter diluent / 0.4 ha) during Feb. 2006 to evaluate the effectiveness of each herbicide rate on *L. microphyllum* and impacts to non-target vegetation. One year post-treatment evaluations were conducted during Dec. 2006, followed by ground treatments to *L. microphyllum* in March 2007. We conducted two year post-treatment evaluations during Jan. 2008 and additional ground herbicide treatments were conducted in March 2008 on *L. microphyllum*. The final evaluation will be conducted in Jan. 2009 to determine the effects of repeated herbicide treatments on *L. microphyllum* and the response of non-target vegetation. We will present the results of this study two years post-treatment.

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Biogeochemistry and Water Quality of the Greater Everglades: Fate and Transport of Contaminants Nitrogen

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For decades, research in the greater Everglades system has focused on phosphorus as the primary limiting nutrient. Consequently, nitrogen cycling has received much less attention and primarily as a limiting nutrient in Florida Bay systems. This review will focus on the state of knowledge regarding the processes, pathways, and environmental controls regulating the forms, distribution, and transport of nitrogen throughout the Everglades-Florida Bay continuum.

During the recent history, predominant inputs of N to the system have been through drainage water discharges to the northernmost Water Conservation Areas. Atmospheric N deposition accounts for an estimated <0.5 g N m^{-2} yr^{-1} while N_2 fixation contributes on the order of between 2 and 10g N m^{-2} yr^{-1}. Denitrification rates are lacking in all Everglades regions except Florida Bay, leaving the overall N budget for most areas unclosed.

Nitrogen accumulation rates range from ~20g N m^{-2} yr^{-1} in the eutrophic northern systems to <10 g N m^{-2} yr^{-1} in the central Everglades regions. In addition to their known role in N2 fixation, recent work in both the northern and southern Everglades regions has also found that periphyton communities exhibit high rates of inorganic N assimilation, and thus are highly active in the process of N accumulation. Much of the assimilated N is lost as dissolved organic nitrogen compounds and the fate of this N remains uncertain. Export and ultimate fate of DON compounds are of particular concern for Florida Bay where organic N has been shown to affect cyanobacterial blooms as well as heterotrophic microbial growth.

Among the factors affecting nitrogen cycling in Everglades systems, phosphorus has a demonstrated effect, with impacted areas exhibiting increased N limitation, changes in macrophyte species, higher N uptake, accumulation, and loss rates. Drying/rewetting cycles have also been shown to affect both nutrient release rates in peat as well as periphyton mats. Restoration of flow in the contiguous Everglades may have an impact on N export with an unknown effect of increased water depth or hydroperiod. Increased flows and associated effects are particularly important in mangrove fringe wetlands due to potential for increased N delivery to Florida Bay ecosystems.

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Biogeochemical Factors Influencing Phosphorus Retention in the Everglades Stormwater Treatment Area Wetlands

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Agricultural runoff contains levels of nutrients and other contaminants that are known to affect and alter the biotic integrity of receiving wetlands or water bodies. In the Everglades, for example, phosphorus (P) enrichment has caused the alteration of plant and periphyton communities. To alleviate this problem and help restore the Everglades, six Stormwater Treatment Areas (STAs), i.e. STA-1 West, STA-1 East, STA-2, STA-3/4, STA-5, and STA-6, encompassing more than 45,000 acres of freshwater wetlands, have been constructed to remove excess P from surface waters before discharging into the Everglades Protection Area.

Since 1994, these STAs have reduced the total P (TP) load that would have entered the Everglades by over 950 metric tons, reducing TP loads by 70% and overall annual flow-weighted mean TP concentrations from 145 down to 45 ppb (Pietro et al, 2008). Total P loading and uptake performance varies among individual STAs. In 2007, the percent of TP retained by STA-1E, STA-2, STA-3/4, and STA-6 exceeds 70%. In STA-1W, which went through construction enhancements and rehabilitation in 2006 and 2007 removed 55% of TP load in 2007. The amount of TP removed by STA-5 was 41%.

Optimization and long-term sustainability of the STAs is a big challenge. The performance of an STA depends on several biogeochemical factors, as well as a variety of other ecological factors including vegetation community, hydrology and hydraulics, inflow TP loads and concentrations, and weather conditions. While treatment wetlands have been successfully utilized for P removal for decades, the Everglades STAs face several unique challenges, related to their massive size, dynamic hydraulic conditions, and extremely low target outflow concentrations. Moreover, because P removed from the water column (via sorption, precipitation, microbial uptake, and plant uptake) is ultimately stored in wetland sediments, there is concern about the sustainability of P removal in STAs.

The STAs originally were designed to be passive systems, with little or no effort expended on vegetation management. Under this regime, the wetlands become dominated by emergent macrophytes, primarily *Typha* monocultures. Over the past decade, however, scientific studies demonstrated that improved STA performance can be achieved by sequencing emergent and submerged aquatic vegetation (SAV) communities.

The condition and performance of the STAs have been affected by recent extreme weather conditions, i.e. back to back hurricanes in 2004 and 2005 and drought periods in 2007 and 2008. Prolonged periods of high water levels have been blamed for poor cattail establishment and the formation of floating cattail islands in some of the STAs. Low water levels during drought and subsequent re-flooding resulted in spikes in TP concentration in certain cells, likely due to P release from mineralization and also from resulting dead biomass. In most cases, the spikes were temporary and stabilized after sufficient amount of water has flowed through the area.

In the past two years, the District performed rehabilitation of STA 1 West, a 6,670 acre STA. After over ten years of excellent performance, this STA's performance began to decline as hydraulic and TP loading increased and was also accelerated by back to back storm events. High levels of turbidity and easily resuspended floc prevented re-establishment of vegetation in three cells. Rehabilitation efforts included sediment stabilization with temporary vegetation, inoculation, and eventually, earthwork to remove tussock materials and accrued soil layer. Planning efforts are currently underway to undergo rehabilitation in STA-5 in order to improve its performance.

Optimizing and sustaining the life of the STAs in the most feasible way is one of the adaptive management goals of these constructed wetlands. Future studies related to biogeochemistry are aimed at understanding the following: i) cost-effective management strategies for maintaining desired vegetation communities, ii) minimizing tussock formation, iii) the role of the microbial community and detrital layers with respect to short-term uptake, iv) long-term P storage mechanisms, and v) floc formation in SAV cells and how to encourage their aggregation.

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Water and Sediment Phosphorus Gradients in Everglades Stormwater Treatment Areas

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Six separate Everglades Stormwater Treatment Areas (STA), ranging in size from 350 to 2670 ha, are comprised of multiple wetland cells, many of which have extremely long flow paths (up to 4.7 km). The large size of these constructed wetlands, which were established on antecedent agricultural soils, coupled with varied inflow water column P concentrations, leads to a diverse assemblage of emergent and submerged macrophyte communities. We selected two STAs, one with an exemplary P removal history (STA-2), and the other with an under-performing record (STA-5), to evaluate internal water column and sediment P gradients.

For all three treatment cells in STA-2, 74% of the inflow water P load of 1.4 g P/m^2-yr was removed between 2002 and 2007, whereas only 42% of the 2.3 g P/m^2-yr P loading was removed in STA-5 during the same period. Concentration gradients within submerged aquatic vegetation (SAV)-dominated Cell 3 of STA-2 indicated removal of most of the water column P concentrations within the front half of the cell (inflow concentration 74 µg/L vs. mid-point concentration of 39 µg/L). The average STA-2 Cell 3 outflow concentration for the sampling dates was 20 µg/L. The porewater P concentration at the mid-point (61 µg/L) in Cell 3 was nearly five-fold lower than the 289 µg/L concentration measured in the inflow region. By contrast, P gradients in the northern flowway of STA-5 (which consists of an emergent macrophyte “front-end” and SAV “back-end”) were not observed in the surface water, and displayed a reverse trend (549 µg/L at the back vs. 68 µg/L for the front end) in the porewater.

For the past five years, STA-2 Cell 3 has shown a consistent P gradient in both soil porewater and surface water, with a decline in concentrations from inflow to outflow locations, likely due to homogeneous soil and vegetation types and a modest P loading history. Based on our initial investigations in STA-5, water P gradients from the inflow to outflow sampling locations are poorly defined. This lack of defined gradients could be due to variable microtopography, soil conditions, and vegetation communities, as well as a higher P loading history.

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Characterizing the Dynamics of Dissolved Organic Matter in the Florida Coastal Everglades: A 3-D Fluorescence Approach

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Dissolved organic matter (DOM) dynamics in wetlands and estuaries are complex and often difficult to assess using traditional geochemical approaches. It has become clear that quantitative measurements (DOC) alone do not properly allow assessing the multitude of sources (e.g. emergent and submerged vegetations, soil/sediments, groundwater, and rainwater) and the various diagenetic processes (e.g. photodegradation, biodegradation) that can alter the DOM characteristics in aquatic ecosystems. In this study, we incorporate bulk DOC measurement with Emission Excitation Matrices fluorescence (EEM) coupled with Parallel Factor Analysis (PARAFAC) in an attempt to better understand the dynamics of DOM in the greater Everglades landscape. DOM in surface and groundwater, dominant vegetation leachates (including senescent leaves of sawgrass, spikerush, mangrove, seagrass, and periphyton) and soil leachates were characterized using EEM-PARAFAC and potential degradation processes were assessed through bio-and photo-degradation studies.

Fluorescence based EEM-PARAFAC analyses revealed seasonal DOM compositional differences such as increased microbial source loadings in some estuarine areas and Florida Bay during the wet season. Compositional differences between waters from the peat based Shark River Slough and the marl-based Taylor Slough as well as clear differences between surface and ground water DOM were also observed. Photo- and bio-degradation of plant leachates readily showed that the combination of both processes was most effective in promoting DOM compositions similar to those in natural surface water of the Florida Coastal Everglades. The data generated in this study will make a significant contribution to a better understanding of subtropical wetland and estuarine DOM characterization and its environmental dynamics, biogeochemical carbon cycling processes, and potential relationships to environmental restoration and global climate change issues.

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Numerical Model Optimization of Surface-Water Inflows to Achieve Restoration Salinity Performance Measures

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Numerical models are often used to evaluate the effectiveness of water management and delivery strategies. These scenario simulations are used to analyze how specific water-management practices affect factors such as water levels, flows, and salinities. Water management scenarios are often developed intuitively rather than analytically. Instead of analyzing simulations using a "trial and error" method, an optimization technique may be used to obtain results that satisfy performance measures with improved accuracy.

To aid in water management decision making, the U.S. Geological Survey has developed numerical models that represent the surface-water and ground-water hydrology of the coastal regions of Florida Bay and Everglades National Park (ENP). Restoring this coastal wetland environment is an important concern, and the Southern Inland and Coastal System (SICS) model is useful in examining the effectiveness of different water management scenarios for the area. The SICS model simulates the area using a two-dimensional hydrodynamic surface-water code coupled with a three-dimensional ground-water code. This coupling produces the Flow and Transport in a Linked Overland/Aquifer Density-Dependent System (FTLOADDS) code, which represents interaction between the two hydrologic systems along with salinity transport. The dependence of flow density on salinity is accounted for in both the surface-water and ground-water models.

In order to develop an optimization technique for the numerical model, the SICS model is executed within the UCODE parameter estimation program. UCODE performs inverse modeling, posed as a parameter-estimation problem, using nonlinear regression. The SICS model runs iteratively while UCODE determines target location salinity responses to regulated ENP inflows and adjusts these inflows between iterations. To adjust the inflows, UCODE creates flow multipliers to adjust the model input values, within an acceptable range, to achieve specified SICS output statistics. The objective is to produce target salinities that meet predetermined ecosystem restoration goals defined in the Florida Bay/Florida Keys Feasibility Study (FBFKFS). These goals include reducing the variability of salinity in coastal areas and maintaining desired salinity ranges.

Preliminary results obtained using two different parameterization methods demonstrate the ability of the model to effectively change salinity values in the target areas to meet desired performance measure goals. The first method uses six multipliers—one for high flows and one for low flows at each of the three inflow locations. The second method uses two multipliers—one for high flows and another for low flows at the main inflow point, with flows at the other two inflow points apportioned based on available volumes. Although the six-parameter method was more computationally intensive, it did not yield significantly better results. Both techniques successfully reduced the salinity variance and effectively moved the salinity range in some target areas toward the FBFKFS criteria. The salinity variance in the primary zone of interest was reduced from an original value of 0.509 psu^2 to 0.418 psu^2 and 0.342 psu^2 using the two methods. Simulations incorporating one to three target areas show that this optimization method was less able to improve values near model or tidal boundaries than at points more to the interior of the domain. These experiments illustrate that the inverse modeling technique is effective for planning water management and restoration strategies that focus on meeting specific water-quality criteria.

The development of numerical model optimization of surface-water inflows has yielded the following contributions toward restoration efforts:

- The technique can be used by water managers to design water delivery schemes for achieving specific restoration objectives (as opposed to testing an existing design).
- The technique can be applied to any model-simulated parameter of interest, including water level, discharge, temperature, constituent concentration, or a derivative of a model-simulated parameter such as a wetland hydroperiod.
- The technique can be applied to models that use input other than inflows. For example, hydraulic structure operating criteria can be adjusted in a management model to achieve water delivery targets.

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Long-term Water Quality Trends and BMPs in the Lake Okeechobee Watershed, Florida

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Presented by: ***Richard (Tom) James***

Considerable effort has been made on the implementation of agricultural best management practices (BMPs) and water quality improvement projects to reduce the discharge of phosphorus from the watershed to Lake Okeechobee since 1990. However, the total phosphorus load to the lake was 630 metric tons per year averaged over the water year of 2003 to 2007 (May 2003 to April 2007). This five-year rolling average load is more than four times higher than the Total Maximum Daily Load (TMDL) of 140 metric tons recently set for the lake. In order for coordinating agencies to better direct resources and plan for additional BMP implementation, baseline conditions and trend analyses pertaining to phosphorus and nitrogen concentrations were developed to determine relationships between BMP implementation and water quality conditions.

The South Florida Water Management District has maintained a long-term, ambient monitoring network in the Lake Okeechobee watershed and some of the sampling sites in this network have period of record data from 1972 till the present. The network consists of 27 sampling locations within the upper and lower tributaries in the basins immediately north of Lake Okeechobee, nine sampling sites within the tributaries of Pools A and C of the Kissimmee River, and 16 sites located at outfalls from historic dairy operations within the watershed. Biweekly samples are collected at each monitoring location for nutrients and physical parameters. Most of the water quality samples are collected only when flow is observed at these monitoring locations.

Statistical significance of mean monthly total phosphorus (TP) and nitrogen (TN) concentration trends over time, by station and basin, were determined using a Seasonal Kendall Tau test. The changes in TP and TN concentrations were examined in relation to BMP and restoration features within the corresponding drainage boundaries. A concomitant analysis and discussion of baseline and trends for total phosphorus at 16 dairy sites was also developed in this paper. The occurrence of significant water quality trends were used to assess the overall performance of BMPs implemented through the Lake Okeechobee Watershed Protection Program and other water quality improvement programs during past two decades.

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Water Quality Trends of the Kissimmee Chain of Lakes, Lake Istokpoga and Lake Okeechobee

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The Kissimmee Chain of Lakes (KCOL), Lakes Istokpoga and Okeechobee are valued for recreation, water supply, flood protection and wildlife. These ecosystem functions can be impacted by poor water quality, which in turn is affected by land use changes, water management practices and in-lake processes. The South Florida Water Management District began monthly water quality monitoring on Lake Okeechobee in the 1970s. This was followed in 1981 for East Lake Tohopekaliga, Lake Tohopekaliga, Lake Hatchineha, Lake Cypress, and Lake Kissimmee in the KCOL. Lake Istokpoga was added in 1988. The monitoring program for these lakes includes analyses of nutrient, chemical, physical and biological variables using standard methods (Germain 1998, South Florida Water Management District (SFWMD) 1999). This presentation (1) identifies changes that have occurred in water quality of the lakes, and (2) provides possible explanations for those changes.

A single sampling site was chosen for each of the KCOL to reflect the longest period of record (i.e. A03-East Lake Tohopekaliga), or the most representative site: B09 – Tohopekaliga, C03 – Cypress, D02 – Hatchineha, and E04 – Kissimmee. For Istokpoga the three sites with the longest period of record (ISTK1, ISTK6, ISTK7) were averaged by month. For Lake Okeechobee data from eight long term monitoring sites (L001 to L008) were averaged by month.

A Seasonal Kendall's Tau trend analysis that accounts for serial correlation (Reckhow et al. 1992) was used to determine if a significant linear trend exists in each lake for each parameter for the period of 1981 to 2007 for all lakes except Istokpoga, which was evaluated for the period of 1988 to 2008. Time series of the variables were graphed and visually inspected for non-linear trends. A number of such trends were found in the KCOL where an asymptote occurred about June 1994. Data from the KCOL were then separated into the periods before and after June 1994 and analyzed as above. A probability value of 0.05 was considered significant.

From 1981 to 2007 a number of changes were observed in the KCOL: total phosphorus (TP) and nitrogen (TN) declined in Lakes Tohopekaliga and Cypress. TN also declined in Lake Kissimmee. Calcium (Ca) increased and turbidity declined in East Lake Tohopekaliga, turbidity declined in Lake Tohopekaliga, and chlorophyll *a* declined in Cypress, East Lake and Lake Tohopekaliga. Soluble reactive phosphorus (SRP) increased in Lake Kissimmee, dissolved inorganic nitrogen (DIN) increased in East Lake Tohopekaliga and Cypress. Silica (Si) declined in all but East Lake and Lake Tohopekaliga and sulfate (SO_4) declined in all but Lake Hatchineha. Secchi transparency increased and DIN and conductivity declined only in Lake Tohopekaliga.

Further analysis showed some significant trends in water quality that reached asymptotes around June 1994. Prior to this time, TP declined in all of the KCOL, except East Lake Tohopekaliga. After this time, TP increased in all but East Lake and Lake Tohopekaliga. Similarly TN and DIN declined prior to June 1994 in lakes Cypress, Hatchineha and Kissimmee. After June 1994 there were no changes in DIN for these three lakes, while TN increased in Lake Hatchineha. Prior to June 1994 infestations of *Hydrilla* had spread to over 40% coverage of Lake Kissimmee. Treatment with herbicides on a lake-wide scale in 1997 reduced this *Hydrilla* coverage to less than 20% and may in part be responsible for the increases in TN and TP in Lake Kissimmee.

From 1988 to 2007, significant increases of TN, TP, turbidity, chlorophyll *a* and reduction of Secchi transparency were found in Lake Istokpoga. In part this could be attributed to excess nutrient loads. Although attempts were made to control *Hydrilla* on a lake-wide scale in the past decade, it is unlikely that these attempts have led to the observed changes in water quality.

From 1982 to 2007, there were significant increases in turbidity, TP, SRP and DIN and significant decreases in Secchi transparency, conductivity, and Cl in Lake Okeechobee. Some of this could also be attributed to increasing nutrient loads, but significant increases in turbidity and TP and decreases in Secchi transparency also occurred as a result of resuspension and mixing of sediments from hurricanes Frances and Jeanne in 2004 and Wilma in 2005.

- No consistent water-quality trends exist among these lakes.
- Causes of observed trends are likely multifaceted and may include changes in point and non-point source loading, management of invasive plant species, and the accumulation of some elements in lake sediments.
- Sediment-water interactions can affect the response of in-lake water chemistry to changes in external loading rates.
- These factors need to be considered when using trend data to gauge the success of state and federal programs to reduce nutrient loads and improve management practices throughout these lakes' watersheds.

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Mechanistic Biogeochemical Model Applications in the Florida Everglades

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This presentation will describe mechanistic biogeochemical model applications in the Florida Everglades. Models are described for biogeochemical cycling processes of significance in the Everglades restoration. Mechanistic models are based on the underlying physics and chemistry governing the processes and seek to describe pheonomena with transferable equations that can be used predictively. This approach is contrasted with empirical methods that are based on observed relationships between variables that may not be transferable in space or time. The first step in developing a mechanistic model is to construct a conceptual model that defines the key interactions between process variables based on fundamental knowledge. Each interaction is then defined mathematically (e.g., first order, Monod, etc). Parameters for these relationships must then be obtained from experimental data. Finally the model should be validated against process data. Advantages of such approaches are that not much data is required for model development, the model development process engenders "deep" knowledge of the system, and the model parameters have physical meanings. Disadvantages are that development can be very time consuming and costly, solving the equations requires more sophisticated numerical techniques than simpler empirical approaches, and adding new functionality requires fundamental understanding of the underlying processes. The degree of process complexity is also an important consideration in development and application of mechanistic models. This presentation will describe the state of mechanistic model development for key biogeochemical processes in the Everglades, and will identify major data gaps and needs relevant to restoration.

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Development of Potential Biological Control Agents for Invasive Plant Species Using Native Pathogens in South Florida

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One of the greatest threats to the native ecosystems in any part of the world is invasion and permanent colonization by non-native species. Florida is no exception to this biological invasion, and currently colonized by an extensive variety of exotic plant species. The unrestricted growth of many of these nonnative plants jeopardizes the survival of an array of native plants in Florida. Originally imported from Asia over thirty years ago, Old World Climbing Fern (*Lygodium microphyllum*) has become one of the most invasive and destructive weeds in southern Florida. To date different effective control measures of its growth and spread has not been successful. Fire and herbicide application is currently in practice, however they are not cost effective and environmentally friendly approach. Biological control is proposed as a tool useful for ecosystem restoration and management. Most of the potential hazards of classical exotic introduced biocontrol agents can be avoided by selecting pathogens that are already endemic in the area where they are to be used. We have initiated studies to discover and develop potential native microbial biocontrol agents of invasive plant species. Brazilian pepper. We have identified sicklepod fungus *Myrothecium verrucaria*, as a possible bioherbicide against *Lygodium microphyllum*. Series of greenhouse studies demonstrated the pathogenicity of *Myrothecium verrucaria* on *Lygodium microphyllum*.

Brazilian pepper an exotic invasive hardwood tree species is now covers hundreds of thousands of acres in south and central Florida, as well as many of the islands on the east and west coasts of the state. Brazilian pepper (*Schinus terebinthifolius* Raddi) is native to Brazil, Argentina and Paraguay. Significant infestation of Everglades National Park (ENP) by Brazilian pepper has occurred in an area known as the “Hole-in-the-Donut”, (HID) covering over 3,000 ha that were previously agricultural lands. Periodic field survey for occurrence of disease were made, putative fungal and bacterial pathogens were isolated and tested for pathogenicity using detached leaf assay and seedling inoculation. We have found that native microbial pathogens of Brazilian pepper trees do occur with capability to cause significant damage. Three fungal isolates were tested in a greenhouse spray inoculation study. All the three isolates caused necrosis of apical buds and only one isolate caused leaf spots and chlorosis on young leaves. Among the bacterial isolates from the pepper tree disease samples, two were found to be pathogenic. Further, evaluation of the two bacteria in a controlled greenhouse spray inoculation study showed only one of the isolates was able to induce leaf spot symptoms on leaves. Another potential bacterial pathogen was isolated from pepper trees showing inflorescence blight with complete absence of drupes. Limited inoculation studies using the bacterial isolate from the blight on pepper inflorescence caused flower discoloration, absence of drupe development and tip dieback. This type of biocontrol method can be incorporated as a valuable tool in the over all management strategy to restore native ecosystems in a cost effective and environmentally friendly manner.

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Effects of Environmental Methylmercury Exposure on Reproduction in White Ibises (*Eudocimus albus*)

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Methylmercury is well known for its potent neurotoxic and teratogenic effects on a variety of taxa. However, effects of chronic exposure at environmentally realistic exposure rates are poorly understood for most endpoints that can be translated to the population level. The Everglades ecosystem is known to be extensively contaminated with methylmercury. We looked experimentally for evidence of impairment on reproduction and behaviour at environmentally relevant doses in the White Ibis (*Eudocimus albus*), a species chronically exposed in the Florida Everglades. We exposed wild-caught birds to methylmercury from 90 d to 3 yrs of age in a large free-flight aviary where breeding could easily be documented. Treatment groups (40 birds each) received 0.0001 (control), 0.01, 0.03 and 0.3 ppm (wet weight) methylmercury in their diet.

In 2006, control birds initiated nesting significantly earlier than the other groups. In both breeding seasons of 2006 and 2007, the control group initiated more nests, had significantly more nests resulting in eggs and a higher number of fledglings per nest start than any dosed groups. We observed homosexual pairing behaviour (nearly all male-male) in all groups. However, in both years, the control group showed significantly fewer males nesting homosexually than the dosed groups and the degree of homosexual pairing increased linearly with dosage. Of the total males who nested in 2006, 20%, 27%, 45% and 52% were homosexually paired for the control, low, medium and high dose groups respectively. The percentages of males that nested homosexually in 2007 were 5%, 27%, 43% and 44%. We did not see any apparent effects of mercury on nest success in heterosexual pairs in either year, and the differences in reproductive success among groups were entirely due to unproductive same-sex pairs.

Key findings of this study to date are that:

- methylmercury exposure at low, chronic levels has a strong effect on reproductive success,
- reproductive success is decreased by affecting pairing behaviour,
- the levels of mercury induced reproductive impairment shown in the aviary would translate into significantly reduced population size in the wild.

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The Effects of Off-Road Vehicles on Small Mammals in Big Cypress National Preserve

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Effects of off-road vehicles (ORVs) on the environment have been debated as many public lands have restricted or closed areas to off-road vehicles. As a result of human disturbances, fragmentation of once contiguous habitat into small isolated patches has increased. The use of ORVs in Big Cypress National Preserve (BCNP) has prompted managers to evaluate ORV impacts on natural resources. The degree of ORV use is well documented in marl prairies of BICY, but the impact on wildlife species other than those listed as threatened or endangered is not well known. Small mammals are an ideal taxonomic group for addressing questions of ORV use in BCNP. There is detailed information regarding biology and natural history of small mammals at the organismal, population, and community levels. Small mammals are easily marked to monitor their movements and behavior. We compared densities and body condition of hispid cotton rat (*Sigmodon hispidus*), marsh rice rat (*Oryzomys palustris*), and cotton mouse (*Peromyscus gossypinus*) on ORV and non-ORV sites.

Densities of the three small mammals were different depending upon the species. Hispid cotton rats had a higher density in non-ORV areas; marsh rice rats showed no difference in density between areas; and cotton mice showed higher density in ORV areas. Body condition for the three species showed no significant differences between ORV and non-ORV areas. These results suggest that the impacts of ORV’s on small mammals are mixed. While some species have negative effects associated with ORV’s, others may benefit from it. Understanding these effects has important implications for land-use policies that promote long-term survival and persistence of wildlife populations.

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Importance Of Hurricane Impacts In A Shallow Lake

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Lake Okeechobee, a large, shallow, and eutrophic lake in south Florida, is a unique study area for hurricane impact analysis since three hurricanes (Frances and Jeanne, and Wilma) swept over the lake in 2004 and 2005. After Hurricanes Frances and Jeanne, high surface inflows led to high external loads of phosphorus and nitrogen as well as increased water levels. Scouring of the bottom during the hurricanes resuspended a large quantity of sediment and released a large amount nutrient into the water column. An increase in thickness of the unconsolidated sediment layer is attributed to sediment mixing during the storms and post-storm settling of resuspended sediment. The unconsolidated layer was then much more easily resuspended, resulting in sustained higher solids and nutrient concentrations and lower light transparency in the water column long after the hurricanes passed. Reduced light transparency and increased water levels reduced the coverage of submersed aquatic vegetation (SAV) and contributed to the decline of biomass of (SAV) and phytoplankton.

The Lake Okeechobee Environmental Model (LOEM), which was calibrated and verified to simulate sediment resuspension and transport in Lake Okeechobee, was used to simulate the environmental impacts caused by hurricanes. The LOEM contains 2126 horizontal grid cells and 5 vertical layers. The primary hydrodynamic and sediment transport driving forces are wind waves, surface wind stresses, and inflows/outflows. The model results indicate that sediment solids are resuspended primarily by wind wave action and transported by lake circulation. The strong relationship between significant wave height and suspended sediment concentration in the lake indicates that sediment resuspension is primarily driven by wind-induced waves. The importance of wind wave, currents, and their interactions to sediment transport is included and discussed.

- Lake Okeechobee was greatly influenced by Hurricanes Frances, Jeanne and Wilma
- Waves resuspended sediments and uprooted aquatic vegetation
- Currents redistributed flocculent mud sediments through the lake
- Resuspension of sediments led to an increased depth of flocculent sediments
- Increased flocculent sediments resulted in increases of turbidity, phosphorus and light limitation in the water column and reduced aquatic plant and phytoplankton growth.

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Assessing Salinity Variability and the Abundance of Fishes Along the Mangrove Shorelines of Biscayne Bay

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Ten years of visual census data collected along the shorelines of Biscayne Bay was used to evaluate the importance of salinity variability along the mainland shoreline and used to examine habitat utilization in the bay. The mainland shoreline was divided into 31 segments and an index of wet season salinity variability (salinity range across years) was developed for each of the segments. Wet season samples were sorted by latitude (across years) and a 21-sample running average of the salinity range was calculated (10 samples before and 10 samples after). Each sample was assigned a range index value of low (<20 psu), medium (20-29 psu), and high (>30 psu) variability and samples were grouped into variability segments of approximately 20 samples based on the similarity of their index values. The mangrove shoreline along the leeward keys were similarly divided in 10 segments of about 25 samples. GIS maps of the three abundance indices were made for the six most abundant species by segment for the wet and dry seasons.

The average catch of the 17 most abundant species were calculated for each segment. We followed a data analysis procedure known as the Delta Approach. Three abundance metrics, frequency of occurrence, concentration (density when present, exclusive of zeros) and "delta-density" (occurrence x concentration) were calculated for each segment of shoreline. Wet season mainland shoreline abundance metrics were plotted against the wet season salinity variability index. A trend line (linear or parabolic) was assessed for each metric. Standard regression techniques were used to explore patterns in these abundance metrics along a salinity variability gradient.

Eight species showed a significant (90%) trend to salinity variability with the frequency metric, seven with the concentration metric, and eight with delta density metric. A negative relationship was found for one or more metrics for *Abudefduf saxatilis*, H*aemulon. sciurus*, *Lagodon rhomboides*, *Lutjanus apodus*, *Lutjanus griseus*, and silversides. All of these above species are typical reef or known higher salinity species except the silversides which we were unable to identify to species and this family contains both low salinity and high salinity forms. In contrast, the mojarras, *Eucinostomus* spp. and *Diapterus. plumieri* showed a positive relationship to salinity variability, while the majority of typical estuarine species showed no significant relationship. *Sphyraena barracuda, Floridichthys carpio*, and *Gerres cinereus* did not show a significant relationship for any of the abundance metrics. Positive or no relationship suggests high tolerance to salinity variability for these species. More significant relationships were found with salinity variability approach that grouped data into salinity segments than with the salinity bin approach which used salinity at the time of sampling.

Maps show that the mojarras occur in relatively high frequency (>45%) throughout all of the shorelines of Biscayne Bay during the wet season. During the dry season, both *Eucinostomus* mojarra frequencies and concentrations in the southern most part of the bay are lower than the central and southern parts of the bay which coincided with higher salinity range. The magnitude of *Eucinostomus* mojarra occurrence and concentration along the Leeward Keys shoreline were similar to that of the Mainland shoreline.

The *F. carpio* was found to occur most often in the northern and central parts of the bay especially during the dry season. Wet season *F. carpio* occurrence tended to be patchier. *F. carpio* concentration and delta density showed similar patterns as occurrence. Occurrence and density of *F. carpio* along the Leeward Key shoreline were of a similar order of magnitude as that of the southern Mainland shoreline.

G. cinereus was found in highest frequency along the Leeward Keys shoreline, although the order of magnitude of the concentration and delta density suggest that it is relative uniform throughout the bay. It was found to be absent in portions of the southern most bay which may be related to recruitment or the high salinity variability.

The *H. sciurus* was absent along the northern and central parts of the bay. It occurred with high frequency along the Keys shoreline and in moderate occurrence levels in the southern part of the bay except in the southernmost portion where recruitment may be limiting its distribution. *H. sciurus* concentration showed similar distribution patterns as occurrence.

L. apodus occurred with highest frequency along the Leeward Keys shoreline in the wet season. *L. apodus* occurrence along the Mainland shoreline in the wet season was highly variable, while in the dry season it tended to be absent in the northern part of the bay and the most southern part of the bay. Wet season *L. apodus* delta density tended to be of a similar order of magnitude throughout most of the bay. Dry season schoolmaster frequency along the Leeward Keys shoreline varied between medium to high. The *L. apodus* tended to be absent from the southern most part of the bay which may be related to recruitment.

Frequency of occurrence of *L. griseus* was high along the Keys shoreline during both seasons. Highest *L. griseus* occurrence and concentration of along the Mainland shoreline was in the southern part of the bay. The *L. griseus* delta density along the Mainland shoreline tended to be relatively stable and was an order of magnitude lower than the Leeward Keys shoreline. There were a few places along the northern part of the Mainland where the *L. griseus* was absent during both seasons.

The *S. barracuda* was found throughout the bay. Highest *S. barracuda* frequency of occurrence was found along the Leeward Keys shoreline and in the central portion of the Mainland shoreline during the wet season. Dry season *S. barracuda* frequencies tended to be more variable. *S. barracuda* concentration and delta density tended to be of a similar order of magnitude throughout the bay during both seasons.

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Development of Habitat Suitability Models for the Biscayne Bay Area Fishes: Assessing Salinity Affinity from Abundance Data

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With the overall objective of determining patterns of fish abundance across salinity gradients, habitat suitability index (HSI) models were developed and presented in both graphic and mathematical form. HSI models represent correlations between salinity and abundance metrics, rather than statements of cause-and-effect. This study represents a meta-analysis of existing Biscayne Bay fish data that has been collected since 1993. These were compared to data from studies conducted in Florida Bay from 1976 to the present.

We followed a data analysis procedure known as the Delta Approach. The Delta Approach is not new and is often used in fisheries applications and in ecological studies on niche overlap. Three abundance metrics were developed for 13 taxon of interest: frequency of occurrence, concentration (density when present, exclusive of zeros) and "delta-density" (occurrence x concentration). These were plotted against a salinity gradient using standard regression techniques.

The three taxon specific metrics were developed from five gear types where they were applicable (visual census, trawl, throw-trap, seine, dropnet studies). Trend analyses between each of the abundance metrics within a collection salinity category (5 psu bins) were conducted and the strength of the trend (R^2), equation of the relationship and significance (p-value) were determined for each trend. We detected significant trends in the one or more abundance metrics along salinity gradients for 11 of the 12 fish taxa and pink shrimp and found 61 significant relationships across species/gear/bay/metric combinations. The general pattern of the relationship trends in density metrics with salinity across species (with a few exceptions) were vastly different between the two bays. The metrics tended to be negative or parabolic for Biscayne Bay fishes, and positive or parabolic for Florida Bay fishes. This may indicate that fishes are adapting to the salinity regime or bay in which they live.

Species richness was estimated across a salinity gradient for individual studies in Biscayne and Florida Bays. Community-level studies were also conducted using Biscayne Bay visual census data using cluster and canonical techniques. Species composition in Biscayne Bay was found to cluster into two main groups, those less than 20 psu and those greater than 20 psu. Canonical analysis showed similar results.

In the absence of quantitative historical data, or large-scale field experiments, there are few options but to examine for fish-habitat correlations as has been conducted here. Therefore, the relationships presented should be used as a "decision tool" rather than a predictive capacity, when considering the setting of minimum flows or for gaining insight into the effects of implementing wetlands restoration scenarios.

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Leveraging Highly Accurate Elevation, Field, and Remotely Sensed Image Data to Enhance Digital Elevation Models for Subregions of the Everglades

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The Everglades Depth Estimation Network (EDEN) offers a consistent and documented dataset that can be used to guide large-scale field operations, integrate hydrologic and ecological responses, and support biological and ecological assessments that measure ecosystem responses to the Comprehensive Everglades Restoration Plan (Telis, 2006). A system-wide digital elevation model (DEM) of the ground surface was developed using geostatistical analysis of data collected using the U.S. Geological Survey (USGS) airborne height finder (AHF) and contracted conventional surveys (Jones and Price, 2007). In combination with the EDEN water level gage data, this DEM is used to produce historic and near-real time maps of water depths.

Several types of data historically collected in the field or as part of the EDEN development may prove useful in enhancing DEMs in subregions of the Everglades. For example, multiple elevation points and elevation data statistics were collected around select EDEN water level gages to evaluate Everglade elevation heterogeneity. In addition, EDEN principle investigators and other scientists have been collecting water depth information during field exercises. When these depth measurements are subtracted from the EDEN application-modeled water surfaces for the appropriate dates, additional information about ground elevation can be derived. Also, drought conditions and storm disturbances of vegetation canopies have allowed increased collection of airborne LiDAR data. These data provide information about specific terrain features and relationships among vegetation and elevation for small areas of the Everglades. Finally, data collected by other Federal agencies, such as the Environmental Protection Agency, form an additional source from which an independent evaluation of modeled elevation can be conducted.

These various data types are being fused to evaluate the EDEN DEM, to create enhanced sub-regional DEMs, or test the extension of the EDEN DEM into previously uncovered areas. This fusion and evaluation contributes to restoration efforts by:

- Providing insights regarding fine-scale Everglades topographic variation.
- Demonstrating how multiple source data may be fused to yield information on wetland ground elevations.
- Creating procedures for indexing the confidence in the EDEN DEM and EDEN modeled water depth estimates.

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Progress and Prospects for Monitoring Landscape-Scale Patterns of Everglades Vegetation from Satellite and Airborne Imagery

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The composition, structure, and productivity patterns of Everglades vegetation reflect and influence patterns in climate, soil, hydroperiod, water flow, salinity, and nutrient availability. Decades of Everglades science have developed a strong base of literature connecting vegetation patterns to geochemistry. However, most work to date has been based on point, transect, or small sub-regional scale analyses. Many changes indicating degradation or loss of natural systems start subtly and occur at spatial and temporal scales unfamiliar to conventional human thinking (Liemgurber and others, 2005). Tools are needed to help uncover and monitor those changes for restoration and adaptive management. To comprehensively monitor and understand the impacts of restoration activities such as flow regime changes, decompartmentalization, and nutrient reduction on the greater Everglades system, we must develop capabilities for efficiently monitoring landscape-scale changes in vegetation patterns. Past attempts to automate satellite-based mapping of vegetation patterns have been challenged given their low spatial resolution and broad level of vegetation taxonomy. But traditional vegetation mapping (i.e., at the species level) may not be needed to understand and monitor the effects of changes in Everglades biochemistry. Landscape-scale maps of vegetation structure, biomass, condition, or functional groups may also provide insights regarding biochemical patterns in the Everglades.

The Landsat data archive collectively constitutes the largest consistent satellite database available for natural resource management today (Draeger et al., 1997, Liembeurger and others, 2005). The USGS has assembled and calibrated an extensive Landsat database spanning 25 years for the greater Everglades. Analysis of variation in vegetation biomass using high spatial resolution, airborne-imagery suggests that average spatial scale lengths for vegetation variation may be characterized with Landsat Thematic Mapper (TM) data (Jones, 2001). Also, techniques for processing TM data have matured with the development of non-parametric and sub-pixel based approaches. Further, the technology for remotely sensed data collection has also diversified, giving rise to new remote sensing platforms with increased temporal resolution, increased spectral resolution/range, and active sensing systems (e.g., RADAR and LiDAR). Given these technological developments and a broader view of mapping vegetation patterns at the landscape scale, the following questions may be addressed. What vegetation changes can be identified at the landscape scale from archived moderate and low resolution imagery? What can we discern regarding short-term vegetation changes identified with current moderate resolution imagery? How do the analyses of data from new systems and the fusion of remotely sensed data from multiple sources improve our ability to map Everglades vegetation patterns at the landscape scale?

This work benefits Everglades and other wetland restoration efforts in the following ways:

- Explores what measurements of landscape vegetation pattern and change are possible at synoptic scales using satellite remote sensing.
- Suggests how timely automated processing of routinely collected satellite-based data might enhance adaptive management.

- Provides insight regarding means of monitoring changes in biogeochemistry at landscape scales.

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Periphyton Constructed Stormwater Treatment Areas (PSTA) Mesocosm Treatment Performance With Four Different Substrates

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The preponderance of the Comprehensive Everglades Restoration Plan (CERP) focuses on the components that collect, store and deliver water to the Everglades. Yet it has been the water quality challenges that have forestalled CERP implementation. Restoration flows to the Everglades require a total phosphorus (TP) concentration of 10 μg/l. Periphyton Stormwater Treatment Areas (PSTA) integrates biochemical dynamics into sustainable restoration.

Subsequent experiments at the STA-1E mesocosm demonstrated that 10 μg/l can be achieved over numerous flow regimes after the periphyton community has been "activated". This "green" technology is attractive as it integrates existing biochemical dynamics and sheet flow hydrology into a sustainable system. This presentation summarizes the results of over two (2) year data collection from four (4) 1000 square foot mesocosm cells. The key finding relevant to restoration is the achievement of 10 μg/l TP in the water column using a green technology.

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Effect of Drainage Flow on Phosphorus Concentrations in Canal Waters Downstream of STA-1E

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Presented by: ***Manohardeep Josan***

The ARM Loxahatchee National Wildlife Refuge is one of three conservation areas in south Florida designed to provide water storage and flood control, as well as habitat for native fish and wildlife populations. Most of the Everglades, including the refuge, developed as a rainfall-driven system with surface waters low in nutrients and inorganic ions. There is concern that increases in flow drainage of agricultural and urban runoff water through Stormwater Treatment Area 1E (STA-1E) may suspend and transport light organic sediments and nutrients from the receiving canal that may negatively impact the fragile ecosystem inside the refuge. The objective of this study was to measure the effect of flow drainage from STA-1E on different P species and other selected water properties in the L40 Canal. The study canal included 12 sampling locations; three above and nine below the STA-1E discharge (S-362). The selected sampling locations provided approximately 32 km of canal that are being used to transport treated water discharged from STA-1E. A total of nine water surveys were conducted in 2006, six surveys were conducted under different flow drainage conditions (16,508 – 163,448 $m^3 h^{-1}$) and three under no flow conditions.

Total P concentrations from samples collected under drainage flow averaged 77 $\mu g L^{-1}$, compared to 56 $\mu g L^{-1}$ during no flow, with concentration steadily decreasing away from the main drainage structures. Phosphorus concentrations from individual surveys showed higher differences in P species concentrations depending on intensity of drainage flow and timing during the rainy season. Contribution of total dissolved P to total P in the water column ranged from as low as 21% (18 $\mu g L^{-1}$) on samples collected during a low drainage event early during the rainy season (34,544 $m^3 h^{-1}$) to as high as 75% (83 $\mu g L^{-1}$) in samples from one of the highest drainage events (163,448 $m^3 h^{-1}$) in 2006. In contrast, particulate P concentrations were considerable higher early in the rainy season (79% of total P, 71 $\mu g L^{-1}$), with concentrations considerably decreasing (25% of total P, 24 $\mu g L^{-1}$) toward the end of the rainy season. The highest particulate P concentrations were measured on June 28th, which correspond to the first significant drainage activity from structure S-362 in 2006. Biological particulate material accumulated in the L40 Canal during this long quiescent period was more likely to be disturbed and transported even at a low drainage flow. The same phenomenon called “first flush effect” is observed in farm drainage canals in the EAA, where biological material grow and accumulate in the canals during long quiescent periods. This fresh and highly mobile material is readily suspended and transported during the first significant pumping event, resulting in high concentrations of suspended solids high in P content during the early periods of the draining season. These results suggest that the net contribution of particulate P most likely resulted from the remobilization of biological generated particulate matter accumulated in the canal during the quiescent dry season.

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Characterization of Southern Florida Marsh Vegetation Using a Landscape Scale Random Sample: R-EMAP Phase III Vegetation Sampling

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Southern Florida marsh vegetation is usually sampled in localized areas and/or for specific investigative needs that bias understanding of landscape-scale patterns. Vegetation analysis using classification of aerial imagery and remote sensing can generate complete snapshots of landscape scale patterns but lack details about species composition and abundance within classification categories. We randomly sampled the Everglades marshes as part of the US EPA Region 4 REMAP sampling across the Everglades ecosystem. The sampling region was from the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA1) through WCA2 and WCA3 to the southern end of Everglades National Park. This region was divided into sampling units using a GRTS (generalized random tessellated stratified) sampling design. A total of 230 sites (111 spring, 119 fall) were sampled in May and Dec. 2005 for a suite of biogeochemical and vegetation parameters. Vegetation sampling included two surveys for invasive exotic species and cattail (*Typha domingensis*): one on the helicopter fly-in and one 360^o site survey from the helicopter pontoons after landing.

Vegetation was censused within a 2 m x 10 m plot by sampling 5 m^2 quadrats spaced every other m and on alternating sides along a central transect. The m^2 quadrats were subdivided into four ¼-m^2 quadrats, and species presence was recorded for each ¼ m^2. If sawgrass (*Cladium jamaicense*) was present in the third m^2 quadrat, the number of culms was counted and the length of the longest leaf was measured to sample sawgrass density and size at the site. This primary transect was an equal-probability random sample of the vegetation within the boundaries of the R-EMAP study. If the vegetation sampling crew identified an alternative vegetation type that was not sampled on the primary transect but was present within a 50 m radius of the sampling point, a second transect was sampled in that vegetation type. The plant sample data were used to identify major plant associations using non-metric multidimensional scaling (NMDS). Presence and relative abundance were mapped for each species, and associations with biogeochemical and hydrological parameters for each site were determined. Hydrological parameters were obtained from 6-year averages of hydroperiod generated from the Everglades Depth Estimation Network (EDEN) hydrologic model as corrected by water depth recorded at the time of biogeochemical sampling.

A total of 187 species was found in the 230 sites; 173 species were present at least once on the first transects, while 106 species were found on the second transects. Fourteen species were found only on the second transect, and all of these were found in only 1 (13 species) or 2 quarter-quads (1 species). Most species (149 of 173 or 88%) occurred in fewer than 10% of the transects, when only transect 1 was considered; results were similar when both transects were considered. Sawgrass is the dominant species across the Everglades, occurring in 82% of the primary transects. Sawgrass density was 14 ± 13 culms/m^2 for all samples; when analyzing only samples where sawgrass was present, the average density was 18 ± 12 culms/m^2. The measurements of sawgrass height had a unimodal distribution, indicating that there were not distinct “tall” and “short” morphs. Sawgrass in Everglades National Park (ENP), however, had significantly shorter (117 ± 41 cm) and narrower (7 ± 3 mm) leaves than sawgrass in the Water Conservation Areas

(WCAs) (length = 186 ± 35 cm,; width = 12 ± 3 mm), although average density did not differ between these regions (ENP = 15 ± 12 culms/m^2; WCAs = 13 ± 14 culms/m^2). The next most common species (the bladderworts *Utricularia foliosa* and *U. purpurea*) occurred on 41% and 40% of the primary transects, followed by spikerush (*Eleocharis cellulosa*, 36%) and another bladderwort (*U. gibba*, 35%). The slough habitat indicator species, *Nymphaea odorata*, was the seventh most common species, occurring on 27% of the primary transects. The more common species were present in relatively equal amounts in both the spring and fall sampling, with the exception of the bladderwort *U. radiata*. This species was present in 12% of the primary transects but only in the fall sampling.

NMDS analysis showed three broad clusters of species, defined by sawgrass, white waterlily, and spikerush (*Eleocharis cellulosa*), but these clusters intergraded with each other. With the exception of sawgrass, which was both present and abundant throughout the landscape, the more common species were not randomly distributed. The most striking example of this finding was the white waterlily, which, as in the 1999 REMAP study, was common and abundant in WCA1, WCA2, and WCA 3 south of Alligator Alley and north of the Tamiami Trail, but was uncommon in the northern part of WCA 3 and almost completely absent from Everglades National Park, occurring at only 3 sites.

Based on the two type of helicopter surveys, 40 sites (17%) had at least one of six exotic species present: *Melaleuca quinquenervia* (34 sites); *Lygodium microphyllum* (12 sites); *Casuarina* sp. (7 sites); *Schinus terebinthifolius* (4 sites); *Pennisetum purpureum* (2 sites); and *Salvinia minima* (1 site). Cattail was much more abundant, occurring at 55% of the sites.

Our results indicate that

- Everglades marsh plant associations can be broadly delimited into sawgrass, waterlily and spikerush-dominated communities, but these can share many species.
- Sawgrass is present and abundant across a wide range of Everglades hydrological and biogeochemical conditions, whereas other common Everglades species have more restricted distributions.
- Both waterlily distribution and sawgrass morphology reflect on a landscape scale the hydrologically impacted environment in ENP as compared to the WCAs; these parameters could be used to monitor restoration success.

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Mercury in the Greater Everglades: Changes in Bio-magnification over Time, and Relationships to Other Contaminants, across the Landscape -- R-EMAP 1995-2005

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The Everglades Regional Environmental Monitoring and Assessment Program (R-EMAP) is described in Scheidt and Kalla (this conference) and Kalla et al. (GEER 2006). Some R-EMAP results for mercury are presented here, including spatial patterns and temporal changes. Strength of association between mercury and other variables is also explored.

Median total whole-body mercury concentration in mosquitofish declined markedly from 1995 to 2005. This decline is evident spatially as well, and is confirmed statistically by tests for difference between cumulative distribution functions. Despite the decline, 40.1 ($\pm$ 6.7) % and 64.7 ($\pm$ 7.3) % of the Everglades Protection Area in the wet season of 2005 still had mosquitofish mercury concentrations exceeding the 100 ug/kg and 77 ug/kg levels recommended for protection of top predators by the U.S. Fish and Wildlife Service and by the U.S. Environmental Protection Agency, respectively. Notable declines of mercury were also found in periphyton, for various combinations of growth form, season, location, and form of mercury.

For the study area as a whole in all of 2005, mercury in mosquitofish was not correlated with mercury in surface water, in either the total or the methyl form, but, in the wet season in a core area of maximum bio-accumulation of mercury in Water Conservation Area 3 and Everglades National Park, it was significantly correlated ($p < .001$, $r = .4702$) with the methyl form. The highest correlation in fish was with methyl mercury in epiphytic periphyton ($r = .6870$; whole area, dry season). Other significant correlations, all from the whole study area in the wet season, were found for alkaline phosphatase activity in surface water ($r = .5054$), total phosphorus in surface water ($r = -.3804$), and total phosphorus in flocculent detrital matter ($r = -.5834$). Results of linear and non-linear multivariate analyses involving mercury, sulfur, phosphorus, and carbon are also presented.

R-EMAP findings on mercury in other media are given in Liu et. al (this conference).

Findings relevant to restoration:

- As of the 2005 wet season, mercury in mosquitofish of the Everglades Protection Area (EPA) had declined to about half of 1995 levels, though at least a third of the Area still had concentrations exceeding predator protection guidelines.
- Mercury declines in mosquitofish were most strongly associated with declines of mercury in periphyton. Data from 2005 suggest that mercury in mosquitofish across the EPA is influenced by multiple environmental variables, including levels of other contaminants, acting in different ways in different parts of the system.

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Effects of Restoration Scenarios on the Floodplain of the Northwest Fork of the Loxahatchee River

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INTRODUCTION

The upper watershed of the Northwest Fork of the Loxahatchee River is home to one of the last remnants of bald cypress (*Taxodium distichum*) swamp in southeast Florida. However, a changing salinity regime in the river and its floodplain has been linked to vegetative changes in the floodplain (SFMWD 2005). Of primary concern is the loss of bald cypress and transition to mangrove-dominated communities as salinity in the floodplain increases. A Minimum Flow and Level (MFL) for the Northwest Fork was adopted in April 2003. However, due to reduced freshwater flow in the Northwest Fork, it was recognized that low dry-season flows would immediately trigger exceedances of the MFL, requiring the development of a Recovery Plan. The proposed Recovery Plan initiated an intensive watershed and hydrodynamic modeling effort focused on predicting river salinity under various management scenarios, with the goal of keeping river salinity below identified threshold levels for bald cypress health (2 parts per thousand, equivalent to an electrical conductivity [EC] of 0.3125 siemens per meter [S/m] at 25º C). As these models have not addressed hydrological conditions in the river floodplain (soil moisture and soil porewater salinity), the aim of this study is to characterize soil moisture and salinity dynamics at several depths and distances from the river in the floodplain during both wet and dry seasons. An additional objective is to derive relationships between river hydrology (stage and salinity) and floodplain soil conditions to better predict the effects of management scenarios proposed by the South Florida Water Management District (SFWMD).

METHODS

Twenty-four combined dielectric probes (Stevens Hydra Water, Beaverton, OR) were installed at four locations and three depths along two previously-established vegetation survey transects perpendicular to the Northwest Fork of the Loxahatchee River. Transect 1 is in an upriver location not impacted by daily tides and is dominated by upland forest and hydric hammock at higher elevations and mature bald cypress swamp in the floodplain. Transect 7 is in a transitional area that receives daily tidal flooding and contains both upper tidal and riverine forest types. At each transect, twelve probes were installed at four distances from the river and three depths below ground surface (bgs) to capture the spatial and temporal variation of hydrological parameters over wet and dry seasons. Data collection began in September 2004 and has been ongoing since.

Effective soil moisture was fit to a common three-parameter sigmoid model at Transect 1 (not shown). Porewater EC values were calculated from bulk EC and soil moisture based on calibrations by Mortl (2006) and compared to river salinity values at each transect and with known bald cypress thresholds. Piezometers, slotted at probe installation depths, were also installed in several locations in 2007 to verify probe EC measurements and fill data gaps due to equipment failure.

RESULTS

Effective soil moisture was plotted against river stage, and fit to a common sigmoid. The Nash-Sutcliffe coefficient of efficiency (*ceff*) was used as a measure of goodness of fit. For soils which exhibited a wide range of θ values, the sigmoid model does a good job of predicting soil moisture based on river stage (0.72 < *ceff* < 0.89). For deeper sandy soils which are below the water table for long periods and surface soils of the lower floodplain, which only rarely dry out, the sigmoid model performed fairly (0.32 < ceff < 0.66). At Transect 7, daily tidal flooding resulted in near-constant soil saturation for all probes, however responses to brief periods of drawdown in the shallowest (i.e., highest elevation) probes were evaluated using a Fourier smoothing technique. When mean tide elevation is above probe elevation, smoothing collected Data from 15-and 30-minute readings to a 6-hour time series revealed a close correlation between measured soil moisture and tidal stage data.

Soil porewater EC in the floodplain at Transect 1 (upriver) is slightly higher closer to the river and is relatively stable for most of the study period, with only the surface probes showing significant variation during the extended dry periods. Soil porewater is consistently higher than river EC (by a factor of 2-3), likely due to concentration of salts due to evapotranspiration. Dry season peaks in soil porewater EC were observed in all probes on Transect 7 (tidal transect), which mirrored peaks in river EC. For the probes furthest from the river (T7-145), these peaks increased in magnitude in each of the study years, but reached the critical limit (2 ppt) only in 2007, and only in the most superficial soils (20 cm bgs). For the station 25 m from the river (T7-25), where floodplain vegetation begins to transition from bald cypress to mangroves, measured porewater EC was higher, exceeding the critical value for 83 days in surface soils (23 cm bgs), 85 days in middle soils (46 cm bgs), and 64 days in deeper soils (66 cm bgs).

KEY FINDINGS

- At Transect 1 (upriver) soil moisture is dominated by distance from river and elevation. Since the health and reproductive success of bald cypress is dependent on freshwater conditions and varying flood levels and soil moisture throughout the year, the functional relationships developed here serves as a useful tool for the SFWMD to evaluate adopted MFL standards and proposed restoration scenarios.
- At Transect 7 (tidal), it is apparent from the collected data that the soil porewater EC in the root zone of the floodplain vegetation reaches critical values (2 ppt) at times, but does not reach levels observed in the river. Higher peaks in soil porewater EC were observed in drier years, and maximum soil porewater EC values were also closer to peak river EC values during these years.
- Increases in soil porewater EC in floodplain during the dry season are related to the magnitude and duration of river salinity, however, there is a time lag between river and porewater EC peaks (22-64 days), which increases with depth and distance from river.

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Development of a Method for Quantifying Aquatic Fauna Standing Stock in South Florida Cypress Forests

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South Florida's cypress forests provide critical habitat for aquatic fauna, wading birds, and higher vertebrates, but they have been significantly understudied compared to other aquatic habitats in the Greater Everglades ecosystem. Complex habitat structure and dramatic intra-annual hydrologic fluctuations in cypress forests present considerable challenges for sampling aquatic fauna using methods traditionally employed in other Everglades habitats. Prior to undertaking restoration efforts that will alter the hydrology of the Greater Everglades ecosystem, it is imperative that a sampling protocol be developed and baseline data be collected in an effort to understand the community structure and function of faunal standing stocks in these habitats. In two separate studies we conducted side-by-side comparisons of sampling gears (both active and passive methods) commonly employed in South Florida, and evaluated their ability to provide quantitative data that can be used to assess the standing stock of aquatic fauna that serve as the wading bird prey-base.

As part of RECOVER (Restoration Coordination and Verification), we sampled aquatic fauna in Big Cypress National Preserve cypress forests in 2005-2007 using three fixed-area traps (9-m^2 drop traps, 6-m^2 bottomless lift nets, 1-m^2 throw trap), experimental gill nets, and drift fence arrays. Estimates of fish density (total fish density and density of most common species) were significantly lower in drop traps than throw traps or lift nets. Lift nets were effective for fish in shallow water, but could not be deployed when water levels exceeded 30 cm. In a comparison of drop traps with and without habitat structure (~20% coverage of tree trunks, large root masses, large woody debris, etc.), we saw no difference in fish density between traps that included habitat structure and those that excluded it. Gill nets and drift fences were not effective in this habitat. The primary limitation of all methods except the 1-m^2 throw trap was the inability to quantify macroinvertebrates, as macroinvertebrates comprise a significant proportion (up to 90%) of the fauna community in this system.

In a second study, we compared data collected as part of a CESI (Critical Ecosystems Studies Initiative) study on wood stork foraging habitat in 2006-2007. We sampled 24 natural and disturbed sites throughout southwest Florida (cypress forests, roadside ditches, golf course ponds, etc.) using 1-m^2 throw traps, Gee's minnow traps (unbaited, 24-h soak) and Breder traps (unbaited, 1-h soak). Excluding fish too large to enter passive traps (SL>55 mm), we found CPUE of flagfish (minnow and Breder traps) and sailfin mollies (Breder traps only) were strongly correlated with density estimates (no./m^2 in throw trap). Total fish CPUE (minnow and Breder traps) was weakly correlated with density. CPUE of grass shrimp (minnow and Breder traps) and total invertebrate CPUE (Breder trap only) were weakly correlated with density. CPUE of all other fish and invertebrate taxa were weakly correlated or uncorrelated with density. All fish and invertebrate species captured in passive traps were also captured in throw traps.

Data collected in these two studies suggest the 1-m^2 throw trap is the most effective and practical method for quantifying aquatic fauna standing stock in this habitat. While passive traps (minnow and Breder traps) can be deployed in many situations where throw traps are ineffective (e.g., water depth > 90 cm, excessive woody debris), data collected using these traps (CPUE) cannot be used to infer faunal densities. We continue to investigate and describe any biases inherent to the use of 1-m^2 throw traps in this habitat. Finally, we provide recommendations for a long-term monitoring program for the Big Cypress Region (BCR) based on power analyses of baseline data (throw trap data collected in Big Cypress National Preserve, 2005-2007). This monitoring program will facilitate the detection of changes in the BCR aquatic fauna community in response to hydrologic changes from restoration efforts.

In summary:

- Aquatic fauna monitoring efforts in the BCR are necessary to determine what impact hydrologic changes (resulting from Everglades restoration efforts) are having on the wading bird prey base
- Macroinvertebrates comprise a significant proportion of the cypress forest aquatic fauna standing stock in the BCR (especially early in the hydrologic year), and must be incorporated in sampling regimes
- We demonstrate that the 1-m^2 throw trap is the most effective and practical method for quantifying aquatic fauna standing stock in the BCR, and provide recommendations for a long-term monitoring program that optimizes effort and maximizes change detection

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Water Quality Monitoring in the Southern Estuaries

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South Florida's coastal environment, including the resident flora and fauna, reflect the quality, quantity, timing, and distribution of freshwater flow into the system. Past changes to freshwater flows may have degraded water quality and compromised estuarine community structure and function in some areas of the southern estuaries (SE). Salinity variability in Florida Bay under pre-restoration conditions shows a large degree of spatial and temporal heterogeneity. Meteorological and climactic processes, including tropical cyclones and El Niño, affect bay-wide salinity means and alter temporal distributions. Spatially, the north-central sub-region of Florida Bay displays the largest and most dramatic variability in salinity. This region is the epicenter for hypersalinity formation in the dry season, which is especially pronounced in years with a delayed onset of wet season precipitation. This variability is due to the extensive system of shallow mud-banks in the north-central that reduce the mean depth and minimize exchange with adjacent waters. It may be possible to mitigate hypersalinity formation by diverting a small amount of freshwater runoff from northeast Florida Bay, which receives an ample supply, to the north-central.

Water quality monitoring programs in the southern estuaries provide adequate spatial and temporal coverage with the exception of the southwest Florida shelf where temporal variability may not be adequately captured. Following the recommendation of the South Florida Ecosystem Restoration Task Force (SFERTF) an indicator (Chlorophyll *a* biomass) was identified and utilized to assess the status of water quality. Chlorophyll *a* biomass is an integrator of many of the water quality factors which may be altered by CERP. Moreover, there is concern that increased freshwater flow due to CERP activities may result in more frequent, intense, and persistent algal blooms in the SE. The baseline conditions that have been established in the southern estuaries indicate that the majority of the region is oligotrophic with median chlorophyll *a* concentrations less than or approximately 1 ppb. The status of the chlorophyll *a* indicator in the southern estuaries was assessed following EPA guidelines with the baseline data establishing the reference condition with which to assess the 2006 data. In 2006, only the Barnes, Manatee, and Blackwater Sound sub-region was found to have significantly higher chlorophyll *a* biomass than the reference condition. This algal bloom was the result of an increase in total phosphorous in this sub-region from the combined effects of highway construction and hurricane impacts, including the pre-hurricane managed freshwater release. It took only a small increase in TP (~10 ppb) to trigger this large algal bloom, which continues to persist. This illustrates the sensitivity of the SE to small increases in nutrient loading. The ability of our methodologies to adequately detect this decline in water quality due to altered environmental conditions demonstrates the suitability of this technique to detect changes in water quality as a result of CERP activities. Understanding quantitatively how CERP activities may affect water quality and salinity in the SE is necessary to facilitate iterative adaptive restoration.

Key Findings:

- A minor increase in freshwater runoff to the north-central sub-region of Florida Bay especially during the dry season is likely to mitigate hypersalinity intensity

- The pre-restoration water quality condition has been established in Biscayne Bay and Florida Bay, but is not adequately quantified on the southwest Florida shelf
- A small increase in TP loading resulted in a large, persistent algal bloom
- The current assessment methodology is capable of detecting change due to human activities

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Everglades Restoration and the Florida Keys National Marine Sanctuary: Monitoring for Possible Ecosystem Effects

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The 9,800-square-kilometer Florida Keys National Marine Sanctuary (FKNMS) is located downstream of the Everglades and may be impacted by increased freshwater flows resulting from implementation of the Comprehensive Everglades Restoration Plan. The FKNMS includes extensive areas of seagrass beds, which are sensitive to levels of eutrophication, and the only system of coral reefs in North America. Everglades restoration intends to "do no harm" to the Florida Reef Tract, and a comprehensive set of monitoring projects will help determine whether this desired outcome occurs and, if not, whether adaptive management of freshwater outflows may need to be considered.

Satellite images and in situ sampling of algal blooms, as well as movements of surface drifters, have documented advection of surface waters from southwestern Florida to the FKNMS. The blackwater event of the winter of 2001-2002 provided graphic evidence of transport from the mouth of Shark River Slough to the FKNMS. Another example of connectivity was the advection of a harmful algal bloom from near Charlotte Harbor to the FKNMS in the winter of 2004-2005.

Baselines for FKNMS monitoring were established as early as 1995 and include physical and chemical properties of surface waters and the water column as well as ecological monitoring of seagrass and coral reef communities. Results to date indicate that nitrogen:phosphorus ratios in seagrasses and relative abundance of seagrasses and macroalgae are particularly informative indicators of changes in water quality.

- Advection of algal blooms from southwestern Florida into the FKNMS demonstrate potential impacts of freshwater outflows associated with Everglades restoration.
- Nitrogen:phosphorus ratios in seagrass tissues show regions of N- and P-limitation in the FKNMS.
- Increased macroalgal biomass in some areas of the FKNMS show where eutrophication has occurred, but sources of nutrient loading have not been identified.

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Ecosystem Restoration Risk Analyses

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Risk analysis, in the context of ecosystem restoration, is the process of assessing, managing, and communicating risks and uncertainties associated with planning forecasts to the stakeholders and decision makers. Addressing the risks and uncertainties associated with environmental restoration projects is inherently challenging because of the complex relationships among the multitude of natural processes and anthropogenic influences that can likely impact project outcomes.

This paper will discuss conclusions and recommendations from the risk and uncertainty analyses conducted for the Lake Okeechobee Watershed (LOW) Project, which is a major component of a Comprehensive Everglades Restoration Plan (CERP). The primary objectives of the LOW Project are to contribute towards holistic restoration of Lake Okeechobee by providing better management of lake water levels, improving lake water quality, and minimizing frequency of damaging freshwater releases to the two northern estuaries. The tentatively selected restoration plan includes construction and operation of approximately 17,600 acres of above-ground reservoir capacity, 12,000 acres of stormwater treatment areas, and restoration of 3, 700 acre of degraded wetlands.

Risk and uncertainty (RUA) analyses were used to guide decision making from the start of the planning process. A scenario analyses was conducted to evaluate the ability of the final array of project alternatives to meet stated project goals and objectives. The results of this analyses guided the selection of the most "robust" alternative plan that performs at an acceptable level (i.e., justifies funding of the project) within the range of uncertainties for selected parameters.

Incorporating RUA into the planning process from the beginning ensured that factors that have the greatest level of uncertainty or pose the largest risk of compromising achievement of project objectives were identified early and appropriately evaluated. RUA recommendations are intended to provide decision makers with critical information on how the tentatively selected plan would perform across a range of selected possible future conditions.

Key findings:

- Identifying and estimating risks and uncertainties associated with environmental restoration projects is inherently difficult.
- Outcome of ecosystem restoration projects is challenging to predict because of the complex relationships among the multitude of natural processes and anthropogenic influences that can likely impact project success.
- It is important to identify key factors that are likely to be the major cause of risk and uncertainty and address them early in the planning process.

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Fish Introductions into Everglades Wetlands: An Unforeseen Consequence of Restoration?

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Everglades National Park (ENP) was established to preserve flora and fauna in a natural state and is managed to maintain natural abundance, diversity, and ecological integrity of native plants and animals. However, non-native fishes currently impede fulfillment of management objectives. Since 2000, seven new species of non-native fishes have been collected during studies in ENP, demonstrating renewed colonization of the region. All seven species were first established the in the canal system outside of ENP prior to their collection in ENP. The timing of these introductions and locations of first collections inside of ENP have coincided with structural and operational changes in the South Florida water management system, such as the Interim Operational Plan (IOP), that redirected water deliveries to protect endangered-species habitat and re-water drained wetlands. After the initial introduction, some of these non-native species have dispersed and increased in numbers. Once established in Everglades marshes, the tools to control or eradicate introduced fishes are limited or nonexistent. Prevention and early detection are key components to the management of non-native species. If non-native fishes are not considered in the development, construction, and operation of water-management structures, simply “getting the water right” may compromise restoration objectives and management mandates for natural areas.

- Non-native species are an important consideration of restoration and management of natural areas.
- The numbers of non-native fishes in Everglades National Park has increased after recent water management changes have occurred.
- Non-native species must be considered in the design and operation of water-management structures.

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A Comparison of Adjacent Ridge and Slough Vegetative Communities

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The Ridge and Slough landscape is fundamental to the Everglades ecosystem. This landscape is slowly being replaced with one that is more topographically and vegetationally uniform. It is likely that these changes are the result of altered hydroperiods caused by human-made barriers and shunts. Studies of the Ridge and Slough landscape throughout the Everglades reveals how these communities are reacting to new hydrological regimes. The broad objective of our study was to compare adjacent Ridge and Slough environments, especially in how they differ in soil biogeochemistry, hydrology, vegetation composition and structure, and nutrient content (Total C, Total N, and Total P).

Three paired 5 x 5 meter plot-sized ridge-and-slough replicates, defined around 14 long-term water level recorders (within 1 km), in 3 distinct hydrologic regions, Everglades National Park, WCA-3B, and WCA-3A, were randomly selected and sampled. In addition to vegetation sampling (measurements of soil depth, water level, vegetation structure, and species cover), soil, flocculent detrital organic matter (floc), surface water, and soil interstitial/porewater samples was collected. Hydroperiods were calculated using historical records of daily stage; ground elevation and the daily stage record for each hydrostation were then joined to determine the six year hydrologic record for Hydro-years 2000-2006.

Vegetation composition and structure differed between Ridge and Slough habitats. Ridges supported significantly higher biomass, taller canopies ($p = <0.001$), and cumulative species cover ($p<.05$); but, sloughs had greater mean species density. 13 of 14 Sloughs exhibited higher water levels than their counterpart Ridges; while, Ridges exhibited greater mean soil depths than Sloughs in 12 of 14 sites. Strong P-limitation was evidenced in both marsh communities by the fact that C content was higher in Ridge plants (44%) than Slough plants (38%) ($p < 0.001$), while nitrogen was much higher in Slough (1.2%) than Ridge (0.7%) ($p < 0.001$). Although, plant phosphorus did not differ significantly between community types, molar N:P ratios were far higher in Slough (~95:1) than in Ridge vegetation (~66:1) ($p = <0.001$). Linear regression predicting biomass from molar N:P for a combined Ridge and Slough data set exhibited a decrease in biomass with increasing N:P ratio ($R^2 = 0.47$). Soil and porewater nutrient concentration analysis will further delineate differences in Ridge and Slough vegetative productivity.

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Phosphorus Cycling in Florida Bay: A Synthesis

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Tropical and subtropical estuaries dominated by fine carbonate particles that efficiently sequester soluble inorganic phosphorus and have low terrestrial P loads can lead to P limitation of primary producers, including both phytoplankton and seagrass. While P limitation is recognized in these marine ecosystems, including Florida Bay at the southern terminus of the south Florida peninsula, P biogeochemical cycling and the factors controlling recurrent cyanobacterial algal blooms in these systems is not well understood. Over the last few years, the authors, independently and in collaboration, have significantly increased our understanding of P cycling in Florida Bay through various research endeavors. In this paper, these studies are coalesced and synthesized to provide a more holistic understanding of P-cycling in the bay. We have determined P*i* uptake kinetics of seagrass, sediment and the water column across an established nutrient gradient in Florida Bay. We have also quantified the potential for organic P sequestration by water column biota and seagrass via surface cell enzyme hydrolysis. Further, organic matter recycling has been examined by determining the decomposition rates of seagrass tissues and total organic mineralization rates through sulfate reduction. We have estimated the rates of P release to porewaters through carbonate dissolution driven by sulfate reduction, and re-sorption potential. The spatial distribution of P pools in Florida Bay's fine sediment fraction and kinetics of P adsorption and exchange with respect to the distribution of iron oxides has also provided bay-wide articulation of sediment P-cycling processes. Results of these studies are incorporated into a conceptual model which defines our current understanding of P cycling in Florida Bay, and contributes to a better understanding of the mechanisms that could shift Florida Bay from a benthic to water column dominated estuary.

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The Resilience of Marine Ecosystems in the Greater Everglades in Response to Multiple Stressors and Climate Change

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Marine ecosystems of the Greater Everglades cover approximately three-quarters of Everglades National Park, and support the high biological productivity and biodiversity of the southern Everglades, the southwestern shelf, the Caloosahatchee and St. Lucie river estuaries, and associated lagoons and reefs. Estuaries and coastal habitats of the Greater Everglades Ecosystem are currently under anthropogenic stress from shifts in quantity, timing and distribution of freshwater flows, nutrient enrichment and associated habitat loss. In addition, over the last few decades, degradation of coral reefs along Florida's Reef Tract has been amplified by the overfishing of key consumer species, climate change, disease, and physical damage from hurricanes and human use. These multiple stressors have resulted in unnatural ecosystems that are poorly equipped to survive the cumulative impacts of these interacting disturbances. A critical management goal is to improve ecosystem health in an effort to optimize the long-term resilience of these important habitats.

The recent 2007 Intergovernmental Panel on Climate Change (IPCC) 4th assessment report predicts that by 2100 mean global temperatures will increase by 2-4^{o}C and atmospheric CO_2 will reach 560-800 ppm. This will lead to higher ocean temperatures and a pH change in the oceans of 0.2-0.5 log units. Tropical and subtropical shallow marine ecosystems, such as Florida Bay and the Reef Tract currently experience temperature and salinity extremes which are at the upper tolerance levels of their respective foundation species, seagrass and corals. Temperature extremes are likely affecting Florida Bay seagrass ecosystem stability indirectly through O_2 demand, and may also be promoting recurrent cyanobacterial algal blooms in the Bay. Carbonates are also important in these systems, and scleractinian reef corals are highly sensitive to both high temperatures and high pCO_2. High temperatures result in episodes of coral "bleaching", in which corals lose their symbiotic algae and turn pale or white, a process which often leads to coral mortality. High pCO_2 results in more acidic conditions lowering aragonite saturation states, which in turn leads to slower rates of coral calcification. Carbonate sediments, which dominate South Florida marine systems, store high amounts of nutrients, and their dissolution is also controlled by pH. Currently, the biological and biogeochemical responses to these changes are poorly understood.

Mechanisms and rates of adaptation and acclimatization to high temperature and low pH are being studied in key marine taxa in South Florida. For example, recent genetic work on corals revealed that their dinoflagellate algal symbionts (*Symbiodinum* spp.) are extraordinarily diverse and some corals are able to change their range of heat tolerance by switching or shuffling the types of algal symbiont they contain. Some marine organisms can also increase calcification as pH is lowered, although up to a point, and at a metabolic cost. Sediment dissolution experiments and nutrient release of P are also being conducted in Florida Bay, indicating a spatial difference in the sediment solubility.

In this presentation, we will discuss current research results and future research requirements that will be necessary to better understand how climate change will affect marine ecosystems within the Greater Everglades, and how greater resilience can be promoted to maintain the ecosystem services provided by these marine habitats. On a landscape scale, effects of sea level rise on linkages and interactions among ecosystems will also be discussed. Effects of climate change and sea level rise are priorities for management and research plans in the next decade.

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Evaluation of CERP Restoration Scenario Simulations with Linked Regional, Coastal, Hydrodynamic, and Trophic Models

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Many different agencies and private companies use sophisticated numerical models to simulate the processes that contribute to a natural system. The investment of time and money in these models justifies the need for specific output to fully visualize and comprehend the physical processes being modeled. GIS has been used for years to provide higher level management with the tools and information needed for decision making. This presentation will discuss the various ways Marco Water Engineering, Inc. has developed tools for the South Florida Water Management District (SFWMD) to support Comprehensive Everglades Restoration Plan (CERP) efforts.

The Florida Bay Florida Keys Feasibility Study (FBFKFS) includes the interaction of multiple models from a regional to project level scale. The utilization of one model's outputs as inputs to other models with iteration between model simulations makes the FBFKFS unique. The SFWMD SFWMM model is used to develop regional input to the smaller scale TIME model. The TIME model then simulates the flow of water from Everglades National Park into Florida Bay. The EFDC model then simulates the hydrodynamics and water quality in Florida Bay. Output is exchanged between the EFDC and TIME models to improve prediction of flows and salinity to EFDC from TIME. The iteration process with TIME and EFDC is an exciting feature of the FBFKFS models. The use of TIME and EFDC outputs in trophic level models like pink shrimp, fish and bird models completes the modeling ensemble.

Also of importance is the manner in which information is disseminated among several organizations through a centralized storage location. The Florida Bay Florida Keys Feasibility Study CERP project implemented and developed specific techniques in GIS and other environments to visualize modeling output. Topics such as transfer of data between models, providing final graphics for reports, figures and presentations, animations from modeling output using multiple environments, the storage of data, and sharing of information over a network, along with many other automation and routine oriented tasks will be discussed. The utility of these tools for determining the hydrologic effects of different restoration scenarios makes them an indispensable tool for water management and planning.

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CERPZone (Comprehensive Everglades Restoration Program)

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Here is the CERPZone: The CERPZone is shared web-based environment for all CERP related activities.

Here is what the CERPZone can do for you: Applications have been created in the CERPZone to support the management of the projects, teams and information involved in the implementation of the Plan. This is a secured area where communication and data sharing takes place.

Here is some of what's in it:

What's new?

Everglades Reading List

If you want to learn more about the Greater Everglades Ecosystem and related topics, this is a great place to start. You'll find both fiction and non-fiction books for all ages, including several in Spanish. Some of the features and benefits include the ability to filter searches by author, genre, reading level and language.

The Everglades Reading List is found at www.evergladesplan.org/read
Contact: Christine Kilger | 561-999-5117 | ckilger@aol.com

Public Access Meeting Manager

With the new Public Access Meeting Manager you can now request and manage your meeting notices and related documents online.

Benefits include the real-time ability to:

- Send notice to request initiation of meeting notice with teleconference needs
- Check the status of your meeting requests,
- Places meeting information on appropriate calendars
- Submit agendas, read a-heads and meeting minutes for posting with automatic conversion to .PDF format
- Automatically archive past events after 30 days in the Documentum Docbases

The Public Access Meeting Manager link can be found at: www.cerpzone.org
Contact: Steven Brittin | 561-683-1577 X36 | Steven.P.Brittin@usace.army.mil

Gazetteer – Phase 3

Due to the nature of the 18,000 square-mile restoration plan, CERP established a need for a gazetteer that would serve as an authority on project place-names and their spatial footprints. The enhanced Florida Digital Gazetteer database schema is ready for use in your ArcGIS Projects and Applications.

The South Florida Gazetteer was created to serve as an authority on project place names and their spatial footprints. The new schema conforms to the USGS National Gazetteer (GNIS) schema. The Florida Digital Gazetteer provides visual representations of projects and helps to maintain workflows and prevent boundary conflicts between the SFWMD, USACE, and various other agencies and partners involved in CERP.

The new enhancements enable GIS users the ability to easily:

- Locate projects and other Place Based locations
- View project boundaries

Contact: Heather Kostura | 561-682-2998 | hkostura@sfwmd.gov

What's coming?

Monitoring Locator

A catalog of all monitoring activities from Shingle Creek to Florida Bay, this application will provide the capability of a spatial, key word, and a specific attribute search for monitoring activities that relate to the specified criteria. Completion is scheduled for the 1st Qtr of fiscal year 2009.

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EDCat 2.0

EDCat is a catalog of metadata describing documents, data and GIS related files in the CERPZone. This application is available today to those individuals with a CERPZone login ID.

EDCat 2.0 will add spatial components, refine the metadata that is captured to adhere to the CERPZone Metadata Standard, and expand the population base of information described. The anticipated release of EDCat 2.0 is the 3rd Qtr of fiscal year 2009.

Until then, EDCat 1.0 is still available through www.cerpzone.org
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Implementing the South Florida Gazetteer to Support Restoration Information Retrieval

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The Comprehensive Everglades Restoration Plan (CERP) guides more than 80 engineering and construction projects aimed at restoring natural systems throughout the Everglades. These restoration efforts are highly targeted to specific landscape features and localized areas commonly referred to as “places” (e.g, the Hole-in-The-Donut). Traditionally, gazetteers exist in paper form and catalog geographic information such as places, place-names, place boundaries, and the social and geographic statistics related to each place. To keep everyone involved in the restoration plan informed and updated about the accurate place-names inside the 18,000-square-mile restoration plan area, the South Florida Water Management District (SFWMD) and the U.S. Army Corps of Engineers (USACE), have led the development of a GIS-based gazetteer to serve as an authority on project place-names and their spatial footprints.

The South Florida Gazetteer was created to provide CERP project managers and stakeholders with a tool to reference and store geographic data related to CERP project areas. The gazetteer's standardized spatial and naming attributes also promote clear communication between the many government agencies and private contractors involved in the multifaceted effort. All CERP stakeholders have access to the data stored in the gazetteer through CERPZone, the project's information technology (IT) intranet system.

ESRI's suite of ArcGIS products, such as ArcView and ArcIMS, are used extensively in CERPZone and within SFWMD and USACE. In addition, many agencies in Florida use ESRI software or can produce spatial data layers in a format suitable for ingestion into an ESRI geodatabase. Because of ESRI software's commonality, the gazetteer project team designed the South Florida Gazetteer database to operate within CERPZone's ArcGIS Desktop environment. The GIS infrastructure of the gazetteer provides visual representations and sharing of project data and helps maintain workflows and prevent boundary conflicts between SFWMD, USACE, and various other agencies and partners involved in CERP.

The public can also access official place-names stored in the gazetteer by visiting the Projects tab of the Web-based CERP GIS Project Locator at www.evergladesplan.org. Through a GIS toolbar and query function, the Project Locator provides users with the ability to locate projects, retrieve project information, print custom-made maps, and view project boundaries. Those with access to desktop GIS can also extract and view metadata from the GIS Project Locator.
Since CERP is a federally funded project, the project team modeled its gazetteer place-names after the place-type standards set by the United States Geological Survey (USGS) for the Geographic Names Information System (GNIS). GNIS is the official vehicle for geographic names and is used by the federal government as a source for applying names to federal maps and the National Map, a GIS-supported online interactive map service. A future CERP goal is to populate the South Florida Gazetteer with enough data that it will be considered for submission in GNIS.

Key findings relative to restoration:

1. Place names are useful for organizing and retrieving restoration data and information.
2. Certain place names have historical recognition and deserve to "authoritative status."
3. Geospatial technology and methods are critical for developing and maintaining gazetteers.
4. Web-based tools enable widespread access to place name-related information.

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A Review of Mercury Research and Monitoring Activities in the Everglades, 1995 to 2008

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Around 1990, elevated levels (greater than 0.05 µg/g) of mercury (Hg) in sport fish caught from the Everglades prompted the issuance of "do not consume" or limited consumption advisories. Because Hg is known to adversely affect several physiological and neurological systems in humans, health concerns arise, especially in areas like south Florida where sport fishing is prominent. In addition, Hg has also been shown to adversely affect the reproductive capability of fish and fish-eating wildlife. Of particular note in the early 1990's was a report that identified Hg as a principal factor in the death of at least one Florida panther. With growing public concern for this issue in south Florida, several state and federal agencies initiated Hg research and monitoring programs in the mid 1990's to provide a better understanding of the causal factors and geographical extent of problem. At the same time, the Everglades Restoration program was in its planning stages, so there were additional concerns as to whether anticipated ecosystem changes might make the Hg problem better or worse. Most of the Hg science programs have remained active in south Florida since the mid 1990's, giving rise to a relatively unique opportunity to examine this problem with long-term data bases.

The two principal Hg research and monitoring efforts in the Everglades are the USGS led Aquatic Cycling of Mercury in the Everglades (ACME) project, which was formed as a collaboration of several state, federal and private agencies; and, the USEPA led Regional Environmental Monitoring and Assessment Project (R-EMAP). These two projects had complimentary goals and objectives, and together provide insights that could not have been otherwise achieved. REMAP primarily focused on conducting ecosystem-wide, intensive surveys at hundreds of sites; whereas the ACME project conducted process-oriented research at nine locations that span most of the north-to-south extent of the Everglades. In combination, the two programs provide ecosystem scale information that can be used to support resource-management decisions.

By the mid 1990's most Hg researchers clearly understood that the key to understanding elevated Hg levels in fish centered on unraveling the immense complexities of Hg methylation. Methylmercury (MeHg) is the most toxic and bioaccumulative form of Hg in the environment. Although MeHg represents a minor fraction (generally less than 5 percent) of the Hg in air, water and sediment, it comprises almost all of the Hg in the edible tissues of sport fish and most other organisms at the top of food webs. Thus, a preponderance of Hg research focuses on understanding the causal factors of MeHg production. In the Everglades, as well as most other ecosystems, MeHg production predominantly results from microbial sulfate reduction, which in turn is controlled by the occurrence environmental settings suitable for methylation (largely anaerobic sediments), and two necessary substrates: organic carbon and sulfate. In order to understand the complexities of Hg, sulfur and carbon cycling, Hg research efforts in the

Everglades have been interdisciplinary by necessity, and thus have provided a great deal of added information and understanding beyond just the Hg problem.

One of the most important discoveries at the beginning of the Hg studies was the revelation of an ecosystem-scale sulfate gradient. The dominant sulfate source originates up gradient of the Everglades, resulting from the application of sulfur application on agricultural fields. Storm water draining from the fields is substantially elevated in sulfate (about 50 to 200 mg/L) and canals and sheet flow serves to spread the sulfate across about 60 percent of the ecosystem. Soon after the sulfate gradient was realized, researchers recognized that the distribution of MeHg in the Everglades was largely coincident with the sulfate plume. However, because the relation between MeHg and sulfate appear nonlinear, additional research was needed to resolve what other causal factors might be affecting fish Hg levels. One important discovery occurred following a significant drought in the spring of 1999, when it was observed that subsequent to rewetting, extremely high levels of MeHg in sediment, water and fish resulted. These observations brought into question what role a "restored Everglades" and a new hydrologic regime could play in future MeHg levels in this dynamic ecosystem. To answer these questions, a new phase of Hg research was initiated that called for in-field experimentation and manipulations. These studies have carried through to the present, and currently researchers are attempting to link the knowledge gained from the combined approaches of widespread monitoring, intensive research, and experimentation. The major findings of these combined programs are as follows:

- The Everglades Hg problem arises from the convergence of two contaminant sources (Hg and sulfate) in an ecosystem that is particularly prone to MeHg production due to the nearly ubiquitous existence of anaerobic, organic soils and sediments.
- Ecosystem-wide sample clearly shows that there are distinct of elevated MeHg, and that these areas have not been stationary over the past 13 years.
- Detailed sampling at fixed stations over decadal time periods has demonstrated the strong link between external sulfate loading and MeHg production.
- Significant changes to fish Hg levels have occurred over the past 13 years, and the combined information from all the state and federal agency programs is providing a means to understand these trends and provide a basis for anticipating future Hg levels.
- Although the Hg research program in the Everglades has provided many new discoveries about the controls of MeHg production and bioaccumulation that are applicable across all aquatic ecosystems, equally important have been this programs contributions to the basic understanding of the biogeochemical processes that are critically important to this sensitive ecosystem.

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Hydrologic Fluxes, Restoration, and the Marsh-Mangrove Ecotone of Ten Thousand Islands National Wildlife Refuge

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Restoration projects have proposed to restore a significant amount of freshwater flow to certain receiving basins across the Tamiami Trail (US Highway 41) in southwestern Florida. This roadway, along with reduced total volumes of freshwater delivery over the past century, has served as a barrier to normal, seasonal sheet flow to the extreme Everglades coastal margin. The goal of hydrological restoration to the region is to mimic as close as possible historic seasonal pulsing of fresh water, and to re-establish a condition more conducive for fostering historic vegetative communities. Since the Ten Thousand Islands National Wildlife Refuge (NWR) is entrusted with protecting marsh area from converting to mangrove for specific wildlife usage – a transition that is related to water management – it is important to develop tools for determining how alterations in water flow might impact habitat transitions. This study proposes to determine how hydrologic restoration projects will affect coastal marshes, mangroves, and transitional habitats between marsh and mangrove within broad areas encompassing the northern Everglades.

Historic mapping efforts indicate that mangroves have encroached onto the Ten Thousand Islands NWR marsh at a pace coincident with major efforts to divert large amounts of fresh water from northern Everglades drainage. Sea-level rise, regional re-distribution of freshwater flow since the early 1900's, and natural vegetation succession dynamics all interact to drive this habitat change. For management considerations, however, it is important to determine which of these factors is most important at keeping mangrove distribution static. Models, hence, should include a strong capacity for modeling local hydrological character, a consideration for sea-level rise, and a link (implied or direct) to hydrological mediation of vegetation shifts.

Pilot projects in Ten Thousand Islands NWR included a modest installation of water level recorders and revealed several important hydrological characteristics of the refuge. First, the hydrograph at the abrupt transition between marsh and mangrove rarely showed a tidal signature, challenging the tidal restriction of mangroves and questioning how sea-level rise might influence mangrove to marsh transitions hydrodynamically. Second, with few exceptions, water level recorders placed at various locations revealed tightly coupled hydrographic character. Third, hydrologic inputs to Ten Thousand Islands NWR are fairly restricted owing to hydrologic confinement and dredging of a major waterway (Faka Union Canal). This project, which is currently in its second funding year, is attempting to develop a fully hydrodynamic model for Ten Thousands NWR that will consider current inputs as well as future project inputs from restoration scenarios to predict within-wetland stage.

Currently, we have 12 water level recorders, three salinity sonds, four rain gages, two Doppler velocity meters, and a weather station monitoring water resources on Ten Thousand Islands NWR in order to determine total water inflows (surface flow across the Hwy. 41, rainfall, tidal inflow) and total water outflows (evapotranspiration, surface flow, tidal outflow). We are also accessing stage and flow data to the Faka Union Canal and Little Wood River from the South

Florida Water Management District and U.S. Geological Survey records. Ten Thousand Islands NWR will be divided into six sectors and a combination of smaller cells, each with different assignments of resistance to water flow based on vegetation type (Mannings coefficients) and combination of inflows and outflows superimposed on a digital elevation model. Initially, we will develop a mass balance model in order to understand basic hydrologic character of Ten Thousand Islands NWR specifically to determine if other variables need to be included (e.g., ground water flow). Then, we will transition this basic model into a fully hydrodynamic model for the refuge that will include porewater salinity concentration as a modeled variable. Future model runs will help to predict stage given particular up-stream water release scenarios, which, based on these results, will allow prediction of future vegetation migration and adaptive management response.

To date, results from this on-going study are few. However, there are at least two important points that can be offered:

- Within-wetland hydrologic characteristics from a number of monitoring stations within Ten Thousand Islands NWR are tightly linked, and segregate by those stations registering tide (e.g., mangrove, *Juncus* marsh) and those stations that do not register tide (e.g., *Spartina* marsh, *Eleocharis* marsh, Ecotone *Distichlis*/*Batis* marsh).
- Water levels crest at a particular level after freshwater loading from up-stream or rainfall, above which drainage is extremely rapid until "bankfull" levels are met.

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City of Naples Multifaceted Approach to Treating Stormwater and Improving Water Quality

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The City of Naples has implemented several programs and initiated a number of ongoing projects in an effort to address current water quality challenges facing the numerous natural and created waterbodies throughout the city. An important aspect is supporting and collaborating with local and state groups such as Collier County, the Big Cypress Basin, Rookery Bay National Estuarine Research Reserve, Florida Gulf Coast University, and others to find creative solutions that can be instigated to improve the overall health of the waterway system. Some challenges the City faces include: an antiquated stormwater system with little to no maintenance, lack of open space to retain stormwater on the uplands, increases in impervious surface, and the excess freshwater flowing into Naples Bay from the Golden Gate Canal.

Filter marshes are proven to have beneficial effects in treating stormwater by assimilating nutrients and through the settling of sediments and metals that takes place. The land required to construct these filter marshes is scarce within City boundaries, so a few smaller areas under City ownership are being retrofitted with filter marshes. Two linear marshes are currently under design and permitting phases.

A city lawn and landscape certification and fertilizer ordinance was passed which makes it mandatory for all lawn and landscape maintenance companies that provide services within the city to have 10% of their employees plus a supervisor complete the Florida Green Industries Best Management Practices (BMPs) course. Upon meeting this requirement, the landscape company applies to the City to become a city-certified business which is reflected by a decal they are required to display on their work vehicles. The second part of the ordinance places a 2% phosphorus limit on fertilizer content as well as requires that at least 50% of the nitrogen is slow release. Businesses and homeowners are also restricted from fertilizing in the wet season (June 1- September 30). Fertilizer cannot be applied within 10 feet of any waterbody and deflector shields are required when adjacent to these areas.

The Residential Lake Planting Program was initiated in 2007 whereby lake front residents can apply to the City and receive up to $500 worth of native, aquatic plants for their shoreline. This encourages residents to plant the littoral zones of their lakes providing positive benefits to water quality through the assimilation of nutrients by the plants. This program also allows for the education of homeowner associations in proper lake maintenance and how they can do their part to limit nutrient runoff from their lawns. Limiting copper sulfate use to kill surface algae is another challenge the city faces. Naples Bay is impaired for copper and an ordinance will likely be developed in the near future to limit the use of copper sulfate by homeowners.

The City supports and encourages efforts of the Big Cypress Basin to create a master plan for the diversion of water from the Golden Gate Canal into water-starved areas such as Henderson Creek and the Belle Meade area. Any reduction of freshwater flow into Naples Bay will help restore the natural regime of the estuary and the habitats found there.

The City has identified some key concepts as a foundation for restoration:

- Creativity is essential when dealing with limited resources and space
- Engage residents in every way possible to be a part of the restoration effort
- Through establishing valuable partnerships, projects that seem insurmountable, are achievable

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Impacts of Gate Discharge and Hurricane Conditions on Water Flow in Everglades National Park

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The specific objectives of this study were to evaluate the effects of nearby gate operation (S12C, S12D, and S333) and hurricanes conditions (as measured during Hurricanes Wilma and Katrina) on water velocities within ENP. Data for this study was measured at five sites along the Shark River Slough, located within ENP. Three sites were situated at the heads of Gumbo Limbo (GL), Satin Leaf (SL), and Black Hammock (BH) Tree Islands, and two were located in sloughs near Chekika (CH) Tree Island and Frog City (FC). These sites housed Sontek Acoustic Doppler Velocity (ADV) units, used for measuring water velocity over time, and Infinites Water Level Loggers used to measure water depth over time. Collected data for water velocity data spans from July 9th 2003 to December 18th 2007 and collected water depth data spans from August 5 2003 to December 18th 2007. Both data sets have been corrected for anomalies and results were averaged into hourly, daily, and monthly time increments. Results showed that during the wet season, when discharge from gates was greatest, water speed ranged from 0.03 to 1.89 cm/s and moved in a southwestward (200^{o}) direction. During the dry season, when gates were closed, water velocity ranged between 0.07 to 0.94 cm/s and maintained a SW direction. The exception was at CH where overall water speed was very low and moved in a southeastward (157^{o}) direction, indicating a weak relation with gate operations. During hurricane conditions, water speed and direction were altered, and the extent of variation was positively related to wind characteristics. In addition, water level at GL was almost constant during the two hurricanes and the hydraulic gradients near GL and SL showed slight fluctuations. Besides wind speed, the vegetative structure and natural flow paths also likely influence water velocity within the Everglades during hurricane conditions.

Overall, measurements show a relatively strong relationship between water discharge from gates and prevailing downstream water velocity. Hurricanes were observed to impact water flow direction. Results should be evaluated further to understand the impacts of altered water velocities on tree island dynamics.

- Water discharge from gates has a significant impact on the downstream water velocity. With gates open water speeds ranged from 0.03 to 1.89 cm/s while during times when gates were closed the speed ranged from 0.07 to 0.94cm/s.
- Water velocity direction remained relatively constant, regardless of gate operations, by maintaining a South Westerly (200^{o}) direction.
- The strength of wind can impact water flow in the Everglades. The extent of variation seemed to be positively related to magnitude of the wind.
- The vegetative structure and an independent natural water flow existing in the wetland may explain why rotation of water flow direction lagged rotation of wind direction.

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An Ecological Value Model for Use in a Land Use Planning Web Tool, Applied to Miami-Dade County

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Land use decision-makers and natural resource managers in Miami-Dade County, Florida must reconcile intense land development pressures with the goal to sustain the natural environment. In an effort to better inform the land use decision making process, the U.S. Geological Survey has partnered with the National Park Service, the University of Pennsylvania, Florida International University, and Florida Atlantic University, to develop the Ecosystem Portfolio Model (EPM). The EPM is a Geographic Information System-based multi-criteria decision support tool that evaluates land use plans in terms of ecological values, land market prices, and community quality-of-life metrics. In short, the EPM is intended to widen the perspectives of its users by integrating natural and social scientific information in a framework that recognizes the diversity of values-at-stake in South Florida land use planning.

This talk focuses on the ecological value model component of the EPM, which compares potential future land cover patterns using: 1) potential habitat models from the perspectives of biodiversity, threatened and endangered or focal species, and rare and unique habitats; 2) measures of landscape patterns and fragmentation, from a landscape ecology perspective; 3) measures of water quality buffer potential; and 4) measures of ecological restoration potential. The ecological value model evaluates a land use/cover pattern by generating a “value map” for each ecological criterion, where the value map reflects spatially-explicit ecological/environmental model outputs, as well as user-elicited preferences for different possible outcomes. The EPM interface allows the user to explore the ecological value maps for each of these criteria individually or, after applying user-chosen weights, as an aggregated multi-criteria ecological value map. The EPM allows users to evaluate and compare potential land use patterns in a variety of ways. For example, users can examine the resulting ecological value maps for one or more land use/cover patterns under different ecological criteria weighting schemes, allowing the user to explore how different prioritizations of ecological objectives affects the evaluation process. More broadly, users can also compare ecological value maps, predicted land price maps, maps of community quality-of-life indicators for sets of land use/cover patterns to characterize regional-scale trade-offs between ecological, economic, and social values. By using maps as the means of comparison, local details are retained, while regional patterns can become apparent.

The ecological value model:

- Is an important component of an integrated ecological, economic, and social land use planning web tool, the Ecosystem Portfolio Model, currently implemented as a prototype (http://lcat.usgs.gov/sflorida/sflorida.html);
- Is organized around a user-friendly web interface that provides access to the models used to implement the underlying ecological criteria;
- Will allow the user to examine longer-term land use/cover changes in terms of scenarios to account for uncertainty in future ecological drivers, like sea level rise, human population growth, and ecosystem responses to restoration efforts.

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The South Florida Ecosystem Portfolio Model: An Integrated Ecological, Economic, and Community Land Use Planning Tool

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Urban development pressures in the remaining agricultural and undeveloped lands in Miami-Dade County, Florida are increasingly intense. Decisions to develop, preserve, or restore individual parcels can cumulatively affect regional ecological, environmental, and socioeconomic patterns in complex ways. These decisions may ultimately lead to changes in land use/cover, with potential impacts for both the Everglades and Biscayne National Parks. In response, researchers at the U.S. Geological Survey and the Everglades National Park have developed a prototype for a web-enabled geospatial information tool (the South Florida Ecosystem Portfolio Model or EPM) that integrates ecological, economic, and social information for land use planning purposes.

The EPM evaluates proposed land use patterns in terms of relevant ecological, economic, and social criteria that combine information about probable outcomes (potential land use consequences), as well as value judgments (preferences) elicited from users. Based on on-going meetings and interviews with stakeholders and potential tool users, we focus on three dimensions of land use/cover-related anthropocentric value: ecological values related to potential ecosystem services, market land price, and indicators of (human) community quality-of-life. Each of these dimensions is implemented as a sub-model of the EPM that generates "value maps" for a given land use pattern, where the value map reflects changes in land attributes, as well as user preferences. These attribute changes are primarily related to land use, including changes in habitat potential and landscape fragmentation, human perceived amenities, community "character", flooding and hurricane evacuation risks, water quality buffer potential, ecological restoration potential, and other relevant criteria.

The EPM web tool:

- Is designed with a variety of users in mind, including natural resource managers, land use planners, and stakeholders;
- Is organized around a user-friendly web interface that provides access to a variety of useful models and data for evaluating land use/cover patterns;
- Will allow the user to examine longer-term land use/cover changes in terms of scenarios to account for uncertainty in future drivers, like sea level rise, population growth, and ecosystem responses to restoration efforts.

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Fine-Scale Spatial Variability of Soil Nutrients in the Everglades

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Soil nutrients and other physical and chemical ecosystem attributes integrate environmental conditions and can be used to evaluate restoration performance in the Everglades. The regional distribution of soil nutrients across the Everglades was recently mapped (**Everglades Soil Mapping** project - ESM), and now serves as a benchmark for regional ecological condition against which future surveys can be compared to assess restoration success. However, such a comparison is predicated on the assumption that any observed differences in nutrient status resulted from regional ecosystem response to restoration efforts and not natural variability, which is known to be substantial in the Everglades. To better detect real ecological change requires additional data on the magnitude and drivers of **fine-scale spatial variability**. Our objective, therefore, is to assess spatial variability of soil nutrients at sites spanning the study domain of ESM (i.e., across the Everglades). Sampling protocols were designed to assess spatial variability occurring at fine and medium scales and a variety of ecological covariates (community type, water depth) that could affect pattern; eight 2x2 km sampling frames were placed on MAP/RECOVER's **probabilistic sampling units** (PSUs) across the Greater Everglades. Within each PSU, 24 sampling location were identified using **spatially-nested random design**. At each sampling location, five soil samples and covariate observations were collected at varying distance and direction using a fixed sampling frame.

Sampling and laboratory analyses are on-going; here we present preliminary results based on **Total Phosphorus** (TP) and **organic matter** (OM) measurements from samples collected at three PSUs. Variance in TP and OM differed significantly among PSUs. There is generally greater variation in TP compared to OM. **Semivariance analyses** showed that both properties have high short range spatial variability; nugget variance occurring within 10 m lag separation accounted for more than half the spatial variance within the PSU in some cases. Further analyses will determine the magnitude and potential covariates of soil spatial variability in the Everglades, aiding inference from future regional soil mapping efforts.

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Climate Change Concerns for Everglades Restoration Planning

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The Comprehensive Everglades Restoration Plan (CERP) was completed in April 1999 and approved by Congress in WRDA 2000 as the basis for additional detailed design studies and subsequent requests for construction authorizations. CERP goals include restoration of natural hydrologic conditions in the remaining 50% of the historic Everglades while maintaining existing levels of flood protection, water supply and other project services in developed areas. Studies during development of the CERP indicated that a potential 0.5 foot sea level rise by 2050 (the project planning horizon) would not significantly impact project performance.

The rate and magnitude of future climate changes and impacts is uncertain, but recent climate change data indicate global warming trends are accelerating significantly and will continue well beyond 2100. This paper will give an overview of forecast climate change concerns related to Everglades Restoration Planning and identify problems to be addressed by current or future studies. These concerns and potential impacts are relevant to water resources planners and others dealing with natural and developed areas in coastal and inland environments. They include sea level rise, salt water intrusion, increases in average annual air and water temperatures, changes in precipitation and evaporation patterns, increases in tropical storm activity, and other items. Significant climate changes may be coming more rapidly than many people anticipate. Proactive interagency cooperation and planning are required now to help reduce future risks and losses.

Key findings:

- In South Florida, relative sea level rose about 1 foot over the past 100 years.
- Estimates of future sea level rise are uncertain, but the rate of rise is accelerating.
- Natural areas need quick restoration of freshwater flows and proactive regional adaptation.
- Developed areas need to reduce risks of future flooding and water supply well damages.
- FY09 start of CERP sea level rise sensitivity analyses for various climate change scenarios.

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Integrated Manatee/Hydrology Models: Synergistic and Predictive Advances Arising from a Charismatic Indicator Species

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The Florida manatee, *Trichechus manatus latirostris*, is listed as endangered under federal and state statutes. As a high-profile trust species, various federal, state, and local organizations are responsible for its management and protection. In the Greater Everglades, a high priority is managing restoration effects consistent with two objectives: do no harm (i.e., "take" no individual manatees in the language of the Endangered Species Act) and restore manatee habitat where possible. To assist with these objectives, our research team undertook the development of two decision-support tools: (1) a spatially-explicit individual-based manatee model to predict changes in habitat use under various restoration scenarios, and (2) statistically robust aerial survey designs and analysis to monitor and assess changes in manatee distribution and abundance in response to restoration.

The new manatee model simulates the movements of manatees along a network that contains resource sites necessary to meet daily metabolic needs (inland freshwater sources for drinking, winter warm-water refugia and offshore seagrass forage). The model is parameterized with data synthesized from satellite and GPS telemetry of tagged manatees from our field studies. As manatees move around the model network within their individual home ranges, we expose them to simulated hydrologic conditions under various restoration scenarios, and model changes in movement and home range as positive or negative reinforcement from the new conditions. Manatee aerial survey data are used to validate the initial model. Critical to this modeling effort is a hydrology model with the ability to predict changes in water temperature. Florida manatees are subject to lethal cold stress in winter and seek warmer water when temperatures drop to or below 20^{o}C. The existing hydrology models lacked a temperature feature, and in 2005 we began an integrated modeling effort between USGS biologists and hydrologists. The result was the development and addition of a heat transport component to the existing Greater Everglades applications of the FTLOADDS model. Satellite-monitored manatees, acting as mobile temperature probes, provided data to fine tune and validate the hydrology model.

Our integrated manatee/hydrology research also led to the need for new 3-dimensional hydrological models for select localized areas. Our telemetry studies identified passive thermal areas consisting of a halocline of warmer salt water trapped below a cooler freshwater lens. These thermal inversions are used by manatees during winter cold spells. A curvilinear hydrodynamic flow and transport model is in development to describe the three-dimensional hydrological properties that create and maintain these temperature inversions. When completed there will be the capability to model restoration effects on these hydrology "hot spots."

The new aerial survey designs and statistical methods use a hierarchical framework to map estimates of manatee abundance across the landscape and to model local abundance in relation to spatially explicit habitat factors, such as output from the FTLOADDS hydrology model. The design and statistical models directly estimate and account for imperfect detectability of manatees in the survey area. Addressing detectability provides more robust estimates of abundance and allows us to estimate trends in abundance over time and space, features lacking in current manatee aerial survey programs.

Although our work is specific to manatees and hydrological restoration, this integrated manatee/hydrology research has wider implications for ecosystem and multi-species restoration objectives:

- The ability to model and simulate water temperature in the FTLOADDS hydrology model is a major advance to model and predict distribution and abundance for many biota.
- 3-dimensional modeling of the hydrological mechanisms creating and maintaining temperature inversions due to haloclines will be important to a variety of native and non-native species that use these inversions as winter refugia.
- The manatee individual-based model is unique among Everglades species models in that it combines the two diverse fields of artificial intelligence and graph theory to realistically simulate animal behavior and movement across the landscape. This modeling advance could be applied to other large mobile species that inhabit the interface between coastal marine and riverine systems.
- We are collaborating with state researchers to incorporate some of our aerial survey methods into new manatee survey designs for state-wide assessments of trends and progress toward recovery. The ability to spatially model distribution and abundance in association with habitat features gives managers a new tool to address a wide variety of potential risks to manatees in the Greater Everglades, as well as throughout Florida.

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The Effects of Vegetation and Water Depth on Wading Bird Foraging Site Selection and Foraging Success in the Everglades

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Successful avian foraging is influenced largely by prey availability, which encompasses both prey density and vulnerability of prey to capture. Habitat features such as water depth and vegetation are among the factors which may affect prey vulnerability. We investigated the effects of water depth and submerged aquatic vegetation (SAV) density on wading bird prey availability and foraging in the Everglades during two replicates of an experiment in January and April 2007. We quantified wading bird foraging site selection and foraging success relative to water depth and vegetation density within 10 × 10 m enclosures in the Loxahatchee Impoundment Landscape Assessment (LILA) project at the Arthur R.Marshall Loxahatchee National Wildlife Refuge. Fish density was kept constant. Numerical response data, analyzed using Manly's standardized selection index, showed that wading birds preferred both shallow water depth and sites with SAV. However, the environmental variables tested in this study had little effect on wading bird foraging success. Capture rate did not vary based upon water depth or SAV density. Capture efficiency did not vary based on SAV density, and was slightly lower in the shallow depth treatment. Our results suggested that, although birds show selection based on environmental cues such as water depth and SAV, these factors did not strongly impact foraging success. Prior studies have shown that prey densities are higher in areas with shallow water and SAV. Therefore, we hypothesize that foraging wading birds were selecting sites with shallow water and SAV present because of an anticipated foraging benefit through elevated prey densities. Given the controlled prey densities used in this experiment, this expected benefit to foraging success was not attained.

- This is one of the first studies to quantify how restoration could affect wading birds through the pathway of water, vegetation, and birds.
- Water depth and SAV density influenced wading bird foraging site selection but not their foraging success.
- Changes in SAV caused by hydrologic restoration could affect the attractiveness of foraging sites to wading birds but it is not yet clear whether birds will attain any energetic benefit.

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A Process-Based Cellular Automata Model of Ridge and Slough Landscape Evolution

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The ridge and slough landscape is a longitudinally patterned, topographically and vegetationally heterogeneous portion of the Everglades that has experienced widespread degradation over the past century. Degraded ridge and slough landscape exhibits a loss of heterogeneity (typically, a loss of sloughs) and slough connectivity. The landscape is now a focus of restoration efforts, and a firm process-based understanding of ecohydrological feedbacks governing landscape evolution is needed. Leading hypotheses of dominant processes in the ridge and slough landscape include a differential peat accretion feedback in ridge and slough vegetation communities responding primarily to surface-water depth, duration, and frequencies, and a sediment redistribution process governed by flow that affects peat topography and vegetation distribution. A cellular automata model of the differential peat accretion feedback and flow/sediment feedback was formulated as a means of testing whether these processes could individually or together reproduce actual landscape structure. The model was based on laboratory and field experiments and high-resolution, partial differential equation-based solutions of velocity profiles to ensure that it captured essential physical details while remaining computationally efficient.

Separate modules within the cellular automata model simulated flow in longitudinal and lateral dimensions, the entrainment, deposition, and transport of floc, the net balance between in-place organic matter production and decomposition, and vegetative propagation of *Cladium*. The flow module was simplified but based on the depth-averaged Navier-Stokes equations and was dominated by the balance between gravitational forcing and vegetative resistance. Mean flow velocities and bed shear stresses were solved using two-dimensional lookup tables based on high-resolution Reynolds-averaged Navier-Stokes simulations of velocity profiles in ridge and slough vegetation communities. Simulated bed shear stresses were coupled to a partial differential equation for advection, dispersion, settling, and entrainment of suspended floc. Both the functional relationship between bed shear stress and entrainment flux and the single effective floc diameter were determined from laboratory experiments that quantified the entrainment, settling, and aggregation of floc. Differential peat accretion on ridge and slough was simulated using a regression relationship with water depth as the independent variable. The regression relationship was based on a numerical model of the differential peat accretion feedback, which was parameterized using results of field and laboratory experiments. Lastly, a vegetative propagation rule ultimately responsible for lateral expansion of peat was formulated.

Natural-system simulations covered a range of surface-water depths and flow velocities representative of pre-drainage conditions. For certain combinations of uncertain fitting parameters, the model predicted emergence of a ridge and slough landscape with dimensions very similar to well-preserved portions of the actual landscape. At early time steps, ridge locations shifted and some of the nascent ridges disappeared, consistent with paleoecological studies of the ridge and slough landscape. However, at later time steps, ridges remained permanent fixtures, and the relative coverage of *Cladium* asymptotically stabilized. Ridge morphology lay on a continuum between features dominated by flow, which were narrow, closely spaced, and highly linear, and features dominated by vegetation growth and expansion, which were more rounded and irregular. A strong flow influence produced landscapes in which the major axis of ridges was within $< 5^{o}$ of the flow direction, ridges had high length-to-width ratios, and sloughs remained interconnected over the long term. While no-flow runs preserved landscape heterogeneity through a simple feedback between water level and the volume of the model domain occupied by peat, *Cladium* features produced in these runs were amorphous, had high variability in orientation, and surrounded isolated sloughs.

Perturbing a well-developed ridge and slough landscape by decreasing mean water level or flow velocity resulted in a rapid expansion of ridges into sloughs, similar to the widespread expansion of *Cladium* observed throughout the actual landscape in the past century. Over the range of surface-water depths and velocities practical for the Everglades under current bed slopes but restored flows, conversion of slough cells to mature ridge cells was irreversible, due to the difficulty of attaining bed shear stresses above the entrainment threshold in dense *Cladium*. However, if vegetational heterogeneity were re-initialized, model results predict its long-term maintenance under restored flow conditions through differential peat accretion and flow/sediment transport feedbacks.

In summary, the cellular automata model qualitatively predicts how the ridge and slough system responds to hydrologic forcing. Key findings of the model that are relevant to restoration are:

- Feedback between two distinct mechanisms is needed to explain the evolution of the ridge and slough landscape. First is the differential peat accretion mechanism that introduces topographic heterogeneity through an autogenic peat accumulation process, and second is a feedback caused by interactions between topographic heterogeneity, vegetation, and flow that reinforces landscape morphology through redistribution of sediment from sloughs to ridges. Individually these mechanisms are not sufficient to explain the origin of the ridge and slough landscape. In addition, episodic events such as hurricanes are not a necessary precursor for the sediment redistribution that supports landscape formation and maintenance.

- Topographic and vegetative heterogeneity of the landscape can be preserved by water level management alone, but flows that induce sediment transport are necessary for interconnected sloughs to persist. However, if sufficient in magnitude, these flows can be intermittent, of a total duration less than 3 weeks/year.

- Vegetation pattern structure responds rapidly to shifts in water level, with decreased surface water levels causing an expansion in the relative coverage of *Cladium.*

- It will not be feasible to restore sloughs to *Cladium* monocultures by manipulating water level and surface water slope alone. However, once *Cladium* is removed by other means, appropriate management of surface-water hydrology could potentially maintain a topographically and vegetationally heterogeneous landscape with high habitat connectivity over the long term.

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The Role of Flow and Transport Processes in Ridge/Slough/Tree Island Pattern Dynamics

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The ridge and slough landscape is a patterned portion of the Everglades peatland, with elongated, elevated ridges colonized by *Cladium jamaicense* and more elevated tree islands interspersed among lower sloughs. The axis of elongation is parallel to the historic flow direction. Heterogeneity of topography and vegetation within this landscape is linked to relatively high biodiversity, but both the landscape structure and its associated high biodiversity have degraded rapidly over the past century. Field surveys suggest that present vegetation communities are out of equilibrium with local hydrology and that further landscape degradation is imminent in the absence of restoration efforts. This chapter summarizes the leading hypotheses for mechanisms responsible for the maintenance of historic landscape stability and for recent landscape degradation, describing research progress on processes and interactions related to flow in this environment. This synthesis will be used to suggest guidance for Everglades restoration efforts.

Leading mechanisms hypothesized to be critical in the formation and maintenance of the ridge and slough landscape include 1) differential peat accretion in different vegetation communities responding to concentrations of phosphorus (a limiting nutrient) and surface-water depth, duration, and frequencies; and 2) entrainment, transport, and redeposition of organic sediment that eventually forms peat. Flow is potentially critical in both mechanisms through its role in transporting phosphorus in surface water and groundwater, in regulating redox potential that affects vegetation colonization and rates of decomposition, and in transporting particulate matter in surface water that can eventually augment the peat topography. Previously hypothesized mechanisms that are less likely to be dominant in the formation and maintenance of the ridge/slough/tree island patterning are fire, which exhibits more localized impacts, erosion of a recently uplifted surface, which is inconsistent with paleoecological records indicating that the ridge and slough landscape originated out of a wetter environment, and spatially constant rates of peat accretion atop a regularly corrugated bedrock, which is inconsistent with field surveys.

Phosphorus transport in groundwater reinforces topographic patterning through a net accumulation of phosphorus on ridges and tree islands, which occurs as a result of evapotranspirative concentration. The effect is most pronounced on tree islands, where phosphorus concentrations are also augmented by faunal inputs, intermediate on ridges in close proximity to tree islands, and less pronounced on ridges in the marsh interior. Elevated porewater concentrations of dissolved phosphorus species enable the relatively rapid production of organic matter and net peat accumulation on elevated surfaces. On tree islands, increased delivery of dissolved nitrogen species to tree island centers via evapotranspiration also exerts a positive feedback on peat accumulation and island development.

Transport of phosphorus also occurs in the particulate form in surface water, where the smallest (bacterial-sized) particles are most enriched in phosphorus and most reactive. Primarily due to the greater depth of sloughs and the longer amount of time that sloughs are inundated relative to ridges, discharge per unit width of these phosphorus-bearing particles is approximately two times as great in sloughs as in ridges. If these particles undergo net redistribution through differential production, settling, or interception on vegetation stems, and if they are not consumed within the water column, they could potentially contribute significantly to the delivery of phosphorus and carbon to the soil of ridges and tree islands. However, at present, field data suggest that small particle accumulation is lower on ridges than in sloughs, in part due to the greater supply of particles in sloughs due to deeper water columns and more abundant periphyton.

Under present-day flow conditions, the entrainment and transport of the volumetrically larger but more phosphorus-depleted (and lower-density) detrital floc particles is also extremely rare, even in fast-flowing margins of tree islands. However, field, laboratory, and numerical experiments indicate that under historic flow conditions, floc would have been entrained and transported from sloughs and redeposited on ridges for a few weeks out of the year, reinforcing the ridge/slough topography and slowing or halting the expansion of ridges. Bed shear stresses and mean flow velocities are highly sensitive to vegetation species, frontal area, and the presence or absence of *Utricularia*, and numerical experiments calibrated to field data indicate that even with restorable flows, entrainment of floc is unlikely in sloughs densely populated with *Eleocharis* spp. However, with a reduction in the abundance of *Eleocharis* so that deep-water sloughs are more common, erosion of floc from within sloughs will occur during periods of elevated water-surface slope associated with pulsed releases from water management structures. For this sediment transport flux to be a mechanism for preserving and/or restoring ridge and slough patterning, managed flow directions in the restoration scenario, in contrast to the present-day flow directions in many locations, will need to be roughly parallel to remnant ridge and slough structure.

Whole-system numerical modeling suggests that interactions between differential peat accretion processes and sediment transport and redistribution are sufficient to cause the development of a patterned ridge/slough/tree island landscape from an initially random, deepwater topography. Remaining uncertainties relevant to restoration are whether the differential transport of fine particles can be manipulated to achieve restoration goals, the role of fine particles in phosphorus spiraling, and the extent of vegetation heterogeneity and habitat connectivity that can be sustained over the long term in the managed system.

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Transport Dynamics of Floc in Ridge and Slough Vegetation Communities: A Laboratory Flume Experiment and Numerical Study

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The ridge and slough landscape is a topographically and vegetationally heterogeneous, patterned region of the Everglades that is valued for its relatively high species diversity. Landscape patterning and heterogeneity have diminished rapidly over the past century, with degradation predominantly taking the form of loss of sloughs. The entrainment of detrital floc within sloughs and deposition of that floc on *Cladium* ridges is a leading hypothesis for the maintenance of lateral ridge stability.

In this study we undertook a series of laboratory experiments to parameterize a numerical model of floc transport in the ridge and slough landscape. An advection-dispersion equation for floc requires knowledge of the distribution of floc settling velocities, particle sizes, aggregation/disaggregation rates in different flow conditions, and entrainment fluxes over a range of bed shear stresses. We collected floc from sites within the best-preserved part of the ridge and slough landscape and performed experiments in a racetrack flume, rotating annular flume, and settling column within days of collection.

Though settling velocity and aggregate size distributions differed between floc from two slough sites with differences in periphyton abundance, these differences were small compared to differences in floc characteristics between the organic Everglades floc and the less organic floc populations in rivers, lakes, and estuaries. Everglades floc settled more slowly and had higher porosity but was also entrained at a threshold bed shear stress (1.0×10^{-2} Pa) an order of magnitude lower than the critical shear stress for entrainment of other floc populations. Unlike many other aquatic environments, floc disaggregation in the Everglades was not significant over the appropriate velocity/shear range. However, particle aggregation became significant at high flow speeds (7.5 cm s^{-1}) and continued via differential settling as the flow speed declined. Thus, from the rising limb to the falling limb of a flow velocity time-series, particle aggregation was hysteretic. Entrainment flux was also hysteretic: floc entrainment was higher on the falling limb of a velocity time-series than on the rising limb, due to resuspension.

Results from the racetrack flume entrainment experiment were coupled to a Reynolds-averaged Navier-Stokes simulation of velocity profiles and bed shear stresses to predict the hydrologic conditions that would induce redistribution of material from sloughs to ridges. Drag coefficients for ridge and slough vegetation communities were calibrated from field and laboratory experiments, and representative vegetation architecture profiles were computed from a statistical analysis on a database of Everglades clip plots. Inputs to the simulation were surface water stage, water surface slope, and vegetation community architecture, and the output was a one-dimensional vertical velocity profile, computed under assumed steady, uniform conditions. The velocity profile was used to compute the depth-averaged drag force from vegetation resistance and bed shear stress.

Simulation results suggested that in slough communities with abundant *Eleocharis*, present-day surface-water slopes are lower than the minimum slopes needed to entrain sediment from within sloughs. Bed shear stress was more sensitive to surface-water slope than water surface level, so raising mean water levels in *Eleocharis* sloughs would not induce floc entrainment, unless the elevated water levels were accompanied by a substantial increase in water surface slopes. However, in deepwater slough communities with less abundant *Eleocharis*, sediment entrainment occurs within sloughs at the present mean water surface slope of 3×10^{-5} for surface-water levels of at least 80 cm. In contrast, at equivalent surface-water depths, entrainment of floc within ridges begins at a water surface slope of 1×10^{-4}; larger water surface slopes are required for floc entrainment at shallower water depths. Predicted bed sediment entrainment thresholds in *Eleocharis* sloughs were validated by elevated flow experiments in a field flume.

Overall, key findings of this study relevant to restoration efforts were:

- The critical bed shear stress threshold for floc entrainment in the Everglades is 1.0×10^{-2} Pa, with the greatest increase in entrainment flux occurring between this threshold and bed shear stresses of 2.0×10^{-2} Pa. Depth-averaged velocities at which these bed shear stresses are obtained vary with vegetation community, flow depth, and water surface slope.

- Under current water surface slopes in the Everglades, floc entrainment by flow will never occur in densely vegetated *Eleocharis* sloughs and will rarely occur in sparser deep-water sloughs. However, redistribution of sediment from sloughs to ridges by flow can be restored by a combination of reducing *Eleocharis* abundance and releasing pulses of water from impounded areas that temporarily increase water surface slope. Above surface-water depths of approximately 45 cm, bed shear stresses vary little with water level but are highly sensitive to water surface slope. For all surface-water depths, bed shear stresses are highly sensitive to vegetation frontal area.

- The duration of flow conditions that induce sediment transport to an extent significant for landscape evolution is on the order of weeks. At a bed shear stress of 2.0×10^{-2} Pa, two weeks of flows that induce sediment transport will result in an annual scour rate in sloughs equivalent to the spatially averaged rate of peat accumulation throughout the ridge and slough landscape.

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The Role of Flow on Ridge and Slough Landscape Dynamics in Shark River Slough, Everglades National Park

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This presentation will synthesize the results of a six year study to evaluate the importance of water flow in maintaining the ridge and slough landscape of the Florida Everglades. The specific objectives of the study were to quantify water flow characteristics and particulate transport patterns in the Shark River Slough in Everglades National Park (ENP). Water flow was characterized at five sites, Gumbo Limbo (GL), Black Hammock (BH), Satin Leaf (SL), Chekika (CH), and Frog City (FC), primarily through temporally intensive measurements of water velocity using fixed Acoustical Doppler Velocity (ADV) units, and continuous measurements of water surface elevation using pressure water level loggers. Water velocity, water depth, particulate deposition and vegetation density/structure also were measured along permanent transects established at GL, CH, and FC. Each transect was oriented normal to flow in order to optimize differences in environment type (i.e. ridge or slough). These data were then used to examine how water depth, microtopography, vegetation density and structure, as well as water management activities interact to control water velocity dynamics in ridge and slough habitats.

During this study, typical water speeds were less than 3 cm s^{-1} with higher values (0.03 to 1.89 cm s^{-1}) during wet seasons and lower values (0.05 to 1 cm s^{-1}) during dry seasons. In general, flow speeds in the sloughs were 1.5 higher than flow speeds on ridges. The higher water speed during wet seasons was strongly associated with higher discharge from upstream gates (S12C, S12D, and S333). To the east of the L67 extension levee, gate influence was reduced as upstream gates do not directly discharge into this part of the slough. Lag times between peaks in gate discharge and downstream velocity were established for two downstream sites (GL and CH) impacted by gate discharge. At CH, which is closer to Tamiami Trail, the lag time was approximately 5 days. At GL (the more distant site), the lag time was approximately 17 days. Stage gradient (water surface slope) in the slough was 0 to 10 cm $km^{-1}$with an average varying from 0.5 to 5 cm km^{-1}. Gate discharges were strongly correlated with stage at five sites in the study area, indicating that discharge was the main controlling factor for water depth in the slough. A simple relationship between stage gradient and water speed could not be established; potentially due to variable water resistance due to vegetation. Vertical flow profiles and a series of clearing experiments showed that flow speeds can increase by as much as three times when submerged biovolume (e.g. utricularia spp. and periphyton) was removed. Interestingly, however, the presence of emergent stems did not appreciably affect mean flow speed. Instead, a series of vegetation clearing experiments has shown that flow speed in the sloughs at two different sites was significantly and negatively correlated with plant biovolume.

Because transport and deposition of particulate organic matter is one critical component of landscape development in the ridge and slough, we also measured particulate accumulation, the depth of the floc layer, and changes in soil elevation. There was no significant difference in accumulation among the study sites when ridge and slough samples were pooled. As expected, the highest accumulation occurred at slough sites; however, these rates were not significantly higher than rates measured at the adjacent ridge site. The thickness of the floc layer never exceeded 20cm and tended to be higher and more variable at sites characterized by well developed sloughs. Interestingly, the highest particulate accumulation rate and floc layer thickness occurred at a site located at the terminal end of a dead-end slough. The greatest increase in elevation occurred at the FC site, where the ridge and slough topography is most degraded. Together, these data corroborate the conceptual model of slough infilling; particularly at the terminal end of sloughs with low connectivity.

In summary, we observed that:

- Water surface elevation in the Shark River Slough correlated very well with discharge measured at gates located at the northern boundary of Everglades National Park; particularly when appropriate lag times are considered.
- Water flow was characterized by slow and seasonally varied water speed driven by the interplay between small water surface slopes and vegetative resistance.
- Consideration of the presence of floating biomass, such as *Utricularia*, is essential to future efforts to develop numeric models of flow as part of restoration efforts.
- Sufficient gate discharge is essential to ensure water flow in the Shark River Slough. Construction of the planned Tamiami Trail Bridge would benefit this area of the East Everglades by providing much needed water to this relatively stagnant and dry area.
- Lastly, restoration efforts should include efforts to monitor floc depth, particulate accumulation/transport and soil depth. These measures are needed to determine if the trapping of floc at the termination of dead end sloughs is a significant mechanism for soil development and infilling of ridge and slough topography.

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SAV as Indicators of Ecosystem Change in South Florida Estuaries

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The research to be presented at the 2008 GEER meeting describes the efforts of two complementary programs, the South Florida Fisheries Habitat Assessment Program and the Nearshore Benthic Habitats Program**,** developed to evaluate baseline status and trends of the SAV communities in the Southern Estuaries Module. By following patterns of distribution, abundance, diversity, and reproductive and physiological status (ecoindicators) of SAV, these programs will provide managers with information in support of the objectives of CERP MAP as well as the data needed to address ecosystem-response issues on a near real-time basis and to weigh alternative restoration options.

The **Florida Bay Fisheries Habitat Assessment Program (FHAP-FB)** provided detailed information on Florida Bay seagrass and macroalgal communities from 1995 to 2004. However, to assess macrophyte changes that may occur in response to CERP implementation, a more spatially comprehensive monitoring program is required. The **South Florida Fisheries Habitat Assessment Program (FHAP-SF)** was initiated in spring 2005, increasing the geographic scope of FHAP from ten sampling locations in Florida Bay to a total of twenty-two locations extending from the Lostman's River to Biscayne Bay. FHAP-SF documents the status and trends of seagrass distribution, abundance, and species composition, and also provides process-oriented data such as photosynthetic quantum yields and epiphyte loads. Specific objectives of FHAP-SF are: 1) to develop a basic understanding of the relationships among salinity, water quality and seagrass species distribution and abundance in south Florida, 2) to provide data to separate anthropogenically induced changes from natural ecosystem variation, and 3) to verify model predictions on species- and ecosystem-level responses to perturbations.

Regional FHAP-SF sampling is conducted once per year, at the end of the dry season (May-June). Salinity stress on seagrasses is generally highest at this time, and this is the period when the dominant seagrass of the region, *Thalassia testudinum* exhibits maximum leaf biomass, increasing our ability to detect changes in cover. Stations are determined using the systematic-random sampling design employed in FHAP-FB. The cover/abundance of seagrass and macroalgal species are visually estimated at approximately 660 stations (30 stations/location) using a modified Braun-Blanquet procedure. Macrophyte species are quantified within eight, haphazardly-placed 0.25 m^2 quadrats at each station. In addition to macrophyte cover, the occurrence of seagrass flowers and fruits are noted. At sites where *T. testudinum* is present, ten short-shoots are collected to determine leaf epiphyte biomass (g dry wt. epiphyte g^{-1} dry wt. leaves), and seagrass morphometric data. Quantum yields and photosynthetic efficiencies are also measured for *T. testudinum* using pulse-amplitude modulated (PAM) fluorescence.

In addition to the annual regional sampling effort, a more intensive sampling is undertaken twice a year at 15 permanent transects within Florida Bay and southern Biscayne Bay. These transects are located adjacent to long-term Southeast Environmental Research Center (SERC) water quality monitoring stations. Transects (50m long) are sampled once at the end of the dry season and at the end of the wet season (October-November). Macrophyte cover and abundance are assessed using Braun-Blanquet analysis within ten randomly selected 0.25 m^2 quadrats, and seagrass short shoots are enumerated by species within ten 10cm x 10cm quadrats. Where *Thalassia testudinum* is present, 10 short shoots will be collected to determine leaf epiphyte biomass and shoot morphometrics. Three 15cm diameter cores will be collected to determine seagrass standing crop and below-ground biomass.

The **Nearshore Benthic Habitats Program** focuses on the nearshore benthic habitats (< 500 m from shore) of Southern Biscayne Bay, from Matheson Hammock to Manatee Bay, which have been largely understudied due to the difficulties associated with access to extreme shallow zones (< 1 m in depth) and are the habitats most likely to experience significant changes in water quality due to CERP components. This program was designed specifically to evaluate spatial and temporal patterns of abundance, diversity, and distribution of SAV in relationship to distance to shore and freshwater discharge from water management canals. Sampling locations are selected based on a stratified random sampling design and each site is surveyed using an innovative survey methodology, the **Shallow Water Positioning System (SWaPS)**. This methodology collects high-resolution digital images of the bottom from a shallow-draft skiff that allows easy access to nearshore habitats. The digital images of the bottom are imprinted with depth and GPS location providing a permanent georeferenced visual record of the benthic community. The images collected are scored to determine the diversity and coverage of SAV. In addition to the benthic images, water quality parameters are collected at each site at the surface and the bottom. These parameters include light intensity (PAR), salinity, DO, and temperature. This methodology was successfully implemented in 2005 at 240 sites during both the dry and wet seasons and was expanded to > 400 sites in 2008. The survey domain will be sampled seasonally (dry season and wet season) for the next three years to establish a baseline that incorporates both seasonal and inter-annual variability in SAV indicators that will be crucial for evaluating the impacts of CERP components on nearshore habitats.

The surveys conducted to date revealed that seagrasses are the principal component of the nearshore SAV community during the dry season (mean cover = 25.5 %), while macroalgae dominated during the wet season (33.4 %). The distribution and abundance of SAV are directly related to the tolerance of each taxon to salinity patterns. Species with high tolerance to low and variable salinity such as *Halodule wrightii* and *Ruppia maritima* are found only in canal-influenced areas and increase in abundance and spatial distribution in the wet season when freshwater inflow is highest. The dominance of rhizophytic macroalgae during the wet season is determined by the high abundance of *Chara*, a taxon commonly associated with freshwater environments. *T. testudinum*, the most abundant seagrass species, is found throughout the study region, but decreases in abundance in the canal-influenced areas during the wet season when lower, more variable salinity results in lowered productivity. These initial findings support the use of SAV as appropriate indicators of changes in water quality resulting from future restoration projects associated with CERP, which will modify the delivery of freshwater into littoral habitats with unknown ecological consequences.

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Hydrologically-Induced Seasonal Changes in Cypress Forest Aquatic Fauna Communities

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Understanding community response to natural hydrologic variation is critical to predicting how the system will respond to changes in hydrology resulting from restoration efforts. The aquatic fauna community in South Florida's freshwater forested wetlands, is remarkably similar to the community inhabiting Everglades graminoid marshes, but community structure and response to changes in hydrology are poorly understood. In the Big Cypress Region (BCR), freshwater forested wetlands provide habitat structure that serves as invaluable cover, spawning, and feeding sites for resident species. As water levels recede in this system and seasonally flooded forests become isolated from continuously inundated areas, competition for food and vulnerability to predators may become increasingly important for aquatic animals.

As part of the Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP), we are sampling aquatic fauna in three regions of Big Cypress National Preserve: Bear Island, Raccoon Point, and an area near the L-28 Interceptor Canal to provide baseline data on communities prior to the initiation of restoration activities. These sites span the range of mixed swamp and cypress forest habitats found in the BCR, and consist of shallow, seasonally inundated forests connected to deeper, continuously inundated forests. At each site, aquatic fauna are collected 5 times annually using a modified 1-m^2 throw trap in a stratified sampling design that targets intermediate-hydroperiod forests (inundated ~8 mo/yr), long-hydroperiod forests (inundated >10 mo/yr), and adjacent wet prairies (inundated ~5 mo/yr) and deep-water refuges (constantly inundated), when present and accessible.

In the first two years of this study (2005-2007), we observed that aquatic fauna communities changed significantly in response to dramatic annual hydrologic variation (range >1 m). Density and biomass of aquatic fauna increased throughout the wet season, reaching a maximum in the late spring. Immediately following cypress forest inundation (July-August), juvenile crayfish and large adult Everglades crayfish were abundant and fish density was low. As with Everglades graminoid marshes, the early wet-season fish community was comprised primarily of species with strong dispersal and colonization abilities (i.e., mosquitofish, juvenile sunfish, flagfish). Least killifish, bluefin killifish, warmouth, and dollar sunfish became abundant later in the wet season. Small tadpoles were most abundant in cypress forests immediately following inundation, but density decreased dramatically as the season progressed; overall, amphibian biomass was quite low.

With the transition from wet season to dry season (December-January), we observed cypress forests shift from a macroinvertebrate (primarily crayfish)-dominated system to a fish-dominated system. During this time, crayfish density and biomass decreased significantly as crayfish began to burrow and grass shrimp density increased, especially in wet prairies and intermediate-hydroperiod forests where a reduced canopy allowed greater grazing opportunity. Fish community structure did not change significantly, but density and biomass continued to increase as water receded and fish began to become concentrated.

Dry season communities were characterized by extremely high densities of fauna as prey were concentrated in depressions at the center of cypress domes, and in sloughs and ponds. Fish density reached a maximum in the mid- to late-dry season (March-April). As fish persisted in refuges, predation pressure increased and water quality decreased, causing a decrease in fish density just prior to desiccation. Large, non-indigenous cichlids and catfish were much more abundant and comprised a greater proportion of the overall fish community in dry-season refuges than any other locations throughout the year.

Because several restoration projects are expected to impact the hydrology of eastern portions of Big Cypress National Preserve, data collected in this study can be directly applied to data needs expressed by RECOVER (Restoration Coordination and Verification) and other restoration initiatives. In summary:

- Aquatic fauna communities (structure, density and biomass) in BCR freshwater forested wetlands appear to be extremely sensitive to hydrologic change
- As the duration of inundation increases, BCR cypress forests change from crayfish-dominated systems to fish-dominated systems
- Refuges that retain water throughout the dry season provide important habitat for fishes throughout the dry season
- Because water recession patterns provide critical cues for aquatic fauna seeking dry-season refuge, timing and duration of seasonal draw-downs are important variables to maintain or restore throughout restoration efforts in the BCR

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Temporal and Spatial Characteristics of Mercury Contamination in the Everglades during the Past Three R-EMAP Phases

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The U.S. Environmental Protection Agency (EPA) Region 4 Regional Environmental Monitoring and Assessment Program (R-EMAP) had collected and analyzed Everglades surface water, marsh soil, flocculent detrital material (floc), periphyton, and mosquitofish samples for total mercury (THg) and methylmercury (MeHg) in three phases (1995-1996, 1999, and 2005). Comparisons of results between different phases would provide us a picture of evolution of Hg contamination in the Everglades. The Everglades is a complicated wetland ecosystem where dikes, levees, roadways, urban development and other landscape features alter water flow, habitat, and nutrient loading, resulting in the spatial variations in corresponding ecological conditions. Owing to the spatial variability in ecological conditions, Hg distribution and cycling exhibits distinct spatial patterns in the Everglades. The ecosystem-wide sampling design of R-EMAP allows us to investigate spatial patterns in Hg cycling and bioaccumulation at the landscape level in the Everglades. Here we analyzed temporal variations in Hg contamination by incorporating Hg data sets obtained in the past 3 sampling events and spatial patterns of Hg distribution in the entire freshwater marshes.

On an ecosystem-wide scale, water THg averaged 2.7, 2.4, and 2.6 ng/L for the 1995-96, 1999, and 2005 sampling events, respectively, with no significant temporal differences being detected from 1995 to 2005. Similarly, soil THg had averages of 124.9 in 1995-96, 117.4 in 1999, and 130.7 ng/g in 2005, none of which were significantly different. Floc THg showed a significant decrease ($p < 0.05$) from 1999 (199.1±12.9 ng/g) to 2005 (117.9±4.3 ng/g) (floc was not sampled in the 1995-96 phase). A clear downward variation was observed for periphyton and mosquitofish THg during the past 3 sampling events.

The temporal changes in MeHg were not always consistent with those in THg. Everglades water was observed to have similar MeHg concentrations in 1999 and 2005, both of which were significantly lower than the 1995-96 data. A spike in MeHg concentrations was observed for soil and floc in the 2005 sampling events, compared to the 1995-96 and 1999 events. Periphyton MeHg basically follows the temporal patterns of water MeHg, with 1995-96 being the highest ($p < 0.05$) and no significant differences between 1999 and 2005.

Both THg and MeHg vary spatially in the Everglades. Higher Hg concentrations generally occurred in the northern Everglades (Water Conservation Areas, WCAs), but with exceptions such as high THg in water in ENP. The "hot spot" areas of MeHg could not duplicate those of THg, indicating spatial differences in Hg cycling due to spatial variations in ecological characteristics. High periphyton THg and MeHg were not observed in the northern Everglades. High mosquitofish THg and bioaccumulation factor (BAF) occurred in the central and southern Everglades (WCA 3 and ENP).

Temporal variations in THg in certain compartments were observed for WCA 1 while MeHg showed no temporal trends in this area. There were no temporal variations in both THg and

MeHg observed for WCA 2, except for THg in periphyton. WCA3 and ENP were similar in THg and MeHg temporal patterns from 1995 to 2005 and both subareas basically followed the ecosystem-wide temporal trends.

In summary,

- At ecosystem-wide level, THg was observed to remain unchanged for water and soil while decrease for floc, periphyton, and mosquitofish from 1995 to 2005.
- Different subareas exhibited different temporal patterns in evolution of Hg contamination from 1995 to 2005, possibly due in part to the different influence of restoration on different subareas.
- Understanding Hg distribution at landscape scale and in long-term period is useful not only for revealing biogeochemical processes that are related to Hg cycling and bioaccumulation, but also for managing the Everglades ecosystem to achieve restoration goals.

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Validation of EDEN Water-Surface Model and Ground Digital Elevation Model (DEM) for the Everglades, Florida

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The Everglades Depth Estimation Network (EDEN), established to support a variety of scientific and water management purposes, is an integrated network of real-time water-level monitoring, ground-elevation modeling, and water-surface modeling for the freshwater Everglades. The EDEN water-surface model was developed to provide spatially-continuous hydrologic data and information, which was based upon the spatial interpolation of daily water-stage data with a 400-square-meter grid spacing. The EDEN ground digital elevation model (DEM) was developed by using Airborne Height Finder data points and airboat-surveyed elevation data.

Two objectives of this study are to validate the EDEN water-surface model by using an independent field-measured dataset, and to validate the EDEN ground DEM by using a combination of field-measured ground elevation data and ground elevation data derived from the EDEN water-surface model and observed water depths.

Water-surface data were collected at the Florida Department of Environmental Protection (FDEP) benchmark sites in Water Conservation Areas (WCA) 3A and 3B from April through September 2007. Ground elevations of 95 water-level gage stations and 24 FDEP benchmarks were measured from 2005 through 2007. Over 19,000 water-depth data, collected by principle investigators from 2000 through 2007, are used to estimate ground elevations with the use of interpolated water levels from the EDEN water-surface model.

Statistical and geographic information systems (GIS) analyses are used to validate the two models. We found that there are no statistically significant differences between model-predicted and field-observed water-stage data in both southern WCA 3A and WCA 3B. The EDEN water-surface model is reliable by a root mean square error (RMSE) of 3.3 cm. By region, the RMSE is 2.48 cm and 7.76 cm in WCA 3A and 3B, respectively. The EDEN water-surface model has wide applications for ongoing research and management efforts that are vital to restoration of the Florida Everglades. The accurate, high-resolution hydrological data, generated over broad spatial and temporal scales by the EDEN water-surface model, provides a previously missing key to understanding the habitat requirements and linkages among native and invasive populations, including fish, wildlife, wading birds, and plants. The comparison results for the EDEN ground DEM will also be presented at the conference.

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Food-Web Structure in Big Cypress Swamp Wetlands Based on Stable-Isotope Results

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Forested wetlands in southern Florida and their contiguous marshes functioned as critical feeding and nesting sites for wading birds, which have declined precipitously in coincidence with hydrological changes in the region. Those changes are hypothesized to have negatively affected the production and availability of prey for the birds. A major target of restoration is the reestablishment of natural hydrological conditions. South Florida wetlands have also been colonized by more than 10 species of non-native fishes in recent years. The Big Cypress Swamp ecosystem has been affected by both of these anthropogenic impacts, yet their effects are unclear because of the lack of prior data. In planning for the restoration of the southern Florida ecosystem, it is critical to have baseline data for communities and food webs so that the success of restoration actions may be measured. This PES-funded study provides information on cypress food webs, including such basic questions as: what species utilize those wetlands, what groups constitute the major biomass pools, and which primary producers support those communities? This study is one of the first food-web investigations of any cypress-swamp ecosystem.

We used stable-isotope analysis in the baseline food-web study of Big Cypress National Preserve (BCNP). Stable-isotope analyses of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) are powerful methods for identifying primary producers in a food web and estimating trophic positions of consumers, respectively. Based on previous sampling data, we selected species of native animals and plants for analysis that dominated the biota in numbers and/or biomass. In addition, we collected samples of non-native fishes for analysis to determine their positions in the food web. In the field, we collected a minimum of three to five individuals or sub-samples of each taxon from cypress domes and adjacent wet prairies. We collected samples three times a year from each habitat to identify primary producers at the base of the aquatic food web, and to define the linkages between producers, their consumers, and higher-level aquatic predators. By collecting biota from domes and prairies, we planned to look for seasonal movements between habitats by the animals. Samples were field-frozen, then identified, weighed, and measured in the lab prior to drying the appropriate tissues at 50 C. Plant material was acid-treated to remove carbonate. Dried tissue was pulverized, weighed, and prepared for analysis in the mass spectrometer. Here we present results of analyses conducted from 2005-07.

Temporal shifts in isotope values occurred within individual sites over time, depending on local hydrological conditions. Both algal and detrital pathways were present in the cypress ecosystem. It appeared that the detrital pathway was important to resident consumers in the cypress domes, based on the depleted carbon isotope values characteristic of detritus. However, in the prairies, isotope pathways to animals such as flagfish and sailfin mollies indicated a diet consistent with algal consumption. As surrounding prairies dried in autumn and winter, aquatic animals moved into the flooded domes, where they were concentrated and made available to wading birds and other predators that utilize cypress habitats for feeding and nesting. In that way, the food web in the domes was subsidized by production from the prairies. Of all organisms measured in the study, eastern mosquitofish, Florida gar, and other predatory fishes and invertebrates had the highest $\delta^{15}N$ values, indicating these taxa feed at a higher relative trophic position.

At a broader landscape scale, $\delta^{15}N$ and $\delta^{13}C$ values for fishes and invertebrates agreed closely with data previously reported from freshwater marshes in neighboring Everglades National Park. Values for $\delta^{15}N$ from the freshwater Everglades were typically enriched by nearly a full "trophic position" for key invertebrates and fishes compared with samples from the cypress domes. Amphipods, snails, grass shrimp, and eastern mosquitofish in Everglades wetlands were examples of abundant taxa common to both ecosystems that showed this enrichment. Similarly, animals were more enriched in mangrove-forest samples than in cypress habitats. Recent studies provide evidence that myriad factors may potentially influence the $\delta^{15}N$ values for aquatic organisms. For example, enrichment may indicate that Everglades organisms function at a higher trophic level than conspecifics in BCNP, or it may imply differences in source, fractionation, and/or assimilation processes in primary producers at the base of the food web. We plan to normalize our isotope data from BCNP to be able to make accurate comparisons of the relative food chain lengths across all habitats associated with the Greater Everglades landscape.

Findings Relevant to Restoration

- CERP success implies that restoration will restore aquatic food webs that support reproducing populations of higher vertebrates. Unfortunately, that premise is difficult to test and manipulate without data on aquatic food webs that currently are poorly defined. Our study provides baseline data for post-restoration comparisons.
- Isotope and standing-stock data indicate that animal movement from prairies to domes in the dry season results in a subsidization of the dome habitat by algal-based primary production from the prairies.
- Resident animals in dome food webs received carbon input mainly from detritus; crayfishes were the dominant primary consumers. Fishes and aquatic insects in domes were carnivorous species, perhaps relying on the subsidy of the surrounding prairies. Connectivity among those habitats must be maintained.

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USGS Modeling Efforts in South Florida and Application to Regional Management

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The USGS has spent considerable time over the last several years designing and developing multiple models for applications within the southern Florida ecosystem. Specifically, these models are the Manatee Model of the Ten Thousand Islands (TTI) in Collier County, the TIME Model of Everglades National Park, and the Biscayne Bay Model of Biscayne National Park and surrounding areas in Miami-Dade County. Each model utilizes the USGS code FTLOADDS (Flow and Transport in a Linked Overland Aquifer Density Dependant System), which couples a 2-D surface-water code (SWIFT2D) with a 3-D variable-density ground-water flow and transport code (SEAWAT). Salinity and heat transport are also included in the models as an important part of the coastal regime.

The Manatee Model developed for the TTI area of southwestern Florida incorporates heat transport capabilities in order to better understand and predict the factors that affect manatee movements among critical resources. This model can now be used to predict the effect of restoration efforts on manatees and other biota. The additional coding developed for heat transport has been added to all of the FTLOADDS models so that habitat suitability based upon heat and salinity parameters can be estimated for all three major southern Florida model domain areas.

A coupled surface- and ground-water model of Biscayne Bay and the surrounding areas was developed using the FTLOADDS code. The model has been used to (1) identify potential sources of hypersalinity events, (2) calculate freshwater discharges to the bay, salinity transport, and ground-water flow rates and (3) identify flow paths in the aquifer. This model encompasses all of Miami-Dade County and is currently being linked with the TIME model to create a larger model that can simulate scenario impacts with connectivity between Everglades National Park and Biscayne National Park. Additionally, with the new heat transport capabilities, the model can now be utilized to simulate global warming effects upon the area. This includes testing the potential impacts of sea-level rise as well as the effects of temperature change upon sensitive habitats, such as coral reefs, in the model domain.

The TIME (Tides and Inflows in the Mangroves of the Everglades) project of the USGS South Florida Ecosystem Program is a joint research effort initiated to study the interacting effects of freshwater inflows and tidal forces in and along the mangrove ecotone of Everglades National Park. TIME simulations predict changes to the flows, stages, and salinity of the coastal marine waters of Florida Bay and the southern Gulf of Mexico. The TIME model is currently being utilized to evaluate three Comprehensive Everglades Restoration Program (CERP) scenarios. This is accomplished using data from the South Florida Water Management District's South Florida Water Management Model (SFWMM) as boundary conditions for the TIME model. Comparisons between scenarios of water levels, coastal creek flows, and salinity help quantify the effects selected changes to the system will have on the southern Everglades and Florida Bay. These simulations provide regional managers with additional information that they can use when developing and deciding upon different potential management plans. The model can also be used as a platform to develop optimized scenarios that best serve the ecosystem as well as regional water supply needs.

All three FTLOADDS models have been tested and calibrated against field collected data. The three main areas where they currently contribute to restoration efforts, and can continue to do so, are as follows:

- The models provide (1) an accurate estimate of the hydrology of the area for incorporation into other models, such as the Across Trophic Level System Simulation (ATLSS) ecological models, and (2) simulation data for many other analytical analyses necessary for restoration efforts.
- Linkages with the SFWMM regional model provide the capability to simulate the potential effects of different restoration scenarios for managers to interpret.
- The models can be utilized to simulate the effects of global warming (sea level rise and temperature changes) upon the area and evaluate how they will affect restoration efforts.

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CERP Process to Apply Adaptive Management

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Congress authorized the use of adaptive management (AM) approach for the Comprehensive Everglades Restoration Plan (CERP or Plan) through the Water Resource Development Act (WRDA), 2000. While many components of CERP's AM process have been developed over time, a specific process (*CERP AM Strategy, 2006*) and technical guidance for implementing AM (*Draft CERP AM Guidance Manual, 2007*) for CERP has only recently been developed. The CERP AM Strategy lays a framework for scientists, managers, and stakeholders to implement AM at both restoration project-level and program-level scales. The CERP AM Guidance Manual provides the details on how to implement AM within the U.S. Army Corps of Engineers (USACE)' Six-Step Planning Process, which has been adopted by both implementing agencies (U.S. Army Corps of Engineers and South Florida Water Management District) as the standard process for CERP project development and implementation. The AM Guidance Manual also utilizes the AM principles identified in the strategy throughout the duration of Everglades restoration effort.

Academic literature identifies six components of AM: 1) Assess, 2) Design, 3) Implement, 4) Monitor, 5) Evaluate, and 6) Adjust (Nyberg, 1999). However, the AM process for CERP integrates this six component AM process into existing institutional planning processes and regulations, resulting in nine important AM activities: 1) stakeholder engagement and collaboration; 2) verification of program-level goals and objectives; 3) identification of unanswered questions (uncertainties); 4) use of conceptual modeling, hypotheses, and performance measures; 5) AM integration into CERP planning; 6) monitoring; 7) assessment; 8) decision-making; and 9) implementation and refinement. These nine activities may be executed at parallel times or repeated as part of the AM iterative learning process. Each activity is currently underway at some scale for CERP. The decision-making aspects of activities seven thru nine will likely be more understood in the near future, when CERP restoration projects are constructed and system-wide operations take affect. This guidance is designed to help CERP agencies and stakeholders work together to implement planning, monitoring, assessment, and decision-making activities designed to address key uncertainties that ensure CERP restoration efforts meet system-wide goals and objectives for the south Florida ecosystem.

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System-wide Planning for Comprehensive Everglades Restoration Plan: CERP Updates and Lessons Learned from the Band 1 Model Run Evaluation

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The Comprehensive Everglades Restoration Plan (CERP or Plan) provides a framework and guide to restore, protect and preserve the water resources of central and southern Florida, including the Everglades. Congress authorized the use of an adaptive management (AM) approach for CERP (*Water Resource Development Act [WRDA], 2000*) to allow the Plan to proceed in the face of complexity and incomplete scientific data (uncertainties). One key element of the CERP AM Strategy is system-wide planning activities that involve periodic modeling updates, integration of new information into the CERP, periodic review of Plan performance, and CERP updates based on new information to ensure program success in meeting restoration goals and objectives. CERP updates are necessary to ensure that the CERP Planning activities (project plan formulation, project sequencing, and system operations manual development) are based on the best available information and also to determine whether the Plan is still able to meet its goals and objectives. The Band 1 performance review included many of initial projects to be completed for CERP and provides an example of periodic Plan system-wide performance review and lessons learned to improve future system-wide plan updates and planning efforts to improve CERP implementation at the program-level.

The Working Group of the South Florida Ecosystem Restoration Task Force requested a review of the predicted performance of the initial "Band 1" projects identified in the Master Implementation Sequence Plan (MISP) for CERP. While the MISP is being replaced by a new integrated delivery schedule (IDS), the Band 1 performance review offers some important lessons learned for future system-wide (program-level) planning efforts, such as CERP A Refinement, sea-level rise contingency analysis, IDS development, or incremental adaptive restoration system-wide formulation: 1) set cut-off dates for model assumption changes and clearly articulate these assumptions when presenting evaluation results; 2) coordinate closely with project managers regarding project assumptions and collectively agree on what final planning documents should be used to define the assumptions; 3) different assumptions of project structures and features will lead to different ecosystem, water supply, and flood control performance results; and 4) provide continuous feedback with managers to ensure system-wide modeling efforts are prioritized and will meet their information needs. The Band 1 model run evaluation also revealed several important performance results to inform future planning activities: 1) regional groupings of projects are likely to provide measurable predicted restoration benefit results using RECOVER system-wide PMs to help evaluate major CERP project alternatives as part of the U.S. Army Corps of Engineers project approval process; 2) total system PMs and regional prioritization evaluation methods are needed to aid future CERP manager efforts to identify projects and operations to achieve strategic restoration benefits in the development of CERP sequencing plans, system operations manuals, and changes to projects as part of major CERP update activities; and 3) Band 1 model results further demonstrate the need to store more water and correctly determine the timing of sending more water South as a part of future CERP program and project-level planning efforts to ensure all CERP restoration goals and objectives are achieved.

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Refinement and Application of Pigment-Based Chemotaxonomy to the Assessment of Periphyton Communities in the Everglades

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Changes in periphyton community structure (taxonomic makeup) can occur rapidly in concert with physicochemical cues (nutrients, hydrology, temperature etc.) over the scales of weeks or even days. "At least three environmental gradients – hydroperiod/water depth, phosphorous concentration, and aspects of water chemistry involving the major ions, especially calcium - affect the taxonomic composition, growth characteristics, structure, and extent of calcite encrustation of Everglades periphyton." (Browder et al., 1994). During the "replumbing" of the modern Everglades that will occur during the implementation phases of the Comprehensive Everglades Restoration Plan (CERP, aka the Plan) all three of these gradients may be influenced. Therefore, methods that will detect any changes and allow rapid notification of mangers to such changes, under the concept of "adaptive management", are being explored.

In the present case, the utilization of taxon-specific biomarker pigments is being pursued in order to provide rapid feedback over broad spatial and temporal scales. These methods, termed pigment-based chemotaxonomy, will only allow taxonomic description to the Division / Class levels and will therefore not replace microscopy or the newer molecular approaches such as cladistics in detail (Genus species). However, pigment-based chemotaxonomy has many advantages over those methods. First, it is less expensive on a per sample basis. Second, turn around times can be on the order of days if required. The only constraint being sample collection to delivery times. Third, each analysis is performed on a larger (sub-) sample (grams) than is microscopic (several visual fields) exam. Thus, the community analyzed is more highly integrated. Forth and deriving from the first 3 points, larger sample sets (suites) can be analyzed allowing for finer scales during spatial and/or temporal monitoring programs.

According to Paerl and others (2003), alterations in natural microalgal populations are expressed at the level of what they have termed PFGs, for phytoplankton functional groups. In the present case, we will extend that to periphyton functional groups. These so-called "functional groups" are in fact algae at the Division and Class level.

Presently, we are using the biomarker pigments given in parentheses to estimate filamentous cyanobacteria (echinenone, myxoxanthophyll), coccoidal cyanobacteria (zeaxanthin), chlorophytes (chlorophyll-*b*), diatoms (fucoxanthin), peridinin-group dinoflagellates (peridinin) and cryptophytes (alloxanthin).Additionally, purple-, brown- and green-sulfur bacteria have been detected and are quantified with this methodology. Their presence indicates active sulfate reduction, producing H_2S and may reveal the low REDOX potential (pE) required for the methylation of mercury. Studies are also underway to add nitrogen-fixing cyanobacteria (aphanizophyll) and calcifying forms. The latter will be determined by a very simple microscopic exam during which a few drops of 0.2N hydrochloric acid will added and any evolution of CO_2 noted. Additionally, a hitherto unreported 'visible light sunscreen pigment', often co-occurring with the well known UVA blocking scytonemin, is being investigated as a potential indicator of low water to drying conditions. Its broad absorption maxima at 440 and 562 nm make it a likely candidate for the protection of the cytochromes involved in electron transport. This phenomenon is actively being studied.

We are currently beginning year two of a three year base-line study of the spatial and annual temporal trends of periphyton in the Everglades using pigment-based chemotaxonomy.
In addition to providing a large data base of existing periphyton communities, we are exploring the use of "CART", a classification and regression tree analysis to predict / hindcast water quality conditions (TP, TKN, pH temperature, conductance and DO) from periphytometer periphyton assemblages. This is a software based exercise which uses the relative abundance of the various algal groups (see McCune and Grace, 2002). Data input for this exercise is the pigment derived algal classifications and the large water quality data bank of the South Florida Water Management District. Once relations are established / ground truthed, future analyses will potentially allow predictive modeling to occur.

To date, pigment-based chemotaxonomic evaluation of periphyton in Water Conservation Areas -1A, -2A and 3A as well in Taylor and Shark River Sloughs match known (literature) distributions and also follow current parameter trends such as total phosphorous and conductivity.

- Pigment-based chemotaxonomy is a rapid and economical method for the estimation of periphyton and other microalgal communities to the Division / Class level.
- Using chemotaxonomic data, broad spatial / temporal monitoring is possible.
- The rapid turn around potential of pigment-based chemotaxonomy should prove to be a valuable *adaptive management* tool.
- Pigment analyses also detect purple-, brown- and green- sulfur bacteria and indicate low redox areas potentially involved with mercury methylation.
- Expanded use of non-photosynthetic sunscreen pigments will likely provide insight into hydroperiod influences on periphyton communities.

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Old World Climbing Fern (*Lygodium microphyllum*) Invasion in Hurricane Caused Treefalls

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We examined effects of a natural disturbance (hurricanes) on potential invasion of tree islands by an exotic plant (Old World climbing fern, *Lygodium microphyllum*) in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Florida. Three major hurricanes (Frances, Jeanne, and Wilma) in 2004 and 2005 caused varying degrees of impacts to trees on tree islands within the Refuge, ranging from a loss of foliage and stripped branches to snapped trunks and treefalls. Physical impacts of hurricanes were hypothesized to promote invasion and growth of *L microphyllum*. We compared presence and density of *L. microphyllum* in plots of disturbed soil created by hurricane caused treefalls to randomly selected non-disturbed plots on 12 tree islands that had noticeable hurricane impacts. We also examined relationships between disturbed area size, canopy cover and presence of standing water on presence and density of *L. microphyllum*. *Lygodium microphyllum* was present in significantly more treefall plots than random non-treefall plots (76% of the treefall plots (N=55), and only 14% of random non-treefall plots (N=55)). Density of *L. microphyllum* was higher in treefall plots compared to random non-disturbed plots (6.0 stems per m^2 for treefall plots, and 0.5 stems per m^2 for random non-disturbed plots) and *L. microphyllum* density was correlated with disturbed area size ($P = 0.005$). *Lygodium microphyllum* presence in treefall sites was significantly related to canopy cover and presence of water, with sites with water having 5 times the probability of having *L. microphyllum* than those without. These results suggest that disturbances, such as hurricanes, that result in canopy openings and the creation of disturbed areas with standing water contribute to the ability of *L. microphyllum* to invade natural areas.

Findings relevant to restoration:

- This study contributes to our knowledge of how disturbance and exotics may influence tree island parameters (i.e. seedling density, species composition, canopy cover) used to assess responses to Everglades restoration activities.
- Forms of hurricane disturbance such as treefalls negatively impact tree island health and hinder ecological restoration of the Everglades by promoting the spread and colonization of *L. microphyllum* across the greater Everglades system. These results are relevant to long term Everglades restoration because hurricanes are a recurring cause of natural disturbance to the ecosystem.
- The presence of *L. microphyllum* on tree islands was significantly correlated to environmental conditions such as presence of water, canopy gaps, and soil disturbance. These findings suggest that *L. microphyllum* has the ability to colonize and thrive in a variety of wetland habitats found across the greater Everglades ecosystem.

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Post Hurricane Colonization of *Lygodium microphyllum* on Pop-up Tree Islands of the Arthur R. Marshall Loxahatchee National Wildlife Refuge

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Tree islands play an important role in maintaining wetland biodiversity, and provide important habitat for wildlife across the Everglades. Because of their importance to the ecosystem, tree islands have been identified as one of the performance measures or indicators for ecological responses to the Comprehensive Everglades Restoration Plan (CERP). Potential parameters for tracking tree island responses to restoration include tree island canopy cover, tree seedling density and species composition, and fern understory density and composition. All of the above parameters can be affected by factors other than hydrology, the primary focus of the CERP. Invasion by exotic plants and hurricanes are two such factors that, if not understood, may confound efforts to monitor tree island responses to hydrologic changes.

Lygodium microphyllum, an extremely invasive exotic fern that is now prevalent in South Florida, is one of the biggest threats to tree islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). Currently, *L. microphyllum* can be found in approximately 44% of the Refuge, primarily on pop up and strand tree islands. The control of this invasive fern and the restoration of tree islands is an urgent management priority for the Refuge.

L. microphyllum colonizes a range of habitats and like many invasive exotics can rapidly establish in disturbed areas. In 2004-2005 three hurricanes impacted Refuge tree islands causing defoliation, broken branches and twigs, snapped trunks, and uprooted trees resulting in large canopy openings on tree islands. It was hypothesized that hurricane impacts would influence the rate of colonization of *L. microphyllum* both on an island and landscapes scale. In 2005, a three year study was initiated on *L. microphyllum* colonization of tree islands, with special emphasis on its relationship to hurricane disturbance.

This poster outlines five projects that were designed to address different questions about hurricane disturbance to tree islands and *L. microphyllum* colonization. The projects include:

1. Effect of hurricane-caused canopy gaps on *L. microphyllum* colonization.
    a. Do hurricane-caused canopy gaps on tree islands promote increased recruitment and growth of *L. microphyllum*?
2. Spore rain in hurricane-caused canopy gaps on tree islands.
    a. Do spores of *L. microphyllum* accumulate in greater numbers under open canopies than in closed canopies?
3. Hurricane impacts on the establishment and spread of *L. microphyllum* patches on tree islands.
    a. Do tree islands with higher levels of hurricane impact become colonized more rapidly and to a greater extent than tree islands with lower levels of hurricane impact?
    b. Is there a conspicuous pattern to *L. microphyllum* colonization of tree islands?

4. Hurricane disturbance and its impact on the colonization of the refuge by *L. microphyllum.*
    a. To what extent have past hurricanes impacted tree islands across the Refuge?
    b. How does hurricane damage impact *L. microphyllum* colonization?
5. *L. microphyllum* invasion in hurricane-caused treefalls.
    a. Does *L. microphyllum* invade disturbed areas (gap, pit, and mound) caused by treefalls more commonly than non-disturbed locations on tree islands?
    b. Are there specific environmental conditions (e.g. water, canopy opening, etc) within disturbed areas that are correlated with *L. microphyllum* invasion?

Results to date, with one year left in the study, suggest that hurricane impacts to tree islands of the Refuge do in fact influence the colonization of *L. microphyllum*. It appears that hurricane-caused canopy gaps, soil disturbance, and tree island location in the refuge all have a significant effect on total *L. microphyllum* cover. Our study of *L. microphyllum* patches on tree islands has revealed a significant increase in the total number, cumulative height, total area, and percent cover of *L. microphyllum* patches on the study islands. On a number of our study islands with moderate hurricane damage we have recorded over 150% increase in the total percent cover of *L. microphyllum*. It will be interesting to see how these trends continue to change following the third year of the study.

Findings relevant to restoration:

- These studies contribute to our knowledge of factors other than hydrology that may influence tree island parameters measured to assess responses to restoration.
- Hurricane disturbance in the form of canopy gaps and soil disturbance threaten ecosystem restoration by promoting the invasion of native habitats by *L. microphyllum*. This information is especially important in South Florida where the ecosystem is left in a constant state of recovery following annual hurricane impacts.
- A steady increase in the number of individuals and total area covered by *L. microphyllum* was observed on tree islands of the Refuge over the past two years. The widespread dispersal and rapid invasion of native habitats by *L. microphyllum* poses a considerable threat to successful ecosystem restoration of the greater Everglades area.

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Everglades Vegetation Community Analysis at the Landscape Scale: R-EMAP

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The Center for Remote Sensing and Mapping Science (CRMS), Department of Geography at The University of Georgia has conducted a landscape-scale study of Everglades vegetation communities as part of a comprehensive Everglades Ecosystem Assessment Program funded by the U.S. Environmental Protection Agency, U.S. Department of the Interior, U.S. Army Corps of Engineers and the Florida Department of Environmental Protection. This work builds on three studies known as EPA's Regional Environmental Monitoring and Assessment Program (R-EMAP) Phase I (1993-1996), Phase II (1999) and Phase III (2005). Everglades R-EMAP is the only comprehensive monitoring and assessment program predating the current Comprehensive Everglades Restoration Program (CERP) efforts to restore the quality, quantity, timing and distribution of water in the Everglades. The CRMS contributed to Phases II and III of R-EMAP by providing a landscape-level perspective of vegetation community distributions centered on the R-EMAP sampling stations.

The CRMS contributed to R-EMAP by developing vegetation databases for the distributions of communities such as cattail, saw grass, wet prairie, open water, shrubs, tropical hardwood tree islands, mangrove scrub, mangrove forest and halophytic prairie within a 1 km^2 area surrounding 347 synoptic sampling stations previously located with the R-EMAP statistical survey design from the Everglades Agricultural Area in the north to the mangrove fringe in the south and from the urban area on the east to Big Cypress on the west. These habitat maps were developed using color infrared (CIR) aerial photographs acquired in 2003/2004 by the South Florida Water Management District (SFWMD) and provided for use by R-EMAP researchers. U.S. Geological Survey (USGS) CIR digital orthophoto quarter quadrangles (DOQQs) of 1994/1995 and 1999 also were used to derive historical distributions of vegetation communities. Summary statistics for the 2003/2004 vegetation database will be discussed, along with changes and trends for the nearly 10-year period between 1994/1995 and 2003/2004 related to conservation, management and human activities such as airboat use in the Everglades.

Findings relevant to Everglades restoration include:

- Everglades vegetation community structure mapped within 1km^2 areas centered on R-EMAP sampling sites was found to adequately represent the entire Everglades ecosystem when compared to comprehensive vegetation community databases for Everglades National Park and South Florida Water Management Area units.
- Changes in Everglades communities, particularly cattail and sawgrass dominated communities, were observed within management units and along latitudinal gradients.
- Vegetation communities dominated by cattail (*Typha* spp.) were positively correlated with the presence of wide airboat trails.

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Comprehensive Everglades Restoration Plan Model Management System (CERP MMS)

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The Comprehensive Everglades Restoration Plan Model Management System (CERP MMS) application is a web-based modeling management system that facilitates the accessibility and availability of CERP and non-CERP modeling information (pre- and post-processed data and modeling documentation) using a Geographic Information System (GIS)-based Internet software. CERP MMS enhances communication among project managers, modeling liaisons, and modelers by providing modeling support and materials in a timely and efficient manner. Using selection criteria, the user can find information regarding CERP Projects and related models. Once the desired model is identified, the user can download model code, input and output files and documentation through the application interface.

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Research Activities at A.R.M. Loxahatchee National Wildlife Refuge

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The A.R.M. Loxahatchee National Wildlife Refuge (Refuge) is the northernmost remnant of the Everglades freshwater marsh ecosystem. The Refuge is owned by the state of Florida and managed by the U.S. Fish and Wildlife Service (Service). Research projects currently being conducted on the Refuge include, but are not limited to, those related to exotic and invasive pest and plant control, water quality, soil chemistry, wading birds, apple snails and alligators. In addition to the Service, multiple other agencies conduct research and monitoring activities on the Refuge including the U.S. Geological Survey (USGS), U.S. Department of Agriculture, U.S. Army Corps of Engineers, Florida Fish and Wildlife Conservation Commission, and the South Florida Water Management District. Universities presently conducting research within the Refuge include Florida Atlantic University, Florida International University, University of Florida, University of Miami, University of Louisiana – Lafayette, and Palm Beach Atlantic University. The Refuge has a Special Use Permit program to facilitate requests to conduct research and monitoring activities that meet criteria for Refuge compatibility and ability to contribute to an increased understanding of the Refuge and/or Everglades. The Refuge maintains an overall SUP approval rate of more than 95%. The Refuge also participates in cooperative efforts through the Critical Ecosystem Studies Units (CESU) program, a mechanism that fosters the ability of the Refuge to actively seek science to answer critical management questions.

Key messages relevant to restoration include:

- There are numerous unanswered questions related to the ecology of the Refuge and Greater Everglades
- Refuge maintains strong Special Use Permit program
- Refuge has creative mechanisms for collaboration, including access to CESU program, etc.
- Strong interest in encouraging new research ideas and requests

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An Initial Evaluation of the Effect of Sea Level Rise on Salinity in Florida Bay Using Statistical Methods and Models

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This study is an initial analysis of the effect of historic and predicted trends in sea level rise (SLR) on future salinities in Florida Bay and the effect that SLR may have on Comprehensive Everglades Restoration Plan (CERP) performance measures. A number of modeling activities and international studies project that sea level will rise dramatically over the 21st century and affect coastal habitat distribution and extent throughout south Florida. Sea level rise and other problems due to global warming may alter the current salinity regime in south Florida estuaries. Trend analysis shows that the salinity at most estuarine monitoring stations in Florida Bay has increased over the period of the data, but it is unclear if this is in response to SLR, or drainage alterations, or both. Sea level rise will cause the salt-fresh water interface to move further landward, exacerbating the saltwater intrusion problem already documented in south Florida groundwater. The purpose of this study is to better understand the role of sea level rise and climate indicators as they relate to the salinity simulation tools being used to evaluate CERP restoration alternatives.

This SLR analysis takes advantage of the fact that strong correlations exist between observed daily salinity values collected at stations throughout Florida Bay by the Everglades National Park (ENP) Marine Monitoring Network (MMN). Because of this, regression models were developed and used in a time series mode for extended periods to estimate changes in mean salinity levels in response to SLR. To evaluate the effect of SLR, the daily salinity at several stations in Florida Bay located near the outer limits of the Bay was increased. Linear regression models were then used to estimate the effect on near shore and mid-Bay locations due to increases in salinity at the outer stations.

The daily salinity at Murray Key, Johnson Key, Bob Allen Key, and Butternut Key was increased in increments to simulate an SLR-induced salinity increase of 1-5 psu. The simulated SLR salinity time series at each of these stations was used to drive the regression models to estimate the salinity at other locations in Florida Bay.

Initial results from one station (Murray Key) show that a 1 ppt increase in salinity results in similar increases (1 ppt) at outer stations, increases of about 1.25 - 1.5 ppt at mid-Bay locations, and 1.75 - 2.25 ppt at near shore stations. By contrast a 5 ppt increase at Murray Key results in increases of 4 - 5 ppt at outer stations, about 6 ppt at mid-Bay stations, and 6 - 10 ppt at near shore stations. These results will be compared to the results of similar evaluations using Johnson Key, Bob Allen Key, and Butternut Key. When the paleo-based salinity regime at Murray Key is adjusted in a similar manner for SLR and input to the regression models, the mean value of paleosalinity at locations throughout Florida Bay was still 5 - 20 ppt less than the observed data. This information may lead to the development of an “offset” for paleo-based targets to account for SLR, thereby more realistically estimating the required additional flows to the Everglades for restoration.

A separate analysis of multivariate linear regression (MLR) salinity models that are currently in use to estimate daily salinity for CERP evaluations shows that the MLR models are very sensitive to changes in stage levels but not sensitive to increases in the elevation of the sea surface at Key West. Just how much the elevation of the water table (stage) in coastal aquifers will increase due to SLR is a subject of debate in the literature. Some researchers indicate that groundwater levels in coastal aquifers with permeable subsurface soil conditions may increase an amount equal to the sea level rise. Other hydrologic studies indicate that the increase in groundwater elevation (stage) may not be as great as the rise in sea level. Because evaporation in coastal areas is already at the maximum, the increase in surface runoff will be balanced by a decrease in groundwater discharge to receiving waters to maintain the hydrostatic equilibrium between inflow and outflow at the interface. The decrease in groundwater discharge means a decrease in the hydraulic gradient, which in turn means that the groundwater stage may not increase in elevation as much as the rise in sea level.

This study shows that statistical models based on existing data can be useful for indirect analysis of the effect of SLR on salinity in Florida Bay. Hydrodynamic models such as FATHOM and EFDC may provide additional information on the direct effect of SLR on upstream stage and downstream salinity. Even so, characterization of the impact of SLR on stage and flow in the watershed must still be estimated to use these higher resolution tools to estimate the effect of SLR on salinity in Florida Bay. Additionally, if the increase in salinity at the outer and mid-bay stations is as small as estimated by the indirect statistical modeling methods, it may be difficult for these models to accurately predict the effects of SLR on hydrology and salinity due to model uncertainty.

In summary, this research:

- Provides a first-cut analysis of the effect of SLR on salinity in Florida Bay,
- Evaluates the sensitivity of MLR salinity models currently being used for CERP performance measures to SLR effects,
- Indicates that water levels in the Everglades have a greater effect on mean values of salinity in Florida Bay than changes in the elevation of the surface of the ocean,
- Estimates that paleo-based salinity regimes will still be less than existing conditions when SLR adjustments are made,
- Integrates climate change into Greater Everglades restoration, using statistical models for planning purposes, and
- Advances the development of new tools for evaluating the impact of climate change on salinity in Florida Bay

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Development of a Consensus Reconstruction of the Pre-drainage Everglades Hydrology and Florida Bay Salinity Using Paleoecological Information from Multiple Sediment Cores Coupled With Statistical Models

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In previously reported research paleoecological data were collected from Whipray Basin in Florida Bay and interpreted by the US Geological Survey and Fish and Wildlife Service to develop an estimate of the salinity regime in Whipray Basin prior to about 1900. Statistical models were developed from observed data that coupled salinity in Whipray Basin and the hydrology in the Everglades to estimate these pre-drainage stage and flow conditions in Shark River Slough and Taylor Slough and salinity in Florida Bay.

The overall mean values produced by the models indicate that existing freshwater flow into the remaining Everglades is about 2-2.5 times lower than it was during the pre-drainage period. The deficit in Taylor Slough is much greater than Shark River Slough in the dry season. Stage values in both Shark River Slough and Taylor Sloughs are about 0.15 meters lower on average now than during the pre-drainage period. The average hydroperiod has also been reduced significantly over pre-drainage estimates, with the Taylor Slough hydroperiod reduced more than Shark River Slough. The pre-drainage salinity regime throughout Florida Bay was more estuarine compared to the existing condition.

In the current research effort described herein, the three phase process developed at Whipray Basin is being used to couple paleoecologic assemblage data from several sites collected by different researchers with regression models. For phase one, the paleoecological analysis establishes the target salinity regime for pre-drainage conditions. Paleoecologic studies provide a method of reconstructing pre-existing biological, physical and chemical parameters of an ecosystem by biochemically or ecologically analyzing the biotic remains of organisms preserved in sediment cores. For phase two, the regression models are developed from observed instrumental data. For phase three, the products of phases one and two are coupled to estimate the paleo-based hydrology (stage and flow) in the Everglades that would create the pre-drainage salinity regime in Florida Bay. Also, in phase three the paleo-based salinity conditions at other locations throughout Florida Bay are estimated.

The salinity regime at five locations in Florida Bay estimated from the paleoecological data collected by the USGS Ecosystem History of South Florida's Estuaries Project using mollusk assemblage data has the potential for use in this evaluation. The salinity regime at three locations in Florida Bay estimated from paleoecological diatom characterizations by Florida International University (FIU) has the potential for use. From these separate research efforts, three to five independent estimates of the pre-drainage salinity regime are being developed for use in phase one as input to regression models and to ultimately compare with the findings of the previous evaluation using paleoecological information from Whipray Basin only.

The link between downstream salinity and upstream hydrology in phase two is accomplished by regression models developed from observed salinity in Florida Bay and observed stage and flow in the Everglades (Shark River Slough and Taylor Sloughs), on a daily basis. In phase three, the various paleo-based salinity regimes drive the various upstream hydrology models to produce an estimate of the freshwater flow needed to Shark River Slough and Taylor Slough to produce the pre-drainage salinity regime. Other salinity-to-salinity regression models are being used with the sediment core based salinity regimes to simulate at least three pre-drainage salinity regimes in Florida Bay.

The information from each site evaluation is being assimilated into a "consensus" pre-drainage hydrology regime for Florida Bay. The ultimate objective is a corroborated estimate of the stage and flow regimes for Shark River Slough and Taylor Slough necessary to meet pre-drainage salinity regimes in Florida Bay using this combined information set, and a spatially-broad, paleo-based salinity regime in Florida Bay.

Performance measures for the evaluation of the effectiveness of Comprehensive Everglades Restoration Plan (CERP) improvements currently utilize Natural System Model based estimates of salinity. Comparison of NSM-based estimates and the Whipray Basin paleo-based estimate shows that the paleo-based salinity condition is fresher than the NSM regime. The multiple lines of evidence approach described herein will verify or modify this single-station estimate of historical hydrology and salinity conditions, and may have implications for CERP evaluations.

In summary, this research:

- Uses multiple lines of paleoecological evidence from independent research efforts to recreate the historical salinity conditions,
- Uses a proven methodology to couple paleoecological information and regression models for estimating paleo-based Everglades hydrology and Florida Bay salinity,
- Utilizes findings from the coupling of paleoecological data and regression models to verify or modify the current Whipray Basin based estimate of historical conditions,
- Improve the use of ecosystem history/paleoecologic data to guide the targets for restoration,
- Revisits performance measures,
- Integrates the hydrology of the managed system with the needs of the natural system, and
- Integrates emerging concepts of paleoecology and coastal salinity to gain information on how much water is needed to restore the remaining natural system.

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GEER Progress from a Total Ecosystem View

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Six Arthur R. Marshall Summer Interns will present their views on GEER progress from a total ecosystem view. The review will include big picture findings on progress and major impediments to Comprehensive Everglades Restoration Plan (CERP) implementation, from the fresh eyes of young scientists from three state universities. Additional details await the Interns' arrival; the course starts May 23, 2008. Part of the intern's final exam will be pro-active participation in the GEER conference. For the senior scientists, please join us in training our replacements.

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Alligators and Crocodiles as Indicators for Restoration of Everglades Ecosystems

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Ecological monitoring is a key part of adaptive management and successful restoration. Not all components of an ecosystem can be monitored so it is important to select indicators that are representative of the system, show clear responses to system change, can be effectively and efficiently monitored, and are easily communicated. Crocodilians (alligators and crocodiles) are indicators that meet these criteria within the Everglades ecosystem. The alligator indicator uses relative density, body condition, nesting effort and success, and occupancy rates of alligator holes, whereas crocodile indicators use growth and survival, and trends in their populations related to hydrology. Correlations between biological responses and environmental conditions contribute to an understanding of species' status and trends over time. Positive or negative trends of crocodilian populations relative to hydrologic changes permit assessment of positive or negative trends in restoration. The crocodilian indicator is currently stable; with alligator trends negative in seven management areas and stable in two, and the crocodile trend is stable in Everglades National Park and the Biscayne Bay Complex. Restoration success or failure can be evaluated by comparing recent and future trends in crocodilian populations with historical or reference population data and model predictions.

- We have developed a monitoring program for alligator populations that can be used to evaluate the effects of restoration throughout the Greater Everglades Ecosystem. This program includes a comprehensive set of performance measures that can evaluate short (body condition), medium (population density, alligator hole occupancy), and long-term (nesting) effects of restoration on alligator populations.

- We have developed a monitoring program for crocodile populations that is effective at detecting impacts of short term disturbances that may impact population responses to ecosystem restoration. This combination of condition, growth, survival, and nesting of crocodiles allows for monitoring response of crocodile populations at different temporal scales.

- Restoration progress can be evaluated by comparing recent and future trends and status of crocodilian populations with historical or reference population data and model predictions.

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Movements, Habitat Use, Diet, Thermal Biology, and Trapping of Burmese Pythons in the Southern Everglades

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Native to Southeast Asia, Burmese pythons (*Python molurus bivittatus*) are a recently established invasive species in South Florida. Burmese pythons have the potential to adversely affect their new environment. The release of Burmese pythons in South Florida is especially troublesome because they appear to thrive in both disturbed and undisturbed habitats within the Everglades. The purpose of this project is to provide science support to develop control measures for Burmese pythons and to evaluate impacts of pythons on native biological diversity. We are using radio telemetry to determine habitat use, extent and timing of movements, and find aggregations of pythons during the breeding season. Since December 2005, 17 adult pythons have been captured and surgically implanted with VHF radio transmitters in Everglades National Park and on lands owned by South Florida Water Management District. Pythons were tracked on the ground and by plane. Distances traveled by the pythons varied from shorter movements of several hundred meters associated with breeding, to distances greater than 78 kilometers for pythons that had been relocated. Movements of longer distances were timed with the onset of heavy rains and surface water when snakes began heading back toward their original capture locations. As a semi aquatic, heavy bodied snake, the onset of surface waters facilitated the rapid long distance movements required by Burmese pythons to ‘home’ in this study. In fact, these pythons actively avoided dry land in their attempt to return home, remaining in areas with surface water. The unique dispersal capabilities of Burmese pythons and affiliation with water indicate that effective management of the rapidly expanding python population in south Florida requires cooperation and involvement of all land managers and relevant agencies.

Burmese pythons are generalist predators that consume a wide variety of mammal and bird species, as well as reptiles, amphibians, and fish. Prey species in the digestive tracts of Burmese pythons were identified by examining hair, bone, and teeth. Fourteen species of mammals, five species of birds, and one species of reptile have been found in the digestive tracts of pythons collected and examined in Florida, including several federally endangered Key Largo woodrats (*Neotoma floridana smalli*); one threatened species, the American alligator (*Alligator mississippiensis*); and two species of special concern, the limpkin (*Aramus guarauna*) and the white ibis (*Endocemus albus*). We have also found the remains of bobcat (*Lynx rufus*), and white-tailed deer (*Odocoileus virginianus*). Given the diverse dietary habits of the Burmese python, it is possible that other federally endangered or threatened species in Florida may be at risk as prey. In addition to the Key Largo woodrat, protected species believed to be at risk include the Florida panther (*Puma concolor coryi*), mangrove fox squirrel (*Sciurus niger avicennia*), Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*), wood stork (*Mycteria americana*), Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), and American crocodile (*Crocodylus acutus*).

Because temperature affects nearly all aspects of the biology of ectotherms, examining patterns of body temperature variation can often provide insight into their activity and behavior. To better understand the ecology of introduced Burmese pythons in ENP, we initiated a radiotelemetry study of pythons within and adjacent to the ENP and monitored their temperatures using surgically implanted micro-dataloggers. We simultaneously monitored environmental temperatures. Snake body temperatures ranged 12C to 36C. During the winter and early spring, pythons were able to maintain body temperatures between 20-33C most of the time and body temperatures rarely dropped below 15C. Minimal body temperatures were recorded in late morning but quickly increased as pythons apparently emerged from retreats. During late spring and summer, variation in python temperatures decreased and maximal body temperatures increased, but pythons rarely exceeded 35C. Using these data, we hope to provide information on python thermal biology, behavior, and activity that will assist in a better understanding of their overall ecology and development of effective population controls.

Trapping is one control method currently under development. The purpose of trapping is to remove pythons from the Everglades system. We are currently testing various trap and trap door designs. We intend to synthesize the knowledge gained from radio-telemetry, diet, and thermal studies to increase trapping success. This multi-faceted approach should increase success in reaching our primary goal of developing control methods for Burmese pythons.

Key findings relevant to restoration include:

- Telemetered Burmese pythons made long movements, especially during periods of high water, and have shown tremendous dispersal abilities. The findings that pythons move farther and faster during periods of inundation necessitates careful monitoring of newly restored and wetted habitats.

- As both predators and competitors, Burmese pythons pose a threat to endangered wildlife in South Florida. A growing wild population of pythons has the potential to create a major ecological problem in Everglades National Park and threaten successful restoration of the greater Everglades.

- Tasks related to capture and removal of pythons and trap development will apply research findings on distribution, abundance, diet, movements, and habitat use to determine how to design, deploy, and bait traps. The results of this work will need to consider changes that will occur as a result of restoration for a successful program.

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The Southwest Florida Feasibility Study: A Framework for Ecosystem Restoration on a Regional Scale

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Authorized as part of the Comprehensive Everglades Restoration Plan (CERP), the Southwest Florida Feasibility Study (SWFFS) is a multi-agency effort to develop a conceptual framework for regional ecosystem restoration. The anticipated level of detail included in the regional plan will be similar to that of the Central and Southern Florida Project Comprehensive Review Study ("Yellow Book"). Incorporating and building upon ongoing regional efforts, the SWFFS proposes over 170 projects for further study and implementation by local, state, and federal agencies in cooperation with public and private land owners. The 4,300 sq. mile study area encompasses all of Lee County and Collier County, as well as portions of Charlotte, Hendry, Glades, and Monroe Counties. Prior to development, the study area was characterized by a mosaic of wetland and upland habitat. The regional water table was shallow and species composition was primarily driven by the hydrologic regime. Short hydroperiod wetlands dominated by mesic and hydric flatwood and hammock communities created habitat unique to the region. Freshwater marsh, swamp forest, wet prairie, and cypress habitat formed numerous flowways that allowed for gradual sheetflow to the coast. In more recent years, urban and agricultural development has lead to channelization of flow throughout the system; draining inland wetlands, lowering the water table, and flushing coastal estuaries with unnatural pulses of freshwater.

The primary goal of the SWFFS is to develop a blueprint for regional ecosystem restoration focused on hydrologic improvement. Proposed projects include: (1) wetlands restoration; (2) construction of reservoirs, stormwater treatment areas (STAs), and algal turf scrubbers (ATS); (3) weir installation; (4) exotic plant removal; (5) stormwater and sewer retrofits; (6) berm removal; and (7) canal backfill. The goal of these proposed projects is to restore habitat and landscape connectivity while improving distribution and quality of water throughout the system. The SWFFS Project Delivery Team (PDT) is currently in the process of developing performance measures and evaluating study alternatives through the use of various regional and sub-regional hydrologic models. Model output will be analyzed to quantify benefits for use during alternative selection. Based on the current approved scheduled, the final Southwest Florida Feasibility Study Report can be expected in early 2009.

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Segregation of Palaemonid Shrimp Species along the Shark River Estuary, Everglades National Park

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Both abiotic and biotic factors have been shown to influence the distribution and abundance of species in space and time. In estuarine systems, salinity plays a key role in determining species abundance, community structure, and ecosystem processes. In the southwest section of Everglades National Park (ENP), freshwater marshes transition to an expansive array of mangrove forests, islands, tidal bays, and creeks where salinity varies both seasonally and spatially throughout the estuary. How organisms respond to this variation in salinity is poorly understood.

In this study, we examined the segregation of multiple species of palaemonid shrimp (Caridea, Palaemonidae) throughout the Shark River estuary, ENP. We examined the relationships of shrimp species presence/absence and abundance with salinity and other abiotic variables. Previous research has found that salinity is a major factor in causing spatial segregation among palaemonid shrimp, although other work shows that competition among species can also limit their distributions.

We sampled shrimp species along a transect starting at marsh-mangrove ecotonal habitats at the downstream end of Shark River Slough and ended in the marine environment of Ponce de Leon Bay on the Gulf of Mexico. Palaemonid shrimp were collected in minnow traps which were attached to mangrove prop-roots at eight sites along the transect. To capture temporal variation in salinity, sampling was repeated in the wet and dry seasons. Our collections detected five species of palaemonid shrimp within the estuary: *Palaemonetes paludosus*, *P. intermedius*, *P. vulgaris*, *P. pugio,* and *Palaemon floridanus*. The species segregated as a function of salinity, and their abundance varied seasonally with decreases in salinity from the dry to the wet season.

Under CERP, increased freshwater flow to the southern part of Everglades National Park is expected to result in prolonged pooling of freshwater at the marsh-mangrove ecotone. This should result in a spatially expanded and seasonally extended oligohaline zone in the upper estuary, and lower salinities in the mid and lower estuary, at least during the wet season. Implications of this study for restoration include the following:

- Because each shrimp species appears to be found at or near their optimal salinity range, these shrimp assemblages can be good indicators of salinity regimes.
- Spatial distributions of shrimp assemblages are expected to shift in response to lower salinity levels resulting from Everglades restoration.
- The implications of shrimp species replacement in the ecology of the estuary as a function of changing salinity regimes will require additional research.

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The Contrasting Mineral Chemistry of the Predrainage and Managed Everglades: Hydrologic Basis and Biogeochemical Significance

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Available scientific evidence indicates that inputs of dissolved minerals (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{2-}) have increased substantially across large portions of remaining Everglades peatlands as a result of water-management actions and land-use changes during the past century. The ecological effects of increased mineral concentrations have largely gone unnoticed and rarely been considered in conservation and restoration efforts. Here we synthesize information from the broader peatland literature and the Everglades to indicate the nature and extent of biogeochemical and ecological changes caused by increased mineral inputs to the Everglades.

Water sources strongly influence peatland mineral chemistry. Ground water and surface runoff typically have higher mineral concentrations than precipitation. Consequently, rainfall-fed or ombrotrophic peatlands often are mineral depleted compared to ground-water-fed or minerotrophic peatlands. Many peatlands evolve predictably towards ombrotrophy as peat accretion progressively isolates the peatland surface from ground-water influences and elevates it above the surrounding land.

The Everglades peatland originated roughly 5000 years ago as a seasonal wetland on top of mineral-rich limestone bedrock. Increased rainfall and longer hydroperiods across the northern and central Everglades promoted the accumulation of peat soils over this bedrock surface, resulting in an ecosystem that was increasingly isolated from bedrock and ground-water mineral influences and more strongly affected by rainfall. Contemporary measurements of rainfall chemistry in south Florida and the low mineral content of water and peat in remaining rainfall-driven portions of the Everglades attest to the mineral depleted nature of peatland areas exposed solely to this water source. However, even the predrainage Everglades likely had higher mineral concentrations than those in many northern ombrotrophic peatlands due to differences in climate, biota, and the importance of mineral inputs from marine sources and some upstream runoff.

Reconstructions of historic water budgets indicate that direct rainfall was the primary source of water to much of the Everglades prior to start of drainage efforts in the late nineteenth century. Seasonal overflows from Lake Okeechobee and runoff from surrounding seasonal wetlands and uplands provided most of the additional water to the predrainage ecosystem. The mineral content of these other water sources was likely higher than that of rainfall but lower than that of surface flows entering the Everglades today. Wetlands in the southern Everglades naturally have a mineral chemistry more strongly influenced by interactions with mineral-rich bedrock and ground water due to thinner peat accumulations, a greater proportion of infrequently flooded marginal wetlands, and a more transmissive underlying aquifer.

Drainage and water management activities over more than a century have converted much of the remaining Everglades from a rainfall-driven system to one strongly influenced by the chemistry of canal discharges. Waters in major conveyance canals have mineral concentrations more than

50-fold higher than that in rainfall and as much as 10-fold higher than that of surface waters in rainfall-fed areas of the Everglades interior. Spatial variation in mineral concentrations across the northern and central Everglades is due largely to differences in the relative importance of rainfall and canal discharges as water sources. Minerals in canal water come from many sources including runoff from upstream agricultural areas, water releases from Lake Okeechobee, and mixing between canal water and ground water. Inputs of minerals from agricultural runoff and deep ground water were not significant in the predrainage system and have increased as a result of land-use changes and water management activities that increase vertical exchange between canals and ground water.

Changing mineral chemistry affects peatland biogeochemistry by altering the availability of limiting nutrients and rates of key processes such as decomposition and by selecting for plant species best adapted to a specific chemical environment. The gamut of responses to increased mineral concentrations in the Everglades has not been thoroughly investigated, but may include changes in geochemical cycles and vegetation, and possibly shifts in the spatial distribution of some aquatic animals. For example, increased concentrations of Ca^{2+} and Mg^{2+} promote soil P storage in stable inorganic forms, thereby reducing P availability. And, elevated levels of SO_4^{2-} have been linked to increased bioavailability of the contaminant Hg and the macronutrients N and P. Certain plant and periphyton species indicative of remaining low-mineral areas have been shown to be sensitive to elevated mineral concentrations. Fish and aquatic invertebrates such as gastropods have surface-water mineral chemistry requirements for survival, growth, and reproduction that may affect their distributions across the Everglades as mineral concentrations change.

A clearer understanding of predrainage chemistry across the Everglades and subsequent changes resulting from human actions will allow for a better understanding of:

- How biogeochemical controls that characterize the ecosystem today may differ from those in the past;
- Ecological responses to restoration activities that alter mineral chemistry;
- The conservation value of preserving remaining rainfall-driven areas having chemical conditions that may approximate those of the predrainage ecosystem.

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Lake Okeechobee: Current and Future Management Challenges

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Lake Okeechobee is a significant natural resource and a central part of the Central & Southern Florida (C&SF) Flood Control Project. Human activities have altered the lake's spatial extent, hydrology, and connections to the surrounding landscape. These changes have affected the lake's ecology and will prevent complete restoration of lost ecosystem functions. Today, the lake is managed for multiple uses of water supply, flood control, recreation, navigation, and environmental benefits. A number of state and federal programs have been implemented to improve the ecological health of the lake while balancing the needs of different stakeholder groups. These programs have focused on three primary challenges to the lake: 1) extreme water levels; 2) elevated phosphorus (P) loads from the surrounding watershed; and 3) the spread of exotic and nuisance species.

Because of its roles of water supply and flood control, Lake Okeechobee is subject to extreme water-level fluctuations that have damaged the plant communities that provide critical fish and wildlife habitat. Past regulation schedules subjected the lake to numerous periods of extreme high lake stages (>15 ft NGVD) that stressed emergent wetland plant communities in shoreline areas. Prolonged high lake levels in the 1990s resulted in declines of key species such as bulrush and the development of an organic berm along the western shoreline. These high stages reduced the acreage of beneficial species such as spikerush and increased the coverage of nuisance species such as cattail. High stages also have increased the movement of nutrient-rich, turbid waters from the pelagic zone into nearshore areas. Increased water depths and turbidity reduce light availability to the submerged aquatic vegetation (SAV) and increased nutrient levels promote algal blooms. Periods of extreme low lake stages have occurred twice since 2000 and resulted in the temporary loss of wetland and some SAV habitat and associated declines in key fish and invertebrate species and reduced foraging by wading birds and snail kites. Dry conditions also promote expansion of exotic plant species such as torpedograss. The proposed revision to the regulation schedule will reduce the threat of high-stage events, but increase the potential for extreme low stages. The strength of the relationship between lake stage and SAV condition was evidenced by the strong rebound in SAV acreage in response to favorable water levels after the 2000-2001 drought.

Sustained anthropogenic P loading from the watershed has increased in-lake TP concentrations from a five-year average near 50 ppb in the mid 1970s to nearly 120 ppb by 2003. This loading also is responsible for the storage of nearly 29,000 metric tons (mt) of P in mud sediments that have accumulated across large areas of the lake's pelagic zone. From 2003 to 2007, the five-year average TP concentration jumped to over 160 ppb. This jump is attributed to the 2004 and 2005 hurricanes, which resuspended a large amount of the P contained in the mud sediments. The high waves and currents generated from these storms also changed the physical properties of these sediments so that they are now more easily resuspended.

Elevated P concentrations increase the frequency and severity of algal blooms, which are sometimes dominated by neurotoxin-producing cyanobacteria, in nearshore areas and may favor expansion of cattail in the littoral zone. A reduction in water-column total P concentrations to 40 ppb is needed to limit algal bloom activity and will require a five-fold reduction in P loading from the watershed to 105 mt/y. Internal P loads from the lake's sediments equal those from external sources and will slow the response of in-lake P concentration to reductions in watershed loading, possibly delaying attainment of the target concentration for decades.

The expansion of exotic and nuisance plant species poses a significant threat to native vegetation and food webs in the littoral zone of Lake Okeechobee. Melaleuca, which had expanded to cover as much as 20,000 acres of the lake littoral zone by the early 1990s, has been successfully eliminated from the lake using chemical treatment. Herbicides supplemented with fire also have been used to reduce the cover of torpedograss from 20,000 acres in 2000 to <12,000 acres in 2007. Routine chemical treatment also is required to control floating exotics such as water hyacinth and the native species cattail when it reaches nuisance proportions. New exotic plant species undoubtedly will become established in the lake in the future. A recent invader, the South American watergrass *Luziola subintegra*, was found spreading rapidly across a portion of Fisheating Bay in 2007 and has been subject to repeated chemical treatments. The lake is home to several exotic animals as well including at least 16 species of non-native fish. It is not clear what ecological impacts these species may be having.

Performance measures and other indicators of ecological condition have been established to gauge the success of current lake rehabilitation programs. Achieving the goals set for these measures will require:

- Water storage and other management strategies that prevent extreme water levels and allow for an operating range of 12.5-15.5 ft NGVD with excursions below 11 ft, but not less than 10 ft, approximately once a decade
- Reductions in watershed P loads to 105 mt/yr to achieve the 40 ppb in-lake TP target and reduce algal bloom activity;
- Continued evaluation of promising methods for sediment-P management in order to hasten the attainment of the in-lake P target;
- Further reductions in torpedograss acreage and proactive identification and management of future exotic threats.

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Potential Influences of Soil Chemistry on the Coexistence of Sawgrass and Slough Habitats in the Everglades

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The managed Everglades is exposed to loading rates of limiting nutrients such as phosphorus (P) and major mineral ions such as calcium (Ca^{2+}) that are much higher than in predrainage times. The presence of relatively pristine and highly impacted water-chemistry conditions in different parts of the Arthur R. Marshall Loxahatchee National Wildlife Refuge allows for the ecological effects of these multiple chemical changes to be examined. The interior of the Refuge is one of the few parts of the Everglades to retain an oligotrophic, soft-water (i.e., mineral-poor) chemistry that likely prevailed across larger areas of the predrainage Everglades. Discharges of canal drainage waters into the Refuge have increased soil P and mineral concentrations near the wetland perimeter and are associated with increased cover of sawgrass and a corresponding reduction in the extent of slough-wet prairie (SWP) habitat. This pattern suggests that changes in water and soil chemistry affect the relative cover of sawgrass and SWP habitats in this wetland.

Hydrologic and soil chemistry measurements were taken in sawgrass and SWP habitats across a canal gradient in the Refuge to generate hypotheses concerning the environmental factors that influence habitat distributions. Although water depths in sawgrass stands at a given site generally were lower than those in adjacent SWP, water-depth distributions for the two habitats exhibited considerable overlap across the gradient and could not explain coverage patterns. Soil (0-10 cm depth) chemistry in adjacent sawgrass and SWP habitats were similar except for soil P, which consistently was twice as high in sawgrass. This finding suggests that P cycling in sawgrass stands creates an enriched environment that is conducive to the maintenance of sawgrass in the same location. Conversely, lower soil P concentrations in SWP may retard the expansion of sawgrass stands into these habitats. Soil P and mineral concentrations in both habitats increased predictably with increasing canal influence along the gradient, and this enrichment may enhance the ability of sawgrass to expand into SWP.

Two laboratory experiments were conducted to test the above hypotheses by measuring sawgrass seedling growth responses to mineral and P enrichment. In the first experiment, seedlings grew 4-times faster in soils from an interior sawgrass stand and a perimeter SWP than in soil from an interior SWP, which had a lower P concentration than the other soil types. Seedling growth in both interior soil types doubled in response to controlled mineral enrichment. In a second experiment, seedlings grew as much as 6-times faster in interior SWP soils enriched with P and minerals than in unenriched soils. While moderate-high P enrichment only elicited growth from the planted seedling, low-level P enrichment and combined P and mineral enrichment elicited rapid production and growth of clones by rhizomatous expansion. Sawgrass seeds germinate in the Everglades during the winter dry season, and faster seedling growth and clonal expansion increase the probability that seedlings will survive to form new stands as water levels rise during the wet season.

A field experiment has been initiated to determine whether seedling growth responses to P and mineral enrichment can be extrapolated to predict the expansion of established sawgrass stands. Enclosures established along a sawgrass-SWP fringe in the Refuge interior are being dosed quarterly with P and/or crushed limerock. Growth and expansion of sawgrass stands into the adjacent SWP within these enclosures will be quantified to test for an enrichment effect.

Findings from this work have important implications for restoring the historic Everglades ridge and slough landscape. Specifically, our results suggest that:

- Plant-soil feedbacks control local nutrient environments and promote the maintenance of sawgrass stands but retard their expansion in oligotrophic Everglades environments;
- Water-quality changes that increase soil P and mineral concentrations favor establishment and expansion of sawgrass stands at the expense of SWP habitats;

If confirmed by additional field studies, these results will require that current conceptual models of the evolution and maintenance of the ridge and slough landscape incorporate chemical as well as hydrologic drivers.

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Origins of Production and Trophic Placement of Biota in Mangrove-Forest Food Webs Using Stable Isotopes

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Southern Florida is the focus of a major hydrological restoration of a vast wetlands ecosystem, the Greater Florida Everglades. The overriding principal of this restoration is that reconstruction of the basic hydrological patterns of water quality and flow will facilitate ecological recovery of populations and communities of freshwater and estuarine animal consumers. A major goal of restoration is to prolong the period of low-salinity conditions in the upper reaches of tidal rivers and streams, a condition historically correlated with the occurrence of vast numbers of nesting colonial wading birds in riverine headwater reaches. Given that estuarine trophic pathways are, in part, driven by salinity regimes, we collected baseline data on food-web relationships along a salinity gradient in Shark River, a major conduit of freshwater outflow from the Greater Everglades Ecosystem. Using stable isotopes of carbon and nitrogen, our objectives were to: (1) identify the major sources of organic matter for representative consumers along the salinity gradient; (2) determine if the relative contribution of organic-matter sources differs over seasons and years; and (3) identify those pathways and sites most likely to reflect trophic changes that could conceivably occur with modified freshwater inflow. Spatial and temporal expansion of the freshwater and low-salinity zones of the estuary would be expected to be reflected in the pool of dissolved inorganic carbon, and thus the phytoplankton carbon isotopic values. Additionally nitrogen isotopic values in phytoplankton might also display enrichment as a result of increased nitrogen availability in inflow. This Priority Ecosystem Science study provided information on the structure of that food web, including such basic questions as: what species use the fringing forests, what groups constitute the major biomass pools, and which primary producers support those communities.

We collected representative plant and animal taxa from three fixed locations along the salinity gradient on Shark River three times a year, from 2005-2007. All samples originated from fringing mangrove forests or adjacent subtidal waters. Following initial processing, all samples were sent to the stable isotope laboratory at Florida International University for analysis.

Preliminary analyses across river locations indicate that both red mangroves and BMA (benthic microalgae) were enriched in $\delta^{15}N$ and depleted in $\delta^{13}C$ at the most upriver site at Tarpon Bay (mean annual salinity = 5 psu). These unique values at the upriver site are indicative of its location at a salinity ecotone where freshwater influence dominates marine influence. The major *in situ* primary producers (red mangrove, benthic microalgae) overlapped considerably in both $\delta^{13}C$ and $\delta^{15}N$ at the upriver location, making it impossible to tease apart the relative contributions of the two identified potential organic matter sources there. Preliminary data indicates that inferences will be possible at the two downriver locations, however, as the values of the two sources are consistently different at those locations.

At the upriver location, the overlapping potential sources of organic matter (red mangrove, BMA) appear to be incorporated into resident killifishes, grass shrimp, and mud crabs, as well as into young life-history stages of snook and gray snapper, both recreational-fishing species. At the upriver location, both fish and invertebrate data suggest the presence of an unidentified source of organic matter that is much depleted in $\delta^{13}C$ and enriched in $\delta^{15}N$ relative to both red mangroves and BMA. This source is hypothesized to be phytoplankton. This source appears to be incorporated into pink shrimp, water-column forage fish (silversides), and filter-feeding clams.

Invertebrates from the upriver site were predictably intermediate in $\delta^{15}N$ values, an indication of a trophic level between plants and fishes. An exception was grass shrimp (*Palaemonetes* spp.) which had relatively enriched (high) values. Grass shrimp in other south Florida systems are one of the highest trophic-level invertebrates, indicating a diet rich in animal material. There were three consumer levels at the upriver location. Low-level consumers included filter-feeding clams and combination detritivorous-herbivorous amphipods and coffee bean snails. Second-level consumers included mud crabs, blue crabs, pink shrimp, grass shrimp and the small killifish, mangrove rivulus. Gray snappers and juvenile snook constituted the top-level consumers. Further analyses await receipt of additional data from the stable-isotope laboratory.

Findings Relevant to Restoration

- These data that provide baseline information on food webs of fringing mangrove forests will be useful for post-CERP restoration comparisons.
- Salinity regimes of coastal habitats will be altered because of increased freshwater flow or because of saltwater encroachment from sea-level rise. Changes in salinity will alter aquatic-community structure and therefore food webs.
- Top predators in the food web associated with the mangrove forest were gray snapper and snook, important gamefish species.

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Soil Phosphorus Storage in Isolated Wetlands of Improved Pastures North of Lake Okeechobee

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In Lake Okeechobee, eutrophication is a problem caused by phosphorus (P) pollution in runoff from agricultural and urban activities in the basin. Four sub-basins, known as the "priority basins," contribute disproportionately high amounts of P to the lake. About 64% of this 121,000 ha area is agriculture, 70% of which is improved pasture. These pastures are important contributors to excessive P loss due to historic fertilizing practices. Wetlands cover 17% of the priority basins but have been ditched to increase pasture area resulting in increased P-movement to streams and the lake. A proposed method to mitigate P loss from pastures is to restore the hydrology of ditched isolated wetlands to store water and associated P.

This study aimed to characterize isolated wetlands in improved pastures and identify factors that relate to total P (TP) storage by investigating: 1) size and distribution of isolated wetlands; 2) extent of wetland ditching and relationship to P; 3) P storage in upland and wetland soils; 4) relationships and comparisons among soil physicochemical characteristics and P in shallow marsh and deeper marsh soils; and 5) relative magnitude of P stored in shallow marsh and deeper marsh soils.

In an analysis using a geographical information system, we found that 60% of all wetlands in the four basins are nonriparian, 88% of those were emergent marsh wetlands (compared to forested, scrub shrub or aquatic bed) and 56% of the nonriparian wetlands were in improved pastures.

In 2003, we conducted a synoptic sampling of 80 historically isolated emergent marsh wetlands in improved pastures of the four priority basins. Median sampled wetland size was 1.3 ha and ranged from 0.2 to 13 ha. Fifty-nine percent of the sampled wetlands had at least one ditch and 46% had one or more large ditches (more than 1 m wide and 15 cm deep). All had emergent marsh vegetation in the shallow areas, but 15 had large areas of open water in the deeper parts. Proportion of wetland that was deeper marsh relative to shallow marsh was visually estimated for each wetland, and the median was 80%.

The top 10 cm of soils were sampled in the shallow marsh and deeper marsh of each wetland and adjacent upland. Inorganic P (soil extracted with 1 *M* HCl) in deeper and shallow marsh soils ranged between 15 and 40% of the soils total P content suggesting that 60-85% of the TP may be in organic forms. Mean TP was significantly higher in deeper marsh soils (533 ± 376 mg P kg^{-1}) compared to shallow marsh (241 ± 231 mg P kg^{-1}) and uplands (180 ± 170 mg P kg^{-1}). Even accounting for bulk density, deeper marsh soils had significantly more mean TP (31 ± 24 g P m^{-2}) than shallow marsh (20 ± 15 g P m^{-2}) or upland soils (19 ± 19 g P m^{-2}). A similar gradient was observed for organic matter (deeper marsh areas had 22% and shallow marsh had 14%), oxalate-extractable aluminum (Al-ox), oxalate-extractable Iron (Fe-ox), and magnesium (Mg). Oxalate-extractable P (plant available) concentration in deeper marsh (avg: 125 ± 122 mg P kg^{-1}) was 50% higher compared to shallow marsh soils, but there was no significant difference when accounting for bulk density.

In scatterplots of TP with organic matter (OM), Al-ox, Fe-ox, Mg and calcium, two populations emerged for both deep and shallow marsh soils: A lower-TP population and a higher-TP population, both with linear relationships with other variables. In higher-TP deep marsh soils (avg: 862 ± 261 mg P kg^{-1}), 65% of the variability was explained by OM (n=29). In lower-TP deep marsh soils (avg: 342 ± 293 mg P kg^{-1}), 88% of the variability was explained by OM and Fe-ox (n=50). In lower-TP shallow marsh soils (avg: 175 ± 107 mg P kg^{-1}), 77% of the variability was explained by OM and Al-ox (n=69). There were not enough higher-TP shallow marsh soils to regress.

We found that deeper marsh soils with overlying open water had significantly higher mean TP (43 ± 28 vs. 29 ± 22 g P m^{-2}) compared to deeper marsh with vegetation while having significantly less OM (13% vs. 24%) indicating higher P loading. We also found that wetlands with at least one large ditch had significantly higher mean TP (36 ± 24 vs. 29 ± 23 g P m^{-2}) in the deeper marsh soils with 65% more plant-available (oxalate-extractable) P (9.1 ± 7.8 vs 5.5 ± 3.7 g P m^{-2}) and more Al-ox, Fe-ox, Mg, and organic matter than in wetlands with smaller ditches.

We concluded that

- Wetland soils have more TP than adjacent upland soils.
- Organic matter and amorphous forms of Al and Fe are the most important physicochemical factors for P storage in wetland soils.
- Deeper marsh soils stored 50% more g TP m^2 in the top 10 cm of soil compared to shallow marsh soils.
- Two easy-to-identify indicators of wetlands that have more TP at risk of being conducted to streams were large ditches and open water areas.
- While deeper marsh soils covered 80% of the surface area of all sampled wetlands, they stored 85% of the total mass of P indicating that deeper marsh areas play a larger role in TP storage.
- Since deeper marsh soils were shown to store more P and more organic matter (the most important variable for P storage), we concluded that there would be long-term benefits to restoring ditches of isolated wetlands to increase hydroperiod, overall wetland size and area of deeper marsh.

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130 Years of Ecohydrological Change in the Everglades: What's Different and What's Not, and Why it Matters

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In 1882, Hamilton Disston cut a canal connecting Lake Okeechobee to the Caloosahatchee River, causing the first lowering of Lake Okeechobee stages. This lowering, in turn, reduced the annual flows from Lake Okeechobee into the Everglades, altering the water balance in the latter. In 1882, no one had installed monitoring equipment in the Everglades; vegetation baseline studies had not been conducted; and fish population densities had not been quantified. Similarly, when manmade drainage intensified in the 1910s, baseline ecological studies still had not yet been carried out.

As we study the remnant Everglades, and as we plan for its restoration, how then do we detect and understand differences from (and similarities to) its original, pre-drainage condition in the 1850s? How do we identify reference areas in the remaining Everglades, areas that retain attributes of the original system? Is the concept of reference areas even valid in this ecosystem? Does the concept need to be adapted and adjusted to reflect differing degrees of alteration for different ecosystem attributes? Can, and how can, post-drainage time trends be distinguished from natural time trends?

We will present an approach to environmental history of the Everglades, illustrating how abductive reasoning has been used to combine information from a diversity of non-traditional sources to reconstruct a picture of the pre-drainage Everglades. In particular, the following specific Everglades ecosystem attributes are followed over the time period 1850 to present: inflows from Lake Okeechobee, flow directions, landscape (peatland) patterning, water depths and the spatial distribution of water depths, vegetative indicator species, ridge and slough microtopography and tree island elevations. Reconstruction of the original conditions of these attributes, as well as their time course over the last 130 years allows predictions to be made, of expected future trends in the Everglades, given various restoration scenarios.

The spatial distributions of attributes, particularly of water depths and flow directions, emerge as key aspects of the original ecosystem. These attributes have wide ranging implications for its health, sustainability, and future restoration.

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The Lake Okeechobee-Everglades Hydrologic Interface: 1850s to 1920s

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Most reconstructions of the pre-drainage relation of Lake Okeechobee to the Everglades have understandably been based primarily on post-drainage observations. Pre-drainage, i.e., pre-1880, observations are fewer and less accessible. Recent, more in-depth investigations into the environmental history of this interface suggests that these reconstructions contain a number of errors, each traceable to post-drainage information. These errors include: inaccurately low estimates of typical pre-drainage lake stages; the concept that all Lake Okeechobee water passed through the custard apple swamp before reaching the Everglades; the assumption of an elevated rim over which lake outflows necessarily passed; and the assumption that pre-drainage outflows from Lake Okeechobee were the exception rather than the rule.

Careful examination of both pre-drainage and early post-drainage firsthand sources suggests that early lowering of Lake Okeechobee in the 1880s and again in the 1910s had dramatic effects on this interface, obscuring the original relationship. Solid corroborated evidence indicates that water originally flowing out of the pre-drainage Lake followed one of two parallel paths: through the custard apple swamp and subsequently into the eastern sawgrass plains downstream from it, or, directly into a western portion of the sawgrass plains. The direct flow path was significant; occurring along about one third of the outflowing southern shoreline. Shoreline vegetation, both before and after the lowering of Lake stages, establishes the absence of an elevated rim along the sawgrass portion.

An elevated rim in the custard apple swamp is not reported in pre-drainage observations, and appears instead to be a post-drainage artifact. The most likely explanation for the post-drainage rim is differential soil subsidence due to the much higher mineral fraction in the custard apple soils compared to the sawgrass soils. The absence of a pre-drainage custard apple rim is physically more plausible in terms of peat formation, meaning that ground elevations in both the custard apple and the sawgrass portions of the southern lake shoreline would have been very similar. Both would have formed in long term equilibrium with the leveling influence of Lake water stages. Hydrologically, the absence of a pre-drainage custard apple rim is also more plausible as its presence would have meant that the sawgrass shoreline would have formed a low spot, leading to preferential outflows and likely to scouring. No evidence was found of increased outflows through the sawgrass portion of the shoreline.

The presence of a significant length of pre-drainage sawgrass shoreline has strong implications for the nature of pre-drainage outflows from Lake Okeechobee. The growth requirements and optimal conditions for sawgrass, the post-drainage progression from absence to presence of shoreline shrub growth, as well as direct pre-drainage observations indicate that, prior to drainage, i.e., prior to 1882, the waters of Lake Okeechobee and of the bordering Everglades were essentially one and the same. The water stages of the Lake and in the bordering landscapes, whether sawgrass or custard apple, were equal along the shoreline interface. With distance southward and downstream from the shoreline, both the peat surface and the overlying water surface sloped very gently downward away from the Lake, approximately 5 cm per km.

The continuous, direct extension of the Lake water surface into the Everglades water surface has sometimes been interpreted to mean that the extent of Lake Okeechobee was significantly larger prior to drainage. Comments from pre-drainage observers do not support this, indicating instead that the Lake edge was generally well-recognized (based on vegetation), and that the edge was in most places within a few kilometers of the eventual diked edge. Additionally, the downward slope of the landscape, with water draining away from the Lake, suggests against considering the Everglades as a littoral zone for Lake Okeechobee.

Eight to perhaps as many as twelve, short, so-called "Dead Rivers" extended out from Lake Okeechobee into the custard apple swamp. All were reported (and mapped) as branching, narrowing and ultimately disappearing and merging into the custard apple swamp. Because of their short length (1-3 km) and diffuse disappearance into the surface waters of the Everglades, the hydrological importance of these rivers was only local. Flow was outward from Lake Okeechobee. With drainage and the subsequent subsidence of the various peat soils bordering the south shoreline of Lake Okeechobee, the Lake-Everglades interface changed dramatically, with ground surface and river beds both sloping into Lake Okeechobee, rather than out.

The record of pre-drainage sources provides no quantitative estimates of pre-drainage outflows, although some early post-drainage observers have made rough estimates. The fairly well-established pre-drainage geometry of the Lake Okeechobee-Everglades interface does however lend itself to modeling of these outflows.

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Ground Water Control of Tree Island Origin, Genesis and Destruction

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Most tree islands develop in local areas associated with more contact with groundwater which is controlled by the regional ground water table patterns. In other words, the local hydrologic parameters that control the origin and development of tree islands are controlled by more regional hydrologic conditions.

Our functional definition of a Tree Island is; "an isolated scrub or tree community surrounded by either grasslands (marsh) or different upland or swamp forest types (hardwood hammocks surrounded by pinelands)". Four major observations have led to a theory of tree island development. They are: 1) numerous types of isolated scrub or tree islands, hammocks and/or domes all share one major characteristic, that of greater conductivity with groundwater than adjacent areas (which are typified by being surrounded by a different plant community that is usually in response to differences in soil moisture and type, hydroperiod, water depth and fire frequency: all interdependent factors), 2) South Florida is a highly karstified plateau with both shallow and deep seated features which dominate hydrologic processes, 3) the Everglades developed in an elongate, narrow, limestone depression with a southern dip, under conditions of Holocene sea level rise (modified from Gleason et al 1984), and 4) the distribution patterns of Holocene sediments and "rocky glades". We interpret the origin of this elongate geomorphic basin as erosional or karst rather than of depositional origin.

With the exception of battery islands (Gleason and Stone, 1974) most tree islands enjoy more groundwater contact than adjacent areas. Increased groundwater influence in tree islands is caused by one of three models; 1) bedrock depressions not sealed with marl, 2) topographic highs consisting of limestone outliers exposed above adjacent marls, 3) level but highly broken up rock surface creating peaty soils locally that accrete and co-evolve with the adjacent marls (constructional). The key is a break in the horizontal continuity of the basal impermeable marl sediment which allows water or increased water moisture to reach the surface. These moister spots reduce oxidation and fire frequency promoting less fire tolerant vegetation to survive in a landscape dominated by fire. Frequently tree islands will exhibit both positive topographic relief and a mounding, higher groundwater elevation than the surrounding areas. Coastal examples exhibit reduced salinity which documents water upwelling by capillary action and hydrologic head differences. Most of these breaks in continuity are the results of karst processes, formation of dolines, solution pipes, surface dissolution features, and erosional remnants.

Studies of the Miami Limestone in West Dade County (Duever et al, 1979) and eastern coastal ridge and Transverse Glades (Meeder et al 2002, 2003 and ongoing) conclude that the present surface topography is an erosional surface which represents as much as one half the original volume of limestone missing by dissolution processes. Indeed the Everglades basin is a karst dissolution surface (erosional feature) and not a depositional topography. This creates a quite different scenario for hydrologic development of tree islands.

As sea level rose during the Holocene, a point was reached when the base of the Basin became inundated and large volumes of calcite mud produced by biogeochemistry of algae (Gleason, 1972) was precipitated and deposited. This marl formation expanded both vertically (accretionary) and laterally with the continued rise of base level forming a dish-shaped water tight sediment package at the rock surface that separated surface from groundwater in the center portion of the Basin. The basin continued to expand with rising sea level until hydroperiods above the marl became sufficient to produce peats. Therefore a typical transect from east to west across the Everglades Basin is: limestone upland - rocky glades (recharge area) - marl soils - peat soils - marl soils - rocky glades- limestone upland.

Because marl formation requires a hydroperiod of at least 210 days (Browder et al 1983) a wide belt exists between the end of marl formation and the high water mark (rocky Everglades) which is the area of most efficient ground water recharge for the Biscayne Aquifer. Therefore, Coastal Ridge groundwater table for much of the year was historically much higher than the Everglades surface water during at least the beginning of the dry season. Groundwater ran both eastward and westward from the Coastal Ridge as dry season water table began dropping and ran westward until the water table dropped below the elevation of the marl basal sediment. During this period of time, their existed a hydrologic head forcing water upwards wherever breaks in the Everglades Basin marl seal occur. This slight hydraulic head, capillary action of the peats and ET processes all combine to draw water upwards maintaining wetter conditions for more of the year than areas with no groundwater source. Since groundwater table has been lowered in adjacent uplands (Parker et al 1955), this upward seepage of ground water no longer occurs and decreased productivity, increased oxidation and fire severity has and will continue to result in the loss of tree islands that have not been drowned, by impoundment. Tree Island upwelling also increases nutrient levels and productivity because moister sites (not inundated) encourage more herbivore and carnivore fecal deposition and maintain diversity. Management options may include: lowering of adjacent water table to allow reestablishment a head that would support upward movement of ground water and therefore support bushes and trees or add fill to maintain positive tree island topography. Elevating adjacent surface water will kill tree islands now because their surfaces are to low and will be inundated.

Significance of the groundwater control on tree island restoration includes:

- Restoration will only work well at large spatial dimensions.
- Lowering the adjacent marsh elevation to return to a surface elevation with proper hydrologic parameters is needed but expensive and intrusive to urban development.
- Elevating flooded tree islands with organic sediment may result in aiding permanence to tree islands.
- Final restoration methodology needs to be determined after good prediction of post restoration water table trend.
- Proper restoration methods are dependant on future conditions of either rising or dropping water table.
- If incorrect management choice is made the rate of continued loss will be accelerated.

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Transverse Glades Karst Origins: the Everglades Water Table Control Mechanism

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The Everglades Basin is a nearly closed topographic valley, with a southern dip suggestive of a collapsed karst underground drainage system. The Everglades Basin developed during low sea level stand when water drainage was downward, resulting in both large scale deep and smaller scale near surface cavity systems and therefore a much drier surface environment. These subterranean cavity systems collapsed along near parallel trends forming elongate, closed valleys (Everglades, Biscayne Bay and Hawk Channel Basins). As sea level raised so did the ground water system decreasing water table slope, increasing horizontal water movement, and producing much wetter surface conditions resulting in the formation of the Everglades Basin and Transverse Glades (TG). The depths of these TG control the Everglades Basin surface water table once the Basin became sealed with impermeable marl deposits.

Traditionally the term, TG, was used for the narrow belts of Glades (or sawgrass marsh) that ran from the Everglades across the coastal limestone ridge to Biscayne Bay. We propose a new definition: a TG is a drainage pathway moving water out of the main Everglades Basin and usually with nick points, classically a rapids or water fall, along their courses which result in the maintenance of the Everglades water table. Based upon this definition, TG would include: 1) the Caloosahatchee River discharging to the west into Charlotte Harbor (historic nick point the rapids west of Ortona Locks) , 2) Lake Okeechobee ground water moving in thee southwestward direction to form the cypress strands of the Big Cypress which discharge into the Ten Thousand Islands, 3) the classic TG along the east coast discharging into Biscayne Bay, Card Sound and Barnes Sound (with nick point rapids or downward drainage under the ridge), and 4) Taylor Creek and Shark Valley draining southward into Florida Bay.

The nick points along these TG control Basin stage and generally decrease in elevation in respect to base line in the southward direction. This controls the slope of the Everglades water surface and soil types. The closed nature of the basin is easily overlooked because the southern end is undergoing rapid submergence although both TG are entrenched into coastal limestone ridges prior to discharge into Florida Bay. The lack of oysters (estuarine conditions) in northern Florida Bay may indicate fresh water discharge through these two glades may have been less significant than believed, at lower sea level stands. As submergence continues the southern restriction of the Everglades will continue to decrease.

Meeder et al (2004) calculated that 550,000 acft/y would be required to restore Biscayne Bay coastal wetland and estuarine zones. Continued study of the Dade County TG estimated that our initial calculations were very low underestimates, minimum discharge from TG-7 (C-100) alone was 310,000 acft/y. These estimates do not address groundwater discharge. Average seepage discharge of 1l/m^2/y (Meeder et al 1999) permit the calculation of a total discharge (20km^2) of 1933acft/d or more than 7 million acft/y. This does not include direct discharge sources nor a greater historic head (x2). We have developed a method for calculating "total" ground water discharge in some individual TG: $Q_{gw} = Q_{sw} (A1 \times V1) – Q_{sw} (A2 \times V2)$, where: Q = discharge, sw = surface water, gq = ground water, A = crossectional area (1= headwaters, 2= mouth), v = water velocity. Although we recognize historic flow volumes are not restorable we believe an understanding of higher historic conditions is important. Most of these TG have been modified by drainage canals lowering the water table and disrupting the geology. Drainage is now controlled by managed structures (coastal and WCA's) that do not permit the natural variability historically found in Everglades's sub-basins controlled by individual TGs.

The surface karst valleys (Everglades Basin and Transverse Glades) may have developed over deeper older karst, at least two periods of surface karstification predating the present have occurred producing many large swallows. The development of the marl seal occurred when carbonate rich waters (produced by intense dissolution of the limestone substrate) formed marl as hydroperiod was extended by rising base level. Blowouts, lakes disappearing overnight, are not uncommon in karst areas. They are more likely to occur when the impermeable basal seal is thin (early genesis) and surface water table is perched above the shallow groundwater, or anytime base level is dropping. When they occur in newly flooded areas in response to rising base level they can cause a partial blowout. Blowouts would result in decreased hydroperiods and water depths which might have the same effect as a period of more arid climate change, resulting in a transition from peat to marl. In addition, a blowout might not affect the entire basin the same depending on its location which explains some correlation problems and may be responsible for the formation of Hydrobiid and other skeletal beds in an area of normally low energy. Natural and anthropogenic analogs exist: Paine's Prairie, Alaucha Co. FL and Lake Erath, SW, LA.

Therefore the Transverse Glades not only controls long term development but might also explain apparently catastrophic or rapid climatic events. Soil and surface water storage capacity is more significant than rainfall in determining plant community and soil type and 2) soil moisture and surface storage also increases with increased water table regardless of rainfall.

The above model has major implications for GEER:

- Sea level is more important than rainfall in determining Everglades development,
- Periods of drier climate may result from lower soil moisture levels not rainfall,
- Karst and karst processes dominate the Ecosystem, creating nick points,
- Degradation of a single TG could result in catastrophic drainage,
- Not understanding the karst origin of the Everglades will probably result in the failure of major "replumbing" operations.

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Hydrologic Heterogeneity and Forest Structure Dynamics on Tree Islands: Monitoring and Assessment to Establish Baseline Conditions

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Tree islands are raised topographical areas within the Everglades that play a significant role as habitat for native flora and fauna. Tree species composition, diversity, and distribution were surveyed on tree islands located in Water Conservation Area (WCA) 3A and 3B in the southern Everglades and Grassy Waters Nature Preserve (GWNP) located in the historic northeastern outflow of the Loxahatchee Slough. Study sites represent a hydrologic gradient ranging from low water levels with short hydroperiods in the northern regions to high water levels with longer hydroperiods in the southern regions. We hypothesize forest structure and vegetative diversity will vary in magnitude across various compartmentalized water conservation areas within the Greater Everglades Area (GEA).

Vegetation sampling followed the North Carolina Vegetation Survey (NCVS) protocol, using 10 x 10 m (0.01 ha) plots at the head and near-tail of each tree island. Statistical analysis indicates that there are significant differences on structural complexity ($p=0.028$) and diversity ($p=0.045$) among the three geographic areas, with GWNP area having the highest structural complexity and diversity. Similarly, the distribution and abundance indicate that *Sabal palmetto*, *Ilex cassine*, and *Quercus laurifoli*a, dominate in GWNP and *Myrica cerifera*, *Schinus teribrinthifolus*, and *Persea borbonia* dominated tree islands in northern 3A. In contrast, tree islands in southern 3A and 3B are dominated by water tolerant species such as *Chrysobalanus icaco, Salix caroliniana, Ilex cassine*, *Magnolia virginiana*, and *Annona glabra*. These results indicate that in the Everglades tree species abundance and distribution reflect the effects of hydroperiod and water level.

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Understanding Florida Bay Hypersalinity and Water Exchange

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Florida Bay is made up of a collection of shallow basins separated by mud banks and mangrove islands situated between the Florida mainland and the Florida Keys. The bay is located downstream of the Everglades discharge that has been altered over the past century due to South Florida land use practices, leading to reduced water delivery to Florida Bay and subsequently elevated salinities. The reduced water flow has had the strongest impacts in the north-central region of the bay where extreme hypersalinity can develop along with degradation of water quality and sea grass die-off. Hypersalinity development was found to be caused by the combination of reduced fresh water inputs during the dry season and with weak basin water renewal rates. Using direct measurements of the volume transports through connecting channels, indirect estimates of the total transport to the subregions from mean sea level variability and a computer-generated animation model of observed sub-tidal sea level anomaly fields combined with wind vectors in the region, we show that interior basin water exchanges are weak and are controlled by local wind forcing.

Florida Bay; Hypersalinity; Transport

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Spatially-explicit Hydrodynamic and Water Quality Modeling of the A.R.M. Loxahatchee National Wildlife Refuge: Part II - Model Application

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) is a 58,275 ha remnant of the Northern Everglades. Changes in water quantity, timing and quality have resulted in different levels of impacts to the Refuge. Therefore, a priority for the Refuge is the development of water quantity and quality models to identify appropriate water management strategies that will maximize benefits for protection of fish and wildlife, while meeting flood control, water supply uses. Modeling provides a better understanding of the impacts of contaminants and nutrient loading, and quantifies benefits of management alternatives.

This presentation focuses on the validation and application of new hydrodynamic and water quality models of the Refuge. Based on MIKE FLOOD and ECO Lab modeling frameworks (DHI), these spatially-explicit models of the Refuge simulate hydrodynamics and water constituent concentrations, including chloride (CL), total phosphorus (TP) and sulfate (SO_4). The model was calibrated for a 5-year period (2000-2004), and validated for two other periods (1995-1999, and 2005-2006). The model results generally are in good agreement with observed stages and concentrations. Statistical analyses demonstrate the applicability of these models for temporal and spatial prediction of water levels and water quality concentrations. Visualization of model results using time series graphs and animations further improve our conceptualization of model mechanisms and predictions. In subsequent evaluations, hydrodynamic model results were compared with the U.S. Geological Survey's Everglades Depth Estimation Network (EDEN). EDEN produces spatial patterns of daily median water surface elevation (at a 400m resolution) across the greater Everglades including the Refuge.

Key messages relevant to restoration include:

- New hydrodynamic and water quality model exists for the Refuge, with potential planning applications related to temporal and spatial prediction of water levels and water quality;
- Constituent calibration for a conservative material (CL), as well as reactive constituents, constrained and improved credibility of the hydrological model as well as the constituent transport and transformation models;
- Consistency of predicted spatial and temporal patterns of constituent concentration with historical observations in both the canal and marsh demonstrate the utility of this model;
- Comparison of models with different underlying assumptions and structures improves our ability to clarify expectations of a model, and focus attention on where additional efforts are needed.

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Caloosahatchee Riverway Alternative to the C-43 West Storage Reservoir and the Everglades Agricultural Area (EAA) Communities

Forest Michael
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2008 Generation 1 reservoirs: prior to the 1980s, Florida's reservoirs used "traditional" dams to contain water on the native landscape. Above the artificial containment stage these reservoirs were lined with the existing vegetation on the new and valuable lakefront properties, some being new public parkland. An early Florida example is Lake Talquin (reservoir) State Park, 1928, in Tallahassee which generates both water supply and hydroelectric energy.

Generation 2 reservoirs: around the 1980s, the Tampa Bay Water Authority began constructing above-grade reservoirs with dams and heavy-duty pumping to fill the raised pool. These reservoirs had a typical Herbert Hoover Dyke styled section with additional concrete hardening to contain the water. No native vegetation lined the edges, only grass. This design was adopted by the Comprehensive Everglades Restoration Plan (CERP) program in the 1990s. CERP reservoirs such as the C-43 West Reservoir (Caloosahatchee) and the Everglades Agricultural Area (EAA) A-1 Reservoir and others were designed to meet the high stormwater storage capacity requirements for the Everglades Restoration. Land costs are reduced since the needed acre-feet are "stacked." Compared with earlier reservoirs, these are actually designed to require large quantities of energy, operations and maintenance ultimately driving up costs.

EcoReservoirs: in the fall of 2007, after learning of the CERP reservoir design, Forest Michael, landscape architect, developed a concept /invention called the "EcoReservoir Program" ©, a system of *financially and ecologically sustainable reservoirs.* EcoReservoirs incorporate Florida's advanced best practices from the SFWMD, FDEP, and other progressive agencies such as the USACE and NPS. Florida is a leader in multiuse public projects providing the *"Greatest Good For The Greatest Number,"* a phase by landscape architect Charles Eliot who designed Boston's Public Reservoir system in the 1890s; a protégé of Fredrick Law Olmstead (Manhattan's Central Park and Boston's Emerald Necklace). EcoReservoirs are fully multiuse contributing to both the community and environment.

EAA A-1 Reservoir: construction was stopped in the spring of 2008, possibly due to the potential acquisition of US Sugar by the State of Florida, coinciding with sparse funding in the 2008 Florida Legislative Session and a pending lawsuit. The US Government, Florida's 50/50 cost share partner, share of funding has also been light. The C-43 West Reservoir received no funding this year and is basically on unofficial hold pending the results of the EAA Sugar land acquisition. Land for both reservoirs is 100% acquired. Much of the Everglades Restoration is paused pending the US Sugar land acquisition. A headline-making concern of the local governments is the affect the US Sugar acquisition will have on their residents, businesses and economies. This acquisition was not anticipated so planning is beginning.

Conceptual application of the EcoReservoir Program to the Caloosahatchee (Riverway Alternative) led to its application to EAA, a contiguous portion of the *"Big Sawgrass."* Alternative water storage and quality opportunities are applicable to the entire Everglades Restoration. Conceptual cost savings result due to the non-reliance on unsustainable energy consumptive pump stations, dams and canals. Communities benefit since EcoReservoirs are large-scale public parks with lakes and associative recreation. All areas include habitat restoration which lowers maintenance costs while providing habitat for Threatened and Endangered species such as the Critically Endangered Florida Panther. Communities benefit from the inclusion of EcoTourism concessionaires that will pay local taxes and revenues helping offset project operations and maintenance costs. The Riverway Alternative conceptually results in the rehydration of the four historic Upper Lakes, drained in the 1880s when Hamilton Disston dynamited the waterfalls which contained the lakes. *Lake Okeechobee is the fifth lake of the Riverway's "Chain of Lakes."*

Initial estimates for the application of EcoReservoir Program to the EAA mirror its application to the Caloosahatchee; including similarly significant cost and energy savings; ecosystems gains and an opportunity to return to a more financially and ecologically sustainable reservoir development pattern. EAA Community gains are amplified with EcoReservoir Program application which helps mitigate the departure of US Sugar by enhancing the existing nature based economy, melded with the remaining agriculture and a potential Chain of Lakes /EcoReservoirs.

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Estimating Effect of Precipitation on Survival of Hatchling American Crocodiles

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High salinity levels are known to stress hatchling American crocodiles (*Crocodylus acutus*) in captive trials. Such stress could potentially reduce survival of hatchling crocodiles in natural settings. Reduced flow of fresh water through the Everglades over the last century has increased salinity levels along the coast of south Florida where crocodiles live. Habitat restoration efforts associated with the Comprehensive Everglades Restoration Plan are expected to reduce salinity levels in at least some portions of Florida Bay inhabited by breeding crocodiles. Such restoration efforts may increase growth and survival of hatchling crocodiles. However, to date the relationship between survival of wild hatchling crocodiles and salinity has not been studied using modern capture – recapture techniques that account for detection probability.

We use long-term capture-mark- recapture data to estimate fall survival of hatchling American crocodiles in three subpopulations during 1977 – 2004 and relate that survival to annual fall precipitation. Salinity and precipitation are inversely correlated. Subpopulations are located in Everglades National Park (ENP), Crocodile Lake National Wildlife Refuge (CLNWR), and at the Florida Power and Light Company Turkey Point Power Plant Site (TP). If high salinity reduces survival of hatchling crocodiles we predicted that survival would increase with increasing precipitation. We predicted this relationship would be strongest in ENP, the least disturbed of the three sites, where the inverse relationship between rainfall and salinity is presumably strongest.

Fall hatchling survival did increase with increasing precipitation for ENP, but decreased with increasing precipitation in the other two sites. Survival generally was lower at ENP than at the other two sites except during extremely wet falls. These results are consistent with the hypothesis that high salinity levels adversely impact survival of hatchling American crocodiles, at least in relatively pristine areas. The models we used do not differentiate between death and permanent emigration. If emigration of hatchlings was greater in CLNWR and TP during falls with abundant precipitation that could explain a decrease in apparent hatchling survival in wet falls.

Findings relevant to restoration include:

- Reducing salinity by increasing freshwater flow to crocodile nesting and nursery areas within ENP may increase hatchling survival and potentially increase abundance of the species.
- A study of the relationship between fall precipitation, salinity, and hatchling dispersal at all three sites could strengthen inference from the present study. Specifically, such a study could address whether the observed negative correlation between hatchling survival and fall precipitation outside ENP is due to increased dispersal from these sites in wet falls. By strengthening inference such a study could help guide future restoration efforts at CLNWR and TP, as well as within ENP.
- Previous researchers have suggested that future research focus on annual survival of large individuals. Few large crocodiles were captured in the present study. Consequently,

temporal and site-specific survival estimates were not obtained for non-hatchling animals. Such estimates could be useful in creating multi-site population matrix models for the American Crocodile which in turn could be used in an adaptive management scenario to monitor and evaluate effects of restoration efforts on the species.

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Development of a Spatially Distributed Flow Dynamics Model in the Everglades Ridge and Slough Landscape

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Human intervention to the Everglades during the last century caused the loss of historic surface flow and the disturbed hydrology has been suspected as a trigger of the partial loss of unique ridge and slough landscape pattern in the central Everglades. For the recent restoration efforts, the role of surface water flow and sediment transport has been highlighted due to the importance of physical and ecological impacts on the landscape formation, maintenance, and degradation.

In this research, a spatially distributed flow dynamics model was developed for the ridge and slough landscape. The flow model will serve as the hydrodynamic foundation of a hydro-ecosystem model. The Regional Simulation Model (RSM), originally developed by South Florida Water Management District, is used as the modeling framework. The selected model domain is a 1.5 by 4 km rectangle located approximately 4 km south of Alligator Alley in Water Conservation Area 3A (WCA 3A). The site is considered as one of well-conserved ridge and slough areas including the historic landscape pattern. The ratio of ridge to slough landscape is about 1:1 in the model domain. The gently sloping landscape was set to be slightly steeper in the slough than the ridges, generating topographic differences between the ridge and slough that increased from 0.17 to 0.19 m along the flow direction. Spatially uniform rates of rainfall and ET were applied and time series water level data monitored around the model domain were used to assign the upper and lower boundaries. Different hydraulic resistances were assigned to ridge and slough finite elements. The flow dynamics model was tested against time series water level and flow velocity data collected from the ridge and slough areas, respectively.

To determine key mechanisms of the landscape degradation and evaluate various restoration strategies, we plan to link the calibrated and validated hydrodynamics model with an optimized ecosystem model, which involves both sediment transport and differential peat accretion that may be different between ridge and slough habitats.

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Phosphorus Dynamics Modeling of Emergent and Submerged Aquatic Vegetation-based Treatment Wetlands in South Florida

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The primary goal of Stormwater Treatment Areas (STAs) in South Florida is to remove phosphorus flowing into the Everglades. For optimizing the design and long-term management of constructed wetlands, input-output mass balance or first-order kinetic modeling approaches have been used successfully. However, these applications are limited to predict performance of the treatment wetlands under varied conditions such as altered hydroperiod and vegetation type/density, because these models are not based on transient flow dynamics. In addition, due to the internal complexity of treatment wetlands and the lack of data on each ecosystem compartment, systematical phosphorus dynamics modeling efforts, coupled with hydrodynamics and solute transport models, have been rarely reported on these large-scaled, subtropical constructed wetlands.

In this work, we develop a phosphorus dynamics model for the treatment wetland ecosystems, which consists of an emergent (EAV) and a submerged aquatic vegetation (SAV)-based treatment cell, using Danish Hydraulic Institute ECO Lab module. Linked with a depth-averaged, spatially distributed flow dynamics and solute transport model (an independently pre-calibrated and validated MIKE 21 HD and AD model), the model is tested against water column phosphorus data (SRP, DOP, and PP) collected from STA 5 northern flow-way for 1.67 years. Direct SRP uptake by vegetation in water column is not considered in EAV system; on the other hand, the direct uptake by submerged vegetation and periphyton in water column is dominant in SAV system, compared to the root uptake. The model results show that phosphorus concentration profiles simulated at four monitoring points in the EAV and SAV cell agree with the measured data reasonably well. Key model parameters, used commonly in water quality models, but not extensively studied in STA-typed constructed wetlands, are estimated and the sensitivities are tested.

To develop more robust phosphorus dynamics models, more in-depth studies and extensive data collecting efforts are required for the following topics:

- Uncertainty of model parameters on spatio-temporal variations of mass transfer mechanisms between water column and floc layer, which are the most sensitive ones in the model, makes it difficult to predict physical processes in phosphorus retention, particularly PP behavior.
- To fully consider the entire ecosystem processes, not just focused on behavior and retention of phosphorous in the water column, it is essential to collect time series field and laboratory data on floc/soil and vegetation (EAV, SAV, and periphyton) phosphorus compartments at several locations in a constructed wetland.

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An Attempt to Model Spatial and Temporal Patterning of the Ridge and Slough System in the Everglades

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A model to study the temporal and spatial variations of hydrology and hydraulics, vegetation and net soil accretion has been developed to simulate the patterns observed in the ridge and slough environment in the Everglades. This model considers: (i) rainfall long term series obtained through a generator routine that was part of this study; (ii) integrated surface water and groundwater flow; (iii) a vegetation dynamics model; and (iv) sediment transport and soil accretion/deposition dynamics. The parameterization of the model was conducted by using the data collected by in Shark River Slough, the time series obtained from the South Florida Water Management District's database (DBHYDRO), among other parameters reported the literature. The model is able to generate spatial patterns overtime, starting from an initial random distribution of water (heads), vegetation and soil elevation. Physical and biological controls on string and cluster pattern formation are being explored through simulations of test cases. Implications for the preservation and restoration of the ridge and slough patterning in the Everglades will be discussed.

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A Model to Describe Spatial and Temporal Variation of Phosphorous Cycling in Tree Islands of Shark River Slough in the Everglades

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A model to study the temporal and spatial variations on the phosphorous cycle around the tree islands on Shark River Slough in the Everglades is proposed and developed in this investigation. It is based on a conceptual formulation that considers the convective and diffusive transport of dissolved phosphorous, adsorption on to soil, input from rainfall and animal activity, and the phosphorous cycle in biomass that includes uptake, release as litter, transport as suspended litter and release from the decomposition of the deposited litter. The water flow and transport of dissolved phosphorous in the model are implemented originally in the hydrologic and hydraulic numerical simulator MODHMS. However, the transport equations for dissolved phosphorous were also coded separately, as well as the balance equation for suspended litter particles and deposited litter. The parameterization of the model was conducted by using the data collected by in the three islands of Shark River Slough, the time series obtained from the South Florida Water Management District's database (DBHYDRO), among other parameters reported the literature. The model was calibrated in three stages. Initially, Manning coefficients were adjusted from surface water velocity available data. Then, the calibration of several groundwater flow parameters was performed from water table data collected at wells by. Finally, the phosphorous input rate from animal activity and the initial concentration of phosphorous were calibrated.

The results of this study suggest that:

- an external input rate from animal activity is necessary to maintain the phosphorous levels in the areas around the head of the tree islands due to losses from rainfall driven transport and suspended litter transport;
- this result points to the importance of the preservation of the wading birds and other wild life forms in the Everglades.
- the modeling results also suggest that the tall sawgrass die-off events observed in the Everglades may be a consequence of the lack of phosphorous caused by the transport of phosphorous in suspended litter;

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A Spatially-Distributed Phosphorus Water-Quality Model for the Linked Surface-Water/Groundwater Variable-Density Hydrology of the Southern Everglades

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The Comprehensive Everglades Restoration Plan calls for the numerical modeling of phosphorus water quality to evaluate potential management scenarios. A tool to meet this demand does not yet exist for the southern Everglades, where hydrology is affected by groundwater/surface-water and freshwater/saltwater interactions that in turn affect nutrient inputs to Florida Bay. A spatially-distributed modeling tool, the Transport And Reactions Simulation Engine (TARSE), was developed for simulating phosphorus water-quality when coupled with a hydrologic model to provide the necessary hydrodynamic inputs. The Flow and Transport in a Linked Overland-Aquifer Density Dependent System model (FTLOADDS) was developed specifically for simulating the hydrology of the southern Everglades, and was thus identified as a suitable hydrodynamic driver for TARSE. Integration of the two models has begun, and the combined tool will be tested on a domain that has already been hydrologically modeled by FTLOADDS; the Southern Inland and Coastal Systems (SICS). The design of TARSE was intentionally generic, and allows the user to define both the modeled components, and to select the nature of the equations used to describe the interactions between the components. This permits the user to dictate the complexity of the conceptual system to be simulated according the nature and extent of available data and the modeling objectives. Furthermore, though the first instance of the model is focused on phosphorus dynamics, the generic nature of TARSE facilitates its application to any constituent that is transported with flow and exchanged or transformed between modeled components. The coupled models therefore represent a unique addition to the suite of modeling tools available to the restoration effort, which will allow managers to explicitly consider phosphorus water-quality in back-calculating suitable restoration management scenarios, and may be conveniently adapted in the future for other constituents of interest.

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The Geographic Distribution of the Non-Native Red Rimmed Melania (*Melanoides tuberculatus*) in Biscayne Bay National Park, Florida

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A study started in Biscayne National Park in 2004 maps the distribution of *Melanoides tuberculatus* (Family Thiaridae; common name Red-Rimmed Melania), a freshwater snail native to Southeast Asia. The presence of *M. tuberculatus* is significant because it is an intermediate host for several human parasitic trematode worms including *Clonorchis sinensis*, *Opisthorchis spp.* (liver flukes) and *Paragonimus westermani* (lung fluke). It is an intermediate host for multiple parasites on waterfowl; e.g. *Philophthalmus megalurus* affects the eyes of birds. *Centrocestus formosanus* also utilizes *M. tuberculatus* as an intermediate host and affects fish, crustaceans, and some mammals. This invasive snail is a significant concern in south Florida where all stages of the trematode life cycle are now in place. The eggs released from a definitive host, whether mammal, bird, etc. into the environment infect the first intermediate host *M. tuberculatus* where the egg develops into a cecaria, its first free living form. From this stage the cecaria infects the next intermediate host commonly a fish or crustacean and becomes a metacecaria. The infected fish or shellfish is consumed by the final host and the metacecaria becomes an adult fluke completing the life cycle. Smoking, salt curing, pickling, and low temperature cooking, common in the multicultural food preparation practices used today, do not kill the metacecaria so this parasite stage can remain infectious. In addition, the recreational use of Biscayne National Park, through fishing, swimming, and other water sports increases the likelihood of exposure to parasites.

Site surveys have found both living *M. tuberculatus* and shell debris near canal mouths and in the nearshore areas in Biscayne National Park (BNP) from the southern boundary (south of the Turkey Point cooling ponds) to beyond the northernmost boundary (near the Cutler Ridge Power plant). Forty three distinct sites were selected for this survey encompassing canals and their entrances into the bay and nearshore locations along the western edge of BNP and radiating seaward. The canals that open into Biscayne Bay all have live *M. tuberculatus* in significant numbers and debris has been found along most of the western boundary of the park and in the connecting canals that lead into Park waters. The highest concentrations of both live and dead animals were in the vicinity of Black Point (BP) following the C-1 canal seaward into the bay. A transect was setup in 2004 at the Black Point canal opening into Biscayne Bay to better quantify the population expansion at this site. Field surveys from 2004 through 2007 show that *M. tuberculatus* are becoming increasingly abundant at Black Point. The estimated numbers of *M. tuberculatus* (live and dead) per square meter (based on raw counts using three random petit ponar samples) approaches 60,000/m^2, in 2006 at the BP transect location 4 (TR4), an increase from 696/m^2 in 2004, at approximately 1400 meters from shore. The numbers, at the seaward most point of the transect (TR6, approximately 2200 meters from shore) increased from 87/m^2 in 2004 to 3826/m^2 in 2006. This illustrates how rapidly this species is increasing its range, and the level of effort needed to monitor the population for associated parasites.

Mitochondrial DNA from *M. tuberculatus* was analyzed from several locations in BNP to determine the probability of single vs. multiple introductions into the surrounding waters. To date it appears that only one introduction occurred in the Black Point area (consisting of samples from C-1 –Black Creek canal and the Black Point transect) and that the resulting population is clonal. The rapid growth of the *M. tuberculatus* populations is likely endangering the native populations of gastropods due to increased competition for food sources. *M. tuberculatus* have been used in the aquarium trade as an aggressive grazer on many algae types. *M. tuberculatus* offspring are live born (the eggs and the young brood internally), which can greatly increase the survival rates of the juveniles.

The presence of *Melanoides tuberculatus* in Biscayne National Park is a significant cause for concern for the following reasons:

- The subtropical temperatures of South Florida currently replicate their native habitat of Southeast Asia; this habitat range is likely to spread with projected global climate change
- Increasing range of a freshwater gastropod into the estuarine and marine environments increasing competition with native species
- Serves as an intermediate host to multiple human parasites endangering human health
- Serves as an intermediate host to multiple parasites on fish, shellfish, birds, and mammals endangering native animal populations.

Resource managers and the general public need to be aware of this non-native/invasive snail and take steps to prevent its spread and additional introductions.

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Resilience to Salinity Changes of the Non Native Freshwater Snail *Melanoides tuberculatus*

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The non-native gastropod *Melanoides tuberculatus* (Family Thiaridae: common name Red-Rimmed Melania) was identified by USGS researchers working in Biscayne National Park (BNP) in 2003. As an intermediate host for several human parasitic worms and multiple parasites on fish, shellfish, birds and other mammals *M. tuberculatus* is a concern for the public and Park management. A study to determine the distribution, genetics, salinity tolerance and threat to the native species that compete for a similar niche as *M. tuberculatus* was begun in 2004. One of the goals was to determine the likelihood of the marine waters of Biscayne Bay forming a saltwater barrier to the expansion of this freshwater snail into the estuarine and marine environments. The snail is present in significant numbers in areas frequently used by park visitors, including Black Point and other canals that are used for many recreational activities. Fishing in the canals is of particular concern due to the risk of fish infected by parasites from *M. tuberculatus*.

Research into the salinity resilience of *M. tuberculatus* was conducted in two different ways: gradual salinity changes over the course of weeks that would duplicate seasonal changes from wet to dry season, and rapid salinity changes that duplicate tide and storm/cycles. The snails used in the first trials were all taken from Black Point along a transect moving out from the mouth of the C-1 canal. Subsequent trials integrated snails from the C-1 canal above the control gates and other canal collections from above control gate locations. Salinities were changed on a weekly basis starting at 5ppt dissolved salts and increasing incrementally up to hypersaline (45ppt), and mid range/estuarine (20-25ppt) salinities. A third system was maintained at the 5ppt dissolved salts as an experimental control. Thirty individuals were used in each system and daily observations were made to monitor population changes, temperature, and salinity. The snails in both the estuarine and the marine systems increased the population size by 300% to 400% while the 5ppt system had no reproduction. The snails in the higher saline waters were maintained at the high salinities for three more months with no die-off. Juveniles grew at a steady rate with no apparent abnormalities. The rapid change (35-40ppt to 5-10ppt) salinity experiments had similar results with no fatalities. The snails would retract in their shells and go into stasis for more than twenty four hours when initially stressed, so normal tide cycles have little affect. When the water is left at the high salinity (40ppt) and the snail emerges, there was a 3% death rate.

These initial results raise important questions about what affect the native populations will suffer. Population growth in *M. tuberculatus* is rapid due to a combination of parthenogenesis and the live bearing of young (the eggs are hatched and brood internally) reproductive strategies used by this animal. Genetic studies are underway to determine if this local group is becoming highly tolerant to salinity changes in comparison to other Florida populations. Experiments are ongoing to compare the salinity resilience of the Florida population to the population from river environments in Texas. The Texas collections contain high numbers of *Centrocestus formosanus* cecaria a parasite that utilizes both *M. tuberculatus* and fish in different phases of its life cycle. Salinity resilience is being tested on the *C. formosanus* cecaria to determine if higher salt levels will stop parasite transfer between hosts.

The presence of *M. tuberculatus* and its apparent ability to withstand broad ranges of salinity raises multiple concerns for BNP and the visitors that use the Park everyday.

- With increased tolerance to salinity, native species of animals will be affected and possibly displaced in BNP
- As the populations and distribution of M. tuberculatus increases due to projected global climate changes the risk of parasite infection to humans will increase
- The parasite risk to fish, shellfish, birds, and other animals will increase as the habitat range increases

Resource managers and the general public need to be aware of this non-native/invasive snail and take steps to monitor and prevent its spread and additional introductions.

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Chronology of the Florida Department of Environmental Protection's (FDEP) Historic Involvement in Lake O Restoration

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From the inception of the State of Florida's Water Resources Act (Chapter 373, Florida Statutes) in 1972, the FDEP (then FDER) has worked in partnership with the South Florida Water Management District (SFWMD) and other agencies to implement Lake Okeechobee restoration measures. Those measures have included:

- **1985** – The Governor asked FDEP to take lead in conducting study of Lake Okeechobee – The Secretary of FDEP formed the Lake Okeechobee Technical Advisory Committee
- **1987** SWIM – The FDEP provided assistance and recommendations to the SFWMD to develop The *Interim Lake Okeechobee SWIM Plan* (1989) under Florida's 1987 Surface Water Improvement Management Act (Section 373.451.-.459, F.S.). The Lake Okeechobee SWIM Plan sets forth concrete mechanisms for achieving load reductions across the Okeechobee watershed.
- **1987** – The FDEP adopted and implemented the Dairy Rule (Chapter 62-670.500, F.A.C.), which required all dairy operations within the Okeechobee watershed and its tributaries to implement best management practices (BMPs) to reduce their phosphorus inputs to the Lake.
- **1994** – The FDEP participated in development of the Everglades Construction Project (ECP), which included diversion of four Chapter 298 special drainage districts and a drainage district on state owned lands (Closter Farms) away from Lake Okeechobee. The ECP was implemented through the Everglades Forever Act (Section 373.4592, F.S.).
- **1999** – In 1999, the FDEP initiated the development of a phosphorus Total Maximum Daily Load (TMDL) for Lake Okeechobee. This TMDL, adopted by rule in May 2001, establishes an annual load of 140 metric tons of phosphorus to Lake Okeechobee to achieve an in-lake target phosphorus concentration of 40 ppb in the pelagic zone of the lake. This restoration target will support a healthy lake system, restore the designated uses of Lake Okeechobee and allow the lake to meet applicable water quality standards. The annual load was calculated using computer models developed with guidance from the Lake Okeechobee TMDL Technical Advisory Committee. The entire load is allocated to the sum of all nonpoint sources.
- **2000** – The FDEP, in concert with the SFWMD and Florida Department of Agriculture and Consumer Services (FDACS), was instrumental in the passage of the Lake Okeechobee Protection Act (Chapter 373.4595, F.S.; LOPA) by the Florida State legislature. Through the LOPA, the implementing agencies (SFWMD, FDACS, and the FDEP) have developed and implemented strategies to restore the lake and its watershed.
- **2004 –** As an implementing agency, the FDEP and FDACS provided assistance and recommendations to the SFWMD in developing the Lake Okeechobee Protection Plan, which was submitted to the Governor and Legislature in XXX, 2004 as required by the LOPA. The LOPP a watershed-based, phased, comprehensive and innovative protection program designed to reduce P loads and implement long-term solutions, to meet the Lake

Okeechobee TMDL. Through the LOPP the Department, in concert with the SFWMD, bears primary responsibility for implementing source control measures in urban areas and also provides verification of the effectiveness of BMP implemented by FDACs in agricultural areas.

- **2007** – The FDEP provided assistance and recommendations to the FDACS in adopting the final statewide Urban Turf Fertilizer Rule. The rule limits the phosphorus and nitrogen content in fertilizers for urban turf and lawns, significantly reducing the amount of nitrogen and phosphorus applied in urban areas and limiting the amount of those compounds reaching Florida's water resources, including Florida's Liquid Heart, Lake Okeechobee.

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Water Conservation Area 1- A Case Study of Hydrology, Nutrient and Mineral Influences on Biogeochemical Processes

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At the northern tip of the remnant Everglades, Water Conservation Area 1, part of the Loxahatchee National Wildlife Refuge, is the only remaining softwater wetland within the Everglades ecosystem. Similar to the entire system, it has experienced altered hydrology, anthropogenic nutrient and mineral enrichment. The spatial pattern of this alteration is distinct, with biogeochemical processes driven as a function of their location along a north-south hydrologic gradient versus west-east nutrient and mineral gradients. While the influence of these factors on plant and in some cases, algal community composition, are apparent, the biogeochemical responses are more subtle.

Key characteristics of hydrologic effects on peatlands are their influence on carbon cycling. Thus, the drier oxidizing regions of the north, compared to the ponded environment in the south likely explains the 10-20 % lower average total carbon concentrations determined in soils in the northern section compared to the southern region. However, few biogeochemistry studies in WCA1 explicitly have examined hydrology and cycling, rather the majority of biogeochemical studies have focused on the effect of nutrients, especially phosphorus, and minerals on biogeochemical cycling.

Phosphorus is a limiting element in WCA1, with the majority stored in organic forms. Solution extracts of surficial floc and soil further defined the organic phosphorus pool to be primarily phosphate diesters, which are a main input of organic phosphorus to soils. Therefore its bioavailability is dependent on enzymatic conversion via phosphodiesterases. Both carbon and nitrogen cycling are strongly tied to phosphorus availability as evidenced by increased decomposition rates and inorganic nitrogen availability upon phosphorus loading. The spatial extent of phosphorus impacts is generally limited to the western boundary, with elevated concentrations in the northern region. While concentrations in soils close to the perimeter have remained fairly constant, recent statistical analysis suggest that a phosphorus enrichment front is expanding from the western and north-east edge towards the interior. Phosphorus effects are long-lived even with the elimination of inputs, as evidenced by a 5 yr field dosing experiment where depressed porewater nitrogen concentrations and elevated floc phosphorus concentrations were observed for 1-4 years following cessation of phosphorus loading.

Because phosphorus is subject to rapid uptake, phosphorus effects in WCA1 have, in recent history, been limited to within a few kilometers of the perimeter canal. In contrast, synoptic surveys have shown the intrusion of mineral rich water, demonstrated by high conductivity, sulfate and chloride levels, has a much greater spatial extent. The degree of penetration is dependent on the relative difference in water levels between the surrounding canal and the marsh interior. Mineral rich water can increase carbon turnover by increasing decomposition rates, likely through a combination of enhanced substrate quality as well as optimizing enzyme catalysis or organic substrates. The intrusion of sulfate, in addition to acting as an electron acceptor enhancing phosphorus availability, has significance in mercury methylation and the subsequent bioaccumulation of mercury.

In summary, WCA1 has three distinct environmental gradients, hydrologic, nutrient and mineral. The spatial extent of the nutrient and mineral gradient is tied to water stage in the canal and the marsh interior. Thus water management should be optimized to limit intrusion while also meeting water depth requirements for habitat and wildlife such that ecological tradeoffs are minimized.

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Biogeochemical Transformations and Transport Related to Flow in the Ridge and Slough Landscape

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Sediment dynamics have important implications for phosphorus (P) biogeochemistry and transport in Everglades wetlands despite a clear water column. A synoptic survey including WCA-1, WCA-2A, WCA-3A, and ENP found that suspended sediment held 31% of total P while its concentration was low (1.5 mg L^{-1}) and particle size was small (9 μm) across Everglades peatlands. Total particulate P concentrations increased from 0.10 μmol L^{-1} to 0.31 μmol L^{-1} while the total particulate N:P ratio decreased along the P-enrichment gradient in WCA-2A. However, total suspended sediment concentrations were similar along the P enrichment gradient, resulting in a three-times greater density of P in suspended sediment at the most P-enriched site. These biogeochemical characteristics of suspended sediment suggest that it is more reactive with P enrichment.

Sequential chemical extraction of suspended particles identified that P fractionation differed with particle size. Fine suspended particles (<100 μm) were dominated by microbial P (65%) with little refractory organic P (2%), while coarse suspended particles (>100 μm) held proportionally less microbial (39%) and more refractory organic P (37%). The density of P in fine particles is ten fold higher than in coarse particles, so that total suspended particle P fractionation is largely microbial (62%) with little refractory organic P (6%). There is very little information on P speciation in Everglades floc. However, we sequentially extracted the surficial 2 cm of peat soils and found that 45% and 31% of total P were held in refractory organic P and microbial P, respectively. The size and chemical fractionation information suggest that the fine suspended and P-rich particles mostly consist of suspended bacteria.

Redistribution of sediment from low elevation sloughs to higher elevation ridges is a leading hypothesis for the formation and maintenance of the Everglades ridge and slough landscape pattern. We tested this hypothesis by measuring the concentration and characteristics of suspended sediment and its associated nutrients in adjacent ridge and slough plant communities that were located in a region of the Everglades with the best remnant ridge and slough pattern (central Water Conservation Area 3A). The concentrations and characteristics of suspended sediment and particulate nutrients over two wet seasons were the same in ridge and slough plant communities. Total suspended sediment mass concentrations were on average 0.94 mg L^{-1} over the duration of the study. Total particulate N and total particulate P concentrations were 4.2 and 0.10 μmol L^{-1}, respectively, on average. Fractionation of P in suspended sediment was also similar in the ridge and slough. Only the concentration of TDP significantly differed, with 8% more dissolved P in the surface water of the ridge.

Despite the low concentration of particulate P in both ridge and slough, 28% of all surface water P was associated with suspended sediment. In contrast, only 5.6% of surface water N was associated with suspended sediment, in part due to the relatively high average TDN concentrations (75 μmol L^{-1}) relative to TDP (0.29 μmol L^{-1}). The mass-weighted, N-weighted, and P-weighted geometric-mean size of particles decreased from 8.6, to 5.2, to 2.9 μm, respectively. The uniformity in suspended sediment concentrations and characteristics suggests that sediment redistribution between ridge and slough is currently rare in the Everglades.

However, the downstream fluxes of suspended sediment and nutrients were roughly 2x greater in the slough than the ridge, due entirely to the greater unit-width discharge in the slough.

Spatial and temporal variation in suspended sediment and particulate nutrient parameters were only slightly related to the observed slow sheetflow velocities, suggesting that the critical shear stress that causes entrainment is not commonly exceeded in the modern Everglades. Spikes of elevated suspended sediment abundance were observed following a hurricane, at night presumably due to bioturbation, and when waters depths were shallow. High resolution sampling using a LISST suspended sediment analyzer revealed strong diel fluctuations in the abundance of the smallest suspended sediment size class. The concentration of particles in the 1.4-2.7 μm size class, which includes the most abundant size class of particulate P, increased two to three orders of magnitude following sunrise and decreased to very low levels following sunset.

A field experiment with enhanced flow velocities in a deep water slough did not change P fractionation in suspended sediment. Volume concentrations ($\mu L\ L^{-1}$) and size of suspended sediment increased; however, total particulate P concentrations and the P fractionation of suspended particles was unvarying and largely microbial P with little refractory P. Thus, advection of labile particulate P increased greatly. Restoration actions intended to increase sheetflow velocity will also transport more labile P downstream with sediment. A better understanding of the sources, transport characteristics, and fate of suspended sediment is needed to improve water quality models and predict the effect of restoration actions on the transport of P.

Implications for restoration include:

- Suspended sediment holds an important proportion of surface water TP, in relatively labile forms, despite its low abundance.
- Concentrations and characteristics of suspended sediment and associated nutrients were similar in adjacent ridge and slough under the current hydrologic regime, suggesting that ridge and slough geomorphology is not currently sustainable.
- Higher discharge results in greater downstream transport of labile particulate P with sloughs transporting more material than ridges.
- Water quality models should consider the transport and fate of dissolved and particulate forms of P.
- Restoration of greater water flow through the Everglades will result in faster spread of the P hotspot in northern WCA-2A to down-gradient unenriched areas through increased transport of P both in the particulate form and in the dissolved form.

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Development of a Sampling Prioritization Model to Optimize the Selection of Tree Islands in the Everglades Wildlife Management Area for Surveying of *Lygodium microphyllum*

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Predicting the probability of presence of the invasive fern, *Lygodium microphyllum*, from habitat characteristics would allow tree islands to be prioritized for intensive ground surveys. We analyzed data from previous *L. microphyllum* surveys, tree island elevation measurements, and hydrological parameters from the Everglades Depth Estimation Network model, to extract significant predictors of *L. microphyllum* presence on tree islands. A simple statistical model reveals a significant spatial trend in the *L. microphyllum* invasion. Analysis of the spatially detrended data revealed no additional effect of hydrology, although hydrology may be confounded with the spatial trend. We use our results to suggest further data collection that can test a model of *L. microphyllum* invasion as a simple spatial process.

- Prioritization of tree islands by likelihood of L. microphyllum presence would assist with ongoing monitoring and management of this invasive species.
- L. microphyllum invasion of tree islands is a spatial process that potentially depends on several habitat variables. Our analysis combines data from ground surveys, habitat measurements, and hydrological model output.
- The results suggest that simple topographic and hydrological variables do not explain the spatial pattern of L. microphyllum invasion. More detailed data on L. microphyllum habitat preferences may be required to predict its spread.

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Effectiveness of Drift Fences as a Method for Monitoring Fish Movement

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Data from drift fences can be treated as an encounter rate, which is an important parameter in modeling foraging. Movement rate could be estimated from encounter rate if an independent estimate of density is available. However, several factors complicate application of simple foraging models when applied to drift fence studies; particularly bias (attraction or repulsion of 'prey' to the traps) and loss (escape from the trap or consumption once inside). We are exploring the use of drift-fence data (catch per unit effort or CPUE) to calculate fish movement rates in Everglades habitats. We examined the effect of the length of sampling on loss of captured fish and bias in fish entering traps by testing differences in CPUE among three sampling-time treatments: two hours at sunrise, two hours at sunset, and twelve hours overnight. In separate work, we marked fish captured after two hours of soak time, replaced them in traps, and returned the next day to determine retention. Changes in number of marked fish provide a quantitative estimate of loss and comparison across species may provide evidence of sample bias. Preliminary results indicate that both crepuscular treatments yielded higher CPUE than longer overnight samples, but only minor differences in community composition. After completion of 86 trap nights, data on retention of marked fishes suggest a high level of turnover inside the trap. Community composition also differed significantly between two and twenty-four hours. We are currently developing use of video cameras to provide detailed records of capture history during sampling events.

This study can produce the following results relevant to restoration:

- Understanding fish movement rates will aid future planning of restoration projects;
- Understanding bias and efficiency of fish sampling methods will improve our ability to interpret monitoring data gathered in support of restoration efforts;
- Replacing minnow traps with cameras will permit documentation of fish movement without removal of the animals.

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Climate Change: Vulnerability Assessment and Modeling Scenarios for Water Resources Management in South Florida

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South Florida is home to over 7 million people and its population is projected to increase to over 10 million people by 2025 and possibly 12-15 million by 2050. Through Federal/State/Local partnerships, the Greater Everglades is being restored under numerous water resources management projects requiring large investments of time and money. Recent climate change projections as published in the most recent report of the Intergovernmental Panel on Climate Change (IPCC) have the potential to cause significant impacts on flood control and water supply functions of water resources management, and on existing and future ecosystem restoration projects in south Florida. More recent estimates of sea level rise for south Florida are much higher than those in the IPCC report and if such projections become a reality, consequences may be disastrous. It is extremely important to understand the extent of global projections for various emission scenarios, their ability to represent the climatology of local regions, and the potential vulnerabilities of both climate change and sea level rise on water resources management.

An assessment of the precipitation projections of the General Circulation Models (GCMs) shows that their ability to represent the landscape of Florida and predict historical climate patterns may be limited. In order to understand the vulnerability of the water management system in south Florida under changing precipitation and evapotranspiration patterns, a sensitivity analysis using the South Florida Water Management Model was conducted. The results show the vulnerability of projected climate change on water supply for all water sectors including the environment, and the potential impact of sea level rise on coastal regions. Adaptation strategies to manage impacts of climate change may be limited due to water management constraints such as flood control in urbanized areas. Questions on the potential impacts of climate change including sea level rise need to be investigated along with the uncertainties of projections to provide critical information for decision making on the planned infrastructure and operational changes in south Florida.

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Hydrologic and Hydrodynamic Modeling

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The natural hydrology of the southern Florida has been greatly altered through drainage, canalization, urbanization, and agriculture to an extent that the Everglades are now one of the most threatened ecosystems in the nation. Planning and implementation of unprecedented restoration projects are underway and hydrologic modeling for analyzing alternatives and providing design information for restoration projects has become essential for the success of the restoration efforts. The unique hydrology of south Florida, with its flat topography, high water tables, sandy soils, high transmissivity of the surficial aquifers, complex coastal systems together with an extensive water control systems, makes the southern Florida water management system one of the most complex in the world. Simulation models have become the only feasible means to estimate regional, subregional, and local impacts of proposed water management plans in south Florida.

Regional-scale (system-wide) hydrologic modeling using SFWMD's premier hydrologic model, the South Florida Water Management Model (SFWMM) has provided information for decision making for over three decades. This tool includes all the important components of the land phase of the hydrologic cycle as well as the system operating procedures and provided critical information of the development of the Comprehensive Everglades Restoration Plan. Often using the boundary conditions generated from a regional model, numerous subregional-scale hydrologic and hydrodynamic models have been developed for evaluating water management plans associated with urban, agricultural, and both inland and coastal ecosystems. These include, but are not limited to, groundwater models based on an enhanced version of MODFLOW, watershed models and estuarine models to integrate the linkage of surface and groundwater discharges into coastal estuaries/bays, and numerous hydrologic simulation models to evaluate the performance of restoration projects. Project-scale models have been used to provide critical information for both planning and design by simulating the project features at a high resolution allowing the inclusion of local processes important for such applications.

A focus of recent research at USGS has been to represent the complex hydrology of coastal areas in southern Florida. Coupled surface-water and ground-water models in coastal areas often require explicit representation of density effects and salt transport processes to account for the freshwater/saltwater interface, both in wetlands and the underlying aquifer. Additional transport capabilities are also required to account for factors that are important to ecologic concerns, such as temperature and nutrient concentrations. Several models have been developed to represent coastal flow and transport processes. The SWIFT2D code simulates hydrodynamic surface-water flow and transport in wetlands and estuaries. The SEAWAT code simulates three-dimensional variable density ground-water flow and solute transport. These codes can be used individually or simultaneously in a coupled version referred to as FTLOADDS (Flow and Transport in a Linked Overland/Aquifer Density-Dependent System). The U.S. Geological Survey has applied these programs in a variety of coastal settings in southern Florida, and has also developed procedures for linking these coastal models to the SFWMM. By using boundaries generated by the

SFWMM, the effects of restoration plans on the coastal hydrology can be assessed, and then transferred to offshore and ecologic models.

Efforts are underway to develop, implement, and apply the next generation hydrologic modeling tools. These include, but are not limited to, finite-volume based Regional Simulation Model, finite element models such as WASH-123D, Bayesian Ecological Models, and a new class for models in the field of hydrology known as Lattice-Boltzmann Models.

Decades of hydrologic modeling by various state and federal agencies have allowed the scientists and engineers to:

1. Understand the unique hydrologic processes in south Florida region and develop appropriate tools for evaluating restoration alternatives at regional, subregional and local-scales linking various subsystems of lakes, regional wetlands, aquifers, and receiving water bodies such as estuaries and bays,
2. Develop information on performance measures and performance indicators of various Everglades restoration alternatives and their effects on current and future water use in urban and agricultural sectors
3. Use new technology in simulation algorithms, software development, and GIS/Database techniques for the development of next generation hydrologic and hydrodynamic models useful for implementation of current and future restoration alternatives.

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The Yellow Book Nine Years Later: Unanticipated and Unresolved Issues

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The Comprehensive Everglades Restoration Plan (CERP) is the framework and guide for the restoration and preservation of the south Florida ecosystem. Although the "Yellow Book" was developed knowing that the system was not fully understood and that there would be unforeseen circumstances, the nine years of CERP planning and implementation since 1999 have been weighed down by a multitude of obstacles, unresolved issues, and unforeseen events impeding the conversion of the conceptual plan into implementable projects. Aside from funding constraints encountered during CERP implementation, many scientific and process issues have also hampered restoration progress in south Florida.

Large system-scale scientific issues encountered during CERP planning and implementation include: (1) the difficulty of agreeing upon the definition of success and (2) the recognition that all goals may not be achievable and restoration trade-offs might be necessary. Regional scale scientific issues include: (1) the difficulty of reaching consensus on tree island restoration goals and (2) the challenge of endangered species living in areas slated to be restored. Additionally, during development of the "Yellow Book" there was the assumption that hydrologic, ecological, and water quality models would be developed quickly and be able to support decision-making. One of the largest unaddressed problems faced by CERP is that although the plan was not designed to address the full range of water quality threats, CERP will fail to meet its restoration objectives unless water quality issues are resolved.

For many reasons, the challenge of planning and implementing CERP has led to a focus more on the success of individual projects and less on the success of restoration of the system. The difficulty of quantifying project-level benefits has been exceeded by the challenge of quantifying benefits at an ecosystem scale. A challenge that is also being faced by other large-scale ecosystem restoration programs. Although CERP was approved under the umbrella of adaptive management, it has been a challenge to apply adaptive management and to resolve ecological uncertainties. Cultural and institutional differences between agencies are additional challenges encountered with implementing CERP.

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Linking Nutrient Impacts on Microbial Community Structure and Function with Biogeochemistry in the Everglades

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The impacts of nutrient runoff into the northern Everglades are well documented with respect to changes in biogeochemical cycling, but it is through changes in microbial community structures and activities that these changes are affected. Considerable work in recent years has been devoted to characterization of changes in soil and periphyton microbial communities at various sites in the Everglades, thereby yielding greater insight into the impacts of nutrient enrichment on ecosystem function and the potential for development of rapid and sensitive indicators of nutrient status. Most work to date has focused on impacts of P on increased microbial activities and resultant biogeochemical processes, although recent work has recognized both direct and indirect impacts of nutrient enrichment on carbon and sulfur cycling in various environmental compartments.

Impacts on community structure

In a detailed study to understand the ecosystem-scale controls on soil microbial composition of selected tree islands (Black Hammock, Gumbo Limbo, Satin Leaf), Amplicon Length Heterogeneity –Polymerase Chain Reaction. (ALH- PCR) was used for semi-quantitative determination of microbial community structure. Our results show that there is significant difference between each tree island ecosystems for per cent total carbon (%TC), moisture content, microbial populations and pH in both surface and subsurface samples. ALH-PCR analysis showed a high relative ratio of 340-361 bp peaks in hammocks compared to bayheads and bayhead swamps. Diversity indices showed hammocks are more diverse than bayhead and bayhead swamps. We believe that diversity in tree island ecosystems may be driven by %TC and %TP under the influence of moisture.

In a separate study of the soil microbial communities in nutrient impacted and unimpacted areas of WCA-2A, the structures of prokaryotic groups that participate in the fermentation and mineralization of organic matter were characterized via a combination of approaches, including traditional and non-culture based methods. Significantly, assemblages of a range of functional groups differed between nutrient impacted and unimpacted soils. The species dominating physiologically-connected groups indicate very different pathways toward mineralization of organic matter, dependent on the nutrient status of the soil. The biological pathways through which acetate is processed and through which methane is produced depend on nutrient status. Stable isotope studies indicated that most acetate is consumed by syntrophic acetate oxidation in nutrient impacted soils, and by methanogens and sulfate reducers in unimpacted soils. In contrast to most terrestrial ecosystems, virtually all of the methane produced in nutrient impacted soils of the Everglades is via the hydrogenotrophic pathway, while a somewhat greater proportion of methane appears to be produced directly from acetate in unimpacted soils.

Enzyme activities

Most studies on enzyme activities have been geared toward understanding P cycling and availability. Phosphatase activity has been proven to be a good indicator of P limitation and an early warning indicator of P enrichment. Unfortunately, methodology varies widely, as does the analysis of the data, making direct comparisons between studies sometimes difficult. Overall, field gradient and P enrichment studies have shown that phosphatase activity within the water column, periphyton mats, detritus, and surficial soils are consistently elevated under P unenriched conditions, and decreases to low/undetectable levels when exposed to external P inputs. While both constitutive and induced are present, phosphatase activity is strongly tied to P concentrations. A recent study examining enriched and reference sites in all 3 Water Conservation Areas and Everglades National Park observed that phosphatase activity was significantly higher in unenriched portions of the ENP, which had the lowest TP concentrations, compared to other P limited areas.

The highest phosphatase activities are generally associated with the periphyton community. Using a fluorescent-labeled enzyme substrate, the location of in situ phosphatase activity was examined in thin sections of a periphyton mat. Most phosphatase producing organisms (PPOs) were concentrated in the lower section of the mat, and the phosphatase activity appears to be associated with heterotrophic organisms that are adjacent to cyanobacteria. The lack of observed phosphatase produced by photosynthetic cells and the close association of these cells with PPOs suggest an interaction wherein PPOs obtain photosynthetically fixed carbon from cyanobacteria and, in turn, provide inorganic phosphorus and other compounds to cyanobacteria.

While most studies of P cycling have focused on the turnover of monoesters, a recent NMR study highlighting relatively high levels of diesters in some regions has resulted in the addition of phosphodiesterase to the suite of enzymes measured in the Everglades. Other enzymes that have been measured in this ecosystem include those associated with the breakdown of cellulose (cellobiohydrase, B- glucosidase); nitrogen availability (aminopeptidase, protease), sulfur cycling (aryl sulfatase) and lignin degradation (phenol oxidase, peroxidase). For the majority of these enzymes, the distinct inverse relationship with distance from nutrient inputs as observed for phosphatase is absent. However, they show the same decreased relationship with soil depth, with highest activity measured in the detrital and floc layers at the soil surface compared to deeper depth increments.

Major findings include:

1. Microbial communities in flooded soils and tree islands respond to nutrient enrichments. Observed shifts in community structure provide detailed information on corresponding shifts in biogeochemical pathways;
2. Phosphatase production is greatest in periphyton, and is associated with heterotrophs;
3. Phosphatase production is a sensitive indicator of P limitation in soil.

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Spatial Distribution of Wetland Vegetation Surrounding Alligator Holes in Everglades National Park, FL, USA

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Alligator holes serve an essential role in the Everglades' landscape today by functioning as dry-season refugia for many species of invertebrates, fish, amphibians, and reptiles, and also by providing important nursery and foraging areas for many bird species. The American alligator, *Alligator mississippiensis*, maintains these small ponds due to its need for deeper areas of water (e.g., for courtship and mating) in an otherwise shallow marsh environment. Additionally, the disturbance created by resident alligators prevents vegetation succession (holes from becoming overgrown with aquatic and emergent vegetation) and increases habitat heterogeneity as the movement of soil to the edge of the hole creates banks of higher elevation supporting vegetation with different requirements for seed germination and survival. While the origin of any particular alligator hole on the landscape is not well understood, possible hypotheses include natural depressions in the limerock, excavation by alligators, peat fires, or some combination of these factors. Indeed, there is evidence that many of them were created as a result of peat fires that burned during a period of increased fire frequency and intensity in the Everglades system in the post-drainage era. Additionally, the edges of many alligator holes are dominated by willows, *Salix caroliniana*, providing increased support for a hypothesis of changes in fire regime contributing to a greater number of alligator holes on the landscape - reports as far back as the late 1950s indicate that willows had become a far more common component of the landscape as a result of the increased frequency of tree island fires. This line of thinking would suggest that the present-day number of alligator holes in slough habitat is much greater than in the pre-drainage system. Combined with the assertion by F. C. Craighead, that in the early decades of the twentieth century, the preferred habitat of alligators was predominately the freshwater marshes and creeks to the landward side of mangrove zone and marl prairie, it seems very likely that a shift in alligator distribution in the twentieth century has resulted in a landscape and ecosystem that is completely novel. With the aim of both understanding how the current landscape evolved and how distribution of alligators and their resultant effects on the landscape will shift as a result of proposed changes in water delivery to Everglades National Park (ENP) from CERP, this research attempts to characterize the spatial variation in the current vegetation composition of alligator holes. Specifically, we explore the relationships between vegetation composition and physiographic region, hydrology, and maintenance by resident alligators, compare the extent of the current distribution and composition of alligator holes to historical conditions (1940s), and attempt to predict the successional trajectory of these holes.

To quantify the current vegetation surrounding alligator holes within ENP, a stratified random sample of alligator holes was selected in physiographic areas in which holes had been mapped from Digital Orthophoto Quarter Quads (DOQQs) and verified by helicopter in 2005. From January 2006 through August 2007, sixty-two alligator holes were visited and sampled in slough and marl prairie habitat within ENP. Sampling was done using two perpendicular transects that extended from the center of each hole, running through the ecotone and into the surrounding marsh. Water depth and muck depth were measured at 1-meter intervals, and vegetation was sampled using the line-intercept method. Additionally, the presence of alligators and other wildlife was noted at each alligator hole. Vegetation communities in three zones along the transects were characterized by using a moving split-window method. EDEN stage data was used to normalize water depths between different dates of sampling. Vegetation-environment relationships were analyzed using Non-Metric Multi-Dimensional Scaling (NMDS), and relationships between ordination axes and two environmental gradients, water depth and physiographic location, were examined. We used 1940s aerial photography to determine if present-day alligator holes were present on the landscape at that time, with the presence or absence of open water and/or alligator trails used as an indicator of presence of an alligator hole. Changes in the surrounding vegetation were noted where this was readily discernible from the imagery. Results of the ordination and image interpretation provided a basis to speculate about the effects of changes in water regime on alligator hole occupation and maintenance. A view from the past to present day vegetation composition surrounding alligator holes provides useful insights into the future of the system. We propose that future research take a systems' view of the landscape, synthesizing work from all physiographic areas within the Everglades where alligators have served as ecosystem engineers.

- Alligators were observed at approximately 50% of sampled alligator holes and evidence of use was noted at the majority of holes.
- *Salix caroliniana* was a dominant species in approximately a third of sampled alligator holes and the presence of this species varied based on physiographic area.
- The composition of vegetation communities surrounding alligator holes is being determined by hydrologic gradients, physiographic area of ENP in which they occur, and active maintenance by alligators.

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Ridge Senescence of *Cladium jamaicense* in the Florida Everglades

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A phenomenon described as sawgrass (*Cladium jamaicense*) die-off, senescence, or decadence has been widely observed in the Water Conservation Areas and Shark River Slough of the Florida Everglades at various times in the last 30 years. However, only limited quantitative and sparse observational data exists to determine how extensive these events are and what mechanisms may be causing these events at the landscape scale. Even the terms have not been adequately defined to communicate the meaning of these events in the ridge slough landscape. Because organic matter accretion on the ridges is thought to be a critical component maintaining the elevation difference between ridges and sloughs, loss of carbon assimilative capacity on the ridges due to ridge senescence events may have significant negative impacts on the long-term viability of the ridge slough landscape. This study aims to develop quantitative definitions for different types and sawgrass mortality events that have been observed within the ridge slough landscape and will determine the severity (rate of incidence and percent of ridges affected) of ridge senescence of sawgrass. The work presented here consists of preliminary data from aerial reconnaissance of 12 Probabilistic Sampling Units (2 km x 5 km) selected to represent areas with prominent ridge slough landscapes (Water Conservation Area 3A, 3B, and Everglades National Park). Aerial photography, Digital Orthophoto Quarter Quadrangles (DOQQs), and ground truthing were employed to classify several types of ridge senescence and to quantify the extent of impact at the landscape level. We propose the following definition for ridge senescence: any contiguous area of sawgrass mortality greater than 75%. We also propose the following working definitions for three types of sawgrass mortality recently identified within the ridge slough landscape.

- **Type I**: Large patches ($>100m^2$) of sawgrass mortality (>75%) that typically occur on the upper most elevations of the ridge. Healthy sawgrass often surrounds the dead sawgrass on the ridge top forming a buffer or halo between the slough and the ridge top. Vegetation remaining on the ridge tops often include *Cephalanthus occidentalis* along with a few remnant sawgrass tussocks.
- **Type II**: Small patches ($<100m^2$) of sawgrass mortality (>75%) that are typically isolated within an otherwise healthy stand of sawgrass on the upper elevation of the ridge. Shape of senesced area can be linear or circular.
- **Type III**: Linear patches of sawgrass mortality (>75%) often paralleling the outer edge of a sawgrass ridge. Width of the dead sawgrass feature ranges from 1-3 meters and length can be up to 500 meters or more. One proposed mechanism of formation is the accumulation of periphyton wrack that resulted from hurricane Wilma, which passed over this area in 2005.

Findings from this project will provide the following information to support Everglades restoration:

a) definitions of ridge senescence that can be used to describe and communicate the type and occurrence of events

b) quantification of the extent to which ridge senescence is occurring within the ridge slough landscape, and

c) tools to identify the occurrence of ridge senescence using, DOQQ images and other remote sensing platforms

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Think Locally, Act Neighborly

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Invasive species know no boundaries and continue to degrade Florida's declining habitats. If landowners and land managers wish to achieve long term success, it is critical for them to reach out and collaborate with all stakeholders, including private landowners.

The Florida Invasive Species Partnerships (FISP), originally formed in 2006 under the Invasive Species Working Group as the Private Land Incentive Sub-working Group, is striving to focus statewide efforts on prevention as well as treatment. By working together, we hope to encourage development of innovative management approaches, provide new tools, decrease implementation costs, and ultimately increase effectiveness. During 2006 and 2007, FISP developed the dynamic "Incentive Program Matrix" of existing federal, state and local funding sources, incentive programs and technical assistance for private landowners in Florida. The interactive matrix database will allow both private and public land managers to determine what current technical and financial assistance is available to best suit their specific needs and coordinate control efforts across boundaries. In 2007, FISP began promoting the concept of Cooperative Weed Management Areas (CWMA) in Florida. The goal of this effort is to encourage development of local partnerships between federal, state, and local government agencies, tribes, individuals and various interested groups to manage noxious weeds or invasive plants in a defined area. To date, there are 10 CWMAs developing across Florida from Walton County to the Florida Key's Invasive Task Force. The Incentive Program Matrix and locally led CWMAs allow us to expand invasive species management efforts across the landscape and build community awareness.

These coordinated efforts serve to protect our valuable conservation areas, public lands and private lands from the continuing colonization of invasive species across the landscape.

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Sulfate Contamination of the Everglades Ecosystem: Review of ACME Findings 1995-2008

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Since 1995, the Aquatic Cycling of Mercury in the Everglades (ACME) group has been examining the biogeochemical controls on the production and bioaccumulation of neurotoxic methylmercury in the greater Everglades ecosystem. The ACME team has produced a wealth of field and experimental data supporting a working conceptual model of mercury methylation in the Everglades, and providing key inputs for the development of a mercury cycling model for the Everglades. Perhaps one of the more surprising outcomes of ACME research has been the documentation of extensive sulfur contamination in the Everglades, and the elucidation of the role of sulfur as a major control on mercury methylation.

Freshwater wetlands typically have low sulfur concentrations, but uncharacteristically high levels of sulfate in surface water and sulfide in soil porewater have been documented by studies conducted by ACME and the U.S. Environmental Protection Agency (EPA). Recent EPA work indicates that about 60% of the ecosystem has concentrations of sulfate in surface water above the 1 mg/L level proposed by ACME to represent the upper limit of background sulfate in the Everglades. Average sulfate concentrations in surface water of marshes of the northern Everglades are up to 60 mg/L, compared to <1 mg/L in pristine parts of the ecosystem to the south. The north-south gradient in sulfate concentration reflects the discharge of canal water with high concentrations of dissolved chemical constituents, including sulfate, into marshes in the northern part of the ecosystem. The canal water originates from Lake Okeechobee and passes through the Everglades Agricultural Area (EAA) where it receives runoff from agricultural fields. Contamination of the Everglades by phosphorus from canal water discharged into the ecosystem, and its impacts on the ecosystem have been well documented, but contamination by other chemical species (including sulfate) has only recently been acknowledged as a problem, and the effects of this contamination on the ecosystem are not fully known.

Sulfate entering wetland ecosystems stimulates microbial sulfate reduction (MSR) in anoxic wetland soils. MSR reduces sulfate to sulfide through the metabolic activity of sulfate reducing bacteria, which are also the primary agents responsible for the methylation of mercury in most wetland ecosystems studies to date. MSR plays an important role in wetland soils through the degradation of organic matter, the recycling of nutrients, the regulation of redox conditions, and the control of metal concentrations. The presence of sulfate in wetlands is a key driver of mercury methylation.

Major Conclusions from ACME studies of sulfur and mercury in the Everglades include the following:

- Excess sulfate originates from EAA canal discharge. Isotopic data is consistent with sulfur used in agriculture (current applications and legacy in soil) as a primary source of the excess sulfate. Currently available data does not support groundwater, rainwater, or dry deposition as a major source of sulfate to the Everglades.

- A unique combination of conditions in the Everglades, including high mercury deposition, sulfate contamination, and favorable environmental conditions (extensive wetland area, wet/dry cycles, high dissolved organic carbon) produce high levels of methylmercury production and bioaccumulation.
- Buildup of toxic sulfide in Everglades' soils from stimulation of MSR by sulfate contamination makes soils more reducing, impacts macrophyte growth, and may impact other flora and fauna. Greenhouse experiments conducted at Louisiana State University show that growth of sawgrass is adversely affected by sulfide toxicity at sulfide levels above 9 ppm. Concentrations as high as 13-15 ppm have been observed in heavily sulfur-impacted parts of the northern Everglades where sawgrass has been replaced by cattail.
- Mesocosm studies in the Everglades have demonstrated that sulfate loading at levels equivalent to those observed at sulfur-contaminated sites in the northern Everglades enhanced remobilization of ammonium, phosphate, and dissolved organic matter from soils to porewater and surface water, and dramatically reduced redox conditions in the soil.

Current restoration plans to deliver more water to the Everglades will likely increase overall sulfur loads to the ecosystem. Delivery of sulfate-contaminated water to areas like Everglades National Park, ARM Loxahatchee National Wildlife Refuge, and Big Cypress National Preserve through the canal system may cause harm, and sheet flow over expansive marsh areas that reduces sulfate loading is preferable. Dry/rewet cycles have been shown to temporarily increase surface water sulfate concentrations (due to oxidation of reduced sulfur in soil), stimulating MSR and methylmercury production. Although dry/rewet cycles are a natural phenomenon in the Everglades, current water management practices and present conditions of sulfur-contaminated soils and high atmospheric mercury deposition make these cycles more damaging by exacerbating methylmercury production and bioaccumulation. Minimizing dry/rewet cycles would help limit methylmercury production in the Everglades. Monitoring data suggests that the ecosystem response to declines (or increases) in sulfate loading is rapid. A decline in sulfate concentrations in surface water in the central Everglades during the late 1990s resulted in a rapid decline in methylmercury production and bioaccumulation there within 3-7 years. Because of the serious impacts of sulfate on the Everglades, and the rapid response of the ecosystem to reductions in sulfate loading, a comprehensive Everglades restoration strategy could include reduction of sulfur loads as a goal. It is clear that any reduction in sulfate loads entering the Everglades will benefit the ecosystem's overall health. A multifaceted approach employing reductions in the many uses of sulfur in agriculture, investigation of methods for passive sequestration of sulfate as solid-phase reduced sulfide, and reengineering of existing stormwater treatment areas (STAs) for better sulfate sequestration will help achieve lower overall sulfate levels in the Everglades, and resulting benefits.

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Landscape Scale Patterns of Significant Nutrients and Contaminants in the Greater Everglades Ecosystem: Past, Present and Future

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Investigations of biogeochemically relevant nutrients and other potential contaminants of concern at the landscape level not only provide restoration scientists with a landscape level perspective of the current status of these critically important parameters, but also allow for the tracking of changes on the landscape level over time. Determination of change at this scale allows for critical evaluation of the success of CERP related activities.

The data and landscape pattern interpretations presented here contain the most up to date status of the Greater Everglades Ecosystem with respect to nutrients such as carbon, nitrogen, phosphorus, and sulfur, as well as contaminants such as mercury. Landscape units include Water Conservation Areas 1, 2A, 2B, 3A, and 3B, Holey Land, Rotenberger, Big Cypress National Preserve, and Everglades National Park. Comparisons to selected older data sets will be presented which support change detection at the landscape level. Future directions and needs for landscape analyses and monitoring will be discussed.

- Landscape level analysis and mapping of elements of interest are useful in determining areas of significant impact and predicting areas of future impact.
- Comparison of landscape level patterns on a temporal scale provides critical change detection at the ecosystem level and evaluation of the effectiveness of efforts to control mercury and phosphorus.

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Cost Effective Regional Phosphorus Concentration Mapping of Oligotrophic Open Water Systems

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A preliminary data set from a pilot program conducted in periphyton stormwater treatment area (PSTA) mesocosms shows that light absorbing properties of dissolved organic carbon (DOC) decrease while the concentration of total phosphorus (TP) also decreases. Evidence from DOC stable isotope values, supported by measurements of DOC light absorption, suggests that new DOC is being produced in the mesocosms. The emerging hypothesis is that the periphyton communities in these mesocosms produce new DOC that is uncolored. The effect of this new DOC production is an increase in DOC concentration and a shift in the stable isotope values reflecting this new carbon source. Further, the new DOC produced dilutes the light absorbing properties, demonstrated as a decrease in the colored dissolved organic matter (CDOM) absorption at 412 nm and a decrease in the spectral slope coefficient (S-value). Driving this production of new, uncolored DOC is the removal of TP by the periphyton communities.

Hyperspectral imagery (HSI) must be acquired simultaneously with CDOM measurements to completely develop the algorithm relating the change in the S-values with a similar change in slope coefficients from HSI spectra. No other combination of CDOM, DOC, and TP data exist that elucidate these possible mechanisms. The hypothesis that periphyton produce low-CDOM DOC must be rigorously tested in the mesocosms and in the treatment cells to document the efficacy of this relationship. We caution that, lacking HSI data, we do not know how robust algorithm development will be, thus the need for further study. The key finding relevant to restoration is the ability to scale up CDOM:TP relationships to remote sensing platforms (ideally, CASI-type HSI instruments on fixed wing aircraft) promises to increase cost-effectiveness for water treatment systems such as PSTA. This study provides some of the first evidence that such a strategy is scientifically valid.

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Characterization of Tree Island Hydrology in the Central Everglades: An Application of the EDEN Water Surface Model

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Restoration of degraded tree islands and protection of intact islands are among the goals for restoration of the Everglades ridge and slough ecosystem. Current restoration plans predict dramatic changes in water depth patterns over extensive portions of the Everglades where large numbers of tree islands are embedded in the ridge and slough landscape. In order to predict how these changes will affect plant community composition, extent, and spatial patterning of tree islands and adjacent sloughs, it is necessary to characterize the topographic gradients and current hydrological conditions for a large number of tree islands across a large spatial extent.

From August 2005 through February 2008, water depth data were collected at 257 tree islands and adjacent sloughs in Water Conservation Area (WCA) 3B and central and southern WCA 3A. Tree islands were chosen by a stratified random design to ensure sampling across a representative range of tree island sizes. Water depths measured on a given day were related to water surface elevation data, generated by the Everglades Depth Estimation Network (EDEN) for the same day, to determine the offsets between the EDEN water surface and the ground level of the tree islands or sloughs; offsets were then used in combination with the EDEN time series data to generate the hydrograph of water depth for each tree island and adjacent slough. Measures of hydrological conditions were derived from the resulting hydrographs for the period from January 2000 through December 2007.

Comparisons of inundation depths, hydroperiod and ground surface slopes from tree islands to adjacent sloughs showed significant spatial trends. The ground surface slopes associated with tree islands were significantly flatter in WCA 3B (0.0053 ± 0.00059) than in central or southern WCA 3A (0.0077 ± 0.00034 and 0.0073 ± 0.00035, respectively), but there was no significant relationship between tree island size and ground surface slope. Results from such geostatistical analyses underscore the importance of understanding the relationship among tree island hydrology, community composition and landscape pattern for Everglades restoration:

- Increases in water flow, duration, and levels may lead to adverse effects from flooding of tree islands.
- Restoration efforts should aim at minimizing ponding in WCA 3B where the relatively flatter ground surface slopes of tree islands increase the potential for adverse effects.
- The ground surface slope of tree islands may be a more important predictor of the potential for adverse effects of flooding than tree island size; large, relatively flat tree islands may be more susceptible to adverse impacts than small, steeper tree islands.
- The EDEN water surface model can serve as a valuable tool for characterizing current and historic hydrological conditions in the Everglades and assessing the potential impacts of restoration.

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Modeling Spatio-Temporal Phosphorus Cycling in a South Florida Stormwater Treatment Wetland

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A spatially distributed water quality model was applied to simulate spatio-temporal phosphorus (P) transport and cycling in a stormwater treatment wetland in South Florida. An integrated modeling framework has been constructed coupling hydrologic and biogeochemical models for marsh wetland systems. This paper examines model performance in predicting total P removal in Cell 4 of Stormwater Treatment Areas 1 West (STA 1W). STA-1W is located in central Palm Beach County, along the northwestern boundary of Water Conservation Area 1 (WCA-1) and on the eastern boundary of the Everglades Agricultural Area (EAA). The STAs are used as buffers to reduce concentrations of nutrients such as P from EAA runoff before entering the adjacent WCA-1. The model includes transport and biogeochemical transformation of P and is based on primary mechanisms regulating P behavior in soils, water column and biomass. The biogeochemical model was linked with the South Florida Water Management District Regional Simulation Model (SFWMD/RSM). In this application, biogeochemical processes were simulated with spatially variable uptake and release parameters between water column and soil stores. The model calibration was performed to fit two years of field measurements, and verified over three additional years at two sampling stations. Model performance was further examined by simulating and comparing the results with non-reactive tracer study (Rhodamine-WT dye) described by Dierberg et al. (2005). Water flow and total P concentrations data were obtained from SFWMD online environmental database (DBHYDRO). The results show that the simulated outflow, water level, non-reactive tracer and total P concentrations correspond well to field observations in both spatial and temporal variations.

Many existing P models that are applicable to treatment wetlands are empirical, and do not necessarily establish cause and effect relationship. On the other hand, spatially distributed, process-based models are able to simulate in spatial scales with varying operating conditions. The model developed in this study provides a complete answer in projecting responses to short- or long-term management options and questions along the spectrum of temporal and spatial variations. The demonstration of the water quality model in Cell 4 of STA 1W provides:

- An efficient means of predicting and assessing the performance of P removal in stormwater treatment wetlands.
- Insights in to the influence of dominant mechanisms and key parameters in removing P from marsh wetland systems.
- An estimation of key model parameters in submerged aquatic vegetation (SAV) dominated wetland

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Data Communication and Decision Support Tools in Everglades Restoration

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Computer-based decision support tools are important for adaptive management because they help provide a bridge between complex, multivariate, and interdisciplinary datasets which decision-makers can use to measure overall impacts of management actions. However, decision-makers using these tools must balance the goals of including as much specific, relevant information as possible without including overwhelming, irrelevant data that can add "noise" to important trends. Scientific experts are typically relied upon to help interpret data and determine the most relevant measures. A multi-agency, interdisciplinary project such as the Comprehensive Everglades Restoration Plan must be able to incorporate all relevant data and often relies upon the scientific expertise of a diverse group of individuals from various agencies to collectively interpret and determine what data belongs in the decision-tools. The goal of this research is to ask (1) How are data communicated from the initial collection of primary data to its incorporation in decision tools? (2) How frequently are agencies communicating about data and (3) How well are experts in different disciplines integrating their data sets? Using a set of survey questions about data use and communication, we will apply social network analysis to analyze links among agencies and experts to help understand how the structure of communication networks affects data sharing in the CERP project.

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Wintering Bird Area Occupancy in a Mosaic of Harvested and Un-harvested Sugarcane Fields

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Landscape changes occur in both natural and human-influenced landscapes and may be due to disturbance such as fire or hurricanes in natural habitat and harvest or clearing in agricultural landscapes. Such alterations may be sudden and dramatic. We studied landscape vegetation change in an agricultural system in south Florida. The sugarcane fields of the Everglades Agricultural Area grow to a height of over three meters and produce a dense monoculture that is used by a small number of breeding songbirds. Migrating and wintering songbirds utilize these agricultural fields resulting in an increased number of birds during fall, winter and spring. Our study focused on birds that were present during harvesting activities. Harvest occurs during the winter and changes the landscape from one of tall, abundant vegetation to fallow fields within a few months. We established 243 study sites throughout a 1500 km^2 area and surveyed wintering birds for occupancy of tall, medium and short sugarcane fields. In addition to sugarcane height, we also measured edge vegetation characteristics and canal water level. Proportion area occupied analysis (PAO) is a statistical measure of occupancy in a particular habitat. We estimate PAO by each species in each habitat type.

Key findings of this research included:

- The most common passerines within the sugarcane habitat were common yellowthroat (*Geothlypis trichas*) and palm warbler (*Dendroica palmarum*). Common yellowthroats were most widespread in tall cane and least widespread in short cane. Palm warblers were equally prevalent in all habitats.
- Red-winged blackbirds (*Agelaius phoeniceus*) were abundant in all sugarcane heights and killdeer (*Charadrius vociferous*) were present in nearly all newly harvested fields.
- Edge vegetation height influenced the presence of some species while others seemed to respond more to edge height.
- Birds species responded to habitat change by occupying appropriate agricultural field types or moving to nearby alternate habitat such as edges.

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Florida Bay Estuarine Habitat Suitability Assessments of Restoration and Sea-Level Rise Interactions

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The coastal habitats of Everglades National Park are at the end of the hydrologic restoration chain, but are the first areas to be impacted by sea-level rise. Both restoration and sea-level rise may cause substantial spatial changes in habitat availability and location. The purpose of this study is to predict potential effects of the interaction of sea-level rise and restoration alternatives on shallow, estuarine habitats for Florida Bay indicator species. Habitat suitability models were constructed for juvenile spotted seatrout (*Cynoscion nebulosus*), eastern oyster (*Crassostrea virginica*), blue crab (*Callinectes sapidus*), and, later, turtle grass (*Thalassia testudinum*). The habitat models are coupled to TIME hydrologic model outputs for restoration and sea-level rise scenarios. An interactive user interface aids exploration of habitat changes and planning options from the interaction of upstream flow restoration projects with sea-level rise. This study is part of a developing program to provide assessment tools for making landscape-level restoration decisions that maximize biodiversity within an ecological system and spatially models how hydrologic targets relate to the landscape-scale assemblages of habitats needed to support Everglades National Park fish and wildlife resources.

Key findings of this new landscape modeling activity include:

- Identification of potential spatial shifts in distribution and habitat suitability for key focal species,
- Applicability of coupled hydrological, ecological, and landscape models to decision-support for coastal Everglades restoration.

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Preliminary Archaeological Context for the Everglades Restoration Study Area - A Cooperative Effort between the South Florida Water Management District, United States Army Corps of Engineers, the State Historic Preservation Officer, Janus Research, and New South Associates

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As part of the Comprehensive Everglades Restoration Plan (CERP), the South Florida Water Management District (SFWMD) requested that Janus Research prepare an updated archaeological context for the CERP Cultural Resources Investigation Area. The preliminary archaeological context that was developed as a result follows the model already established by the Florida Division of Historical Resources (FDHR) and detailed in *Archaeological and Historic Contexts from the Comprehensive Historic Preservation Plan* (1993). The purpose of the revised context was to identify and describe significant patterns of cultural development that took place within the region beginning with the Paleoindian period and extending through the post-Archaic periods.

The objective was to develop an interim document for use by the internal Comprehensive Everglades Restoration Project (CERP)/ACCELER8 cultural resource management team. This interim document is not intended to be an exhaustive review of the archaeological literature nor should it be considered a definitive revision of the existing contexts. Rather, this document is intended to provide a preliminary revision of the existing 1993 South Florida contexts that is pertinent to the CERP/ACCELER8 project area. It is intended, along with a companion document developed by the United States Army Corps of Engineers (USACE), to be a component of a research design for the Everglades Restoration Cultural Resources study area. As such, both documents represent joint efforts by the SFWMD and USACE.

This context was developed through an updated literature review and synthesis of major previous investigations conducted within the CERP Cultural Resources Investigation Area. This investigation area encompasses portions of Broward, Charlotte, Collier, Miami-Dade, Glades, Hendry, Highlands, Lee, Martin, Monroe, Okeechobee, Palm Beach, and St. Lucie counties, Florida.

The importance of this undertaking is underscored by the fact that, although over 1,700 Precolumbian archaeological sites have been recorded within the CERP Cultural Resources Investigation Area, relatively little is known about the archaeology of the area. Instead, most archaeological research in southern Florida has focused on larger and/or more accessible coastal sites.

This synthesis indicates that current models for the archaeology of post-Archaic (post 2,500 BP) southern Florida are generally useful, although more research still needs to be conducted for certain areas and time periods. By contrast, this study also indicates that previous models for the Archaic period (11,500 – 2,500 BP), especially the Late Archaic (5,000 – 2,500 BP), of southern Florida are probably inadequate. Our understanding of the archaeology of southern Florida for this time period is still in a transitional phase as more research is done and more data is collected.

As further research is conducted, it is hoped that this context will serve as a framework within which archaeological sites identified in the future can be evaluated according to the eligibility criteria established by the National Register of Historic Places (*NRHP)*. It will also allow informed decisions to be made regarding the appropriate treatment of archaeological resources located within the Everglades Restoration Cultural Resources project area.

- Because of the scale of the lands purchased for CERP related projects, an opportunity exists to increase and refine what is known about the cultural resources of the greater Everglades area.
- Cooperation between state and federal agencies is imperative to ensure appropriate handling of cultural resources that may be affected by CERP projects while still working to achieve the goals of Everglades Restoration.
- State and Federal agencies coordinate frequently with the Miccosukee Tribe of Indians of Florida and the Seminole Tribe of Florida during CERP project planning to ensure both tribes are involved in discussions concerning cultural resources.
- Tools and methods used to locate and identify cultural resources in the greater Everglades region need to incorporate the latest findings in order to maximize their utility.
- The definition of what makes a cultural resource eligible for protection needs to be explored in the framework of the cultural resources investigations being performed for the CERP projects.
- There is a great variety of cultural resources in the Everglades Cultural Resources Study area, requiring innovative approaches to management of those resources.

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Atmospheric Deposition of Nutrients and Contaminants

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Atmospheric deposition can be the predominant pathway for a number of critical chemical species entering the Everglades landscape. For example, based on measurements of total mercury in both runoff and wet deposition, Atkeson et al. (2003) estimated that over 99% of the mercury delivered to the Everglades Protection Area is due to direct inputs of atmospheric mercury. Likewise, for portions of the Everglades relatively far removed from canal discharges or hydrologically disjoint from the canal system draining the EAA (such as the interior of the Loxahatchee National Wildlife Refuge), atmospheric deposition is the primary source of phosphorus. This paper is a synthesis of both historical and ongoing measurements of the atmospheric depositional flux of a series of nutrient and contaminants of critical interest in the Everglades, including phosphorus, nitrogen, sulfate, and mercury.

Atmospheric deposition occurs via two broad processes: wet and dry deposition. Of the two fluxes, wet deposition is comparatively straightforward to measure, although considerable care needs to be undertaken regarding collection technique and sample processing. Techniques for measuring dry deposition directly are operationally defined and, given the heterogeneity of physical landscapes such as the Everglades, difficult to translate to ecosystem levels. As a result, most dry deposition measurements are inferential based on measuring ambient air concentrations coupled with an estimate of appropriate deposition velocity that can vary given differing meteorology, surface landscape features and surface roughness. Given the complexity of and large uncertainty in dry deposition measurements, most studies on atmospheric deposition have focused on measuring wet deposition alone.

Of the contaminants considered in this paper, the most well-studied with respect to atmospheric deposition is mercury. Wet deposition studies of mercury in the Everglades region span the spectrum of both spatial and temporal scales, ranging from the highly intensive South Florida Atmospheric Mercury Monitory Study (SoFAMMs; 17 sites within the urban south Florida fringe, measurements of wet deposition and aerosol chemistry daily for one month in 1995; Dvonch et al., 1999) to the spatially extensive Florida Atmospheric Mercury study (FAMS; up to 10 sites across Florida, including three Everglades sites and one at the western edge of the Big Cypress National Preserve, with monthly integrated samples between 1992 and 1996; Guentzel et al., 2001). Currently, monitoring of wet deposition of mercury in the Everglades is conducted at three sites in south Florida as part of the Mercury Deposition Network (MDN). One of the MDN sites located at Beard Research Center in the Everglades National Park (ENP) contains the third longest unbroken period of record of mercury wet deposition in the United States, with measurements extending back to late 1993 initiated as part of the FAMS program.

Dry deposition of mercury in the Everglades has also been the focus of two studies using different techniques. As part of the Florida Everglades Dry Deposition Study (FEDDS), Marsik et al. (2005) used micrometeorological and dynamic flux chamber techniques to study the air-surface exchange of gaseous elemental mercury over a mixed sawgrass/cattail marsh within Water Conservation Area 3. In addition, Keeler et al. (2003) computed daily fluxes of dry deposited reactive gaseous and particulate mercury across the Everglades for June 1995 through June 1996 based on modeled emission fluxes and meteorology.

Measurements of nitrogen and sulfate in wet deposition in the Everglades are available only through monitoring of weekly fluxes of these two constituents in conjunction with other major ions at the National Atmospheric Deposition Program (NADP) site at the Beard Research Center in the ENP. Wet deposition of major ions at this site began in June 1980 and temporal trends in nitrate, ammonia, and sulfate deposition will be discussed. Dry deposition fluxes of nitrogen and sulfur species are currently estimated at more than 80 sites across the United States as part of the Clean Air Status and Trends Network (CASTNET), including one site co-located with the ENP NADP site. Each CASTNET site measures weekly average atmospheric concentrations of sulfate, nitrate, ammonium, sulfur dioxide, and nitric acid, as well as meteorological conditions required for calculating dry deposition rates.

Although phosphorus has not been included as part of the NADP, there are a couple of studies to help define the magnitude of this flux to the Everglades landscape. Wet deposition studies of phosphorus include the ground-breaking work of Hendry et al. (1981), who measured wet deposition of phosphorus and major ions at five sites throughout Florida during 1978 – 1979. Pollman et al. (2002) subsequently measured wet deposition of phosphorus as part of the FAMS. A comparison of results between the two studies suggests the importance of scrupulous, clean protocols when collecting wet deposition samples for trace contaminants. For example, the volume weighted mean concentration and flux for wet deposition across the FAMS study sites averaged 0.005 mg/L and 7.5 mg P/m^2-yr, respectively, which is approximately 50% and 32% lower
than reported by Hendry et al. (1981). Pollman et al. attributed their lower measurements to three factors: (1) the ultra-trace element sampling and analytical protocols; (2) improved collector design to eliminate sampling artifacts (e.g., splash-off contamination and transfer of contaminants from the dry bucket); and (3) placement of collectors off the ground surface. No reliable estimates for the dry deposition of phosphorus within the Everglades are available, and the implication of the omission of this flux from a mass balance modeling perspective will be briefly discussed.

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An Evaluation of the Impact of Two Introduced Cichlids on Native Fish Communities in Everglades Wetlandst

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The primary goal of this study was to examine inter-specific interactions between two invasive cichlid species found in Everglades National Park (ENP) to gain a greater understanding of their effects on native Everglades aquatic fauna. Specific objectives included comparing the individual predatory impacts of the African jewelfish (*Hemichromis letourneuxi*) and the Mayan cichlid (*Cichlasoma urophthalmus*) on common native fishes and macroinvertebrates, documenting the community-level effects of the invasive cichlids on native fauna, and examining inter-specific interactions (predation and competition) between the cichlid species. Using an *in situ* enclosure experiment in an intermediate- to long-hydroperiod ENP marshes, we examined cichlid predation on a representative array of aquatic fauna, including: riverine grass shrimp (*Palaemonetes paludosus*), eastern mosquitofish (G*ambusia holbrooki*), bluefin killifish (*Lucania goodei*), least killifish (*Heterandria formosa*), and flagfish (*Jordanella floridae*).

Our analyses revealed that Mayan cichlids exhibited higher total predation rates on native biota than African jewelfish. Additionally, the two cichlid species had different preferences for native prey, indicating distinctive impacts on lower trophic levels. In general, the diet of Mayan cichlids appeared broader than that of African jewelfish. We found no evidence that native biota would experience a release from predation through competitive interference when the cichlids co-occur. This supports the idea that these invasive cichlids pose a threat to native Everglades aquatic biota

Although the management and control of invasive species is not a principal feature of the Comprehensive Everglades Restoration Plan (CERP), invasive species are a major conservation concern in the restoration of the Everglades and may be affected indirectly by CERP actions. For instance, the projected removal of 386 km of canals and levees will remove canal habitat that is home to a number of non-native fish species, which seems to serve as a cold-temperature refuge, allowing recolonization of marshes after severe winters. However, new structures and canals are also planned to move water in CERP projects, and ramifications for invasive species should be considered in that planning. Overall, restoration should enhance Everglades habitats and the functional quality of the ecosystem, which has been shown by research to benefit native species to the detriment of non-native taxa. Implications for restoration of our findings include:

- Predation by non-native fishes is a major mechanism by which they impact native aquatic biota.
- The predatory effects of non-native fishes vary among species, indicating that certain invaders may pose a greater threat to natives than others.
- Interactions among non-native taxa have the potential to affect both the nature and the strength of impact on native species, and this topic needs additional study.

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Survival, Growth, and Reproduction of Red Mangroves (*Rhizophora mangle*) in Restoration: Importance and Interaction of Genetic and Environmental Factors

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Plant populations respond to physio-chemical variables in the environment and also to biotic forces such as competition, herbivory, and parasitism. Some plant species may also facilitate the survival and growth of others by ameliorating the effects of some edaphic stressors. The role of maternal and genetic factors are not well understood for the foundation or ecosystem engineer species, such as mangrove dominants *Rhizophora mangle* and *Avicennia germinans*; although we have conducted some experiments and field surveys for the salt marsh dominant *Spartina alterniflora*.

We surveyed the genetic structure and mating systems of *R. mangle* populations from around Florida using AFLP markers and field surveys of reproductive output and incidence of albinism. Populations were characterized by relatively low genetic diversity produced by high rates of selfing. However, outcrossing rates varied substantially among coasts and between estuaries within coasts. Thus, there exists considerable potential for local adaptation and for variation in survival and growth of plants colonizing new substrata such as is available in restoration sites.

We report three years of data from an on-going field experiment that is evaluating: a) differences in survival, growth, and reproduction of seedlings at lower and higher intertidal settings, b) differences arising from the local environment of the seedlings' maternal tree, c) effects of propagule size, and d) influences of genetic and maternal factors independent of local maternal environment and propagule size.

As anticipated, on average *R. mangle* survived and grew best and produced more offspring at the lower elevations over the first 3 years. Seedlings arising from larger propagules did better over the first year, but that advantage was lost in subsequent years. Reproduction occurred early in life, with 70% of the experimental plants having produced propagules in either year 2 or 3 or both. There was no effect of maternal tree environment, as estimated by comparing seedlings from different maternal trees from various local embayment within Tampa Bay.

The effect size of maternal tree source, independent of maternal tree location and propagule size, was as large as the effect of the 15 cm elevation gradient. This is suggestive of genetic differences, although maternal effects other than propagule size cannot be ruled out. We found cohorts of seedlings from different maternal trees that survived and grew better at lower elevations (usually considered the "typical condition"), but also a substantial number of maternal families that performed better at the higher experimental elevation. This finding supports the idea that different genotypes of *R. mangle* may be adapted to very different physio-chemical conditions, which may account for the co-dominance of this species over a broad range of micro-habitats. Further evaluation of the heritability of these effects will begin this year with a new experiment using the F_1 offspring of the plants in the current experiment.

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Effects of Burn Temperature on Ash Nutrient Forms and Availability of Cattail (*Typha domingensis*) and Sawgrass (*Cladium jamaicense*) Growing along a Nutrient Gradient in the Florida Everglades

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To accelerate the ecosystem recovery process, active management of the existing cattail marsh, including prescribed fires, is considered a potential tool for Everglades restoration. A large-scale and long-term ecosystem study (the Fire Project) conducted by South Florida Water Management District (the District) is currently undergoing at Water Conservation Area 2A (WCA 2A) to assess whether repeated fire can be an effective management tool to accelerate recovery in highly nutrient enriched area. Therefore, it is essential to evaluate nutrient composition and redistribution from plant ash and residual into sediment-water system for assessing fire effects on nutrient availability in the Everglades.

Plant ash derived from fire plays an important role in nutrient balance and cycling in ecosystems. Factors that determine the composition and availability of ash nutrients include: fire intensity (consisting of burn temperature and duration); plant species; habitat nutrient enrichment; and leaf type (live or dead leaf). Our objective was to use laboratory simulation methods to evaluate temperature effects on nutrient composition and metals in the residual ash of sawgrass (*Cladium jamaicense*) and cattail (*Typha domingensis*), particularly on post-fire phosphorus (P) availability in plant ash. Live and dead leaf samples were collected from WCA 2A in the northern Everglades along a soil P gradient, where prescribed fire may be used to accelerate recovery of this unique ecosystem. Significant decreases in total carbon (TC) and total nitrogen (TN) were detected with increasing fire temperature. Organic matter combustion was nearly complete at temperatures of 450°C or greater. HCl-extractable P (average of 50%) and NH_4Cl-extractable P (average of 33%) are by far the predominant P fractions for laboratory-burned ash. While a low intensity fire could induce an elevation of P availability, an intense fire generally resulted in a decrease of water soluble P. Significant differences in nutrient compositions were observed between species, habit nutrient status, and leaf types. More labile inorganic P remained in sawgrass ash than in cattail ash, and hence sawgrass ash has a greater potential to release available P than cattail.

Key findings of this study relevant to restoration include:

1. Overall, fire intensity affected plant ash nutrient composition, particularly P availability and the effects varied with plant species and leaf type. These factors influence post-fire nutrient release to the ecosystem. Therefore, it is important to consider fire intensity (intense or not) and vegetation community when utilizing a prescribed fire for ecosystem management. In addition, this study provides insights for ecologists and modelers to estimate post-fire nutrient release.
2. It is useful that intense fires tend to accelerate the precipitation of P with Ca/Mg in ash in ecosystems suffering from P enrichment including the Everglades, and Stormwater Treatment Areas (STAs), which are designed to reduce phosphorus loading in the northern Everglades and Loxahatchee National Wildlife Refuge, and others.

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Aquatic Probabilistic Ecological Risk Assessment of Endosulfan in South Florida

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Endosulfan is a semi-volatile, persistent cyclodiene insecticide used in vegetable production in south Florida. Technical grade endosulfan is a diastereomeric mixture of two biologically active isomers (α- and β-endosulfan) in a 70:30 ratio. Several transformation products have been identified in the environment but endosulfan sulfate is the dominant one. The U.S. EPA reports that since 1971 endosulfan accounted for the majority of cyclodiene ecological incidents in the aquatic environment. Since 1990 to the present, regulatory agencies have been monitoring endosulfan and endosulfan sulate in freshwater and saltwater systems in south Florida.

A probabilistic aquatic risk assessment was conducted for endosulfan and endosulfan sulfate using distributions of surface water concentrations in south Florida and acute and chronic toxicity data. We also conducted additional aquatic toxicity studies with endosulfan sulfate because of the limited data with the metabolite. The probabilistic aquatic risk assessment indicates that potential acute and chronic risks for endosulfan (total) and endosulfan sulfate are highest at a limited number of localized sites near agriculture in south Florida.

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Biogeochemistry and Water Quality of the Greater Everglades: Fate and Transport of Nutrients and Other Contaminants — Symposium Overview

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Excess nutrients and other contaminant inputs from various sources including agricultural and urban landuse activities, atmospheric deposition, and weathering of natural minerals can significantly impact trophic conditions of wetlands and aquatic systems in the Greater Everglades ecosystem. Many biogeochemical processes functioning in soil, water, periphyton, and vegetation components influence fate and transport of nutrients and other contaminants. The scales at which many of the biogeochemical processes are studied vary, with some researchers conducting studies at small-scale (microbial cell or particle level or laboratory-scale), while others are involved at a relatively large-scale (field-plot or ecosystem level). Conclusions derived from the studies conducted at different scales are usually influenced by the disciplinary bias. Although, the research conducted by each of these scientists is very important, it lacks the linkage or common targeted goal to solve the problem. At present, there are no effective mechanisms to establish the linkage between scientists and users of the scientific information. Linkage among these groups will provide an opportunity to exchange technical information and will aid in effectively solving more practical problems.

The objective of this symposium is to provide a framework for synthesis and interpretation of the research findings related to fate and transport of excess nutrients and other contaminants in the Greater Everglades Ecosystem. The focus of the symposium will be to review our current understanding on the role of biogeochemical cycles in regulating the fate and transport of nutrients and other contaminants as related to ecosystem restoration and recovery. In addition new approaches and techniques that link community structure at the micro, and macro, scales to better understand the mechanisms that control the fate of chemicals at ecosystem scale will be discussed at the symposium. The symposium will also review current management strategies to abate the impact of nutrients and other contaminants and identify key water quality indicators to assess the recovery.

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Phosphorus Biogeochemistry of the Everglades Ecosystem

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Phosphorus (P) retention in wetlands is an important function in watershed nutrient cycling particularly in drainage basins with significant non-point nutrient contributions from agriculture and urban sources. Phosphorus storage involves complex inter-related physical, chemical, and biological processes that ultimately retain P in organic and inorganic forms. These biogeochemical processes interact with the P loaded to the wetland ecosystem within various internal storage compartments (soils, vegetation, detritus, microorganisms, and fauna). When evaluating P retention by wetland ecosystems, both short-term storage (assimilation into vegetation, translocation within above- and below-ground plant tissues, microorganisms, periphyton, and detritus) and long-term storage components (retention by inorganic and organic soil particles and net accretion of organic matter) need to be considered.

The majority of the Everglades is P-limited, however, increased P loading to this ecosystem over the past four decades has resulted in zones with non-limiting conditions proximal to the inflows, and nutrient limiting conditions further from these sources. Between these two extremes there exists a gradient in quality and quantity of organic matter, nutrient accumulation, microbial communities and biogeochemical cycles, resulting in a diverse algal/ microbial/plant communities with distinct biogeochemical processes. These biogeochemical differences are observed in the detrital layer, and the soil and water columns of various hydrologic units of the Everglades frequently along nutrient gradients.

Historically, the major source of nutrients to the Everglades has been from atmospheric deposition, with minimum secondary nutrient inputs through overland flow from Lake Okeechobee. At present, approximately two-thirds of the phosphorus load from Lake Okeechobee is discharged to the east and west to the St. Lucie and Caloosahatchee estuaries, respectively. The remaining one-third of the phosphorus load from Lake Okeechobee enters the EAA and other small basins. The EAA is subsequently the primary source of elevated P loads downstream to Water Conservation Areas (WCAs). Nutrient loading to WCAs of the northern Everglades has not only increased nutrient accumulation rates and changed nutrient cycling processes, it has altered the structure of algal and plant communities. Phosphorus accumulation rates of 0.11 - 1.14 g P m^{-2} yr^{-1} have been reported for the Everglades. Although P loading increased the storage through organic soil accretion, it also resulted in increased levels of dissolved P and other bioavailable forms. Distinct gradients with distance are noted in areas adjacent to canals and inflow structures, suggesting the influence of hydrologic connection with the marsh and nutrient loading. In addition, oxidation of organic matter, resulting from microbial decomposition processes or fire, also increases soil inorganic P levels, as observed for the WCA3A, HWMA, and EAA soils. Much of the nutrient-loading effects are confined to the shallow soil layers. Thus, both biotic and abiotic mechanisms regulate relative pool sizes and transformations of P compounds within the water column and soil. Alterations in these fractions can occur during flow in wetlands that depend on the physical, chemical, and biological characteristics of the systems. Thus, when evaluating P retention capacities of the Everglades wetlands, both biotic and abiotic processes must be considered. Biotic processes in the Everglades wetlands include; assimilation by vegetation, periphyton and microorganisms, and abiotic processes include: sedimentation, adsorption by soils, precipitation, and exchange processes between soil and the overlying water column. The **"phosphorus memory or legacy phosphorus"** (phosphorus retained in soils of impacted areas of the Everglades and potential release from these sources) can extend the time required for restoration and recovery to a lower nutrient status that will support historic Everglades vegetation and biogeochemical processes that dominated under more oligotrophic conditions. This lag time for recovery should be considered in developing restoration and management strategies in reducing P loads.

In this presentation, we will discuss both biotic and abiotic biogeochemical processes regulating P reactivity and mobility and P-memory (internal load) in several hydrologic units of the Everglades.

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Phosphorus Composition of Wetlands within an Agricultural Landscape

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The hydrological restoration of isolated wetlands within an agricultural landscape has been suggested as a potential best management practice (BMP). Enabling the retention of impacted waters, and the onsite sequestration of phosphorus, reducing nutrient load conducted off site. In the evaluation of the long term efficacy of such a BMPs, efforts are hindered by a lack of information on phosphorus composition and stability in hydrologically isolated wetlands that undergo periodic drydown and reflood. Further there is little information on the organic and inorganic phosphorus characteristics at the wetland-upland interface. As wetlands under go restoration, it is important to know the nature of the sequestered phosphorus as well as to predict the fate of phosphorus in the surrounding upland soils.

A series of historically isolated wetlands within improved pasture operations north of Lake Okeechobee were studied for basic soil properties and phosphorus composition via solution ^{31}P nuclear magnetic resonance (NMR) spectroscopy. When linked to information on phosphorus availability and net fluxes during flooding events, predictions can be made on the total, and composition, of phosphorus sequestered during hydrological restoration.

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Calculation Carbon Storage Performance of Three St. Johns River Water Management District Wetland Restoration Projects

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Analysis of peat soil cores collected from wetlands and shallow lakes in the Upper St. Johns River Basin area of central Florida, USA indicate that peat soil accumulation rates are similar to those found in the northern Everglades and the freshwater wetlands of southern Louisiana. A retrospective analysis indicates that net carbon accumulation rates decrease as a function of soil age which suggests that the decrease is likely associated with ongoing anaerobic soil respiration processes. When these area-specific accumulation rate profiles are applied to projections of peat accumulation in recently restored wetlands of the same region, minimum estimates of approximately 34 thousand metric tons of carbon accumulated per 1000 acres of restored long hydroperiod marsh or shallow lake per century are obtained. Rehydrating wetlands also reverses the trend of carbon loss that occurs from the carbon-rich soils once they are drained and operated for agricultural purposes. Although this carbon sequestration budget does not account for total greenhouse effect of a marsh restoration project, the combination of active sequestration and the reversal of carbon release that occurs when peat soils are rehydrated as a part of a habitat restoration project, can be added to existing water quality and wildlife enhancement benefits that marsh restoration programs provide to regional watersheds.

The key contributions of this paper for Everglades restoration include:

- An empirically based estimate of carbon accumulation for restored long hydroperiod wetlands in the region.
- An initial, area based projection of the scale of carbon sequestration that one could expect to occur in the next century.
- A demonstration of the use of the linear mixed effects analytical tool which may be widely applicable to the large number of time-series based analyses that are a critical to evaluating possible alternative water infrastructure configurations and operational strategies that will be considered as part of the Comprehensive Everglades Restoration Program.

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Predicting CERP influences on Extreme High and Low Water Levels in Greater Everglades Wetlands

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The RECOVER Evaluation Team, Greater Everglades (GE) sub-team refined the Extreme High and Low Water Levels in the Greater Everglades Wetlands Performance Measure to address the issue of extensive peat subsidence that has occurred in the northern areas of Water Conservation Area 3A (WCA-3A). Refinements include relaxed targets for extreme high water events in areas that have experienced significant subsidence of peat soils, and the development of a dry-down intensity and duration index score. Because water stages above a minimum threshold are required in a more passive system for effective delivery of water to the southern Everglades, and 1-3.5 feet of subsidence has already occurred in some areas of WCA 3A, a re-evaluation of how the extreme high water level performance measure is applied in this region is required. Additionally, prevention of continued degradation requires attention to cumulative intensity of low water events and avoidance of conditions that might exacerbate, or increase the risk of further peat loss. The dry-down intensity index score provides the opportunity to detect if projects or proposed alternatives are reducing drought intensity at specific locations throughout the roughly 1800 square miles of Greater Everglades Wetlands that are within the restoration areas.

The key contributions of this evaluation tool refinement for Everglades restoration include:

- Increased focus on events that might yield additional subsidence and the ability to account for both duration and intensity of dry events over an extended period of climate records.
- Application of regionally cohesive targets in a manner that is consistent with restoring the health of the entire ecosystem.
- Summary graphics are intuitive and provide a mechanism to effectively communicate with both scientists and non-scientists.

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Predicting the Impact of CERP on Wet Prairie Vegetation Communities Located on Marl Soils

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The RECOVER Evaluation Team, Greater Everglades (GE) sub-team developed the Wet Prairie Performance measure for use in evaluating the impacts of CERP related projects on this sensitive, short-hydroperiod, ecotonal plant community that has been historically persistent throughout the marl soil areas of the southern Everglades; particularly Everglades National Park. Vegetation within the wet prairies has been monitored regularly since the 1980's, and recent efforts have been coupled with hydrologic monitoring which allowed the development of the empirical target upon which this metric is based. The specific wet prairie indicator areas utilized in this RECOVER approved performance measure are regularly monitored by the GE Assessment module. This plant community type has demonstrated sensitivity to between-year changes in water availability and is therefore a strong indicator of performance in portions of the Everglades that range from under-hydrated (Eastern Everglades National Park) to over-hydrated (immediately west of Shark Slough). This Performance Measure is likely to be sensitive to the impacts of the CERP program, and has been developed around empirically determined targets based on extant vegetation communities within a historical range. By directly comparing the distribution of hydroperiods across marl prairie habitats, including wet prairie indicator areas, to the empirically determined target distribution, the Greater Everglades sub-team is able to differentiate performance between alternative CERP project designs and program formulation strategies and rank the alternatives in terms of which provides the greatest benefit to this sensitive and diverse wetland community. This Performance Measure has been accepted, but RECOVER application of this metric is pending based on the outcome of a technical review of the high-resolution water budget formulation that is a requisite process for the application of this Performance Measure.

The key contributions of this evaluation tool for Everglades restoration include:

- The first Greater Everglades ecological Performance Measure with predictive capabilities for CERP.
- Target conditions are based on spatially explicit monitoring data. A corresponding MAP monitoring component supports field assessment of the Wet Prairie Vegetation PM.
- Spatially explicit summary graphics that are intuitive and communicate effects of projects to both scientists and non-scientists.

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Temporal and Spatial Dynamics in the Fish Community of Marsh-Mangrove Ecotonal Habitats in the Southwest Region of Everglades National Park

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The role abiotic factors play in the structuring of natural communities is a fundamental question in ecology. This structuring effect may be particularly strong along ecotonal habitats. In the southwestern Everglades, mangrove-lined creeks link freshwater marshes to estuarine mangrove regions downstream, providing habitat for a diverse fish community composed of saltwater, estuarine, and freshwater taxa. Historically, channels and pools along this ecotone served to concentrate fishes for avian predators, and thus provided an important food source for nesting colonies nearby. We examined spatial and temporal dynamics in the fish community along the oligohaline to mesohaline reaches of tidal creeks within the southwestern region of Everglades National Park. Specifically, we asked: (a) how does the fish community vary over spatial and temporal scales, (b) how does this variation relate to variation in abiotic conditions? and (c) how do fish dynamics in creeks relate to hydrologic conditions in upstream marshes?

We sampled 15 mangrove creeks in two drainages: Rookery Branch (RB) and North and Roberts rivers (NRR). Sampling involved electrofishing to target large-bodied predatory species and minnow traps to target small-bodied forage fish. Sampling started in the wet season of 2004, and was conducted three times per year: November (wet season), February (transition), and April (dry season). Abundance and species composition differed between drainages, and across seasons and years. Overall, fish abundances were higher and catches more diverse in RB creeks, particularly during the drier sampling events. This was due to a large influx of freshwater species into creeks that occurred in the dry season as water levels upstream receded. The timing of these influxes was strongly linked to the pattern of dry-down in upstream marshes. Influxes were, at times, short-lived, particularly for the smaller taxa, suggesting heavy predation once fish moved from marshes into creeks.

Under CERP, increased freshwater inflow from upstream marshes is expected to prolong the pooling of freshwater at the ecotone and result in a wider and seasonally-extended oligohaline zone. Implications of this study under CERP conditions include the following:

- If marshes upstream of creeks do not dry as often, pulses of the smaller fishes into creeks may be expected to be decreased and thus forage biomass would remain in marshes where it is available to avian predators.
- Expanded oligohaline conditions should result in higher biomass and abundance of large-bodied freshwater species, since more of the estuary would experience low salinity regimes that are more suitable for freshwater taxa.
- Further study is needed to better understand how fresher conditions would affect the use of ecotonal creeks by estuarine residents and marine transients.

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Environmental Impacts of the Annual Agricultural Drawdown in Southern Miami-Dade County

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Water managers annually manipulate groundwater storage in Southern Miami-Dade County at the end of the wet season to support agricultural interests. The "agricultural drawdown" in Southern Miami-Dade County involves a 0.8 ft reduction in groundwater stages via the release of large volumes of water each fall to Biscayne Bay. An average of 21.4 billion gallons (65,800 ac-ft) of freshwater are released each year from the Biscayne Aquifer via the C-103 and C-102 canals during the drawdown in anticipation of the winter growing season. The side-effects of this groundwater drawdown and loss of stored water are felt primarily by the environment in, and adjacent to, southern Biscayne Bay. Without the rapid drainage of freshwater, these large volumes of water would gradually leak into Biscayne Bay and its low-lying coastal wetlands, providing freshwater flows further into the dry season. The rapid and sudden release of water from the Biscayne Aquifer within a few weeks of the end of the wet season brings about an artificially early start to the dry season. The following dry season is thus unnaturally dry, leading to long periods of dry marshes and high salinities along the shoreline. The result threatens productive estuarine fish and shellfish habitat, enhances predation of nearshore species by marine fish, encourages exotic plant species within the coastal wetland zone, and promotes a loss of wading bird foraging habitat during nesting season. The threat of saltwater intrusion into the Biscayne Aquifer is enhanced by this operational practice as well, since sea levels are at their seasonal maximums in October and November. The effects of the agricultural drawdown, the possible enhancements to the coastal ecosystem that could be realized by its elimination and its future within the context of the Comprehensive Everglades Restoration Plan's Biscayne Bay Coastal Wetlands project will be explored.

- The lack of storage features in the Biscayne Bay Coastal Wetlands Component of the Comprehensive Everglades Restoration Plan is a major drawback to maintaining an estuarine zone along the western shoreline of Biscayne Bay during the dry season.
- Maintaining the groundwater at the same level throughout the year would retain a large quantity of water that is currently discharged to tide, providing freshwater flows further into the dry season.

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Methods for Evaluating Landscape-Scale Sheet Flow Properties in Greater Everglades Wetlands

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The RECOVER Evaluation Team (ET), Greater Everglades (GE) sub-team developed the Sheetflow Performance Measure (PM) in order to detect the ability of CERP projects to deliver more natural temporal and spatial distributions of sheetflow across the landscape of the greater Everglades during evaluation of hydrologic simulation output. The key elements of this PM include measures of seasonal timing and spatial distribution relative to target values over a wide-range of climatic conditions, a measure of sheetflow continuity, an arithmetic scoring approach for each of the three categories of sheetflow characteristics, and an easily-modified and scalable modular transect design. Volumetrically explicit targets that are based on field scale ecological and landscape forming processes are not available because observed flow records in south Florida prior to construction of the canal system are scant. Until empirically-based targets are developed, “natural system” hydrology simulated by the Natural System Model (NSM) version 4.6.2 is used as a surrogate. This PM characterizes monthly flow volumes as a fraction of the corresponding annual total crossing each transect; a sub-transect’s flow volume as a fraction of discharge crossing the entire transect; and the degree to which the continuum of sheetflow is disrupted by barriers to flow, such as roads and levees. The results from this flow-based PM provide insights into how well the seasonal timing, spatial distribution, and continuity of sheetflow yielded by a project alternative matches what one might expect in a stable wetland system characteristic of pre-drainage Central and Southern Florida Project hydrology. This PM has been designed with the flexibility to scale and modify transects to allow for application of the PM at smaller or larger spatial and temporal scales as deemed necessary by the planning team of any given project of interest. The combination of 1) applied targets, 2) flexible transects, 3) intuitive summary graphics, and 4) index scores make this PM a significant improvement to RECOVER’s analytical toolkit thereby enhancing the ET’s ability to evaluate performance of alternative project designs.

The key contributions of this evaluation tool for Everglades restoration include:

- Characterizing temporal distribution, spatial distribution, and continuity of sheetflow provides meaningful insight for planning and operations.
- The flexibility of the methods allows each to be applied to output of different hydrologic models (of differing scales and resolutions).
- Summary graphics are intuitive and provide a mechanism to effectively communicate with both scientists and non-scientists.
- Volumetric flow targets based on empirical relationships between regional spatiotemporal patterns in sheetflow and ecological processes of the Everglades' are needed.

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The Role of the Mangrove Ecotone Region in Regulating Nutrient Cycling and Wetland Productivity in South Florida

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The mangrove ecotone region located in South Florida includes coastal bays, mangroves, salt marsh and tidal creeks and upland hammocks. This region is a functional estuarine landscape unit that conveys freshwater flows and regulates nutrient exchange with Florida Bay and the Gulf of Mexico. Reduced freshwater delivery over the past 50 years combined with Everglades compartmentalization and a 10 cm rise in coastal sea level has led to the landward transgression (~1.5 km in 54 years) of the mangrove ecotone. The structural changes associated with this transgression are hypothesized to have altered the fluxes of nutrients (especially nitrogen) to Florida Bay. Previous studies have shown variation in nitrogen (N) flux within dwarf and fringe mangrove areas of Taylor River (i.e., lower Taylor Slough) and Shark River (lower Shark River Slough), while other studies have quantified N fluxes through this mangrove ecotone utilizing a hydrologic modeling approach. Recent studies using Shuttle Radar Topography Mission elevation data show that approximately 49 % of the total area of mangrove wetlands in the mangrove ecotone is covered by tree canopies with tree heights < 3m, mainly in the southeastern region along Taylor Slough. Low stature scrub mangroves are widely distributed in the southeastern Everglades region. Scrub mangroves are apparently the result of a combination of low soil phosphorus (<59 μg P g dw^{-1}) in the calcareous marl substrate, particularly low inorganic P concentrations and a long hydro-period. In contrast to other subtropical and tropical costal ecosystems where the estuarine region is N-limited and the upstream freshwater areas are P-limited, the estuarine mangrove ecotone landscape and its freshwater watersheds are limited by P due to the lack of terrigenous sediment input. Thus, the primary source of P to this wetland ecosystem is the Gulf of Mexico instead of the upland watershed. This P supply from the Gulf is provided in pulses by tropical storms and hurricanes, which can deposit up to 6-63% of the TP already stored in the soil (735 μg g dw^{-1}) in a single event--supporting high mangrove net primary productivity (1100 g C m^{-2} yr^{-1}). As result of spatially variable storm deposition of P the mangrove forest show a strong productivity gradient from the western south Florida n coastline (e.g., Shark River) to Taylor River slough and Florida bay. Current estimates of annual N (0.46 g N m^{-2}) and P (0.007 g P m^{-2}) export from the mangrove ecotone (Taylor Slough) to adjacent coastal waters indicates the regulatory effect of land and water use upstream, which can drive major alterations in productivity and spatial distribution of wetland vegetation in the mangrove ecotone zone. Seasonal variation in freshwater input strongly controls the temporal variation of N and P exports (99%) to Florida Bay. Rapid changes in nutrient availability and vegetation distribution during the last 50 years show that future land use decisions might exert, on the short term, a major influence at a scale similar to sea level rise, in regulating nutrient cycling and wetland productivity in the mangrove ecotone region.

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Applications of Remote Sensing and Multivariate Geostatistics in Order to Improve Spatial Modeling of Soil Phosphorus Predictions in Wetland Areas Study Case: WCA-2A, Everglades

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Although this study is not the first one that addresses spatial variability and distribution in the Everglades, and in particular Water Conservation Area - 2A (WCA-2A), there is still much uncertainty related to changes of soil and ecological properties in this region. There is no doubt that WCA-2A has received a lot of attention in the last two decades, in part because it provides the best representation of impacted, transition and non-impacted areas due to nutrient influx, in particular phosphorus (P)-enriched waters.

Remote sensing offers an opportunity to improve mapping and monitoring of a variety of biophysical properties in this area, particularly if integrated with geostatistical methods to improve prediction capabilities. Remote sensing can be used to measure biophysical vegetation properties (e.g., chlorophyll content) and productivity in both vegetation and in the assemblage of algae and microorganisms (periphyton) that is present in the aquatic portion of the system. Since vegetation and periphyton are sensitive to soil nutrient enrichment, inference models have value to estimate the magnitude and distribution of nutrient enrichment in soils across both impacted and non-impacted areas.

The objective of this study was to prove these ideas, integrating field observations of soils with remote sensing and spatial environmental data layers. Our specific objectives were to (i) Investigate relationships between floc and soil total phosphorus (TP) and spectral data derived from remote sensing images; (ii) Compare univariate and multivariate geostatistical methods to predict floc and soil TP across WCA-2A.

We used two sources of data: a collection of 111 soil and floc TP samples, and 2 satellite images, Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER) and Landsat Enhanced Thematic Mapper (ETM). Three spectral indices were derived from these sensors: Normalized Difference Vegetation Index (NDVI), NDVI green, and Normalized Difference Water Index (NDWI). In addition, various environmental data layers (e.g. distance to water control structures) were assembled in a geographic information system (ArcGIS), and in a matrix on which exploratory analysis, correlation, scatter-plots and regression analysis were performed. In addition, one univariate geostatistical and three multivariate geostatistical methods were tested to compare predictions in floc and soil surface TP. Spatial results and cross-validation statistics were generated for each model, and a visual qualitative assessment in three representative areas around selected sampling sites was performed (cattail dominant areas, marsh vegetation/slough, and tree islands tails).

Overall, multivariate methods performed better than univariate methods in predicting floc and soil surface TP. The NDVI green was found to be the most effective in predicting floc TP values, due to its capacity to capture small variations in chlorophyll *a* that are associated to TP levels in periphyton, especially in aquatic/non-impacted areas. On the other hand, NDVI, a more traditionally used vegetation index, was still a good indicator of TP variability in the area, particularly in the soil surface layer, due to its stronger relationship with impacted areas with dominance of cattail.

Findings from this study indicate that:

- Integration of remote sensing and geostatistical methods can play an important role in optimizing monitoring of environmental variables, particularly below-ground properties of floc and soils. These methods were tested to improve predictions of nutrient levels in WCA-2A. In our study several characteristics of a wetland area were captured by these sensors.
- Since there are, and will be limitations about the numbers and frequency of soil samples that can be taken, the combination of remote sensing and geostatistics could represent a non-invasive and cost-effective method to monitor soil nutrient status in complex wetland systems, such as WCA-2A.
- Variations of traditional remote sensing indices can be used to better capture the spatial and seasonal variability associated with soil and floc TP.

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The Rise and Fall of Lake Okeechobee: Changes to Lake Morphology from 1913 to Present Day

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Lake Okeechobee represents an essential component of the Greater Everglades ecosystem, not only for its historic function as a water source to meet the environmental needs of the Everglades, but also for its intrinsic ecological value as a shallow lake community. Lake Okeechobee continues to provide an important hydrologic link between the watershed north of the lake, the remaining natural communities to the south, and the coastal estuaries. Using a geospatial approach, we investigated changes to the physical features of Lake Okeechobee from 1913 to current conditions relative to the lake's historic hydrologic function.

Our research focused on historic changes to the physical features of the lake by integrating various sources of data into a GIS analysis, including written historic accounts, engineering reports, and historic bathymetry, maps, and data from U.S. Coast and Geodetic Survey and the National Oceanic and Atmospheric Administration. Pre-drainage maps from 1913 and 1925 were geometrically corrected to match existing GIS datasets, and features such as bathymetry points, shorelines, and in-lake islands were digitized and integrated using ArcGIS.

A hydrographic survey conducted in 1925 by U.S. Coast and Geodetic Survey, between January and April, served as the primary source for historic bathymetry, along with a subset of shoreline and island points from the 1913 map. Data were standardized to match different metrics units and datum, and soundings were converted to elevations and interpolated using ordinary kriging to produce elevation surfaces that could be used to quantify changes through time.

Results indicate that the normal lake stage, prior to the completion of major drainage canals (circa 1913), was 20.4 ft National Geodetic Vertical Datum (NGVD 29) and the lake at that time was surrounded by sawgrass communities to the west and south, indicative of a 8-month hydroperiod condition. By 1925, water levels had been lowered to 18 ft NGVD with the completion of most major drainage canals, and to 12.5-15.5 NGVD by 1938, with the construction of the Herbert Hoover Dike and the implementation of water regulation schedules.

We estimated the areal extent of the lake in 1913, at 19 ft NGVD, to be 752 square miles, and 714 square miles at 15 ft NGVD, which is the same estimated area enclosed by the Herbert Hoover Dike today. We compared this to the 1925 Coast and Geodetic Survey, correcting for excluded embayments (Pelican Bay and areas south of Kreamer and Torry islands), and found that the 18 ft NGVD contour, that is, the elevation of the shoreline for the 1925 map, represents an areal extent of 737 square miles, a difference of only 3 percent from the 1913 result. These results are consistent with information recorded in historic documents from 1914 and 1927.

Findings relevant to restoration include:

- Lake stages have changed from pre-drainage conditions, with an average between 21 feet and 18 feet NGVD, to the present management regime between 13.5 feet and 15.5 feet NGVD.

- The shoreline and the areal extension that historically defined the lake have not changed significantly; even after the construction of the Herbert Hoover Dike, the areal extent of the lake remains over 700 square miles.
- Our analysis confirms a lakeward progression of the current "Okeechobee marsh" that began with the lowering of lake stages and subsequent shallower water depths.
- The lowering of lake stages has resulted in significant loss in water storage, which has implications for storage options currently under consideration within restoration efforts for the Greater Everglades ecosystem.

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Comparison of Juvenile Pink-Shrimp Abundance in South Florida Mangrove- and Seagrass-Dominated Estuaries

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The pink shrimp, *Farfantepenaeus duorarum*, has been proposed as a biological indicator of estuarine responses to the Comprehensive Everglades Restoration Plan (CERP). Estuaries downstream from CERP projects will be affected by changes in the quantity, timing, and distribution of freshwater inflows; changes in estuarine salinity regimes and subsequent, longer-term changes in benthic vegetation are anticipated. The pink shrimp, familiar to most Floridians as either food or bait shrimp, is ubiquitous in both seagrass- and mangrove-dominated south Florida coastal waters, is strongly associated with benthic vegetation, and is ecologically and economically important. The relationship of pink-shrimp density with salinity based on long-term data and laboratory experiments suggests that water management affects inshore juvenile pink-shrimp abundance.

The South Florida Fish and Invertebrate Assessment Network (FIAN) is a monitoring element of CERP that supports the pink-shrimp indicator by quantifying change and trend in density. FIAN includes 19 sampling locations distributed among three south Florida regions: Florida Bay (8 locations), Biscayne Bay including Card and Barnes Sound and Manatee Bay (7 locations), and the southwest mangrove coast that includes Whitewater Bay (4 locations). A 30-cell sampling grid of equally sized hexagonal cells defines each location; grid size differs among locations. Within each cell a single randomly located 1-m^2 throw-trap sample is used to collect seagrass-associated fish and shrimp, including the pink shrimp, and crabs. Five separate passes with a 1-m-wide sweep net are used to sample the throw-trap. Each sweep is processed separately providing a removal sample of the animals initially trapped in the throw-trap. Water depth, salinity, water temperature, turbidity, sediment depth, and seagrass and associated algae are measured with each throw-trap sample

Hierarchical modeling is used to analyze the removal sample (consecutive counts) of pink shrimp from each throw-trap. This multilevel model formally accounts for the FIAN sampling design, which includes removal counts from each throw-trap (n=5), the clustering of observations within each location (n=30), and stratification of locations (n=19) between mangrove and seagrass-dominated regions. Our goals are to estimate “true” shrimp abundance and to quantify associations between shrimp and salinity and benthic habitat while accounting for unobserved sources of variation in shrimp abundance and capture rate.

FIAN provides the first regional view of the distribution of the pink shrimp in south Florida. The density of juvenile pink shrimp varies both regionally and locally, as well as seasonally, being most abundant in late summer and fall; pink-shrimp abundance is greatest in Johnson Key Basin in western Florida Bay. Estimates of pink-shrimp density are comparable among sampling locations and years. Variation in benthic vegetation, salinity regime, and accessibility to settlement-stage larvae are thought to account for density differences among locations. Future sampling will help test these ideas.

- FIAN provides the first regional view of the distribution of the pink shrimp in south Florida.
- FIAN provides estimates of mean density, spring and fall, for the pink shrimp performance measure evaluating the effect of CERP in south Florida estuaries.
- Removal sampling, an integrated element of FIAN, improves estimates of shrimp abundance by accounting for unobserved sources of variation in shrimp abundance and capture rate.

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Patterns of Mercury Bioaccumulation in Fish in the Greater Everglades

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Mercury is a persistent, bioaccumulative toxic contaminant of concern in south Florida which can build up in aquatic food webs to levels that are harmful to human and ecosystem health. Fish consumption advisories are now widespread in both freshwater and coastal marine environments. As the Comprehensive Everglades Restoration Plan (CERP) moves forward, monitoring of mercury in sentinel fish species has been implemented to establish a baseline against which to gauge the impacts of hydrological and ecological changes accompanying restoration activities. The goal is to ensure that CERP does not inadvertently worsen the existing mercury problem in South Florida to the point that risks to humans or wildlife outweigh restoration benefits.

Ongoing work, now its third year of annual sampling, collects fish from 23 regions of south Florida within the influence of CERP. Ten regions are in freshwater habitats and 13 are coastal marine habitats. Twenty individual fish of two species, representing two different trophic levels, have been collected and analyzed for mercury in each region at multiple sites within each region. Largemouth bass and bluegill are target species in the freshwater regions. Crevalle jack and gray snapper are target species in coastal marine regions. During the first two years 2294 fish were collected and analyzed. Changes in annually monitored concentrations are being assessed to determine trends in concentrations that may be linked to CERP activities. A database of mercury concentrations in these same species and regions for the period 1989 through 2005 has been developed with 3270 records. Another 4821 records for the target fish have been documented within the CERP area of interest, but outside the 23 specific regions of interest. This database provides an initial estimate of baseline mercury concentrations before CERP implementation. Historical samples are heterogeneously distributed among regions with some regions represented by few analyses. Because not all regions have sufficient historical data to establish a baseline, our new three year database will be used to augment the historical data.

Mercury criteria in fish exist to protect both human health and that of wildlife. Florida has a multi-tiered criteria system to protect human health: Mercury concentrations above 1.50 ppm wet weight trigger a no-consumption advisory in the general population, with a lesser criterion of 0.85 ppm for more sensitive groups such as pregnant mothers. Concentrations as low as 0.20 ppm can trigger advisories to limit fish consumption. Among Federal agencies, FDA employs 1.0 ppm criterion, while EPA sets its criterion at 0.3 ppm. Because many species of wildlife prey almost entirely on fish, criteria to protect their health can be lower than that for humans.

Among coastal marine regions, highest mercury concentrations in crevalle jacks are found along the extreme southeast tip of Florida, from Florida Bay through Biscayne Bay. Across all regions, mercury concentrations averaged 0.597 ppm with a range from 0.149 to 1.900 ppm. Gray snapper had lower mercury concentrations, averaging 0.182 ppm with a range from 0.033 to 0.714 ppm. Lowest mercury concentrations in gray snapper were observed along the Atlantic coast north of upper Biscayne Bay. Sites with high concentrations seemed be associated with restricted flushing.

Among freshwater regions, highest average mercury concentrations in bluegill were observed in Big Cypress National Preserve, Model Lands, and Everglades National Park. Mean mercury concentrations in bluegill averaged 0.196 ppm with a range from 0.015 to 1.360 ppm. The same regions had the highest mercury concentrations for largemouth bass, with the addition of Grassy Waters Preserve. Mercury concentrations in largemouth bass averaged 0.482 ppm with a range of 0.063 to 1.782. ppm. High concentration regions are dominated by shallow wetlands. Regions with lower mercury concentrations in bluegill and largemouth bass were either rivers, canals, or a lake (Lake Okeechobee). As in coastal marine regions with limited flushing and longer water residence time seem to contribute to development of mercury bioaccumulation hotspots.

Our results suggest the following implications of Everglades restoration on mercury bioaccumulation:

- Prior to the implementation of most CERP projects, mercury concentrations in the sentinel fish already exist in the Greater Everglades at levels exceeding criteria to protect human and wildlife health.
- Mercury concentrations vary substantially across regions, with areas of restricted water flushing seeming to have highest concentrations.
- Altered water flow accompany CERP is likely to change mercury bioaccumulation. Hotspots, with limited water flushing, are likely to experience reduced mercury bioaccumulation if increased water input accompanies CERP. Diversion of water from well flushed areas (e.g. St. Lucie estuary) may increase mercury bioaccumulation through increased water residence time.

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Habitat Use and Movement Patterns of the American Alligator (*Alligator mississippiensis*) in the Florida Coastal Everglades

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American alligators (*Alligator mississippiensis*) are top predators in the Florida Coastal Everglades, but their movement patterns and role in the ecosystem are largely unknown. Proposed restoration and management efforts in the Everglades are likely to influence both alligator movements and the spatiotemporal patterns of their effects on ecosystem and community dynamics, making studies of the factors influencing alligator movements important at this time. In October 2007, we initiated a study of alligators in the Shark River Slough of Everglades National Park using two tracking techniques that have yet to be used on crocodilians: GPS tracking and passive acoustic telemetry. GPS units attached to two alligators have provided 120 positions over a two month period while acoustic transmitters attached to 12 alligators have been detected 34,000 times on an array of 8 monitoring stations within the river system. GPS positions are more accurate than acoustic monitoring and can provide data over the entire range an alligator might move, but acoustic transmitters provide more temporally detailed information on movements within a monitoring array and over a longer duration (potentially years rather than months). Our preliminary results show that alligators may remain in localized areas for weeks at a time, but make long-distance moves from the mouth of the river system to the marsh-mangrove ecotone and likely into the marsh. In general, most alligators moved upstream as freshwater inputs decreased, but some individuals remained near the river mouth even when salinities were high. Ultimately, by characterizing alligator movements in relation to spatiotemporal variation in environmental factors we will be able to predict how alligator distributions and populations will respond to planned increases in freshwater flow. Furthermore, movement data combined with dietary and stable isotopic studies may shed light on the possible role of alligators in the redistribution of nutrients throughout the Shark River system.

Key findings relevant to restoration:

1. Alligator movements may be heavily impacted by an altered hydrological regime
2. Passive acoustic telemetry may be a good method to track the movement patterns of aquatic species that are predicted to be impacted by planned restoration
3. Some alligators spend time in high salinity habitats when lower salinity habitats are available to them, suggesting predicted patterns of movement may not hold for this species

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Assessing Several Vegetation Indicators of Everglades Water Management

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Plant communities form the habitat template for all terrestrial Everglades wildlife, and therefore are key elements in any program that includes maximization of biological diversity and ecosystem function among its objectives. During the last century, numerous studies directed at broad-scale patterns have demonstrated that hydrology is one of the major axes along which Everglades plant communities are arranged. The pervasiveness of this vegetation-hydrology relationship is Everglades restoration's fundamental assumption. For this reason, identification of measurable vegetation responses to water management will remain a priority for establishing an effective system of adaptive management, both in the current run-up to CERP and once CERP comes fully on-line.

Several ongoing monitoring efforts in the MAP Greater Everglades Landscape Module address vegetation-hydrology relationships in Everglades National Park and adjacent wetlands. Building on previous Park-supported research on the topic, these projects collectively provide an opportunity to assess alternative indicators of hydrologic response. In this paper, we examine these databases to evaluate the extent that several measures of tree island structure and function (tree and seedling composition and structure, tree radial growth, forest litter production, canopy leaf area, leaf $\delta^{13}C$, transpiration rate via sapflow measurement) and marsh structure (plant species composition, standing biomass) track hydrologic variation in space and time. These analyses will aid in assessing which vegetation measures respond rapidly, which over longer periods, and which not at all, to changes in water management operations.

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Arthur R. Marshall Loxahatchee National Wildlife Refuge Completely Mixed Flow Model

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Arthur R. Marshall Loxahatchee National Wildlife Refuge exists as the only soft-water remnant (58,275 ha) of the Northern Everglades. Alterations in the water quality, quantity, and timing have resulted in myriad impacts to the Refuge. Therefore, it is paramount to develop an effective means to study the impact of the hydrodynamic and water quality changes.

This presentation cites further development of a Completely Mixed Flow (CMF) model of the Refuge. The initial approach divided the area into several compartments (cells), and modeled both a water budget and the constituent transport for the Refuge. At its inception, this model was developed as a spreadsheet (Microsoft Excel) water balance model driving the USEPA water quality model WASP. Both represent the initial step toward an effective management tool for studying various hydro/nutrient loading scenarios for the Refuge.

The compartments from the initial model have been refined to better represent a pseudo-spatial variance in the Refuge. The new cell design is based upon a cluster analysis of the water quality data collected at marsh sampling sites in the Refuge. This analysis grouped sites with similar water quality into individual clusters. Each of the station clusters now defines an area (cell) within the Refuge. The resultant model structure is compartmentalized based on these cells, and is implemented using the differential equations solver Berkeley Madonna (www.**berkeleymadonna**.com). In addition to chloride and sulfate, this version of the model incorporates phosphorus cycling as described by Walker and Kadlec in the Dynamic Model for Everglades Stormwater Treatment Areas (DMSTA).

Key messages relevant to restoration:

- Cluster analysis showing trends in water quality data provides an analytic approach to model compartment delineation.
- The Berkeley Madonna program provides a convenient user interface paired with an efficient computational engine, both of which support the development of a simple model for the Refuge.
- Simple compartmental model efficient for simulating and analyzing first-order scenarios.

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The Vegetation of Biscayne National Park, Homestead, FL, USA

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Established as a National Park in 1980, Biscayne National Park (BNP) comprises an area of nearly 700 km^2, most of which is under water. The terrestrial portions of BNP include a coastal strip on the south Florida mainland and a set of limestone barrier islands forming the eastern rim of Biscayne Bay. The upland vegetation component of BNP is embedded within an extensive coastal wetland network, including an archipelago of 27 mangrove-dominated islands with extensive areas of tropical hardwood forests or hammocks. While these terrestrial and wetland communities are limited in area, they extend over many kilometers, and account for a significant portion of the Park's biodiversity, which includes many threatened and endangered species of flora and fauna. Several databases and vegetation maps describe these terrestrial communities. However, these sources are outdated, incomplete, incompatible, or/and inaccurate. For example, the current vegetation map of BNP is more than 10 years old and represents the conditions of Biscayne National Park shortly after Hurricane Andrew. As a result, a new terrestrial vegetation map was commissioned by The National Park Service Inventory and Monitoring Program South Florida / Caribbean Network (SFCN).

A vector map was developed using: a comprehensive set of 2005 5-band (Red, Green, Blue, NIR, and Pan-Chromatic) 30cm pixel aerial photographs; NDVI (calculated from the 2005 aerials); 2002 LiDAR data, available only for mainland portions of BNP; and over 1,000 ground reference points. In general, NDVI helped delineate low productivity zones (Mangrove Scrub) and Non-Vegetative features from adjacent Shrubland and Forest communities. The availability of LiDAR for the mainland proved invaluable and greatly enhanced the overall map resolution and accuracy. In conjunction with traditional aerial photo-interpretations, eCognition® remote sensing software was used to create highly accurate and precise 1:300 scale shorelines. However, we failed to derive an algorithm in eCognition® capable of consistently and accurately segmenting the varied community types found in this region. Vegetation communities were classified to the highest feasible level of resolution within the six-tiered hierarchical vegetation classification system developed by Rutchey et al. (2007). Level 3 of the hierarchy was the minimum resolution accepted, but some communities were mapped to Level 6. However, not all communities mapped or observed in the field were listed in the Rutchey et al. classification system. As a result, we added and modified the classification system as needed. A total of 47 community types were identified and mapped at Level 3. At Level 6, 91 different community types were mapped. Total area mapped was 36.69 km^2.

This map calls attention to the importance of vegetation maps as management tools by directing managers to focus their attention on either rare and/or fragmented communities that are generally more vulnerable to anthropogenic and natural perturbations. This is particularly true in the case of the Coastal Hardwood Hammock community. This highly fragmented upland community serves as refugia for many threatened and endangered species, both flora and fauna. However, since this community is only found on the eastern rim of Biscayne Bay, at a few meters above mean sea level, it is highly vulnerable to the affects of hurricanes and tropical storms and their accompanying storm surge, and, without question, sea-level rise. In conjunction with existing data, managers can use this map to focus on areas where community types are more indicative of pristine conditions and/or areas that would benefit the most from restoration efforts. And finally, this map, with its highly accurate and precise 1:300 scale shoreline, serves as a turn-of-the-century baseline for the extent of mangroves within Biscayne National Park and, as a result, can be used to monitor the affects of seal-level rise in the years to come.

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Developing a Data-driven Classification of South Florida Plant Communities

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South Florida vegetation classification systems that are currently in use were largely arrived at subjectively and intuitively with the involvement of experienced botanical observers and ecologists, but with little support in terms of quantitative field data. In practice, this has led to a few problems: instances of confusion in terminology, difficulty in application to detailed mapping efforts, and lack of fit within regional, national or global classification systems. The need to develop a field data-driven classification that builds on the ecological organization recognized by generations of south Florida ecologists, and that also fits seamlessly into the US National Vegetation Classification (NVC), has been recognized by the National Park Service and vegetation practitioners in the region. The present work covers the first stage of a larger project whose goal is to apply extant vegetation data to test, and revise as necessary, an existing, widely used classification (Rutchey et al. 2006), and ultimately to develop the revised classification in the National Vegetation Classification System format. The objectives of the first phase of the project were (1) to identify useful existing datasets, (2) to collect these data and compile them into a geo-database, (3) to conduct an initial classification analysis of seasonally flooded tropical or sub-tropical grasslands, and (4) to design a strategy for augmenting existing information from poorly represented landscapes in order to develop a more comprehensive south Florida classification.

Thirty three data sets, comprising vegetation data from 7,980 sites, were received from researchers working in various organizations. The structure and completeness of available data sets were examined in terms of sampling design, the number and size of sampling units, spatial distribution, taxonomic resolution, and method of estimating species abundance. The data were then summarized at the site level and were incorporated into a geo-database. Finally, vegetation classification for seasonally-flooded tropical and sub-tropical grasslands in the region was developed using a hierarchical cluster analysis of the sites-by-species matrix. The analytical summary of the datasets in geo-database provided the basis for identifying current gaps in the vegetation data needed to develop a comprehensive south Florida vegetation classification. The results from the cluster analysis of species data for seasonally flooded grasslands were used to cross-walk with the recently updated and hierarchical *Vegetation Classification System for South Florida Natural Areas* (Rutchey *et al*, 2006), to evaluate whether vegetation classes at various levels identified in this system were well substantiated by the classification achieved through field-data based cluster analysis. A robust and comprehensive classification system of south Florida vegetation supported by quantitative vegetation data will provide a strong basis to identify and evaluate vegetation indicators of hydrologic changes due to Everglades restoration.

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Water Source Utilization and Foliar Nutrient Status in Upland and Lowland Plant Communities in Tree Islands of the Shark River Slough, Everglades National Park

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Tree islands in the southern Everglades are centers of biodiversity and are the only areas that are not flooded in the wet season. They have two sharply distinct plant communities: (a) the upland community consisting of flood intolerant neotropical hammock species and (b) the flooded lowlands having a hydroperiod of 1-7 months with flood tolerant species. Two potential water sources exist for the upland community: (i) nutrient-rich entrapped rainwater in this organic soil (referred to as soilwater) and (ii) nutrient-poor regional surfacewater/groundwater.

We tested the hypothesis that upland communities access the nutrient-rich entrapped rainwater while lowland communities only have access to the nutrient-poor regional water. We linked access to the water sources having different nutrient concentrations with foliar nutrient levels and photosynthetic performance as determined by carbon isotope ratios.

Upland plants used soilwater in the wet season and shifted gradually to greater regional water uptake in the dry season, while lowland plants used regional water throughout the year.

Consistent with the nutrient concentration of the two water sources used in the two communities, uplands had a greater annual mean foliar phosphorus concentration at the community level over lowlands and a lower foliar nitrogen annual average than lowlands. The higher foliar phosphorus supports the idea of tree islands being nutrient hotspots in the oligotrophic phosphorus-limited Everglades.

High foliar N concentration in lowland plants was associated with eventual stomatal limitation of photosynthesis.

Scientific inputs for restoration:

- Upland species being intolerant of flooded soils are thus restricted to water uptake in the shallow unsaturated soil layer in the wet season. *Hence monitoring water levels at tree island sites is the first step to ensure water levels are below tree island hammock ground*
- In the dry season, upland hammocks access the lowered groundwater table because of drying up of surface soilwater. Water stress exhibited by upland plants in the dry season imply limitations to water uptake that can result from plant roots having to access groundwater via cracks in the limestone bedrock. *Hence lower than normal water levels caused by extended droughts can harm upland hammocks.*

This dependence of on a relatively narrow annual range of water table levels (around 1-2 meters) should be considered in South Florida water management and restoration of tree islands, as both flooding and drought can negatively affect upland hammock communities in tree islands.

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Effects of Abiotic Gradients and Trophic Interactions on Food Web Structure of Everglades Aquatic Consumers

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Identifying determinants of community and food web structure is of central importance in ecology, particularly because biodiversity and food webs are frequently linked to ecosystem functioning. Using data collected during the wet season 2005 REMAP sampling event, we investigated food web fragments consisting of periphyton primary producers, and fish and macroinvertebrates as primary and secondary consumers. Aquatic animals were sampled at 54 locations that were a subset of REMAP study sites with vegetation and water depths amenable to sampling by throw trap. At each site, we collected three throw-trap samples to document small fish and large macroinvertebrates, and three periphyton and three floc core samples to examine smaller macroinvertebrates. We also collected periphyton samples to determine the relative abundance of algal species, total phosphorus, and chlorophyll *a*. Hydrological data were obtained using the Everglades Depth Estimation Network (EDEN) hydrological estimation tools. In order to address how environmental gradients influence the abundance and trophic diversity of small fish and large macroinvertebrates, we 1) used path analysis to identify indirect and direct effects of nutrients (phosphorus) and disturbance (hydrology) on fish and macroinvertebrates, with indirect effects acting via transmission through the food web (i.e., through their effects on periphyton and smaller macroinvertebrates); and 2) used analysis of stable isotope ratios from a selected subset of fish and macroinvertebrate species to identify changes in trophic diversity. Our findings reveal potential alteration of the food web resulting from changes in density, biomass, and relative abundances of fish and prey species, as well as from functional changes in energy flow through the food web resulting from shifts in fish diets.

Restoration implications of our findings include:

- Increased specification of mechanistic models describing how nutrient enrichment and hydrological changes affect basal consumers;
- Greater insight into how food webs are influenced by changes in species composition versus changes in trophic position;
- Evaluation of the importance of indirect effects of phosphorus through periphyton species composition relative to periphyton chlorophyll *a* and biomass.

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Ground Water Flow and Quality near the Everglades National Park, Florida

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The long-term plan to restore the Everglades to a more natural state may elevate the water table in adjacent areas of South Florida. This could result in flooding during the wet season and have an effect on agricultural production. The quality of water seeping into the aquifer also is a major environmental concern. Therefore, understanding the surface and subsurface hydrology as well as agriculture's effect on ground water quality in south Miami-Dade county Florida is important prior to implementation of the Comprehensive Everglades Restoration Plan (CERP). The objectives of this study were: 1) to determine if periodic flooding due to tropical storms affect the quality of the ground water, 2) establish relationship between the water level and water quality of the agriculture area and the major canal near the Everglades National Park, 3) establish a relationship between ground water level fluctuation to rainfall and canal water level, and 4) assess the quality of ground water in the agricultural area and the adjacent canal. A typical vegetable farm (tomato– bean rotation) near the Everglades National Park was selected for this study. Monitoring wells were drilled in the presumed direction of ground water flow and water level and ground water quality were monitored for three years on weekly bases during the rainy season (May- Sept) and once monthly during the dry season (Oct to May). In addition, the adjacent canal (L31N) water level and water quality was monitored. The water quality parameter, water soluble P, was well below the risk level at the farm, as well as in the L31N canal. It was found that, during the wet season, the groundwater level fluctuation is highly correlated with the canal water stage. There was no significant correlation between the P concentration measured in the ground water at the farm and in the canal water. The results also indicate that the P concentration in the canal water does not seem to be affected by the farm. Changes in canal water P seem to be more correlated to concentrations upstream and downstream than ground water P concentration at the farm. The results also indicates that there was not a significant correlation (α=0.05) between water table fluctuations and the concentration of phosphorus during this study.

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So Many Rules and Regulations! What's an Environmental Restoration Project to Do?

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The objective of an environmental restoration project is to restore an area to its previously existing natural conditions, or as close as possible to those conditions, so as to affect a substantial increase in environmental benefits as opposed to the current use. However, much like any other construction activity or operational facility, there are several regulatory processes in place through which one must navigate prior to affecting such change. As a restoration project proceeds through the planning stages; preconstruction, engineering and design; and finally into the construction and operations phases, there are several federal, state and even local rules and regulations with which the project must comply. In addition to these processes, determining which rules and regulations apply to a specific project and who monitors compliance of the project can depend upon the entity performing the restoration.

Ecosystem restoration projects require the entity(ies) proposing such projects to take into consideration several federal requirements including, but not limited to, the National Environmental Policy Act (NEPA), Clean Water Act (CWA), Endangered Species Act (ESA), Rivers and Harbors Act, Coastal Zone Management Act (CZMA), Fish and Wildlife Coordination Act, Magnuson-Stevens Fishery Conservation and Management Act, and the National Historic Preservation Act. In the State of Florida, restoration projects may be subject to the provisions of several regulatory programs including, but not limited to, the Comprehensive Everglades Restoration Plan Regulation Act (CERPRA), the Everglades Forever Act (EFA), the Northern Everglades and Estuaries Protection Plan Act (NEEPPA), Environmental Resource Permitting, consumptive use authorizations, water reservations for the natural system, and several federal permitting programs for which the State has been entrusted with the authority to administer (delegated to the State). In addition to federal and state rules and regulations, there are often local requirements these projects must conform to prior to such restoration projects taking place.

In recognition of the significance of these large scale restoration projects and the challenges they pose, the Florida Legislature enacted the CERPRA [373.1502, Florida Statutes (F.S.)], the EFA (373.4592 F.S.), and the NEEPPA (373.4595 F.S.) which, amongst other provisions, provided specific regulatory authority for permitting to provide an efficient and effective regulatory process for specific restoration projects. These provisions were seen as critical steps toward simplifying and reducing administrative procedures associated with their implementation - procedures which may otherwise slow down the implementation of such projects and postpone the realization of benefits. However, Federal programs which have been delegated to the State of Florida such as the National Pollutant Discharge Elimination System (NPDES) permits (issued pursuant to Section 402 permit under the Clean Water Act), the Coastal Zone Management Program (CZMP), and Title V under the Clean Air Act, despite being issued by the State, still require a separate administrative process as these authorizations have applications outside the restoration realm. In addition to issuing permits pursuant to the aforementioned authorities, the U.S. Army Corps of Engineers (USACE) and the State of Florida have adopted the practice of working closely with other state and federal agencies through the planning process and subsequent to permit issuance to ensure that all of the requirements are met. Such efforts have proven to further expedite the administrative processes and facilitate the implementation of these important restoration efforts.

While some of the information necessary for a permit application is easily obtained, other needed information - to determine compliance with federal, state and local requirements - is produced (or can be produced) during the planning and preconstruction engineering and design. This information usually revolves around considering all the costs of a project – not just monetary, but also ecological and cultural effects that can be seen as costs. If federal, state and local requirements are acknowledged as the project is planned and designed, providing the required information to such agencies becomes less of a labor intensive exercise and thus much easier to complete the required regulatory and administrative processes.

In addition, Federal regulators realize there may be instances where non-Federal sponsors who have worked beside the USACE to develop ecosystem restoration projects decide to proceed with project implementation on their own. In these instances, the implemented project would no longer be a Federal project and the implementing entity would need to apply for all necessary Federal permits (as well as State and local permits) instead of determining Federal compliance through the Federal NEPA process. In such cases, the NEPA documentation and other federal requirements completed as part of the earlier conceived project (with the USACE) may be used to provide information useful to the regulatory process and thus avoid duplication and redundancy.

While the objective of an ecosystem restoration project is to benefit the environment, there are still federal, state and local processes which must be considered. Through these processes, federal, state and local governments obtain the reasonable assurances they need in order to properly authorize such undertakings. In such context, where the project has several potential benefits to the environment, it is incumbent upon the regulators and project team members to keep the following issues in mind.

- Despite the nature of the intended project, restoration activities are still subject to regulatory processes.
- While often time regulatory programs can be prohibitive to progress, staff with a working knowledge of rules and regulations and willingness to work closely with the permittee can often find ways to work regulatory needs into planning processes very efficiently.
- Collaborative efforts on the part of federal, state, and local agencies can save not only time, but agency resources. Preservation of such resources allows those resources to be better allocated towards other agency priorities or additional restoration efforts.
- State and local governments have the flexibility to custom tailor specific legislation and rules to simplify permitting for restoration projects/programs.

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Controls on Flow Velocity and Flow Resistance in the Heterogeneous Floodplain Landscape of the Everglades

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Surface-water flow was measured for several years in Water Conservation Area 3A (WCA-3A) at a site with a landscape pattern once common throughout the central Everglades, i.e. flow-parallel, ridges and sloughs that are topographically and vegetatively distinctive. Our purpose was to determine the primary controls on flow velocity and discharge in this heterogeneous floodplain with laminar to transitional flow conditions. Flow velocity and ancillary variables were measured every 30 minutes in the field over three wet seasons (2005-2006, 2006-2007, and 2007-2008). Velocity measurements were made at a single depth in a slough and on the adjacent ridge with corresponding measurements of water-level, wind, and precipitation. Velocity profiles were measured in both slough and ridge on monthly site visits, resulting in a total of 17 slough velocity profiles and 11 ridge profiles that were useful in selecting the best physically-based rate law to interpret controls on flow. Application of that rate law also allowed us to develop a method to estimate mean water column velocities from the monitoring records of single-point velocity and flow discharge for the three-year data set. Topography and vegetation architecture were measured early in the study on transects oriented perpendicular to the slough-ridge interface. Additional measurements of ground-surface elevation, water level, and flow through water management structures were obtained from the USGS and SFWMD to estimate water-surface slope in the vicinity of our research site and to characterize the timing and volume of water inflows to WCA-3A.

A key hypothesis regarding formation and maintenance of ridge and slough topographic and vegetative patterns is that high flow velocities redistribute sediment from sloughs to ridges. Time periods with relatively high flow velocities (0.6 – 0.8 cm s^{-1} velocities compared with 0.2 – 0.3 cm s^{-1} at other times) only occurred on the rising limb of flow pulses when water-surface slope was relatively high (2.5×10^{-5} compared with 1.2×10^{-5} at other times). Flow pulses propagate southward through the wetland following major flow releases through water management structures separating the WCAs. Only during the rising limb of the flow pulses did flow velocities approach the conditions typical of Everglades National Park. Previous measurements by USGS at two sites in Shark Slough (an *Eleocharis* slough site, GS33, and a sawgrass site, GS203) indicated a mean of approximately 0.7 cm s^{-1} compared to mean velocities of 0.36 and 0.28 cm s^{-1} in the slough and ridge respectively at our site in WCA-3A. Higher average flow velocities in Shark Slough result from the greater water-surface slope in Shark Slough (6×10^{-5} compared to 1.2×10^{-5} at our site in WCA-3A) which is due at least in part to Shark Slough's greater topographic slope (5.6×10^{-5} compared to 3.3×10^{-5} at our site).

Over three wet seasons the average velocity in the slough (0.36 cm s^{-1}) was 30% greater than the ridge and flow discharge per unit width was 115% greater in the slough on average compared with the ridge (where the peat elevation was 20-cm higher). The average velocity on the ridge was lower than in the slough due to vegetative flow resistance that was approximately a factor of four higher on the ridge compared to the slough. Flow discharge per unit width was more than 100% greater in the slough because of greater water depths (typically 30% to 200% greater in the slough compared with the ridge) and also the longer time period of flow in sloughs (e.g. 448 days of flow in the slough compared with 285 days in the ridge over three wet seasons). Flow contributions were not distributed evenly across all water levels. Thirty percent of the slough's discharge occurred at water depths of up to 30 cm (relative to the slough bottom) which is too shallow for substantial flow to occur in the ridge. In contrast, a larger proportion of the ridge's discharge (40% compared with 20% for the slough) occurred at relatively high water levels greater than 65 cm above the slough bottom. The remaining discharge was contributed equally across the intermediate water levels. Everglades flow is also influenced by episodic events such as Hurricane Wilma, which elevated flow velocities by an order of magnitude (from 0.3 to a maximum of 4 cm s^{-1}) and water levels by approximately 50 % (from 53 to 75 cm) for a number of hours and rafted dislodged vegetation into concentric rings around ridges. These findings have general implications for predicting hydrological flows on heterogeneous, vegetated floodplains and also specific implications for wetland water managers seeking to manipulate flow velocity to optimize sediment entrainment, sediment redistribution, and other processes envisioned to be important in restoring and maintaining Everglades topographical pattern and biodiversity.

Summary points and implications for restoration include:

- Average ambient velocities measured in the Everglades are typically on the order of 0.3 cm s^{-1} in central WCA-3A and 0.7 cm s^{-1} in Shark Slough (with some locations in Shark Slough averaging over 1 cm s^{-1}).
- Flow was primarily through sloughs at our study location in central WCA-3A. The average flow velocity was 30% higher and the flow discharge per unit-width was more than 100% greater in sloughs compared with ridges over the 3-year measurement period. The ridge-slough difference in flow velocity was small relative to 2 - 3 times variation associated with gravity waves that propagate through WCA-3A as a result of sudden pulses of water released from WCA-2A through water control structures. Severe storms such as Hurricane Wilma also locally increased flow velocity for short periods of time (by as much as 10 times).
- In general the most effective management actions that increase flow velocity will be the ones that increase water-surface slope rather than those that simply increase water depth. Pulsed flow operations at water control structures are potentially an effective means to increase water-surface slope and flow velocity, although the high velocities needed for floc entrainment possibly can only be restored for short periods of time and only in small areas of the Everglades, i.e. similar to what can be expected from severe storms.

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R-EMAP: Phosphorus and Sulfur in the Everglades: Landscape Patterns and Temporal Trends 1995-2005

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The Everglades Regional Environmental Monitoring and Assessment Program (R-EMAP) is a probability-based, multi-media effort that has documented conditions throughout the Everglades Protection Area for over a decade. The Program sampled biogeochemical constituents, including sulfur and phosphorus, at 415 locations throughout the freshwater Everglades during 1995-1996, 238 locations in 1999, and 228 locations in 2005. Total Phosphorus (TP) and sulfur data are presented. Spatial patterns and temporal trends are explored, as are TP associations with macrophytes.

Florida's Everglades TP criterion specifies a definition of impacted as being where soil exceeds 500 milligrams TP per kilogram of soil (mg/kg). The Comprehensive Everglades Restoration Plan (CERP) has adopted a restoration goal of maintaining or reducing soil TP concentrations to 400 mg/kg or less. R-EMAP data indicate that in 2005 the area of the Everglades with soil TP exceeding 500 mg/kg was 24.5 $\pm$ 6.4%, while 49.3 $\pm$ 7.1% exceeded 400 mg/kg. This contrasts with 16.3 $\pm$ 4.1% exceeding 500 mg/kg in 1995-96 and 33.7 $\pm$ 5.4% exceeding 400 mg/kg. Statistical testing for differences in the cumulative distribution of frequency between sample years (Wald, mean Eigenvalue, Satterthwaite) indicates that in 2005 wet season soil TP was higher than in 1995-96 (median of 390 mg/kg versus 343mg/kg). These results are consistent with three other independent studies that also found that Everglades soil TP increased from the early 1990s to about 2000.

Significant, unprecedented phosphorus control efforts were initiated by Florida in the early 1990s. From 1994 to 2006 these efforts resulted in the cumulative removal of over 2600 metric tons (mt) of TP from stormwater prior to discharge into the Everglades. Florida has adopted a numeric TP criterion of 10 micrograms per liter [or parts per billion (ppb)] for the Everglades. The 10 ppb criterion has been calculated to translate into an equivalent annual flow-weighted concentration of about 16 ppb. Although this 16 ppb number has no regulatory meaning, it is illustrative to calculate TP loading into the Everglades that is in excess of this flow-weighted concentration. During water year 2006, the stormwater treatment areas retained 177 mt of TP, and agricultural best management practices removed 117 mt. About 169 metric tons were discharged into the Everglades excluding the Park, which had TP inflows of only 9 ppb. Had the water discharged into the rest of the Everglades been at 16 ppb, this load would have been 42 mt instead of 169 mt. This approach assumes that the Everglades marsh and canals have no assimilative capacity above the criterion.

Sulfur is of environmental restoration importance in that it affects methylmercury production and bioaccumulation, it can be toxic to plants and animals, and it can mobilize phosphorus. Sulfate concentration varies markedly throughout the Everglades landscape, depending upon proximity to the Everglades Agricultural Area and the relative contribution of stormwater, rain water and groundwater. Interior portions of the marsh have sulfate concentrations <0.1 milligrams per liter (mg/L), while Water Conservation Area 2A is subjected to inputs exceeding 100 mg/L. Program data indicate that in November 2005 about 57.3 $\pm$ 6.0% of the Everglades marsh had a sulfate concentration exceeding 1.0 mg/L, the CERP restoration goal. This contrasts with 66.1 $\pm$ 7.0% during 1995. Less stormwater is the likely explanation for the decline, as the discharge of stormwater enriched with sulfate during the 60 days prior to the 1995 sampling was double that during the 60 days prior to the 2005 sampling. Dilution cannot explain the lower sulfate concentrations observed in 2005 since the water depth was also shallower. Background Everglades porewater sulfide concentrations are <0.02 mg/L, while in Water Conservation Area 2A they are as high as 10 mg/L, consistent with concentrations reported to inhibit the growth of sawgrass.

Findings relevant to restoration:

- As of 2005, about 25% of the Everglades Protection Area had soil TP greater than 500 mg/kg, Florida's definition of impacted, while 49% exceeded the restoration goal of 400 mg/kg. Statistical analyses indicate that these proportions are higher than the 16% and 34% observed in 1995-1996.
- During November 2005, about 57% of the Everglades Protection Area had a surface water sulfate concentration exceeding 1.0 mg/L, the restoration goal. Interior marsh locations have background concentrations < 0.1 mg/L. Sulfate varies spatially and temporally in the Everglades marsh, depending upon water management practices and stormwater pumping, proximity to canals, and proximity to the Everglades Agricultural Area.

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Biological Monitoring of Treefrogs for the Picayune Strand Restoration Project (2005-2007)

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Global amphibian declines are a focus for many researchers especially in the New World where over half of all amphibian species are found. There are many factors contributing to global amphibian declines, which include disease and malformation, parasitism, invasive species, toxic chemicals along with possible UV-b light and changing climate conditions. However, the most critical threats to amphibian populations in the United States are habitat loss and degradation; while the vitality of populations are also a reflection of water quality parameters and water levels, either naturally fluctuating or anthropomorphically altered, in these biologic systems.

The main objective of the treefrog data collection was to develop a baseline that could serve as an indicator of ecosystem change in response to the hydrologic restoration of the Picayune Strand State Forest (PSSF). The data were collected by conducting repeatable surveys in major plant communities at restoration sites in PSSF (n=27) and in downstream habitats of the Ten Thousand Islands National Wildlife Refuge (TTINWR; n=2). In addition, baseline data were collected at reference sites in the Fakahatchee Strand State Preserve (FSSP; n=6) and Florida Panther National Wildlife Refuge (FPNWR; n=6).

Treefrogs were sampled using polyvinyl chloride pipes as artificial refugia. Two sets of three 1 m lengths of pipe, each with different inner diameters (1.3, 2.5, and 3.8 cm), were placed randomly at each of the study sites. Three pipes were attached at arms reach on a tree trunk and when trees were not present, attached to tall grass stems. Additionally, three pipes were stuck a few inches into the ground. Pipes were checked monthly from August 2005 – December 2005, and bimonthly thereafter throughout the remainder of the study. Frogs were carefully extracted from the pipes and collected in mesh bags using a dowel rod plunger and a section of sponge pushed through each pipe. Captured frogs were identified to species, measured (snout-vent/urostyle length) to the nearest 1.0 mm, weighed to the nearest 1.00 gram, and then released on site.

A total of 1,732 anurans consisting of three species of treefrog, *Osteopilus septentrionalis* (Cuban treefrog), *Hyla squirella* (Squirrel treefrog) and *Hyla cinerea* (Green treefrog) were sampled. *O. septentrionalis* was the most abundant species and accounted for 64% of all individuals captured. *H. squirella* accounted for 20% of all individuals captured and *H. cinerea* accounted for 16% of the total. Community analysis of treefrogs indicated two Primary groupings corresponding to 1) all restoration sites in the PSSF and one reference site in the FSSP had a higher percent composition of *O. septentrionalis* and 2) all reference sites, (with the exception of the one in FSSP) and including saltwater marsh sites that had a higher percent composition of *H. squirella* and *H. cinerea*. The introduced species *O. septentrionalis* was clearly more abundant in the restoration sites of PSSF while the native *H. cinerea* and *H. squirella* were dominant at the reference sites. This suggests that hydrological restoration of PSSF could result in an increase in the population of green and squirrel treefrogs, contingent on their ability to compete with a well established population of Cuban treefrogs.

In regards to how this study, and others like it, holds relevance to the restoration:

- Hydrological restoration of PSSF could result in an increase in the population of green and squirrel treefrogs, contingent on their ability to compete with a well established population of Cuban treefrogs.
- Determining the requirements of native treefrog population's during pre-restoration offers the potential for adaptive management as the restoration proceeds.
- Treefrogs are a valuable food source for many higher trophic level animals, therefore accurate data that could be put towards helping to ensure stable and abundant populations of treefrogs will in the long term help ensure the continued success of these other species.

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Shell Mounds and Middens of the Ten Thousand Islands: Prehistoric Landscapes and Paleo-environmental Records of Regional Holocene Variability and Early Human Settlement of the Everglades Ecosystem

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While interdisciplinary scientific studies of the Everglades ecosystem are critical to successful ecosystem restoration, to date, few archeological studies have been considered in paleo-environmental reconstructions. There remains a limited consideration of the prehistoric human component to Everglades ecosystem development and history, and the great potential for archaeological evidence to provide significant paleo-environmental data on pre-drainage conditions in the Everglades.

Archaeological data provides one of the best data-sets for reconstructing past environmental conditions, providing a significant record of when and how prehistoric humans first appeared and settled into the region and moved throughout the landscape, what faunal and floral resources were available, and what local environmental conditions may have been extant. Preserved in rich archaeological contexts, prehistoric humans created anthropogenic sediments and middens that evidence and preserve this record, and reflect unique human adaptations to a dynamic ecosystem.

The Ten Thousand Islands contain dozens of extensive prehistoric shell mound and midden sites, and are among the largest and most complicated prehistoric shell constructions in the world. These immense sites were built by the prehistoric coastal foragers of south Florida, a rare example of a sub-tropical, non-agricultural society with a subsistence based principally on coastal resources. These significant sites are akin to warehouses of paleo-environmental data, providing a potential record of landscape change, including shifts in sea-level, climatic fluctuations, island geomorphology, vegetation change, and broader ecosystem changes reflected in the human settlement and adaptation of the greater Everglades ecosystem.

In the interior Everglades, recent archeological investigations of tree islands identified a buried, shallow-lying hard carbonate layer on 30 tree-islands. This layer could not be penetrated with hand tools or corers, but on two tree islands, a concrete saw was used to break through the hardened layer, and at least 50 cm of well-preserved organic soil and sediment was present beneath it. Archeological remains were found both above and below the layer, and dating of *in situ* archeological remains above and below the layer has bracketed the period of the formation of the layer to roughly 3800 to 2700 cal years BP. Absence of artifacts within the hardest zone of the carbonate layer suggests that the tree islands were abandoned during the formation of this layer, and that human settlement of tree islands shifted, or followed changes in water levels, climate or environmental conditions. Ongoing archeological and interdisciplinary studies from this finding have the strong potential to elucidate regional Mid-Holocene climactic shifts important to understanding ecosystem development.

On the coast, the recent discovery of Archaic shell midden rings, the earliest dated sites in the Ten Thousand Islands, suggests that populations settled along the coast earlier than previously thought, indicating that productive estuaries were extant by at least 3300 cal years BP. This finding may support a correlation between human abandonment of interior tree island sites and movement to the coast during this time. Examining the timing of shifts in population movements from interior tree islands in Shark River Slough to shell mound and midden sites along the coast provides an opportunity to further model changing environmental conditions on a regional scale.

Future work, and researchers currently working in Everglades restoration and management should consider archaeological evidence in reconstructing Everglades ecosystem history, and the potential benefits that archaeological data has in enhancing paleo-environmental reconstruction and Everglades restoration, including:

- Prehistoric humans created anthropogenic sediments and middens, preserving important paleo-environmental data reflecting broad trends or shifts in climate; sea-level; geomorphology of coastal and interior tree islands; and the timing of ecosystem development. This data is an important component in reconstructing past conditions.
- The locations and temporality of shell mounds and midden sites provide a record of estuary development, and additional data for modeling past climate and sea-level conditions.
- Archeological data from tree island sites provide additional paleo-environmental data that will enhance reconstruction of pre-drainage water levels and local environmental conditions.
- Ecofacts, such as vertebrate and invertebrate faunal remains, provide additional data on past ecological conditions, site habitat, and the presence of animal species targeted by prehistoric populations.

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Trends in Biogeochemical Processes across the Greater Everglades Landscape – Results of R-EMAP III

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The U.S. Environmental Protection Agency, Regional Environmental Monitoring and Assessment Program (R-EMAP) has completed the third phase of a synoptic sampling across the Greater Everglades Landscape, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LOX), Water Conservation Areas 2 and 3 (WCA2 and WCA3, respectively) and Everglades National Park (ENP). Phase III involved sample and data collection of 125 sites in the dry season (May) and another 125 sites in the wet season (Nov-Dec) of 2005 in a spatially balanced design. Biogeochemical parameters were measured in soil, flocculent detrital organic matter (floc), surface and porewater, vegetation and periphyton samples. Sample-appropriate analysis included: pH, redox potential, organic matter content, total and soluble nutrients, assays of microbial activity, and Hg concentrations.

Across the Everglades, there was significantly less floc present during the dry season when compared to the wet season suggesting a largely temporary biogeochemical storage in most of the system. There was a corresponding increase in surface water dissolved organic carbon. Dry season floc total P significantly influenced rates of phosphatase ($r = -0.492$, $P < 0.001$) and glucosidase ($r = 0.594$, $P < 0.001$) activities (assayed utilizing methyllumbelliferyl substrates). However, enzyme activities were not significantly related to CO_2 or CH_4 evolution. Similar results were found during the wet season. Soil total P influenced the rates of CO_2 and CH_4 evolution ($r = 0.234$, $P < 0.001$ and $r = 0.178$, $P < 0.007$, respectively) and were positively correlated with glucosidase activity and negatively correlated with phosphatase activity ($r = 0.351$, $P < 0.001$ and $r = -0.260$, $P = 0.005$, respectively). Soil CO_2 and CH_4 evolution rates were greater when conducted on wet season vs. dry season samples, suggesting seasonal variations in soil carbon lability. The wet season evolution of CO_2 from floc averaged approximately 2 to 10 times greater than that of the soil on a mass basis. The assay of CH_4 evolution was also greater in wet season floc samples compared with the soil but to a lesser extent than CO_2 evolution. Additional relationships between biogeochemical parameters and ecosystem processes across the Everglades will be presented.

Implications of these data for managers are:

- Hydrologic alterations should consider that seasonal dry-downs influence the presence and size of temporary ecosystem chemical storages (e.g. oxidation of the floc layer and release of the contained chemical elements).
- Because chemical and microbial activities change spatially and seasonally across the Everglades, increases in hydrologic loading may shift the balance between organic and inorganic C dynamics.
- Nutrient loading (e.g. phosphate) influences rates of microbially-mediated processes which can effect ecosystem chemical processing on landscape scales.

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The Hole-in-the-Donut Wetland Restoration Project

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The Hole-in-the-Donut (HID) wetland mitigation project was established on an area of former agricultural land inside Everglades National Park. Though the park was established in 1947, the HID was private farmland until the mid 1970s. Photointerpretation of historical aerial photos from 1940 through 1980 has been used to characterize the temporal history of farming in areas throughout the HID. Initially, farming was confined to areas with deeper marl soils. With the advent of rockplowing in the early 1950s, farming moved to higher elevation areas, which typically had thin, rocky soils. Rockplowing broke up the underlying limestone bedrock, thereby increasing soil depth, aeration and drainage. Impacts on soils varied considerably, depending on whether an area was rockplowed, how heavily the area was fertilized and how long crops were grown on the site.

As agriculture ceased, succession led to a number of different vegetation communities. Presumably the differing outcomes relate to differences in the nature and degree of soil alteration. Rockplowed areas were typically invaded by dense, nearly monospecific stands of Brazilian pepper. Some non-rockplowed areas also became dominated by Brazilian pepper, while others were either invaded by a mixture of native woody species, or continue to support marl prairie vegetation very similar to that found in comparable areas that were not farmed. Within the HID, rockplowed soils have much higher total phosphorus concentrations and lower total nitrogen concentrations than adjacent undisturbed soils. Phosphorus enrichment is believed to have facilitated invasion of enriched areas by Brazilian pepper. Non-rockplowed areas that were not invaded by Brazilian pepper are currently being investigated to test the hypothesis that phosphorus concentrations in these areas are lower than those in areas where Brazilian pepper dominates.

Following the transfer of HID farmland to the park, a variety of methods for restoring Brazilian pepper-dominated areas were tested, including chopping, root raking, mowing, bulldozing, burning, herbicides, disking, partial substrate removal and complete substrate removal. Only complete substrate removal accomplished long-term wetland restoration of Brazilian pepper-dominated areas. In most parts of the HID, complete substrate removal scrapes away 7 to 15 cm of soil and roots, leaving only a very thin remaining soil layer, if any. An effort is made to remove soil from solution holes, but most retain a fairly deep soil layer.

Following restoration, areas retain nutrient concentrations similar to those present prior to restoration. Post-restoration nutrient availability for plant growth is presumably low due to the very shallow soil depth. This interpretation is corroborated by the development of a plant community consisting primarily of native wetland plants where soil removal was complete. Native and exotic species that are indicators of nutrient enrichment, such at cattail and Brazilian pepper, thrive primarily in soil-filled solution holes or other areas where complete soil removal was not achieved.

In areas restored by removing substrate, marl soils gradually accrete as the result of the activities of periphyton. By 14 years post-restoration, an average of 3.7 cm of soil had developed. This soil depth is at the low end of the range (3-7 cm) described as optimal by the Hydrogeomorphic Model of everglades rocky flats wetlands. It is therefore likely that soil-related wetland functions are beginning to approach natural conditions by 15-20 years post restoration. A conceptual model of post-restoration nutrient changes suggests that initially low nitrogen concentrations increase post restoration, as the microbial community fixes nitrogen. Phosphorus in the post-restoration soils is gradually converted to organic forms, reducing phosphorus availability. In the absence of significant external phosphorus loading, total phosphorus concentrations are expected to decline with time, as the residual phosphorus left over from agricultural fertilization will be diluted by the accumulation of microbially produced marl. The result of these changes is a gradual switch in the biotic community from nitrogen limitation to phosphorus limitation, eventually mirroring the situation in adjacent undisturbed wetland sites.

In conclusion:

- Rockplowing and subsequent fertilization in the Hole-in-the-Donut altered thin, poorly aerated, nutrient poor soils, making them deeper, more aerated, moderately well drained and richer in phosphorus.
- Brazilian pepper most readily invaded and dominated areas with elevated soil phosphorus concentrations.
- Successful restoration of Brazilian pepper-dominated former farmland requires the nearly complete removal of altered, nutrient-enriched soil.
- Following soil removal, restored areas gradually accrete periphyton-produced marl and nitrogen, phosphorus is converted from inorganic forms to less available organic forms and diluted by the accumulating marl. With time, these processes are expected to result in a switch from initial nitrogen limitation to phosphorus limitation, similar to that observed in nearby undisturbed locations.

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Evaluating Alternative Plans for the CERP Biscayne Bay Coastal Wetlands Project

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The Biscayne Bay Coastal Wetlands (BBCW) project is part of the Comprehensive Everglades Restoration Plan (CERP). CERP provides a framework to restore, protect and preserve the water resources of central and southern Florida and was developed by the U.S. Army Corps of Engineers (USACE), the South Florida Water Management District (SFWMD), and many other federal, state, tribal and local partners. The BBCW study area is in southeast Miami-Dade County in an area where coastal freshwater and saltwater wetlands have been fragmented and/or converted for agricultural and suburban development, and historic flows to Biscayne Bay have been altered by humans. The project seeks to improve the quality, quantity, timing and distribution of flows to restore and maintain desirable biological communities in Biscayne Bay, Biscayne Bay National Park, and adjacent coastal wetlands.

Regulations dictate how USACE ecosystem restoration and other Civil Works projects are formulated, evaluated and selected for implementation. In USACE mission areas where both costs and benefits can be calculated in monetary terms, alternative plans are evaluated using benefit-cost ratio analysis and net economic development (NED) values. While monetary costs can be determined for ecosystem restoration projects, no equivalent, universal method for quantifying the monetary return of environmental benefits exists. Instead, the economic tools of cost effectiveness analysis and incremental cost analysis, a measure of production efficiency, are used to support decision making. To conduct these analyses, ecosystem restoration outputs must be clearly identified and quantified in measures comparable across alternatives. These outputs, generally referred to as Habitat Units (HU's) for CERP decision making, are typically calculated utilizing models including Habitat Evaluation Procedures (HEP), Hydrogeomorphic (HGM) Approach to Assessing Wetland Functions, Index of Biotic Integrity (IBI), Macroinvertebrate IBI (MIBI), Floristic Quality Assessment (FQA). Qualitative Habitat Evaluation Index (QHEI), and other US Fish and Wildlife Service Habitat Suitability Index Models.

For the BBCW project, the study team developed a unique tool called the Criteria Based Ecological Evaluation Matrix (CBEEM) to compare alternative restoration plans. The CBEEM was derived from a well documented method known as the Multi-Criteria Decision Making (MCDM) approach. MCDM is a holistic decision making tool utilizing measures and procedures that aim to combine multiple criteria, which can be either conflicting or supporting, and provides credence to investment decisions. Based on this approach, the CBEEM was developed by a multi-agency team of ecologists and scientists familiar with the study area and knowledgeable about the ecological stressors the BBCW project seeks to influence. This poster describes the CBEEM and provides examples of its output.

CBEEM was developed to assess the relative ecological benefits and consequences of BBCW project alternatives to guide selection of the recommended restoration plan. CBEEM is a Microsoft (MS) Excel spreadsheet tool that utilizes hydrologic modeling results, management measure size and operation, and available hydrologic data to calculate a HU score for each alternative. CBEEM is used to evaluate ecological benefits for each of the three major ecological zones present within the project area separately using performance measures (PMs). The three ecological zones include the near shore bay estuarine zone, the saltwater or tidal wetlands zone, and the freshwater wetlands zone. Each PM addresses project objectives, relates to conceptual ecological models that have been developed for Biscayne Bay and the adjacent mangrove transition zone, and quantifies to the extent possible the ecological benefits provided by the measure. The PMs include: (1) restoration of near shore salinity regime, (2) restoration of tidal wetland salinity regime, (3) reduction in harmful point source canal discharges, (4) potential freshwater rehydration, (5) reduction in nitrogen concentrations, (6) reduction in phosphorus loading to Biscayne Bay, (7) reduction in non-native vegetation, and (8) decompartmentalization of the wetlands and basins.

The CBEEM evaluation is accomplished in four steps: (1) calculate PM output, (2) normalize PM output, (3) compute quality index, and (4) compute HUs. PMs are quantified to the extent possible using model output, hydrologic data, project feature operation, and Geographic Information System data. Numeric targets for evaluation metrics were established whenever possible. For these metrics, the scores were converted to percent of target achieved to compare and contrast between and among evaluation metrics, and to normalize the output. Establishing targets for some metrics was not possible. In these cases, scores were normalized against the alternative with the highest score. Normalizing output allowed evaluation metrics to be combined to produce an ecological benefits index for each ecological zone. For this project, the scores from all the evaluation metrics applicable to a given ecological zone were simply averaged to provide a single index value for that zone (i.e., all PMs were equally weighted). The indices were then applied to the total spatial extent of each ecological zone (in acres) to produce HUs. Thus, HUs were provided separately for the near shore, saltwater wetlands, and freshwater wetlands zones. The Cost Effective/Incremental Cost Analysis was performed for each of the three ecological zones.

Preliminary results show that certain PMs indicate significant differences in performance between project alternatives; other PMs indicate relatively little difference. However, when all PMs applicable to a given ecological zone are aggregated to provide an overall ecological index for that zone, sufficient differences in index values provide reasonable separation in alternative performance. Output from the CBEEM, including examples of PM and index scoring, will be provided in the poster presentation.

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Tree Composition, Recruitment and Mortality of Hammocks in Biscayne National Park, Homestead, FL, USA

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Vegetative composition, recruitment and mortality in tropical hardwood hammocks on the islands within Biscayne National Park were studied for the purpose of gathering baseline data for defining hammock types and the factors that influence them in order to develop strategy for restoration of hammocks within Biscayne National Park and the Florida Keys. Understanding the dynamics and restoration of these hammocks are important, as they may be a pathway for seeds colonizing the tree island communities within Shark Slough.

Thirty-two 20m x 20m tree plots were randomly established on four islands (Elliott Key, Sands Key, Old Rhodes Key, and Totten Key) in Biscayne National Park. Each tree plot was sampled for tree (≥ 2.5cm diameter at breast height (dbh)) composition, recruitment, and mortality. Nested subplots within each tree plot were also monitored for saplings (5m x 5m) and seedlings (0.5m x 0.5m). Repeated sampling was done each year over a three year period (1995-1998). A total of 30 tree, 23 shrub, and 10 vine species were recorded, and 6189 trees were tagged, and their dbh measured. We calculated species importance values (IV) as the sum of a species relative dominance, or relative basal area (RD), and relative frequency (RF). The formula used for its calculation is; $IV_i = RD_i + RF_i$. Species with the highest importance values were *Coccoloba diversifolia, Metopium toxiferum,* and *Bourreria ovata.* Relatively rare species with low importance values were *Ficus aurea, Guaiacum sanctum, Schefferia fructescens*, and *Chrysophyllum oliviforme*.

Average tree density for the four islands ranged from 2741 trees/ha on Sands Key to 5534 trees/ha on Old Rhodes Key. Annual average tree mortality for all four islands was 2.94%/year. Elliott Key had the highest annual tree mortality at 5.5%/year and Sands Key had the lowest tree mortality at 1.51%/year. Annual average tree recruitment for the four islands was 2%/year, and ranged from a low of 1.06%/year on Old Rhodes Key to a high of 2.72%/year on Totten Key.

Tropical hammocks of the Florida Keys may be an important source of tree seeds colonizing the tree islands in Shark Slough. Many dominant tree species in Biscayne National Park are also a large component of tree island composition in Shark Slough, including *Bursera simaruba, Sideroxylon foetidissimum, Eugenia axillaris* and *Coccoloba diversifolia*.

The vegetation study provides managers with data needed for effective management of Biscayne National Park's upland plant communities.

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The Potential for Aquaculture to Support the Recovery of Apple Snail, *Pomacea paludosa*, Populations in Florida Wetlands and Lakes

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The Florida apple snail (*Pomacea paludosa* Say) is a critical component of Florida freshwater lakes and wetlands, serving as prey to many aquatic and avian predators, including the endangered Snail Kite (*Rostrahmus socialibilis*). The snail kite utilizes a network of freshwater wetlands and lakes that are influenced by natural hydrologic cycles as well as water management. In the last eight years, habitat quality and snail availability has been substantially reduced, contributing to the decline of the kite population. Natural reestablishment of wild snail populations to support kite foraging may take many years. The South Florida Water Management District (SFWMD), in cooperation with Harbor Branch Oceanographic Institute (HBOI), has implemented a pilot study to explore the possibility of using aquacultured snails to speed up the recovery of decimated snail populations through restocking. HBOI has successfully raised snails hatched from eggs collected in the field, and they have produced two generations of cultured snails. Hatch success, egg size, survival and other measures of snail viability are being assessed and will be compared to data from field studies. In addition, questions regarding genetics and how to scale up the culture to levels applicable to restoring large marsh areas will be discussed. A pilot level release is planned for spring 2008 and in collaboration with the University of West Florida, in which the efficacy of a restocking effort will be examined. The snail culture project will be discussed in the context of other SFWMD approaches to restoring habitat quality and hydrologic conditions to support the recovery of snails and their predators.

Key Words Relevant to Restoration:

- Stock enhancement and restoration of fauna
- Snail kite recovery
- Apple snail recovery and enhancement

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Water Quality in Everglades National Park, Part II: Statistical Summary, Trend Analysis and Influence of Water Sources

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Surface water inputs to Everglades National Park (ENP) include natural and anthropogenic sources. Water quality varies spatially across ENP because of natural variations in hydrology, landscape and water delivery practices. An evaluation of water-quality data provides a general distribution of hydrochemical characteristics within ENP.

The data analyses were based on statistical methods. All records were inspected visually and filtered for outliers by removing values that were either extremely high or abnormally low and appeared erroneous. Values below the MDLs (methods detection level) were flagged and received special attention. Multiple MDLs were observed for some constituents, as analytical methods and laboratory equipment have evolved and improved over time, resulting in better detection capabilities. As explained in Part I of the study, the adjusted maximum likelihood estimator (AMLE) and the log-probability regression (MR) methods were applied to data sets having both censored and uncensored data. These methods provided unbiased estimates of means, standard deviations, and quartiles. The analysis included marsh water-quality stations and surface water-delivery stations. The USGS library for S-PLUS for Windows -- Release 2.1 was used for trend analysis and for application of AMLE and MR methods.

The chemical composition of ENP's surface water inflows has changed and is affecting the quality of water at interior stations. Historically, surface water was a calcium bicarbonate type, mildly alkaline, with very low nutrient content. Presently, the water is slowly changing to a sodium chloride type, mildly acidic in nature with elevated nutrient content and contains low but persistent levels of pesticides. Although some of the water quality changes are related to weather, other changes and trends are the result of up-stream water management practices.

Specific conductance and concentration of chloride (Cl) ions can be used to evaluate not only the relative quality but also to elucidate the sources of water. At inflow station S333, specific conductance is elevated compared to historical levels (465 μS/cm). The shift from unregulated marsh flow to regulated canal deliveries within ENP has resulted in a 140-percent increase in specific conductance and a 300-400 percent increase in Na (sodium) and Cl concentrations since the early 1960s. A significant increase in nutrients is also noticeable.

The Wilcoxon signed-rank test showed that water sources for ENP's eastern (S332, S332D) and northern (S333) boundaries differed significantly in Cl concentration. A historical review of Cl concentration in Shark River Slough (SRS) using pooled data from the NE1, P33 and P35 stations, showed that averages were about 73 mg/L during 1985-97, decreased to 43 mg/L in 1998-02 and increased again to 59 mg/L in 2003-05.

Synthesis of the ENP water quality data revealed that P34 (northwestern corner) has the best water quality with the lowest concentrations and smallest concentration ranges of all monitoring sites. By contrast, inflow station S333 (at Tamiami Trail, northern border) has the highest concentrations and the largest concentration ranges (with exceptions). Site EP (southeastern corner) has the highest concentration and the largest concentration range for Cl and specific conductance, but the lowest concentration for total phosphorus. In general, canal water delivered to ENP inflow structures (S333 and S176/S332D) has the poorest quality.

During the next 30 years, numerous restoration projects will try to restore the ecology of the Everglades by re-arranging the existing hydrology to be more like the original natural system. Clearly, the fate and success of these projects will depend on the quality of the future water.

The key findings of this study are:

- Water management of the water conservation areas has a strong influence on the chemical composition of the water in ENP. Since 1979, water deliveries to ENP have followed multiple schemes. Invariably, with the implementation of each new management practice, a distinctive shift in the inflow water ionic composition has been observed.
- Water quality in Taylor Slough has been gradually improving since the 1980s. The majority of the constituents show only slight increases in concentration from historical levels; the exceptions are nitrates and nitrites.
- In SRS, most constituents show slight increases in concentration levels from historical levels; the exceptions are Cl, Na, sulfate, and specific conductance, which show strong increases. Water quality in SRS deteriorated in the late 1980s, improved in the middle 1990s, and appears to be deteriorating in recent years again.
- Water quality at S333 appears to have improved since the 1980s but to have slightly deteriorated in recent years. More than one-half of the constituents have nearly doubled their historical concentration levels. The assessment from the 1980s to the present shows that more than one-half of the constituents have decreasing trends; the exceptions are phosphorus and sulfate, which have increasing trends. Since 2000, specific conductance, sulfate and phosphorous, have strong increasing trends.

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Pre-construction Baseline Monitoring Survey of Florida Panther (*Puma concolor coryi*) and Their Primary Prey in the Picayune Strand Restoration Project Area

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The Picayune Strand Restoration Project (PSRP), an important component of the Comprehensive Everglades Restoration Plan, will remove the infrastructure and restore the natural hydrology and vegetation of the 23,995 ha Southern Golden Gate Estates subdivision (SGGE) in Collier County, Florida. A primary objective of the PSRP is the restoration and enhancement fish and wildlife resources, including listed species such as the Florida panther (*Puma concolor coryi*), affected by the habitat impacts of the SGGE development. The quality and quantity of panther habitat in the PSRP area has been affected by past land use practices, hydrologic alterations, road construction, exotic plant invasion, and the lack of fire management. Anecdotal information suggested that the reduced panther occurrence in the PSRP area was likely attributed to a reduction in prey abundance, primarily white-tailed deer (*Odocoileus virginianus*) and feral hog (*Sus scrofa*), stemming from the degraded habitat quality associated with water management practices and the high levels of human disturbance aggravated by the primary and secondary road grid. We described the present extent of Florida panther and its primary prey within the PSRP area from July 2005 – March 2007 based primarily on indicies of relative abundance (RAI) generated from infrared-triggered remote camera surveys that will serve as a basis for future evaluations of project restoration impacts on and benefits to panther habitat. We identified at least 12 individual adult panthers (7M, 5F) using the PSRP area on at least one occasion during the 20-month survey period and confirmed that pre-construction conditions in the PSRP area supported a reproductive segment of the panther population. The RAIs and spatial distribution of deer documented within the PSRP area should provide a sufficient benchmark to objectively monitor changes in deer distribution and relative abundance over time and evaluate the impacts of these changes on panther presence and relative abundance. To our knowledge, this is the most intensive standardized survey of panther and their prey in the PSRP area.

- We provided 3 indices of Florida panther and their primary prey in the PSRP area based on systematic infrared-triggered remote cameras that captured both a literal and figurative snapshot of pre-construction conditions related to the quality of panther habitat.
- Pre-construction conditions in the PSRP area provided a sufficient prey base to support a reproductive segment of the Florida panther population.
- We confirmed that at least 4 adult female panthers with dependent-aged kittens used the PSRP area concurrently during late 2006 and early 2007.
- The relative abundance indices and spatial distributions of Florida panther and primary prey species should provide sufficient pre-construction project baselines to adaptively evaluate post-project impacts on and benefits to panther habitat in the PSRP area.

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Effects of Turbulent Ground-Water Flow on Hydraulic Heads and Parameter Sensitivities in Preferential Groundwater Flow Layers within the Biscayne Aquifer in Southeastern Florida

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The U.S. Geological Survey created a Conduit Flow Process (CFP) for the Modular Finite-Difference Ground-Water Flow Model, MODFLOW-2005. An application of the CFP on the Biscayne aquifer in southern Florida is described that examines (1) the potential for turbulent groundwater flow, and (2) the effects of turbulent flow on hydraulic heads and parameter sensitivities. Turbulent flow was spatially extensive in preferential groundwater flow layers with mean void diameters equal to about 3.5 centimeters, groundwater temperature equal to about 25 degrees Celsius, and critical Reynolds numbers less than about 400. Turbulence either increased or decreased simulated heads from laminar altitudes. Specifically, head differences from laminar altitudes ranged from about -18 to +27 centimeters, and were explained by the magnitude of net flow to the finite-difference model cell. Turbulence also influenced the sensitivities of model parameters. Specifically, the composite-scaled sensitivities of horizontal hydraulic conductivities decrease by as much as 70% when turbulence is removed. Resultant hydraulic head and sensitivity differences due to turbulent groundwater flow highlight potential errors in models which assume laminar flow in an equivalent porous-media having uniformly distributed void spaces. These key findings are relevant for researchers interested in developing realistic hydrologic models for restoration analysis.

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Watershed-scale Impacts of Using Stormwater Impoundments as an Alternative Source of Water Supply

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South Florida is facing water-quantity and –quality challenges. Increasing population in southern Florida has dramatically increased water demand. Water quality has been adversely affected by both point and nonpoint human sources. Water demand in the region is expected to increase by 27% by 2020. State agencies are exploring alternative sources of water supply to meet the increasing demand. Capture and use of storm water is one of the options that can help meet part of the water supply shortfalls. One example of this option is capture and use of agricultural drainage and runoff. Currently stormwater impoundments are used in most of the agricultural areas in the southern Florida to temporarily detain stormwater. These impoundments were constructed to meet the requirements for storm water management, which involves capturing the first 1-inch of runoff and drainage from the design area for both water quantity and quality control. In the watershed of Caloosahatchee River (CR), one of the main sources of water supply in southwest Florida, more than 16,000 acres are devoted to agricultural impoundments.

A study was conducted to evaluate the feasibility of using stormwater impoundments as an alternative source of water supply. The study involved monitoring and modeling of water dynamics of an agricultural impoundment in the CR watershed. Monitoring data from the impoundment indicated that water levels drop below the ground surface soon after the beginning of the dry season. Water levels are above the ground surface soon after the beginning of the wet season. Several scenarios, from lining the impoundments to capturing and repumping of seepage, were evaluated using a hydrologic model MIKE-SHE. Results indicated that storm water impoundments can be a viable source of water supply, and may provide up to three months of water supply with impoundment Modifications.

Use of distributed impoundments as an alternative source of water supply at the watershed scale can result in economic and environmental benefits. Impoundment water use for irrigation can reduce amount of water pumped by agriculture from traditional surface and ground water sources, increasing the amount of water available to other water consumers. If appropriate policy mechanism exists, farmers can “sell” their reductions in water use to urban water supply utilities, which are demanding additional water for their growing populations. If landowners are allowed to trade water with urban communities, it could potentially generate an additional source of income for agricultural landowners. Use of impoundment storage for irrigation can reduce farm-scale discharges to the CR and help meet maximum flow levels to the Caloosahatchee estuary. Using storm water for irrigation also has the potential to reduce nutrient loadings to the CR. Modification of impoundments to increase dry period storage can have positive impacts on wildlife. A 5-year avian-count study to evaluate the wildlife use in a similar agricultural impoundment located in southwest Florida showed wetland habitats within the impoundments attracted a variety of avian species. Compared to other water supply storage structures such as reservoirs, impoundments do not require additional land area.

Although there are several potential environmental and economic benefits, some benefits have not been quantified. Future research needs for use of impoundments as an alternative water supply source at the watershed-scale are: 1) effect on watershed-scale water savings and flows to the river and estuarine systems; 2) effect on nutrient loadings to the river; 3) effect on wildlife; 4) costs of alternative impoundment modifications to a farmer; and 5) design of a policy mechanism to allow farmers to receive compensations for their reductions in water use, either in the form of cost-share subsidy to cover impoundment modification costs, or as a compensation received from a "trade" with urban entities.

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RECOVER Monitoring and Assessment in the Northern Estuaries

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Regional and system-wide science-based ecosystem assessments are a major component of understanding the environmental restoration benefits of the Comprehensive Everglades Restoration Plan (CERP). This interagency program has been established as part of the Monitoring and Assessment Plan (MAP) by the REstoration COordination and VERification (RECOVER) branch of CERP. To date, MAP monitoring has focused on providing an assessment of the pre-CERP status and condition of four geographic modules of the South Florida ecosystem given currently-available data.

The GEER workshop entitled *System-wide Assessment of South Florida Ecosystems – Where Are We Today and Where Are We Going Tomorrow* touches upon many components of the RECOVER program; the state of scientific knowledge, the health of the South Florida system, and how scientific information generated from system-wide monitoring and assessment is being applied, specifically with respect to integration with CERP projects.

The Northern Estuaries Module Team is responsible for water bodies on both Florida coasts with the Caloosahatchee River and Estuary, San Carlos Bay and Estero Bay on the west coast and St. Lucie Estuary, the Southern Indian River Lagoon, the Loxahatchee River estuary and Lake Worth Lagoon on the east coast. Historically, natural freshwater discharges into these water bodies sustained an ecologically appropriate range of salinity conditions to facilitate the presence of healthy floral and faunal communities. The urbanization of Florida's coastal regions and the ensuing increased demand for water and flood protection has led to frequent high and low salinity extremes within the coastal water bodies. Managing for these demands has subsequently resulted in a shift in the ecological components that historically defined the coastal water bodies to communities deemed less desirable.

In the Northern Estuaries, the monitoring and assessment program has been designed around the conceptual ecological models presented in Wetlands (Sime 2005). The key indicator species have been identified as Oysters, Submerged Aquatic Vegetation, Benthic Invertebrates and Fisheries. The conceptual ecological models for each of these indicators outline the relationships between the stressors, key drivers and biological indicators themselves. This workshop is structured around presenting the monitoring programs for the key indicators in the Northern Estuaries. Each monitoring program examines the past, current and future of these indicators in the context of their use as key indicators of ecosystem response to restoration activities to track the progress toward interim and final targets and their ability to inform through a science/management linkage that will be used to help operate the system and fine-tune restoration solutions.

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Potential Water Balance Impacts of Global Climate Change on the Extant Everglades in Comparison to a Simulated Pre-Drainage Everglades

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Operational decisions associated with the management of the extensive canals and numerous water control structures in South Florida have had a significant impact on the transport of water across both natural and man-made boundaries and availability of water in different regions. These decisions are driven by the need for society to balance the requirements of water supply, flood control, and environmental protection. As a result, current discharge to tide along the Atlantic coast is twice that estimated for the pre-drainage watershed, while total surface inflows to the Everglades National Park from historic upstream basins has declined by some 44% . Considering future climate change, major shifts in the way water moves from one region of the watershed to another may need to be adjusted to compensate for extreme temperature increases, evapotranspiration increases, and rainfall decreases. From an ecological perspective, this comparison highlights the resilience of the pre-drainage water budget to the vagaries of climate. From a water management perspective, this comparison highlights the uncertainty of climate change predictions for South Florida and the potential severity of a “worse-case” scenario on the potential water budget impacts to both nature and society.

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A Review of Our Understanding of the Biogeochemical Processes on Tree Islands in the Greater Everglades

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Soil nutrient concentrations appear to be an order of magnitude greater on tree islands than any other habitat in the greater Everglades, except those impacted by phosphorus runoff. Mechanisms that have been suggested to concentrate large quantities of nutrients that may otherwise be released to the Everglades include nutrient displacement by wading birds, dry deposition capture by trees, slow nutrient turn-over rates, groundwater upwelling, and biologically-mediated evapotranspirational pumping of surficial water.

This newly discovered functional aspect provided by tree islands might make the steady conversion of islands into marsh a critical restoration uncertainty and an important element for scientific discussion. Tree islands appear to concentrate large quantities of phosphorus (P) and sequester inorganic nitrogen (N). Enrichment with both P and N in surface water of the Everglades has been documented to dramatically change the ecological structure and function of wetland communities in the Everglades. Nitrogen loading has been linked to algal blooms in the more phosphorus enriched parts of Florida Bay, and phosphorus loading has been linked to slough closure and cattail invasion.

Comparison of marsh and tree island biogeochemical characteristics indicate that tree islands have higher soil bulk P and N content and lower inorganic N in soil porewater relative to adjacent marsh soils. Total soil phosphorus (TP) levels in the upper 10 cm averaged 421 g m^{-2} compared with only 6 g m^{-2} in the surrounding marsh. However, TP levels on the heads of islands can be highly variable, ranging from 6 - 3576 g m^{-2}. Near tail TP levels were on average, 20 times lower than on the heads, while far tail levels at 10 cm soil depth tend to be the same as the adjacent marsh. These soil properties suggest that seasonally flooded tree islands sequester nutrients, thus promoting retention and reducing nutrient loads to downstream estuaries and near-shore coastal systems. As the hydrologic restoration of upstream freshwater marshes of the Everglades occurs, and tree islands are restored, the nutrient sequestration function of tree islands is likely to change as the tree island-marsh linkages become more conducive to an oligotrophic ecosystem.

Little is known about the specific forms of phosphorus on tree islands. An island with an active rookery was found to have a soil TP fraction composed of some 70-90% inorganic phosphorus, while the surrounding marsh had only 10% inorganic phosphorus. It has also been noticed on non-rookery islands that microbial stocks of P are some two times greater on the head (3,164 g m^{-2}) than on the near tail (1,444 g m^{-2}). Recent analyses of subsurface hydrologic TP, N+N, and NH_4 fluxes on reference island 3AS3 indicated net annual accumulations of 6.1, 0.7, and 19.4 g m^{-2}, respectively.

Our goal of this review is to investigate the ecological contribution of tree islands to the nutrient balance of the Everglades landscape and ask the question: Why is it that the Everglades is not a homogeneous oligotrophic system? We will summarize data from the plants, soils, water, animals and air around tree islands to characterize important hydrological drivers and describe their effects on restoration trajectories of key tree island ecosystem parameters, and address the hypothesis that tree islands are "open" to external fluxes of nutrients, thus having the potential to sequester nutrients from the surrounding environment. If it is found that focused redistribution of phosphorus and nitrogen from surrounding marshes to tree islands is significant, then the Everglades will be a unique example of a habitat-mediated, biogeochemical feedback landscape that is essential to its geomorphology and biodiversity.

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Discovery and Delineation of Seagrass Beds in the Ten Thousand Islands Using Manatee Radiotelemetry Data, Spatial Modeling, and Stratified Field Sampling

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The Florida manatee (*Trichechus manatus latirostris*) is an endangered species that inhabits most coastal waters of the state. They are excellent indicators and sentinels of estuarine health, and are being used as a gauge of Comprehensive Everglades Restoration Plan (CERP) success. One of the habitat needs of manatees is seagrasses or other aquatic vegetation for forage. Documentation of the extent and availability of seagrass forage is valuable for assessing habitat suitability and change. Many waters in Florida are clear, and seagrass beds can be mapped from aerial imagery. In southwest Florida, especially within the Ten Thousand Islands (TTI) area, waters are generally turbid, and attempts to map available seagrass beds have been largely unsuccessful. Here, we analyzed GPS telemetry records from radio-tagged manatees tracked in the TTI region to delineate foraging areas. We found distinct seagrass foraging areas in water of less than 3ft depth offshore of most islands, with total foraging area approximately four times the extent of previously mapped beds. We are currently performing Bayesian analysis to determine the likelihood of the existence of further forage areas not mapped by the animals, and constructing a complementary spatial model to predict locations of these unvisited beds using physical and geographical covariates. We are also performing stratified field sampling with point and transect samples to validate and refine the analysis, and to determine seagrass species community patterns. This technique can be used as an efficient tool for monitoring changes in seagrass beds that may result from CERP efforts or sea level rise. It can also be fitted to existing or future manatee telemetry data from other regions.

Importance to Restoration and CERP Goals

The seagrass beds in the TTI area serve as forage to manatees year round, and may be especially critical for manatees that take refuge in Port of the Islands (POI) during cold periods. POI is identified in the Manatee Recovery Plan as a primary winter aggregation site, with over 100 manatees commonly using it each winter. As such, this study will provide a needed recovery goal for this area, the mapping of manatee foraging areas. This study addresses or will be of assistance with several identified needs in the recovery plan for the TTI area:

- Protect, identify, evaluate, and monitor manatee habitats
- Protect existing submerged aquatic vegetation (SAV) and promote re-establishment of native submerged aquatic vegetation (NSAV)
- Conduct research to understand and define manatee ecology
- Conduct research and improve databases on manatee habitat
- Continue and improve telemetry and other instrumentation research and methods
- Define response to changes in fresh water flow patterns in south Florida as a consequence of the Everglades' Restoration

- Maintain, improve, and develop tools to monitor and evaluate manatee habitat
- Improve evaluation and prediction of the effects of Everglades restoration on listed species
- Improve monitoring of endangered, threatened, candidate, or imperiled species and the ecological communities upon which they depend.

Specifically, this research will provide:

- Improved detection and mapping of the offshore seagrass beds that the Florida manatee and many other species of interest rely on for forage.
- A baseline map of foraging areas prior to restoration efforts currently underway that will affect water delivery to the study area, including the Picayune Strand Restoration Project.
- An estimate of additional carrying capacity projected from the number of manatees that could be supported by unused forage in the area. This would be important information because the manatee population in the region is expected to grow as manatees displaced from power plant shutdowns migrate to the region.
- A means of tracking and quantifying changes in offshore seagrass beds brought about by PSRP or other restoration projects, or climate change.

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Freshwater Flow through Joe Bay Relative to Flow through Taylor Slough and C111 Structures

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Salinity, a critical habitat variable in northern and central Florida Bay, is a function of the balance between rainfall, evaporation, and freshwater inflow from the Taylor Slough and C111 basins north of the Bay. The quantity and timing of water delivered to freshwater marshes in Taylor Slough and the C111 basin as a result of CERP Projects will determine the degree to which salinity conditions in Florida Bay will be restored. The C111 Spreader Canal Project and other efforts to restore marshes and marine systems in the southern everglades will benefit from both improved modeling and analysis of field monitoring data. Roughly half of all measured flow to Florida Bay moves through the Joe Bay system and Trout Creek. This project analyzes field data to better define the relationship between freshwater delivered to Florida Bay through Joe Bay and water flowing through 1) Taylor Slough at the Park road and 2) lower C111 canal between S18C and S197.

USGS began monitoring creek discharges to northern Florida Bay in 1996 and data from this effort has been essential for development and calibration of the SICS and TIME models by the USGS. Starting in 1999 the USGS began measuring discharge, salinity and stage at 4 small creeks that flow into Joe Bay and at Stillwater creek that connects the Joe Bay system to Long Sound to the east. Mark Zucker with the USGS has previously described the spatial pattern of flow into Joe Bay and addresses temporal and spatial salinity patterns in a related abstract. Wind, rainfall and evaporation data from the ENP/SFWMD station in Joe Bay will be needed to define the salt and water budget and compute net freshwater flow through Trout Creek. Flow through Taylor Slough is monitored by Everglades National Park and structure flows through the C111 canal are monitored by the SFWMD. Ed Kearns *et. al*. with Everglades National Park describes operation of structures on the C111 relative to flows through The Taylor Slough section in a related abstract.

Findings relevant to restoration include the following:

- Fresh water budget for Joe Bay
- Salt budget for Joe Bay
- Relationship between freshwater export from Joe Bay and upstream structure flow

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Comprehensive Everglades Restoration Plan: Cultural Resources Overview and Survey Strategy

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As part of the Comprehensive Everglades Restoration Plan (CERP), the U.S. Army Corps of Engineers, Jacksonville District, requested that New South Associates prepare an updated archaeological survey strategy to more effectively identify probability areas and locate sites. The CERP cultural resource study area covers most of southern Florida and comprises some or all of thirteen counties. Development of the CERP survey strategy required a consideration of known cultural resources; an evaluation of past survey procedures; the identification of site probability variables; and development of a regional survey approach. Existing Florida Master Site File (FMSF) data were used in combination with historical maps and records, aerial photographs, Geographic Information System (GIS) layers, and other sources. The survey strategy is designed to have applicability to any project in the CERP project area and, because of its extensive geographic focus, to have benefits for both academic research and cultural resource management. An important aspect of the survey strategy is its analysis of past and present landscape features as they relate to known and probable site settings, as well as consideration of landuse history that may have impacted site preservation. As a supplement to the survey strategy, GIS Data Sets were created that illustrate site location patterns within eight CERP subregions. These introduce a basic toolkit of variables to consider when using GIS capabilities to identify site probability areas.

The findings are relevant to CERP restoration in terms of: cultural resource survey, archaeological site probability, regional planning, and GIS.

A Cooperative Effort between U.S. Army Corps of Engineers, Jacksonville District; the South Florida Water Management District; the Division of Historical Resources; New South Associates; and Janus Research

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A Decade of Surface Elevation Change in Wetlands of the Southwest Coastal Everglades: Sea-Level, Disturbance and Freshwater Inflow

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The ability of coastal wetlands to maintain elevation in a time of rising sea-level is critical for their continued persistence. We measured patterns of wetland surface elevation change, sediment accretion and shallow subsidence at eight sites in the southwest coastal wetlands of Everglades National Park beginning in 1998. Each site has surface- and ground-water wells for measuring water level and conductivity. Permanent plots for monitoring wetland vegetation dynamics have also been established. The sites are arranged along two upstream to downstream transects, on the Shark and Lostmans Rivers. The upstream sites are in non-tidal, freshwater marsh systems dominated by sawgrass and spikerush. The mid-river sites are in mixed brackish marsh / mangrove vegetation. Downstream sites are in tall, riverine type mangrove forests near the mouths of the rivers. A final site along Big Sable Creek (BSC), on the northwest side of Cape Sable, consists of mangrove forests and adjacent, barren mudflats. The mudflats were forested in the 1920s then converted to mudflat following the passage of the Labor Day hurricane of 1935.

Both upstream freshwater marsh sites had high variation in elevation over time with large increases followed by rapid decreases. These variations are sometimes related to annual periods of low water when flocculent material in the water column and periphyton settle to the wetland surface. However, long-term accretion at these sites has been low (≈2 cm) on the Lostmans River and virtually nothing on the Shark River. The mid-river sites had different patterns of elevation change. Elevation at the mid-river site on the Lostmans had decreases followed by increases in a fashion similar to the upstream sites. The mid-river site on Shark River had a pattern similar to the downstream sites. Here there was a slow accretion of 2 cm of sediment. Elevation was variable at first and then steadily increased by 4 cm. This indicates that there has been a swelling in the sub-surface peats at this site.

The downstream mangrove forested sites show similar patterns, a slow and low amount of sediment accretion (1-4 cm) from 1998 to late 2005. However, in approximately four hours, on 24 October 2005, Hurricane Wilma deposited as much sediment as had accreted during the previous seven years. At BSC, the mudflats lost 4 cm in elevation in the first eight years of sampling and lost an additional 2 cm during the passage of Hurricane Wilma. The BSC forest sites accreted 3.5 cm of sediment in the first eight years of sampling. Sediment surface elevation did not change due to Hurricane Wilma. It appears as if erosion from the storm surge was balanced by deposition as the surge ebbed. Since Hurricane Wilma, continuing mortality of mangrove trees has occurred in the lower Shark River and at BSC, and appears to be responsible for elevation losses of 2 – 3 cm in just 2 years.

Sea-level (SL) at Key West Florida has increased ≈20 cm since 1913. Additionally, there is a pronounced annual cycle in SL of approximately 25 cm, with the high in October and low in February. Over the time period of our work SL has not increased and the variation in surface elevation does not appear to be related to the annual SL cycle.

The major drivers of elevation change at our sites appear to be annual hydrologic variation at the upstream sites and periodic disturbances at sites near the coast.

Our project directly addresses the RECOVER Monitoring and Assessment Plan, Hypothesis #4: Sea level and freshwater flow as determinants of production, organic soil accretion and resilience of coastal mangrove forests. Specifically we have:

- Developed a long-term base-line of sediment surface elevation that will be compared to elevations when freshwater flows are increased upstream.
- Determined that disturbance can have major and long lasting consequences.

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Ecological Shifts on an Everglades Tree Island over the Last 100 Years

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Tree islands are accepted as one of the most ecologically important settings within the Everglades. However, little is known about how these islands have changed ecologically over the last 100 years. It is during this time that major modifications have taken place within the Everglades and surrounding areas. Drainage was the focus during the first half of the 20th century. Then starting around the 1950s the major impoundment efforts began. The impoundments caused water to be held for longer periods of time therefore lengthening the hydroperiod. It was during this period of impoundment that many tree islands were degraded and the number of tree islands decreased. Most investigators attribute the decline in the tree islands directly with the hydrological changes that occurred since the 1950s impoundment. This investigation uses the sediment record to document the ecological shifts on a tree island in response to the hydrologic modifications over the last 100 years.

Three sediment cores were collected from Tree Island 3AS3 and one core was collected from the adjacent slough. Dates and accumulation rates for the sediment cores were established through ^{210}Pb dating. Lead-210 is an ideal tracer for determining dates and accumulation rates on a 100 year time scale, which is the most relevant time scale for examining consequences of recent change. Total phosphorus, total nitrogen, organic carbon, δ^{15}N, δ^{13}C and sedimentary photosynthetic pigments (chlorophylls and carotenoids) were measured as proxies to interpret the past ecological conditions on this tree island. The timing of ecological shifts was examined through these proxies.

The results reveal that mass accumulation rates began to increase circa 1950s on this tree island. Coincident with increasing mass accumulation rates both δ^{15}N and δ^{13}C values of sediment organic matter decreased. The decrease in δ^{15}N could indicate a change in the vegetation on the island as a result of change in hydroperiod and/or a decrease in bird population on this island. The former hypothesis is supported by the C/N ratios which increased since the 1950s and by sedimentary photosynthetic pigment data that indicate increases in macrophytes and algae on the island since the 1950s. This does not exclude the possibility that bird populations on this island decreased along with a shift in vegetation. Decrease in bird population reduced the contribution of bird guano which was enriched in ^{15}N. In conclusion impoundment produced longer periods of high water beginning in the 1950s and promoted encroachment of different vegetation on the island or a change in the dominant vegetation. The 1950s was a period of major change in the Everglades with the transition from drainage to impoundment.

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Restoration of Disturbed Pond-cypress Savannas

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The development of privately held mineral rights within Big Cypress National Preserve results in surface disturbances in the form of elevated access roads and oil pads. Once extraction is completed, the operators are required to reclaim the sites. Open pond-cypress (*Taxodium ascendens*) savannas with graminoid-dominated herb layers cover much of Big Cypress National Preserve and therefore are commonly subject to such disturbances. We carried out a study to evaluate the importance of substrate and revegetation method in the restoration of native vegetation on disturbed cypress savanna.

The study was replicated at three sites within Big Cypress National Preserve where cypress savanna or prairie had been cleared and filled with crushed limerock. At each site we tested three revegetation treatments applied to three blocks of substrate. One substrate was residual limerock fill mixed with native soil that remained when the limerock fill was removed down to grade (limerock). The other two substrates were created by completely removing the limerock material and bringing the site back up to grade with either widely available construction fill material (sand) or topsoil from a local fill pit that more closely resembled the native cypress savanna soil than the sand (soil).

Within each substrate type three 10 x 20 m plots were established and three revegetation treatments were randomly applied. One treatment consisted of planting individuals of 10 common cypress prairie species: pond-cypress, wax myrtle (*Myrica cerifera*), corkwood (*Stillingia aquatica*), three grasses, three sedges, and a forb. The second method involved collecting donor mulch by scraping surface soil, litter, and plant material from a nearby site with native vegetation and spreading the material on the plot surface. The third method was passive, in which no plant material was introduced. Revegetation on these plots was derived entirely from propagules in the substrate or by immigration. The plots were established in May 1989 and the active revegetation treatments were applied within two months.

Fifteen years after establishing the experiment, treatment effects were still apparent. The number of commonly occurring species was highest on the soil substrate and lowest on the limerock substrate. The exception to this was at one site where the sand substrate had the lowest diversity because it was completely dominated by the non-native torpedo grass (*Panicum repens*). Other than in this particular instance, non-native species were not a problem. The mulching treatment introduced many species to the restoration plots and the effect was still noticeable after 15 years. The planting treatment was particularly successful in establishing one of the common grasses, gulfdune paspalum (*Paspalum monostachyum*), which spread aggressively by rhizomes. Planted pond-cypress did well if they survived the first year, some reaching >5 m height by year 15. Treatment differences in species diversity, plant cover, and cypress survival and growth will be discussed and related to possible restoration methods for disturbed cypress savannas.

This study demonstrates that

- physically disturbed pond-cypress savannas can be restored to some semblance of their original condition.

- substrate and revegetation method influence the rate and degree of restoration.

passive revegetation can be successful if the disturbed site is contiguous to intact pond-cypress savanna.

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Staying in Tune with South Florida's Water Cycle for Scientists, Managers, and Policy Makers in Five Minutes per Week

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The **South Florida Watershed Journal** (http://sfwj.blogspot.com) is an online journal that illuminates and celebrates the complex inner workings of the interconnected wetlands and waterways of the Kissimmee-Okeechobee-Everglades and adjacent Big Cypress watersheds. The best part is that it only takes about five minutes per week to keep yourself up-to-date.

In the same spirit that investors grab the financials to view stock market trend lines or fans scan the sports page to track statistics for their favorite teams, this journal provides a narrative voice and Rosetta Stone for helping stakeholders and the interested public decode and stay in tune with the constant tick of South Florida's water cycle and watersheds. With a few mouse clicks you can visually assimilate rainfall patterns throughout south Florida, the record-setting drought at Lake Okeechobee, or structural inflows into Everglades National Park; all relative to past years and decades.

The journal provides a portal for both the lay public and technical professionals – with a strong editorial eye on framing the event horizon relative to the parade of historical data that came before, current ecological thresholds, operational criteria, and other topical and comparative categories. The journal's front page specializes in converting scientific subject matter into language and images oriented to the lay audience. The front page is connected via hyperlinks to a historically robust, interactive, and easy-to-use hydrologic fantasy land that allows experts to scrutinize data sets in particular areas or time periods in more vivid detail. This dual design gives viewers the option of either a swift five-minute weekly update, or digging deeper as needed.

The journal receives a few hundred visits per week – making it a potent and multi-faceted outreach tool (i.e., informational, educational) for an otherwise geographically diffuse and hard to reach network of Everglades professionals, stakeholders, and enthusiasts; and a potential model for application in other regions.

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Monitoring the Storm Tide of Hurricane Wilma in Southwestern Florida, October 2005

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Temporary storm tide monitoring stations have demonstrated their value by allowing the U.S. Geological Survey to extend the scope of data collection beyond that of existing networks, and serving as backup data collection to existing monitoring stations. Temporary monitoring stations employing non-vented pressure transducers were used to augment an existing U.S. Geological Survey coastal monitoring network to document the storm tide of Hurricane Wilma. On October 22, 2005, an experimental network consisting of 30 temporary stations was deployed over 90 miles of coastline to record the magnitude, extent, and timing of hurricane storm tide and coastal flooding. Sensors were programmed to record time, temperature, and barometric or water pressure. Water pressure was adjusted for changes in barometric pressure and salinity, and then converted to depth of water above the sensor. Elevation surveys using optical levels were conducted to reference storm tide water-level data to the North American Vertical Datum of 1988 (NAVD 88). The monitoring network revealed that when Hurricane Wilma made landfall just south of Marco Island, the storm tide substantially affected water levels within the 10,000 Islands National Wildlife Refuge and Coastal Everglades National Park. Specifically, storm tide was 4 to 5 ft at major coastal rivers of Everglades National Park, and decreased to 1 to 2 ft as it traveled inland.

Data collected through this monitoring effort can:

- Offer a better understanding of the impacts of hurricanes on the hydrology of Coastal Everglades National Park and the10,000 Islands.
- Help improve modeling of storm tide and improve forecasting of storm tide magnitude.
- Provide an improved alternative to traditional high water marks for measuring storm tide.

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Geographical and Temporal Distribution of Flows into Northeast Shark River Slough

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Among the many goals of the Comprehensive Everglades Restoration Plan is the restoration of flows into northeast Shark River Slough, located at the northeast corner of Everglades National Park. Historically, water flowed into the Slough from the north throughout most of the year, with the Slough draining to the south-southwest. This was this primary source of freshwater flow to Florida Bay during the dry season. Currently, levees block the flow of water from the north. Canals, control structures, and culverts control the timing and distribution of flow into the Slough. Additionally, surface water enters the Slough through ground-water seepage beneath Levee 29 on the north and Levee 67 Extension on the west.

Surface water flows into the Slough through a series of 19 culverts underneath Tamiami Trail, connecting the Levee 29 Canal to the north with the Slough to the south. Discharge measurements in the culverts have generally been made twice a month since 1940 by the United States Geological Survey. Evaluation of trends in the individual culvert flows for the past 20 years indicate the primary controls on the culvert flows are stage in Levee 29 Canal on the north, flows through control structure S-333 on the west, and stage in L31N canal on the east. Additional controls are from the L67 Extension levee to the west and control structure S-334 to the east.

In all culverts, flow increases with increasing stage in the Levee 29 Canal. Very few culverts have measurable flow when the stage in Levee 29 Canal is below approximately 7 feet or when S-333 is closed. Culvert 45, which is connected to the Blue Shanty Canal in Everglades National Park, is an exception to both constraints. The highest flows are found in culvert 45, where the Blue Shanty Canal provides significant drainage to the south. The culverts closest to the L31N Canal will have flow when S-333 is closed. This is the result of the relatively large head gradient between the Slough and L31N Canal, resulting in seepage of water out of the marsh. The highest flows in this section are in the eastern culvert (culvert 59), with flows decreasing to the west. Reverse (negative) flows are seen in the western culverts (culverts 41 to 46), possibly a result of seepage through and beneath the L67 Extension levee into the Slough just downstream of the culverts.

Plans for restoration of northeast Shark River Slough are currently being evaluated. Based on the trends in the culvert flow data and an evaluation of the current operating conditions for control structures affecting the Slough, several conclusions can be drawn:

- The primary source of surface water flow to the slough is water routed from Water Conservation Area 3A through S-333
- Constraints on stage in the Levee 29 Canal intended to prevent damage to Tamiami Trail currently limit the amount of flow that can pass through the culverts into the Slough.
- Routing water into northeast Shark River Slough as far from the L31N Canal as feasible is the best way to minimize seepage losses
- Design limitations on flow through S-333 currently cap the rate at which water can be routed to the Slough from Water Conservation 3A

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Hydrology of the Florida Panther National Wildlife Refuge

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Biological communities in the Florida Panther National Wildlife Refuge (FPNWR) and surrounding Big Cypress swamp ecotone have been affected by changes in hydrology associated with historical highway and canal construction. As part of the Department of Interior Critical Ecosystems Studies Initiative and the USGS Priority Ecosystems Science Initiative, a two year study was initiated in October 2005 to collect and analyze water-level data in the FPNWR.

Surface-water and shallow ground-water levels, as well as interaction between the two regimes, affect the ecology within the FPNWR. Surface water consists of wetlands within, and canals bordering, the refuge. The water-table is very shallow throughout the refuge, usually at or near land surface. A layer of hard limestone or caprock was observed within 3 feet of land surface in all eight geologic-core test sites drilled for this project. In core material recovered from five of the sites, the caprock contained calcrete at or near the soil-rock interface.

Historical surface-water flow into the refuge has been reduced by the construction of State Road 29 and an associated canal along its eastern boundary. Although three bridges over the slough connect the headwaters of the Okaloacoochee Slough in Big Cypress National Preserve to the east with the portion of the slough in the refuge, a small berm restricts the flow of the slough into the refuge except during high water conditions. Additionally, the canal acts as a drain that channels water southward into Barron River.

The I-75 borrow canal along the southern FPNWR boundary drains surface water from the refuge southward through Merritt Canal. Although an earthen dam restricts the hydraulic connection between these two canals, water was observed to flow over the dam during much of the year. The effects of this drainage into Merritt Canal and the operation of a gated and weir control structure on the Merritt Canal south of the intersection with the I-75 canal can be seen in the ground-water levels recorded within the refuge. Specifically, ground-water levels decline rapidly in monitoring wells near the I-75 canal after recharge (rainfall).events

Within the refuge, water levels rarely rose above the land surface during the 2-year monitoring period. This low water-level condition was associated with extreme low rainfall in southern Florida during the monitoring period. Ground-water levels in the area rise rapidly following recharge events, but then recede quickly due to canal drainage and evapotranspiration. Field observations of land surface morphology, along with water-level, geological and geophysical (ground penetrating radar) data indicate little or no confinement exists between surface water and the water-table aquifer. The near-surface caprock, therefore, does not act as a confining layer between surface water and shallow ground water in the study area. Although the caprock contains dense, impermeable limestone, it appears to be pierced by epikarst features such as dissolved fractures, solution pipes, and soil filled pits.

This study and ground-water monitoring network will provide the water-level data needed to answer the following science and management questions relevant to restoration:

- How have water levels been altered, particularly due to increased drainage of the area by canals?

- How do altered water levels and flows affect the spread of exotic plants, wading bird feeding and nesting success, and native plant communities?
- What are the anticipated effects on the threatened and endangered species in the project area?
- How does the increasing development in the vicinity of the refuge and the resulting need for additional flood control affect the maintenance of ecologically favorable water levels within the refuge?

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Species Conservation in South Florida and the Challenge of Climate Change

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The *Intergovernmental Panel on Climate Change* (IPCC) report describes changes in natural ecosystems with potential wide-spread effects on many organisms, including marine mammals and migratory birds. The potential for rapid and lasting climate warming poses a significant challenge for fish and wildlife conservation. Species' abundance and distribution are dynamic, relative to a variety of factors, including climate. As climate changes, the abundance and distribution of fish and wildlife will also change. Highly specialized or endemic species are likely to be most susceptible to the stresses of changing climate.

Climactic changes in south Florida could amplify current management challenges involving habitat fragmentation, urbanization, invasive species, disease, parasites, and water management. Climate warming will be a particular challenge for endangered, threatened and other "at risk" species.

It will be difficult to estimate, with any degree of precision, which species will be affected by climate change or exactly how. The Fish and Wildlife Service is interested in the development of user-friendly tools that will incorporate potential climate change impacts into all of our activities for species conservation in south Florida.

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Hydrologic Impacts of the C-111 Canal

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The C-111 canal is a major component of the Central and South Florida Project which provides flood protection for southwestern Miami-Dade County. Located between the wetlands of Everglades National Park and the developed area of Miami-Dade, the canal has undesired drainage impacts on the marsh induced largely through the maintenance of low stages in the canal. Several projects have been or are being undertaken to neutralize the negative effects of the C-111 and promote a more natural distribution of waters in the adjacent natural areas while still providing at least the same level of flood protection. Direct measurements of flows along the full length of the C-111 canal were collected in 2007 and 2008 under various conditions to better describe the impacts of the canal system as well as to plan for future restoration efforts. The drainage pattern which results from the C-111 operations, as well as the effectiveness of the series of mitigating pumps and detention areas already built along its western bank, are evaluated using these measurements combined with estimates of flow at SFWMD structures and stage data from the area. While some marsh waters are kept in the natural area near the head of Taylor Slough, the current system continues to drain the marsh waters back into the canal and preferentially moves this water further east than would be expected in the natural system. The effects on Manatee Bay salinities due to both leakage through the S-197 structure as well as flood control releases is also evaluated using salinity and flow measurements from 2004-2007. These data can be used to provide recommendations for base flows required to maintain stable estuarine conditions in Manatee Bay and Barnes Sound.

- The C-111 canal drains the surrounding natural marshes as far south as the S-18C structure.
- Water is quickly returned from the detention areas along the eastern boundary of Everglades National Park to the C-111 canal.
- Freshwater leaking through S-197 maintains a salinity gradient between Manatee Bay and Barnes Sound. Establishing base flows may help reach restoration targets for extreme southern Biscayne Bay.

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Integration of an Individual-based Manatee Model and the FTLOADDS Hydrology Model to Assess Restoration Effects in the Picayune Strand and Greater Everglades

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Restoration projects within the Picayune Strand and the Greater Everglades will alter hydrologic components that are vital to native, imperiled, and invasive species downstream from these projects. A large population of manatees within the project boundaries regularly uses multiple habitat zones including freshwater, estuarine, and near-offshore areas. Manatees are a good indicator species of a healthy aquatic ecosystem, as they respond measurably to key hydrologic or habitat components that vary across the landscape, such as freshwater for drinking, healthy beds of aquatic vegetation for forage, and passive thermal basins used for refuge from potentially lethal cold temperatures during winter. To evaluate the potential impacts of restoration, we are integrating an individual-based manatee model with the FTLOADDS hydrodynamic surface-water/ground-water model code. A new application of the FTLOADDS model has been extended west of Everglades National Park to include important manatee habitat in the Acceler-8 Picayune Strand restoration area and the Big Cypress region. Two key hydrologic parameters generated by FTLOADDS that manatees respond to include salinity, and a recently developed capability to model water temperature. Water monitoring stations in the area were used to calibrate the hydrology model, and alternative restoration scenarios have been run to provide hydrologic output relevant to manatees.

We present a summary of the hydrology model output for the Picayune Strand restoration scenarios from a manatee perspective, and describe how the data are incorporated into the individual-based manatee model. Several new approaches for analyzing data and structuring the model increase the efficiency and realism. The movement of manatees between different habitat zones (offshore, inshore bays, river systems) is simulated using a Markov Chain approach to transition manatees among different zones. Transition probabilities of inter-zone movements were estimated with multi-state modeling of telemetry data obtained from manatees tracked in the region. A network data structure represents the possible movement pathways between nodes representing destination sites for feeding, drinking, and thermal sheltering. An “A*” game programming algorithm is used to search the network data structure efficiently and to predict movement pathways between sites chosen by manatees. Aerial survey data provides seasonal snapshots of distribution and relative abundance used to validate the model. The FTLOADDS model provides salinities and water temperature along the landscape network at 6 hour time intervals, representing actual or forecast hydrologic conditions experienced by manatees under different scenarios. As manatees move within this network they receive positive and negative feedback which is used in a temporal difference, reinforcement learning model to control how manatees learn and respond to changes in the availability of critical resources. Using an integrated modeling approach allows the monitoring data to be incorporated into hydrologic and biological models that can forecast the response of manatees to hydrologic changes due to restoration, and provides feedback that can be incorporated into an adaptive management framework.

- Multistate modeling provides a robust statistical method of analyzing telemetry data within a statistical framework that can handle covariates associated with restoration. The method generates transition probability matrices that are used directly to parameterize the individual-based model.
- Representing the landscape as a network rather than a grid greatly reduces memory required to integrate the hydrology data with the manatee model, since hydrology data are only represented at nodes. The network data structure allows the use of very efficient graph theory algorithms to simulate realistic, goal oriented manatee movement around the network.
- Reinforcement learning theory provides a realistic model for predicting manatee response to hydrologic changes through positive and negative reinforcement as manatees move across the landscape seeking resources.
- These methods of modeling manatee movement and integrating it with hydrology models are applicable to other mobile species.

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Tree Growth, Survival and Biomass in LILA Tree Islands

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Many different tree species dominate the vegetation on tree islands in the Everglades and there is evidence that their distribution on a given island is correlated with elevation, via its interaction with hydrology. The Loxahatchee Impoundment Landscape Assessment (LILA) site, with its controlled hydrologic framework provides an excellent opportunity to investigate processes involved in the development of tree islands. An experiment was therefore designed to (1) test hydrologic effects on seedling growth and survivorship, (2) determine, in the long term, the effects of tree spacing on individual tree and stand growth, and (3) estimate tree biomass and nutrient content in order to understand its role in island formation and development.

Four ca. 8 ha enclosed marsh areas, called "macrocosms" (M1-4) form the main structure of the LILA site. Each macrocosm includes two tree islands, each constructed on either a limestone core covered with peat, or wholly peat. Eight to ten species were planted on all eight islands following a stratified random selection procedure that assigned a species to each planting position. The islands were divided into four quadrants (24 x 16 m each), with each planted at different spacings, e.g., 1.0 m, 1.66 m, 2.33 m, 3.0 m. In each quadrant the centermost 18 x 10 m was delineated as high ground and the rest as low ground.

Four of the eight islands were planted in March 2006. The remaining four were planted in March 2007 following the same general procedure, with a few changes made to the original selection of tree species due to nursery availability. At planting time in March 2007, *Ilex cassine* showed the lowest mean biomass, which was approximately one-sixth of the most massive species, *Persea palustris*. Stem and root biomass were more alike among species than leaf biomass. Four species (*Acer rubrum, Ficus aurea, Myrica cerifera* and *P. palustris*) contributed most of the total tree island biomass at planting.

One year and a half later, in September 2007, the cumulative average survival for all species was 78 %, across all tree islands. *Bursera simaruba, F. aurea* and *P. palustris* were among the species which increased in survival with elevation. Another four species (*Chrysobalanus icaco, I. cassine, M. cerifera, A. rubrum*) also changed in survival with elevation, but in this group survival was higher at low elevations. *Annona glabra* exhibited the least sensitivity to elevation. A March – September period of growth acceleration was observed across all tree islands, probably related with the wet season. Species growth rates also responded positively to elevation but in a weaker way compared with survival. Effects of island type (peat vs. limestone core) and planting density were also tested. *B. simaruba* and *I. cassine* growth differed significantly between island types, with higher growth for both species in peat based tree islands. Planting density did not affect growth of any species.

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Climatic Changes in Rainfall Regime Suggested by Holocene Freshwater Wetland Sediments in South Florida

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Freshwater wetland sediments in South Florida show several widespread, distinct (visually obvious) stratigraphic changes that required hydrologic changes and suggest shifts in the rainfall regime. Some evidence for climatic involvement is strong even for a single area or stratum and other is strong mainly by a concurrence of shifts over a large area, including more elevated sites on the sandy axial ridge of south-central Florida. There are hints that some shifts were sharp (changeover maybe within a century or so) and others at least relatively rapid compared to the lengths of stages before and succeeding. That is, certain shifts appear to represent more than mere crossings of thresholds in a slow long-term continuous increase in rainfall. Reversals to longer trends provide some of the strongest evidence for episodic climate change.

The last of glacial times (say, 15,000-20,000 BP, "before present" in ^{14}C years) were apparently considerably drier than now and few or none of today's typical wetlands are evidenced. Low sea level promoted both surface runoff and ground-water drainage. Reduced rainfall is suggested weakly by slightly younger fossil pollen from open oak-hickory forest around newly reflooded south-central Florida lakes on the sandy ridge (ca. 13, 000 BP: Watts' work at Lake Annie, south of Lake Placid). Conditions got wetter by roughly 13,000-11,000 BP) based on the onset of the oldest freshwater marsh sediments in three areas, one being that lake, plus Corkscrew Swamp, and wetland (of unknown onset date) on the present lakebed of Lake Okeechobee. Early-Holocene sediments (continuing to roughly 6000 BP) in the lowlands were mainly marls, indicating only seasonally flooded wetland. In mid-Holocene times (mainly ca. 5500-4500 BP) conditions got notably wetter still in South Florida, with a virtual "explosion" of peatland initiation, especially the vast Everglades, but also at smaller Corkscrew Swamp, localities in Fakahatchee Strand, The Savannahs (near Ft. Pierce), and some isolated tiny wetlands (and possibly most others still undated). Complicating inferences to sharp changes in rainfall include sea level rising to within ca. 5 meters of present by then and large areas having started to accumulate a lower-permeability marl cover. However, further suggestion for a climatic effect comes from concurrent changes in elevated areas that are more isolated from baselevel effects: 1) certain peatlands in local depressions on elevated ridges in SEUS also initiated in mid-Holocene times (e.g., Polk County; FL [T. Gurr, thesis, UF]; Okefenokee Swamp, GA [Cohen], both ≥30 m msl), and 2) dry sandy uplands on the ridge were shifting to pine forest, as now exist (Watts).

These two main shifts—onset of Holocene wetland conditions and mid-Holocene establishment of peatland—1) were both to wetter conditions, 2) both have suggestion of a change in local rainfall, and 3) the latter shift to peatland initiated the modern wetland landscape and thus presumably represents onset of the overall modern climate. Toward the middle of this era of presumed modern climate, however, occurred one (or perhaps several interrelated) substages as prolonged excursions of significant hydrological difference, mainly evidenced in the Everglades but with some roughly concurrent hints elsewhere. That these shifts eventually reversed and terminated the substages is some of the strongest evidence for climatic involvement.

Within the marsh-peat profile itself, a mineral layer and a mineral-rich layer (each sometimes as multiple thinner strata) lay at mid-level over two extensive and widely separated parts of the Everglades: 1) marl, near the latitude of Tamiami Trail, and 2) muck (an organic-codominated mud), to a few kilometers south of the border with southern Lake Okeechobee. Marl presently indicates a shorter-hydroperiod marsh (wet-prairie) compared to marsh peat from waterlily or sawgrass communities. Marl additionally requires water enriched in calcium and bicarbonate. To produce muck, the abundant mineral matter seems to require an energetic communication with a turbid lake, either by a high lake stage alone, with induced rapid outflow, or possibly a common occurrence of wind-surge overflow and outflow. The marl stage is reasonably well dated at several sites, and encompasses roughly 3000-2000 BP, with several hundred years wider range (either direction) at some sites. The interlayered muck is very poorly preserved and dated, but one thinner zone at a surviving site dated toward the end of the marl stage. Suggestions for concurrent lower water and higher water only ~100 km separated along flow in the Everglades is hard yet to resolve (Increased seasonality? Muck era actually just after the marl era?).

The most intriguing mid-level stratum is a hard carbonate layer (or sometimes carbonate-cemented detritus) within peaty sediments of the hammock "heads" of tree-islands nearer the southeastern edge of the peatland. The onset age is sometime after ca. 3500 and ca. 4400 BP at two tree-islands dated. Archeological debris is abundant even below the layer, but the layer appears mainly to be formed naturally. One of two ^{14}C analyses strongly suggests a ground-water source and this implies a long period of at least seasonal deficit in rainfall over ET losses by the presumed forest patch (the other analysis is at least compatible). Deposition possibly continues even today. The roughly mid-peatland-era timing and the apparent conditions in origin give reasonable hint for a shift to lesser rainfall, at least seasonally.

Many critical (and here mainly unstated) assessments are required to interpret probable shifts in local climate by eliminating other factors in hydrologic changes, mainly sea level rise, feedback mechanisms (e.g., sediment sealing, basin infilling and eventual overflow), and mimicry (i.e., probable ash layers, ingrowths vs. depositional episodes). More subtle but important evidence for even younger prehistoric shifting has been found by paleontologists (Winkler, Willard) and additional is hinted at by peat-type stratigraphy.

- The present regime of overall climate appears to be susceptible to substantial and very prolonged excursions in terms of average or seasonal rainfall, with drier conditions seemingly more common, but with Lake Okeechobee flooding (either by rainfall or winds) also suggested.
- Despite evidence for occurrence, we know very little in detail or with high confidence about changes in regional rainfall in South Florida even for recent prehistoric times.

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High-Resolution X-ray Computed Tomography of Macroporous Karst for Permeability Measurement and Non-Darcian Flow via Lattice Boltzmann Models

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The permeability of macroporous karstic rocks is extremely difficult to measure in a laboratory setting due to flow-rate limitations of the measuring apparatus, and issues related to maintaining and measuring the extremely small gradients needed to sustain Darcian flow regimes. High-resolution X-ray computed tomography (HRXCT) can provide digital reconstructions of porous media that are essential for detailed pore-scale flow modeling. The HRXCT provides rendering data for lattice Boltzmann calculation of permeability in samples with well-connected macropores.

Samples representative of biomoldic and trace-fossil related macroporosity were collected from the Fort Thompson Formation and Miami Limestone of the Biscayne aquifer in southeastern Florida and scanned using HRXCT methods that provided resolutions on the order of 0.3 mm per pixel. Permeability measurements were conducted using lattice Boltzmann techniques applied to seven renderings of samples created from the HRXCT scans. Non-Darcian inertial flows were avoided by applying extremely small gradients while making the permeability measurements. The lattice Boltzmann method was verified against analytical solutions for pipe and conduit flow.

Measured permeabilities derived from lattice Boltzmann methods correspond to hydraulic conductivity values ranging from 0 m/s (for a sample lacking well-connected macroporosity) to 167 m/s (vertical), and are as much as five orders of magnitude greater than the largest values typically reported by testing laboratories. Non-Darcian effects are of considerable interest if they occur under field-scale conditions and lattice Boltzmann models permit investigation of the potential significance of non-Darcian effects. For one limestone sample from the Biscayne aquifer with extremely high, well-connected macroporosity, it is concluded that non-Darcian behavior due to inertial flow under field-scale gradients could effectively reduce the apparent hydraulic conductivity by nearly 50 percent.

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Lattice Boltzmann Methods Applied to Three-Dimensional Virtual Cores Constructed from Digital Optical Borehole Images of a Karst Carbonate Aquifer

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Recovery of whole-core samples from macroporous karst carbonate is nearly impossible with conventional drilling technology. Thus, the most porous part of coreholes drilled in karst systems rarely yield whole-core samples. The consequent lack of samples for measurement of fluid-flow properties in karst carbonate aquifers impedes characterization of ground-water flow within these systems.

This study uses advanced modeling techniques together with geophysical corehole data acquired from the karst carbonate Biscayne aquifer of southeastern Florida, USA, to explore a combination of innovative technologies designed to compensate for the lack of macroporous whole-core sample data. Specifically, these methods are being used to better understand the ground-water flow regime in the Biscayne aquifer. In this study, digital optical borehole image logs were compiled for test coreholes that penetrate the rocks of the Biscayne aquifer. The borehole image data were then processed to map the 3-D distribution of macropores and rock matrix present on the borehole walls using Stanford geostatistical software (SGeMS). The SGeMS program was used to compute variograms that were used as input for a computer simulation. The simulation results provided virtual 3-D renderings of the complex karst macropore network of the Biscayne aquifer that statistically replicate the borehole wall image data. These renderings provided 3-D visual records of areas of the aquifer that are composed of a carbonate eogenetic macropore system dominated by centimeter-scale vugs produced by fossil molds and voids associated with trace fossils. The vugs can coalesce over broad areas in the Biscayne aquifer to form laterally persistent zones of preferential ground-water flow.

Lattice Boltzmann methods (LBMs) were used to measure the intrinsic permeability of the 3-D aquifer renderings. When using LBMs the rock matrix was assumed to be a nonporous media, thus permeability was only measured within the network of macropores. Comparison of LBM-derived permeabilities to those obtained from conventional laboratory techniques show that the measured permeability of whole-core samples are substantially challenged in areas where centimeter-scale vuggy macroporosity is present and for this type of porosity, LBMs are preferred. The results obtained using LBMs closely conform to the analytical solutions for pipeflow, providing the impetus and justification for its use in obtaining intrinsic permeability values for virtual macropore systems.

LBMs were also used to simulate 3-D fluid flow through the renderings of macropores and rock matrix. LBMs were especially useful for simulations of inertial (non-Darcian) fluid flow, which may dominate flow in macroporous zones in parts of the Biscayne aquifer. The methods being developed in this study are providing a means for estimating and correlating the permeability of macroporous zones, as well as determining whether flow is primarily laminar or turbulent.

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Seasonal Variations in Tree Island Hydrology at Loxahatchee Impound Landscape Assessment (LILA)

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Recently, it has been recognized that tree islands act as indicators of Everglades ecosystem health. To identify the ecosystem function of tree islands in the Everglades it is critical to investigate tree islands' hydrology. To gain a finer understanding of tree islands' hydrology, groundwater-surface water interactions were studied on man-made tree islands at Loxahatchee Impound Landscape Assessment (LILA). LILA is a large physical model of the Everglades that contains eight tree islands, constructed either entirely of peat or of a thin peat layer over a limestone rubble core. Each island consists of four different tree planting quadrants with tree spacing ranging from 1m in the high density tree planting quadrants to 3m in the low density tree planting quadrants. Nine one-inch groundwater wells were installed on each island to an average depth of 1.34m. One well was located in each of the planting quadrants and the remaining five wells were located adjacent to the planting quadrants. Groundwater and surface water temperature, water level and chemistry were used to detect seasonal patterns in groundwater-surface water interactions.

Over two years, groundwater and surface water level and temperature were recorded on a fifteen-minute time step using In-situ 500 Level Troll Pressure Transducers. Seasonal groundwater levels suggested unique groundwater-surface water interactions on islands of differing geologic cores. Throughout the year the peat core islands had groundwater levels higher than the surface water level while the limestone core islands only had groundwater levels higher then the surface water at the beginning of the wet season. In addition, the limestone core tree islands had a much larger hydraulic response to rain events as compared to the peat islands. During the dry season a diurnal evapotranspiration signal of 1cm-3.2cm was detected in the groundwater on all tree islands. The majority of the variation in the diurnal drawdown was correlated to location of the wells within differing density tree-planting quadrants. A one-tailed test with an $\alpha=0.10$ revealed that the diurnal groundwater drawdown in the wells located in the high density tree-planting quadrants were significantly higher than the diurnal drawdown in the wells located in the low density tree-planting quadrants

A similar diurnal signal was detected in the groundwater in the winter. When the surface water temperature dropped below the groundwater temperature, a diurnal oscillation of 0.7-1°C was detected in the groundwater. This diurnal groundwater temperature oscillation was directly correlated to the diurnal oscillation of the surface water temperature and may indicate that cold surface water was sinking into the ground and displacing warmer groundwater. In addition, the average monthly groundwater temperature signal in the peat and limestone core islands typically differed by 1-2°C. When the surface water temperature was cool the groundwater temperature for the limestone core islands was cooler than the groundwater temperature in the peat core islands. During the summer the opposite was true, when the surface water was warm the groundwater temperature in the limestone islands was warmer than that of the peat islands. This suggested that the limestone islands had increased groundwater-surface water interactions as compared to the peat islands.

Additionally, groundwater and surface water samples were from the wet and dry seasons of 2007-08. These samples were analyzed for various chemical constituents to determine seasonal variations and nutrient concentrations in the groundwater under differing tree planting quadrants. The oxygen and hydrogen isotopes, along with conductivity, chloride and alkalinity concentrations, suggested that the groundwater in the center of the islands had increased residence time and decreased groundwater-surface water interactions as compared to the edges of the islands. Elevated concentration of ammonium, total organic carbon and total phosphorus detected in the groundwater under the high density tree-planting quadrants suggested that the density of the overlying tree may play a significant role in the chemistry of the groundwater. The results from this study suggest significant seasonal variations in the groundwater-surface water interactions on tree islands.

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Periphyton Community Changes in Response to Water Quality Changes within the A.R.M. Loxahatchee National Wildlife Refuge, Florida (USA)

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Periphyton forms the trophic structure base of the A.R.M. Loxahatchee National Wildlife Refuge (Refuge) marsh ecosystem. Thus, assessing periphyton is fundamental to understanding the ecosystem health of the Refuge. The Refuge is the last northern remnant of the greater Everglades and is impacted by polluted waters that enter the interior from canals that surround the Refuge marsh. Water quality and soil impacts of these polluted waters have been characterized in the Refuge, but there is limited information regarding the spatial distribution of periphyton communities or community dynamics as influenced by nutrient- and mineral-enriched water. Extensive spatial and temporal periphyton analysis is time-consuming and expensive, thus we developed periphyton response functions based on Refuge water quality.

First, we attempted to develop response functions for desmids, diatoms, green algae, and cyanobacteria periphyton. Historically, desmids and diatoms were the more abundant species in the Refuge trophic structure, while cyanobacteria were notably less dominant. The literature further suggests that desmids and diatoms are influenced directly by water quality; in particular, elevated conductivity is related to lower desmids abundance and higher abundance of some diatoms. In January 2008, we collected periphyton and measured surface water conductivity at 61 sites throughout the Refuge. We used this dataset (PERI08) to establish periphyton compositional response functions to different water quality parameters. To test whether the same response functions were found in historical periphyton data sets, we examined a periphyton and associated surface water conductivity dataset (49 sites in February 2004; PERI04) courtesy of Scot Hagerthey and Sue Newman of the South Florida Water Management District. Linear, logarithmic, natural log, exponential, and polynomial response functions were tested in both data sets. Further, periphyton data were arcsine transformed and conductivity data were square root transformed to meet normal distribution criteria in order to test Gaussian and Weibull models fits for the datasets.

Next, we characterized spatial differences between the PERI08 and PERI04 datasets. To analyze periphyton as a function of Refuge water quality gradients, we divided the Refuge into compartments for analysis. The Refuge marsh was divided into perimeter (0 – 2.5 km into the marsh from the canals), transition (2.5 – 4.5 km into the marsh), and interior (> 4.5 km into the marsh) zones using previously-established water quality compartments. The Refuge was divided further into equal north, central, and south compartments. We used the periphyton composition and spatial data to examine distribution differences between the two datasets and arcsine-transformed data to statistically test differences.

After characterizing composition and spatial differences in the two datasets, it was necessary to understand how these changes were related to changes in water quality, particularly conductivity. We examined conductivity for the seven months leading to each sampling event, allowing us to incorporate marsh dry-down and rewetting events into our interpretation. Marsh dry-down and rewetting have been shown to have a strong impact on periphyton compositional development. Conductivity for these seven-month periods were estimated from the Everglades Protection Area monitoring network established at 14 sites in the Refuge marsh. For simple spatial characterization, we used conductivity data to determine distribution differences between 2004 and 2008, while we used the square-root transformed datasets to statistically test differences in the datasets.

No clear relationships existed between conductivity and any of the periphyton groups for the PERI08 dataset. This finding is in contrast to, a strong, conductivity-based exponential response function ($r^2 = 0.71$) observed for desmids in the PERI04 dataset. Interestingly, compartment-based response functions for desmids and diatoms in PERI08 were strong, with r^2 greater than 0.8 in each compartment. However, these response functions were not transferable to the analysis of the PERI04 dataset. Based on the spatial characterization of the datasets, it appears that a major driver for this lack of transferability was a conductivity decline in the perimeter zone, where gradients of conductivity-sensitive desmids and diatoms were present in the PERI04 dataset. In the PERI08 dataset, the abundance gradient and spatial extent of desmids and diatoms had changed, with both groups appearing to be more uniformly distributed in the northern Refuge. The most significant change observed in the Refuge was a more than doubling of cyanobacteria abundance over four years, with this hard-water-insensitive community now comprising the greatest percent abundances of all periphyton.

Our findings have important implications for Refuge management as related to the larger Everglades restoration efforts. Specifically, we have:

- established spatially-explicit, water quality-based functional responses for periphyton in the Refuge;
- identified differences in functional responses of periphyton over a period of four years potentially coupled to changes in water quality;
- documented a shift in periphyton dominance to cyanobacteria species, which are less desirable for soft-water Everglades; and
- aided in identifying challenges for developing periphyton predictive modeling tools.

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Numerical Model Development to Address the Effects of Climate Change on Coastal Hydrology and Ecology in Southern Florida

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Sea-level rise is an important climate change issue for coastal regions worldwide, affecting freshwater habitats, urban flooding, and saltwater intrusion in aquifers. The ability to predict how climate change affects ecosystems is complicated by environmental and hydrologic interactions that occur in urban, agricultural, and natural areas; as well as surface-water and ground-water connections, topographic variation, and other factors. All such interactions occur in southern Florida ecosystems, where complex hydrologic models have been developed to predict how restoration efforts will affect the Everglades. Model capabilities have steadily advanced in recent years, ranging from the coupling of dynamic surface-water and ground-water code to incorporating salinity and heat transport. The resulting computational tools are well suited to represent and predict how climate change may affect hydrologic and ecological systems.

The Flow and Transport in a Linked Overland/Aquifer Density-Dependent System (FTLOADDS) modeling code incorporates a two-dimensional hydrodynamic surface-water model coupled with a three-dimensional ground-water model to simulate the interconnectivity between the two hydrologic systems. Two primary concerns of global climate change are increased sea temperature and increased salinity induced by sea-level rise, both of which are simulated by FTLOADDS through heat and salt transport. The Intergovernmental Panel on Climate Change currently estimates that temperature will increase between 1.1 and 6.4 °C and sea-level will rise between 18 and 59 cm during the 21st century. By accurately simulating the complex hydrologic interactions resulting from these projected increases, the FTLOADDS code can be used to quantify local and regional effects on ecosystem-controlling parameters.

The FTLOADDS code is currently being used in several applications in southern Florida. One application, Tides and Inflows in the Mangroves of the Everglades (TIME), is currently being used to determine how different Comprehensive Everglades Restoration Plan (CERP) scenarios may affect Everglades National Park ecology and hydrology. TIME has been interfaced with the ALFISHES fish population dynamics model to examine how restoration-related hydrologic changes may affect fish abundance in the TIME domain. A FTLOADDS application to the coastal Biscayne Bay area is being connected with the TIME model to simulate hydrologic change along the entire southeastern coast of Florida, including interactions between undeveloped and urban areas. The westernmost application of FTLOADDS is in the Ten Thousands Islands (TTI) area. The TTI application is being used to examine potential restoration effects in the Picayune Strand area; specifically, the effects on Manatee refugia. The TTI application has been integrated with the Florida manatee individual-based ecological model. The relatively rapid and easily observed response of manatees to coastal changes in salinity, water temperature, and seagrass quality makes them a valuable indicator species. The manatee model, therefore, is an informative tool for addressing climate change and predicting possible effects to the ecosystem.

The applications presented herein can be used to provide insight into how sea-level rise and temperature change may affect hydroperiods, inundation patterns, inland salinities, and minimum/maximum water temperatures—all of which are factors that affect many plant and animal species. One of the first FTLOADDS applications used to examine the effects of sea-level rise is the Southern Inland and Coastal Systems (SICS) application, the domain of which is located in the southeastern part of the TIME area. When a minor sea-level rise of 8 cm was applied to the SICS tidal boundary, salinity values at a number of coastal sites increased, but the temporal pattern of the salinity increase varied between locations. At the coastal Taylor River site, minimum salinities were about 5 psu higher than values without sea-level rise applied, although the peak salinities did not change substantially. A different pattern was observed farther east at West Highway Creek, which has a weaker hydraulic connection to the Everglades. At this site, minimum salinities were similar to corresponding minimum salinities without sea-level rise applied, but peak salinities increased by more than 5 psu. Circulation patterns and available freshwater primarily determined how sea-level rise affected salinity in the different areas.

The integration of the TTI application with the manatee model and the TIME application with the ALFISHES model provides an informative platform for predicting and assessing the collective effects of climate change and restoration efforts. Applying these techniques to other areas and species, and with different restoration, sea-level rise and temperature change scenarios will help resource managers, scientists, and policy makers effectively manage protected Everglades landscapes in the following ways:

- Southeastern Florida is threatened by sea-level rise and its effects on urban areas, flood control practices, water supplies, and undeveloped areas. Simulations can predict how climate change affects landscapes, species populations, and ecosystems in the region.
- The Greater Everglades is highly affected by human activity, and climate change will add uncertainty and complexity to restoration and management efforts in these landscapes. Simulations can predict how the effects of climate change differ under recently implemented and planned restoration scenarios as compared to current ecosystem conditions.
- Given that restoration implementation is in its early stages, the simulations provide insight into whether additional restoration scenarios not yet considered might best protect ecosystems and species against additional expected environmental stresses caused by climate change.

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Lake Okeechobee Watershed Construction Project Phase II Technical Plan

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During the 2007 legislative session the Florida Legislature amended section 373.4595, Florida Statutes (known as the Lake Okeechobee Protection Act) to read “Northern Everglades and Estuaries Protection Program” with the passage of Senate Bill No. 392. This legislation was signed by Governor Crist and took effect July 1st, 2007. The amended section required the development and submittal of the Technical Plan for Phase II of the Lake Okeechobee Watershed Construction Project (Phase II Technical Plan) by February 1st, 2008. This plan which covers the entire Lake Okeechobee Watershed was developed by the District, in cooperation with the other coordinating agencies, Department of Agriculture and Consumer Services, and the Department of Environmental Protection. The objectives of this plan are to identify projects needed to meet the Lake Okeechobee Total Maximum Daily Load and to identify the water storage necessary to manage Lake Okeechobee water levels within an ecologically desirable range and manage flows to meet desirable salinity ranges for the St. Lucie and Caloosahatchee estuaries while meeting other water-related needs of the region, including water supply and flood protection. The plan that was submitted to the legislature identifies a broad range of projects to meet the Lake Okeechobee Total Maximum Daily Load and to store 900,000 to 1.3 million acre feet of water.

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CERP AM Program Implementation

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The Comprehensive Everglades Restoration Plan (CERP or Plan) provides a framework to restore, protect and preserve the water resources of central and southern Florida, including the Everglades. Congress authorized the use of an adaptive management (AM) approach for CERP (*Water Resource Development Act [WRDA], 2000*) to allow the Plan to proceed in the face of complexity and incomplete scientific data (uncertainties). AM has been applied to small-scale projects in numerous ecosystem restoration programs across the country and in large-scale forestry and fishery management programs. However, a comprehensive AM program in support of a system-wide ecosystem restoration program at the size and scale of CERP has never before been attempted. This presentation details the status of the CERP AM Program development and implementation.

Though many components of the CERP AM Program have been developed since CERP was authorized in 2000 (*e.g.*, creation of a monitoring and assessment plan as well as performance measures, conceptual ecological modeling, development of interim goals and targets etc.), the specific documents describing the AM Program have only recently been developed. These include the CERP AM Strategy and the CERP AM Implementation Guidance Manual. The CERP AM Strategy provides a framework for integrating AM into:

1. Implementation of AM at both project-level and system-wide scales;
2. Measuring and assessing natural and human system responses to Plan implementation;
3. Identification of potential solutions to performance issues with the Plan; and
4. Decision-making for Plan improvement.

The CERP AM Implementation Guidance Manual provides the details on how to implement AM within the six-step planning process utilized by the U.S. Army Corps of Engineers (Corps); this process governs the planning and implementation of CERP projects. The CERP AM Implementation Guidance Manual provides details about AM application for CERP, specifically step-by-step guidance on:

1. How to facilitate stakeholder engagement and collaboration;
2. Determination of when it is appropriate to apply AM (project-level);
3. How AM can be applied at both the project-level and system-wide scales via specific activities;
4. Identification of legal and policy issues to consider;
5. Development of criteria for determining successful implementation of AM; and

6. Presentation of case studies on Corps ecosystem restoration projects that apply AM.

Implementation of the CERP AM Implementation Guidance Manual will help ensure CERP restoration efforts meet the system-wide goals and objectives for the South Florida ecosystem and increase the chance for restoration success.

The AM Strategy was finalized in 2006. The CERP AM Implementation Guidance Manual is currently under development (both project-level and system-wide AM guidance) and is slated for completion in fall 2008, after which it will be reviewed by the RECOVER Leadership Group and conveyed to the implementing agencies (U.S. Army Corps of Engineers and South Florida Water Management District) for their consideration. Beyond distribution and implementation of the AM Implementation Guidance Manual, there are a multitude of steps required for AM Program implementation; these include both outreach and training activities that will facilitate the integration of AM into CERP. These activities include: (1) management briefings on AM at all leadership levels; (2) CERP AM training using the AM Implementation Guidance Manual as a tool (audiences include planners, scientists, managers and decision-makers etc.); (3) workshops for communicating performance issues; and (4) identification of potential solutions, evaluation of options, and decision-making to address these performance issues and ensure restoration goals are achieved.

Key messages relevant to larger-scale ecosystem restoration include:

- There is currently limited guidance available on how to implement AM for large-scale ecosystem restoration programs. The CERP AM Implementation Guidance Manual represent one of the first attempts to provide this type of detail.
- Adaptive management is a management approach that must be integrated into all phases of implementation (project-level and system-wide) and should not just be simply viewed as a tool for restoration.

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Investigating Food Quality Effects on the Florida Apple Snail: Water Chemistry Effects on Periphyton Assemblages in the Northern Everglades

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Increasing anthropogenic pressures on the Everglades has induced drastic changes in vegetation, water quality, and hydrology. Alterations from previous undeveloped marsh lands to current conditions include increases in water mineral concentrations, extensions of cattail (*Typha* spp.) intrusions into the marsh interior, and modified hydrological patterns that are regulated through a series of canals and pumps. One repercussion of this altered ecosystem, in addition to habitat reduction, includes a decline of the endangered snail kite, *Rostrahamus sociabilis*, and its primary food source the Florida apple snail, *Pomacea paludosa* (Say). In response to declining apple snail populations since the 1970s in Water Conservation Area 1 (WCA-1), snail kite populations have been greatly reduced with limited sightings in the interior and low reported nesting populations. Gaining a thorough understanding of food and water chemistry requirements for the apple snail will supply information to assist marsh managers in making decisions that promote habitats that support greater apple snail production, in turn providing a food source for snail kites and a variety of other ecologically important wildlife, including alligators, limpkins, turtles and crayfish.

The A.R.M. Loxahatchee N.W.R. (Refuge) is entirely within the boundaries of WCA-1 and encompasses over 147,000 acres of the last remnant of northern Everglades wetland. Because of urban and agricultural runoff, water in surrounding canals is higher in specific conductivity values than the marsh interior. Canal water intrusion from the perimeter canals introduces nutrient-rich water into the marsh interior. The resulting water chemistry gradients affect chemically-sensitive periphyton assemblages which is a main food source of apple snails. Previous studies indicate periphyton in the perimeter marsh is primarily composed of filamentous blue-green algae; assemblages in intermediate marsh areas contain mineral-tolerant diatoms; and the soft-water interior marsh of the Refuge supports desmids and filamentous green algae. Previous studies suggest that apple snails selectively feed on high quality food sources such as diatoms and desmids. Therefore, periphyton assemblages lacking these organisms may not provide adequate nourishment to snails, which may result in inferior snail growth, survival, and ultimately recruitment.

This study investigates how water chemistry-driven changes in periphyton affect apple snail growth and survival in Everglades field conditions. Specific objectives include: (1) characterizing the nutrition value of periphyton assemblages along the existing water quality gradient; (2) determining how different water chemistry-driven periphyton affects apple snail growth and survival; and (3) characterizing the periphyton composition in the diet of wild snails in different areas via stomach content analysis. Experiments will be replicated in both wet and dry seasons from approximately mid April 2008 to mid June 2008 and mid August 2008 to mid October 2008. Experimental mesocosms are placed along the water quality gradient that extends from the marsh perimeter to the marsh interior. Mesocosms are supplied with ample amounts of periphyton and its associated macrophytes from each site. Lab raised experimental snails placed in each mesocosm are monitored for growth and survival for a period of approximately 2 months. Water chemistry parameters including specific conductivity and pH and snail growth/survival data are collected at each mesocosms at week 0, week 4, and week 8. Snail growth and survival data includes aperture length, shell length, ash free dry mass, and rates of growth and survival. Surface water from each site is analyzed for total phosphorus, calcium, and sulfate at the end of each exposure. Periphyton samples from each mesocosm collected at the end of each season study are analyzed for taxonomic identification, organic carbon to nitrogen ratios, carbohydrates, crude lipids, and protein. Experimental snails are harvested and analyzed for ash free dry mass as an additional measure of growth.

Preliminary data from a pilot study conducted from December 2007 to February 2008 suggests snail growth is positively correlated with diatom percentage and negatively correlated with filamentous green algae. Specific conductivity data shows positive correlations with diatoms and negative correlations with filamentous green algae. Additional data analyses will examine water quality as a covariate and look explicitly at snail growth and periphyton composition and nutrition value.

In order to protect remaining resources and restore lost habitat and biodiversity, a thorough understanding must be gained of vital Everglades primary producers and consumers such as periphyton, and apple snails, respectively. Key findings relevant to the understanding of optimal environmental conditions to apple snail growth and to overall Everglades restoration will be presented, including:

- Relationships between apple snail growth and periphyton composition;
- Correlation of periphyton composition and water gradients within the Refuge;
- Nutritional value of water quality-driven periphyton assemblages found along the water quality gradient within the Refuge.

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Aquatic Fauna as Indicators for Everglades Restoration: Applying Dynamic Targets in Assessments for CERP-MAP

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Reversing marked decreases in wading bird nesting success and displacement of their rookeries from historical sites in Everglades National Park is a major goal for the Comprehensive Everglades Restoration Plan (CERP). To directly assess efforts to restore wading birds, a trophic hypothesis was developed for the Monitoring and Assessment Plan (MAP) and states that the loss of seasonal concentrations of small fish and crustaceans that provide food for wading birds is a key factor in their decline and displacement from historical sites. Furthermore, it is hypothesized that recovering historical hydrological patterns will restore concentrated prey in locations and at times they are needed to support wading bird nesting in the southern Everglades. We identified a set of indicators using small fish and crustaceans that can be predicted from hydrological targets and used to assess management success in regaining wading bird foraging opportunities. Small fish and crustaceans are key links in the Everglades food web that are sensitive to hydrological management, track hydrological history with little time lag, and that can be studied at the landscape scale. The dynamic hydrology of the Everglades is the source of seasonal prey concentrations and also presents a challenge to interpreting monitoring data. We developed targets that are dynamic in response to two parameters, water depth and time since marshes were flooded after drying events. We determine targets for prey density with empirically derived functional relationships between aquatic fauna and hydrological drivers. Target values are calculated by solving equations to predict prey density based on hydrological model output. Hydrological models that describe historical patterns of water flow are the primary source of management targets for the Everglades. We use functional relationships derived from species representing four different life-history responses to drought. We illustrate this method for assessment using CERP-MAP aquatic fauna monitoring data and describe a report-card methodology to communicate the results of model-based assessments for general application.

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Effects of Phosphorus Availability on Aquatic Food Webs and Community Structure in the Everglades

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Variation in phosphorus (P) availability has major effects on food-web function and community structure in the freshwater Everglades. Much work as focused on the impacts of P as a limiting nutrient for plant growth and the impact of P enrichment on food-web function. In this presentation, we will review existing knowledge on the effects of anthropogenic phosphorus and dissolved mineral enrichment on aquatic communities in the Everglades.

P is naturally in low supply relative to demand by plants in karst wetlands because $CaCo_3$ binds with it, making it unavailable to plants. Numerous lines of evidence indicate that P is a limiting factor to plant growth the Everglades. When it is added, vascular plant and algal growth is stimulated, changing both habitat structure and food availability for aquatic animals. Periphyton composition and ash-free dry mass (AFDM) are affected by P addition. AFDM displays a subsidy-stress pattern, increasing with initial P addition above ambient, followed by a decline. Mat structure in oligotrophic Everglades wetlands is dominated by calcium-secreting blue-green algae and is a consortium of algae, fungi, and bacteria, as well as detritus. As P levels in the environment increase, the mat-like structure is lost and phytoplankton come to dominate the algal community. Loss of periphyton structure has profound effects on the aquatic animal communities and, thus, on food-web function.

Extensive mats of periphyton are characteristic of the Everglades and provide an important habitat for macroinvertebrates. Algae in the Everglades are found in floating mats, epiphyton growing around emergent plant stems, and in loose association with flocculent detritus on the substrate (floc). Macroinvertebrate communities differ among these three microhabitats, with the floating mat home to the highest density of most taxa (e.g., *Hyalella azteca*, *Dasyhelea* spp., and Cladocera). Submerged epiphyton is home to higher densities of Chironomidae and *Planorbella* spp. than found in floating mats. Finally, floc is home to the lowest densities of macroinvertebrates, 3 or more times lower than in adjacent floating mats. Floating-mat coverage and biomass changes seasonally, with important implications for aquatic animals. Mat coverage increases from the early to late wet season and densities of the most common invertebrate infauna increase 3 to 15 times over the same period. This density increase is coupled with the higher mat coverage, yielding marked seasonal variation in macroinvertebrate density. Responses of macroinvertebrate density to P encrichment have not been consistent across studies. This could be from inconsistency of sampling methodology, variation in microhabitat targeted for sampling, or recent hydrological history of the sites sampled. Short-hydroperiod sites tend to have fewer fish, releasing macroinvertebrate communities there to increase in the presence on P enrichment; fish predation may crop increased macroinvertebrate production with nutrient enrichment at long-hydroperiod sites. These results have implications for the use of macroinvertebrates as indicators of water quality in wetlands and suggest the substrate sampled can influence interpretation of ecological responses observed in these communities.

Fish density generally increases with P enrichment, until it reaches levels that stimulate eutrophication and anoxia, at which point their density is diminished. Most species of native Everglades fishes are highly tolerant to low dissolved oxygen (DO), so decreased fish density requires very high levels of enrichment to be manifested. However, food-web structure is affected at lower levels of P enrichment than fish biomass, and moderate levels of enrichment favor herbivorous and low DO tolerant taxa. Though P enrichment at moderate and even high levels can lead to increased fish density, this does not lead to more food availability for wading birds that consume fish. Nutrient enriched sites are characterized by dense emergent vegetation and often by cattail monocultures. This vegetation structure limits feeding by wading birds to vegetation gaps, such as in airboat trails or areas that have recently burned. The higher local prey density does not compensate for the loss in total area of foraging habitat that accompanies high levels of P enrichment.

Key findings relevant to restoration:

- Periphyton mats provide both food and structure for macroinvertebrates that serve as important links in the aquatic food web of the Everglades;
- Small amounts of P enrichment have major impacts on food-web function in the Everglades by modify periphyton mat composition and structure, which alter food quality and hiding places for macroinvertebrates;
- Initial additions of P stimulate increased productivity throughout the food web, but is followed by a loss in productivity, a pattern described as subsidy-stress;
- Nutrient dosing studies indicate that P loading in the Everglades triggers an accumulation of this nutrient that lead to a cascading effect of subsidy, then stress, over time.
- Nutrient addition trickles up the food web, affecting bacterial and periphyton production at very low levels and very rapidly, and in turn impacting the aquatic animals that feed on algae and live in periphyton mats. Vascular plants respond more slowly because they mine P from the soil and time is required for added P to become buried and available to their roots. Once they receive P fertilization, their increased growth changes water column structure and detrital dynamics with important impacts on fish and larger macroinvertebrates, as well as wading birds that consume them.

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Scaling Revealed by Spatial Cross-Correlation Analysis of Aquatic Communities and Environmental Drivers

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Understanding the spatial scale of communities is critical to designing a spatially referenced monitoring program that permits sensitive detection of changes in environmental drivers controlled by managers. Spatial cross-correlation analysis illustrates the correlation between two variables at sites separated by incrementally increasing distance. The spatial scale of correlations between the two variables can be identified by the distance separating samples with the highest correlations and by the shape of a correlation-by-distance graph. Comparing cross-correlation graphs for sites fitting specific spatial arrangements, for example sites at different latitudes but the same longitude versus those at the same latitude and different longitudes, can identify spatial patterns of relationships. Such analyses can test for impacts of stream flow on biotic relationships (compare correlations for sites arranged parallel to flow to those that are perpendicular to flow).

We used data collected in the wet season of 2005 from EPA's REMAP monitoring program and data collected from the Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP) to provide a spatially dense map of aquatic communities across the Greater Everglades landscape. Sets of three throw-trap samples from over 150 locations were available by combining results from these two efforts. Sampling sites ranged from the littoral zone of Lake Okeechobee to the southern freshwater marshes of Shark and Taylor Sloughs in Everglades National Park. Performance measures examined included fish and macroinvertebrate density, periphyton ash-free dry mass, and biogeochemical parameters such as phosphorus in periphyton tissues, floc, and soil. Hydrological parameters were also examined.

Key findings relevant to restoration:

- Density of bluefin killifish and grass shrimp are positively correlated with number of days since a site was last dry and the correlation is retained for up to 5 kms reflecting the scale of recovery from drying;
- Periphyton composition was correlated with soil nutrients, but the relationship decreased rapidly as the space separating the sites of data collection increased.
- These and other scaling relationships can be used to improve the design of sampling for future monitoring programs.

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Application of *HYMAN* Model to Evaluate Water and Salt Budgets in Shark River Estuary

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Mangrove swamps are unique to coastal wetlands and primarily limited in the United States to the southern tip of Florida peninsula. Due to their transitional position along continental margins and coastal waters, mangrove wetlands play a substantial role in ecological biodiversity, nutrient cycling, environmental protection, and commercial and recreational activities. Among all physical, chemical and ecological interactions in mangrove wetlands, hydrology and salinity are the most important regulators of plant community patterns in that they are critical to the growth and distribution of mangrove trees. To quantify how changes in landscape-level hydrology will influence these regulators in mangrove wetlands, the hydrology model (HYMAN) is applied to three sites along the Shark River estuary in the Everglades National Park. The HYMAN model uses mass balance equations to determine daily water and salt budgets as the combined effects of inputs from precipitation and tide, and losses through evapotranspiration, seepage, and runoff. Three distinct sites were chosen to investigate how different physical forcings and geomorphologic settings influence the intensity and hydroperiod in the ecosystem.

In this study, statistical analyses of the surface water levels in the forest and channel water were used to develop relations among model parameters. Evapotranspiration is estimated from the empirical Thornthwaite Equation based on readily-available meteorological data from the study area. Other hydrological inputs, such as precipitation and tide, are determined from adjacent monitoring stations. Elevation data is also needed to understand the site-specific topography, such as bowl shaped or flat setting. HYMAN was calibrated to the three sites based upon the 2003 year soil salinity values collected at the sites. The model was then validated using 2004 and 2005 year data. The primary result from the simulations is the soil salinity that regulates plant production. The success of the HYMAN model to quantitatively produce soil salinity values at these three sites can be generalized to other coastal wetland systems with similar hydrological signals and topography and thus, can be used as a tool to predict how ecosystems may respond to future climate change, freshwater management, and other disturbances.

Within the conceptual framework of the Comprehensive Everglades Restoration Plan (CERP), which is to redistribute freshwater sheet flow back to its natural passage through Everglades National Park, HYMAN can be used to:

- Predict the short-term soil salinity along Shark River sites and the long-term salt budget due to the freshwater inputs;
- Quantify the changes of hydrologic forcings and hydroperiod in the forest; and
- Provide restoration managers an evaluation tool to understand the relationship between water management and expected long-term plant community response.

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Ecological Disturbances in the St. Lucie Estuary and the Southern Indian River Lagoon, Eastern Florida, Elucidated Through Macrobenthic Monitoring

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Benthic infauna are important indicators of aquatic environmental quality and are used in many monitoring programs to assess overall estuarine health and to follow long-term trends in estuarine communities related to anthropogenic impacts. Soft-bottom macrofauna have been monitored quarterly since February 2005 from 13 sites in the St. Lucie Estuary (SLE) and the Indian River Lagoon (IRL). Frequent discharges of nutrient rich freshwater from the C-44 Canal (Lake Okeechobee) have contributed to very poor environmental conditions in large parts of the SLE, with an infaunal community dominated by a few opportunistic (r-strategic) species. However, the diversity and abundance of the benthic community improve significantly further downstream toward the St. Lucie Inlet. Under the Comprehensive Everglades Restoration Plan (CERP), managed freshwater inputs and decreased sedimentation in the SLE are expected to improve the environmental conditions in the entire SLE. The data clearly indicate that the benthic communities respond quickly to environmental changes and that they reflect changes in discrete zones within the studied areas in the SLE and IRL.

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Pilot Study to Establish Monitoring Sites for Nesting Habitat of the Florida Snail Kite (*Rostrhamus sociabilis*)

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There are three features that remain constant within habitats selected by snail kites: presence of apple snails (*Pomacea paludosa*), sparsely distributed emergent vegetation for foraging (Sykes 1983, 1987), and suitable nesting substrates. The protocol developed for this study was designed to monitor both the foraging and nesting habitats across the snail kite's historic nesting range. In order to collect data pertaining to foraging vegetation, a series of transects were set up in WCA3B, WCA2B, Everglades National Park, Grassy Waters Preserve, St. Johns Marsh, and around the littoral edges of Lake Kissimmee and Lake Tohopekaliga. Destructive and non-destructive vegetation sampling was conducted throughout these transects and dominant species were identified. Available nesting habitat areas were determined for the aforementioned sites as well as for WCA3A. The size of areas with suitable nesting vegetation decreased significantly between 1995 and 2004 with the greatest decrease seen in WCA3A. In this report, we offer a proof of concept for a snail kite vegetation monitoring system and make specific recommendations to alter and expand the study.

- A thorough understanding of snail kite habitat will be beneficial to natural resource managers involved in present and future Everglades restoration efforts.
- An interdisciplinary approach that studies the hydrology, vegetative communities for foraging of prey species, and vegetative communities where nesting occurs will be beneficial to the snail kite and it will increase the field of knowledge of the Everglades' ecosystem.
- By considering the range of the snail kite, this study emphasizes a large scale approach that considers the entire Everglades watershed.

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Comparison of Growth Between Newly-Hatched Young of Two Species of Crayfish, *Procambarus alleni* (Faxon) and *Procambarus fallax* (Hagen), from South Florida

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Life history information (biology and ecology) is critical for understanding the role of a species within an ecosystem, the structure of populations within the community, and for conservation of biodiveristy within any ecosystem. Each stage of life history has specific requirements that support successful survival of the species, and interacts differently within the community. Although outcomes of life history studies, such as that of growth, can indicate the relative importance of a species in the ecosystem and whether one species has a competitive advantage over the other, few comprehensive studies of this type have been conducted on any crayfish, much less those that live in the Everglades. Two native keystone crayfish species inhabiting south Florida wetlands, *Procambarus alleni* (Everglades crayfish) and *Procambarus fallax* (Slough crayfish), were reared for 12 weeks in the laboratory during 2001 and 2002. Newly hatched young of each species were raised separately under similar controlled conditions. Growth of the two species was compared based on measurements of weight and length taken on each crayfish at approximately four to five week intervals. Data was analyzed through regression analysis and comparison of weighted means of weight and length. Everglades crayfish had significantly greater weight and total length than Slough crayfish after 12 weeks. However, at a given length, Slough crayfish were heavier than Everglades crayfish. More Slough crayfish juveniles had grown gonopods, and the gonopods were more developed than those of Everglades crayfish.

This is the first study that compares early growth of Everglades and Slough crayfish hatchlings of known age. This data is important to restoration of Florida's Everglades because:

- baseline data on crayfish growth rates are critically important for use in models that predict the availability of crayfish in Everglades food webs and to enhance biodiversity of wetland flora and fauna.
- known age of crayfish used in life history studies is important, because size in natural populations does not necessarily reflect age;
- data on the age/size at which crayfish reach reproductive maturity is also critical for modeling, since these factors can affect crayfish abundance and rates of population change;
- size and maturation rate in crayfish populations may influence competition, leading to successful survival of one species over the other;
- understanding differences in the life history of these two species will provide a basis to better manage crayfish populations as Everglades restoration progresses.

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Examination and Comparison of Mandibles and Gastric Mill Teeth in Two Species of Crayfish, *Procambarus alleni* (Faxon) and *Procambarus fallax* (Hagen), that Inhabit Everglades Wetlands

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Although most crayfish are considered to be opportunistic omnivores, morphological similarities or differences of masticatory structures among crayfish species can yield more specific clues as to their diet and habitat preferences. Previous studies of several crayfish species, including procambarids, have shown that differences in relative size and structure of mandibles and gastric mill teeth (found in the cardiac stomach), can sometimes be correlated to food choices, which, in turn, can indicate the type of habitat in which the crayfish lives. Modifications of these structures might be factors that allow for microhabitat variation, and may account for the observed syntopic distribution (in the same location) of the two native epigean (living above ground) species of crayfish in the Everglades, *Procambarus alleni* (Everglades crayfish) and *P. fallax* (Slough crayfish). There is some evidence to suggest that each species prefers different hydroperiods, but no studies of food preferences of either species have been conducted. Adult crayfish were collected from several different sites in south Florida during December 2007 and March 2008. The mandibles and gastric mill teeth of both species were compared, by microscopic examination, photographs, and measurements. It is hypothesized that there will be significant morphological differences in sizes and structure of both mandibles and gastric mill teeth between the two species, which may, in turn, indicate differences in dietary preferences. Everglades crayfish are expected to have proportionally larger mandibles and gastric mill teeth (both median and lateral) than Slough crayfish, because they grow faster and are larger in size than Slough crayfish. Because studies suggest that Everglades crayfish inhabit a wider range of habitats, their masticatory structures might reflect a more diverse diet as evidenced by possibly sharper and more complex mandibular teeth and gastric mill lateral and medial teeth than Slough crayfish.

This research is important to Everglades restoration because:

- morphological differences in mandibles and gastric mill teeth may be factors that contribute to resource partitioning on a microhabitat level, affecting distribution and abundance of crayfish species in Everglades wetlands;
- sizes and shapes of masticatory structures can indicate the type of food eaten, hence help clarify the herbivore/carnivore role of both species of crayfish in Everglades food webs;
- dietary differences (food preferences) may be a factor in explaining how two species seem to live in syntopic distribution in Northern Everglades habitats
- differences in dietary preferences of the two species may be a factor to consider in refinement of crayfish prediction models.

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Measurements and Modelling of Vegetation Effects on Flow in Ridge and Slough Landscape

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To manage flow in the Everglades so as to maintain ecosystem health, one must understand the combined effects of basin – scale flow control (by engineers) and the local – scale flow control (by aquatic vegetation). We contribute to this fledgling understanding with a series of field measurements in the Everglades. Through a series of tracer releases we directly measure the mixing and transport in a variety of representative locations. Our measurement scale is 1 – 4 km^2, which is large enough to include several ridges and sloughs at each site. Such large-scale measurements are accomplished using the high – precision and low – cost tracer Sulfur Hexafluoride (SF_6), which is monitored with a portable and rugged apparatus designed to extract dissolved gases and measure them via chromatography.

These field measurements provide a basis for understanding the aggregate effects of heterogeneous landscapes such as the ridge and slough on hydrodynamics. Vegetation patterning provides spatially variable flow resistance, which can channel flow into locally accelerated regions.

We use the tracer data to condition two numerical models. The first is an extended advection – dispersion model that gives, among other outputs, the air – water gas exchange rate in the ridge and slough system as well as quantifying the "trapping" behavior of vegetation. The second model uses a Lattice – Boltzmann scheme to obtain a high – resolution flow field. In combination, the two models allow us to determine the drag presented by individual ridges and sloughs, as well as the combined drag that is used in coarse – scale models such as the SFWMM. With this tool, we can use aerial images and spatially averaged water surface slopes to predict the velocity patterns in the ridges and sloughs. This information is expected to be useful when assessing the effects of altered hydrologic conditions on vegetation community dynamics and sediment transport (and thus the feedbacks that help maintain ridge – slough patterning).

Key findings relevant to restoration include:

- Water flow direction is not always aligned with landscape patterning
- Tracer measurements provide values of advection and dispersion rates
- Numerical models will enable more detailed representations of flow-biology interactions

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History of Lake Okeechobee Operating Criteria

James Vearil
U.S. Army Corps of Engineers

Between 1905-1931 the State of Florida's Everglades Drainage District constructed a number of features around Lake Okeechobee for the purpose of draining and reclaiming the Everglades. The hurricanes of 1926 and 1928 killed between 2000 to 3000 people and caused much property damage due to flooding from Lake Okeechobee. The Everglades Drainage District for many years used a regulation range of 14-17 feet, Lake Okeechobee Datum (or 12.56-15.56 feet, NGVD) as a regulation range. Following the hurricanes of 1926 and 1928, Congress provided disaster relief in the form of flood control and navigation in the 1930 Rivers and Harbor Act that authorized the Corps of Engineers to construct some protective works for Lake Okeechobee. In the 1930's Herbert Hoover Dike was constructed to protect the South Shore Area and the Town of Okeechobee from flooding. The U.S. Army Corps of Engineers continued the use of a Lake Okeechobee regulation range between 12.56-15.56 feet, NGVD. After the 1947 flood, the Flood Control Act of 1948 authorized a comprehensive water resource project known as the Central and Southern Florida (C&SF) Project to address the complex set of water related problems in that area. In the 1960's Herbert Hoover Dike was raised and levees on the Northeast and Northwest Shores were constructed.

In 1951 a flat schedule of 16.4 feet, NGVD was approved for Lake Okeechobee. Subsequent studies lead to the approval of a 15.5-16.5 feet, NGVD seasonally variable regulation schedule. In the 1959 report it was concluded that this schedule provided about the same level of agricultural water supply benefits as the flat 16.4 foot schedule, provide seasonal flood storage to help reduce damaging regulatory releases to the estuaries, and that large additional benefits could be obtained from sufficient conservation storage in the lake to supply the needs of the urban areas along the east coast during droughts. The top of the flood control pool was considered the maximum lake level reached during the Standard Project Flood (SPF). A variety of regulation schedules were used during construction of C&SF Project facilities necessary to permit implementation of the 15.5-16.5 foot schedule. In 1978 a 15.5-17.5 feet, NGVD regulation schedule was approved, which retained the design parameters of the 15.5-16.5 foot schedule, but provided some additional water supply storage. A revised regulation schedule known as "Run 25" was tested in 1992 for two years, and then implemented as interim regulation schedule in 1994. In 2000 that Lake Okeechobee regulation schedule was replaced by the "WSE" regulation schedule.

The Lake Okeechobee regulation schedules used have varied from high stages in the late fall and winter to low stages at the beginning of the wet season. Runoff during the wet season has been stored for use during the dry season. When lake levels have exceeded the regulation schedule, flood control releases have been made from the lake. Outlet capacity from the lake is small compared to the immense storage capacity of the lake. When the lake level has been below schedule, releases have been made from the lake for water supply, navigation, prevention of saltwater intrusion, and environmental enhancement. Water has been transferred to the Water Conservation Areas (WCA) from Lake Okeechobee when inadequate storage has been available in the WCA's to meet demands.

The shallow bottom topography of Lake Okeechobee combined with the long fetch, can result in significant wind tides on the lake. The principle factors that determined the required levee grades around Lake Okeechobee were lake level prior to the hurricane, and the wind tide and waverunup expected during the hurricane. The three hydraulic conditions analyzed were Maximum Probable Hurricane (MPH) with the lake at the top of the conservation pool, Standard Project Hurricane (SPH) with the lake at the highest 30-day average 100-year flood stage, and Moderate Hurricane at highest 30-day average Standard Project Flood (SPF) stage.

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Effects of Elevation, Plant Age and Planting Density on Revegetation of Freshwater Marl Prairie Ponds at the Florida Panther National Wildlife Refuge, Naples, Florida

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Removal of invasive and undesirable vegetation often results in highly degraded conditions. Ecosystem recovery can be accelerated by means of revegetation. However, little is known about the factors that control revegetation success. In this study, *Salix caroliniana* (Carolina willow) was removed from two formerly open-water ponds (approximately 1 mile apart) at the Florida Panther National Wildlife Refuge, Naples, Florida, USA. For a related study, a seedbank assay was performed prior to *S. caroliniana* removal. Via the assay, plant material native to the site was provided for this study, and native plant species were selected amongst the available species pool based on wildlife value and survival. Two elevations were tested along with a dense and sparse planting, 0.457 m and 0.914 m centers, respectively. Plant age (1" plug and 5" pot) was also tested as a function of elevation. Of the 8 native species planted, *Verbena scabra* (Sandpipe vervain) was the only species to have a significantly high (>90%) mortality rate. On the contrary, *Cyperus haspan* (Haspan flatsedge) had rigorous growth and spread. Overall, planting at different elevations had little effect on plant growth and survival for either density. The dense planting treatment resulted in greater plant volume than the sparse planting treatment. Transplants from 5" pots had a greater survival rate and establishment rate than 1" plugs at either elevation. The results herein will provide useful information for revegetation of wetland basins for restoration purposes.

From the preliminary data, no concrete conclusions can be derived. However, the findings thus far have shown that:

- Elevation has little effect on native plant establishment and growth rates.
- Growth rates of select species with respect to using different propagule sizes is species-specific.
- Dense planting treatments resulted in greater plant volume than the sparse planting treatments.

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Spatial and Temporal Changes in the Chemical Characteristics and Distribution of Lake Okeechobee Sediments

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Lake Okeechobee has been impacted by nutrient loading from human activities in its watershed. Water quality has degraded over decades; the principal driver of ecological changes has been increases in lake water phosphorus (P) concentrations. As the lake has progressed towards a more eutrophic state, shifts in phytoplankton communities, dominance of algae over emergent and submerged aquatic vegetation, increased incidence of harmful algal blooms, and increased turbidity in the water column have ensued. Lake sediments have acted as a net sink for phosphorus, but when the water column P concentrations decline, the sediments also provide a large internal load of soluble P. Changes in P concentrations, fractionation, and other chemical characteristics of the sediments were recently sampled at 174 sites across the lake (at which sediments were previously sampled in 1988 and 1998) in order to investigate how this large P storage pool is shifting in spatial extent, and responding to efforts to reduce the external load to the lake. Available data from previous whole lake sampling efforts (1988, 1998) were used for comparison with present day conditions to estimate the sign and magnitude of changes in P storage.

- P levels in Okeechobee's sediments significantly increased between 1988 and 1998, and decreased between 1998 and 2006.
- The mud zone has increased in extent over time, while decreasing in depth.
- Spatial structure of sediment chemical properties tends to be weaker than might be expected by differences between sediment types.

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Eastern Oysters (*Crassostrea virginica*) as an Indicator for Restoration of Everglades Ecosystems

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The Comprehensive Everglades Restoration Plan (CERP) attempts to restore hydrology in the Northern and Southern Estuaries in Florida. The Eastern oyster *Crassostrea virginica* is a dominant feature of the estuaries along the Southwest Florida coast including the Caloosahatchee estuary. Oysters are benthic, sessile filter-feeding organisms that provide ecosystem services by filtering the water column, providing food, shelter and habitat for over 300 species of associated organisms, and making an excellent sentinel organism for examining the impacts of restoration on marine ecosystems. The implementation of CERP attempts to improve the hydrology, spatial and structural characteristics of oyster reefs, improve the recruitment and survivorship of *Crassostrea virginica* and its associated communities of organisms.

In this project a link between biological responses and environmental conditions relative to hydrological changes as a means of assessing positive or negative trends in restoration was made. Using oyster responses from 2000 – 2007 in the Caloosahatchee estuary, we have developed a communication tool (Stoplight Report Card) based on CERP performance measures that is expected to be able to distinguish between responses to restoration and natural patterns. The Stoplight Report Card system is a communication tool that uses MAP performance measures to grade an estuaries response to changes brought about by anthropogenic input or restoration efforts. The Stoplight Report Card involves a suitability index score for each organism metric as well as a trend score (- decreasing trend, +/- no change in trend, and + increasing trend). Based on these two measures, a component score (e.g., living density) is calculated by averaging the suitability index score plus the trend score. The final Eastern oyster index score is obtained by taking the geometric mean score of each oyster component and translating it into a stoplight color for success (green), caution (yellow), or failure (red).

Based on the available data of oyster populations and the responses of oysters in the Caloosahatchee Estuary, the system is at a stage "caution". This communication tool instantly conveys the status of the indicator, and the suitability and trend curves provide information on progress towards reaching a target. The tool also has the advantage of being able to be applied regionally, by species, and collectively system-wide.

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Release from Natural Enemies Belowground Helps Explains the Invasiveness of *Lygodium microphyllum* in Florida: A Cross-continental Comparison

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Lygodium microphyllum, a climbing fern native to the Pantropics of the Old World, is aggressively colonizing natural ecosystems in the Florida Peninsula. Here we examine edaphic factors potentially influencing the fern's invasiveness, specifically addressing the hypotheses that its behavior in Florida ecosystems can be explained in part by a release from natural belowground enemies. We also investigate phenotypic differences, expressed in similar growing conditions, between source populations from Florida and from the fern's native range in Australia, hypothesizing that the former would possess traits resulting in faster growth and superior competitive ability compared to the latter. We tested these hypotheses in four parallel studies, two in Australia and two in Florida. In each location we planted common garden studies, one in a native *L. microphyllum* wetland site in Australia and one in a recently colonized wetland site in Florida. In addition, on both continents, using soils from *L. microphyllum* sites, we also performed control pot studies in order to gain a more mechanistic explanation for potential differences between continents. To facilitate comparisons between the two control studies, a common sand culture was included in each. Fern growth rate and its principal determinants were compared among treatments in which soil was altered through either sterilization or nutrient amendment, or both. Relative growth rate (RGR) was generally stimulated by nutrient amendment and sterilization. The overall effect of sterilization, however, was muted under high-nutrient conditions, except for the population originating from the same region as the soil used in the Australian study. Regardless of nutrient treatment, plants in this population had a significantly greater RGR in sterilized than in non-sterilized soil. Our results indicate that the invasiveness of *L. microphyllum* in Florida may be partially explained by release from natural soil-borne enemies, but likely not from an evolution of increased competitive ability.

- *Lygodium microphyllum*, one of the fastest spreading non-native invasive species in southern Florida, threatens to greatly impact Everglades restoration.
- Understanding *L. microphyllum* physiology and ecology in both its native and introduced range is paramount to develop effective control measures, both mechanical and biological.
- Our cross-continental comparison of *L. microphyllum* in controlled and field studies indicates that release from natural soil-borne enemies (pathogens and insects) may help explain its aggressive spreading habit in Florida and indicates that more investigation into potential belowground biocontrol agents in *L. microphyllum's* native range is necessary, which will ultimately effect restoration success in Florida.

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Comparison of the South Florida Water Management Model (SFWMM) with a Simple Refuge Stage Model (SRSM) for the A.R.M. Loxahatchee National Wildlife Refuge

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There can be utility in having a suite of alternative models available for research and management applications. Model credibility is improved when alternative models are in substantial agreement; model limitations and deficiencies can be highlighted when differences in model projections are identified. The latter is valuable both for identifying where to focus additional resources in model refinement and for articulating model limitations. The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) overlays Water Conservation Area 1 (WCA-1) in the Florida Everglades. This presentation compares modeling results from two models projecting WCA-1 water stage – the South Florida Water Management Model (SFWMM) and the Simple Refuge Stage Model (SRSM) when simulating similar inflow and climatological conditions.

The South Florida Water Management District (SFWMD) developed the SFWMM for assessing water management options and to support water management decisions. The SFWMM projects water stages and flows over an area from Lake Okeechobee to Florida Bay using a 2-mile by 2-mile square grid of cells that are linked by water flow from overland, groundwater, and canal interconnections. Within the SFWMM domain, WCA-1 is represented by 57 grid cells and one canal element. When simulating alternative scenarios, outflows from WCA-1 are determined in the SFWMM primarily by simulated water supply withdrawals and regulatory releases consistent with the WCA-1 Water Regulation Schedule.

The SRSM simulates stage in WCA-1 by integrating water budget terms for a single canal cell, and a single marsh cell. Marsh stages were calibrated to represent the average of the 1-7 and 1-9 gages in WCA-1. Inflows to the canal are imposed as a boundary time series. Rain and evapotranspiration similarly are represented by time series. Outflow may be optionally calculated from a relationship based on the Water Regulation Schedule, plus an imposed time series of actual water supply discharges. Groundwater outflow from both the canal and marsh also are calculated from simulated water stage. The SRSM currently is implemented using the Berkeley Madonna simulation program, which can, depending on integration algorithm selected, run multi-decadal SRSM simulations in under a second.

A SFWMM scenario run, ECPBASE, was used to compare results between modeling programs. This scenario simulates the water control structures and management controls anticipated to be in place in 2010. Climatic data for a 36-year period from 1965 through 2000 are applied in this scenario. The current WCA-1 Water Regulation Schedule is assumed to apply throughout the simulation. Input and results of the ECPBASE run of the SFWMM are available publicly, and were provided by the SFWMD to our modeling team. An analogous SRSM simulation was performed based on the ECPBASE SFWMM model run.

Differences in daily marsh stage projections between the models typically were less than 0.1 feet. A notable exception to this agreement occurred during 1989, an extreme drought year, when the SRSM projected higher stages than the SFWMM. We believe that this difference results from the limitation of the SRSM to simulate groundwater drawdown below the marsh surface. Sensitivity runs using the SRSM demonstrate that marsh stage is quite sensitive to assumed water supply demand, and to operational rules used to implement Water Regulation Schedule regulatory releases.

Findings from this study relevant to Everglades restoration include:

- There is value in having multiple models available that are based on different assumptions and levels of complexity.
- Comparison of alternative models can increase model projection credibility, and help identify specific model limitations and areas for future investigation and improvement.
- Marsh stage in the Refuge is quite sensitive to water supply withdrawals.
- Refuge marsh stage also is quite sensitive to operational rules used to implement Water Regulation Schedule mandated releases.
- Simplified water budget modeling is efficient and should be one of multiple tools used to evaluate hydrological impacts of alternative water management scenarios,

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Modeling Phosphorus Dynamics in Everglades Wetlands and Stormwater Treatment Areas

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As water with elevated phosphorus (P) moves through a wetland ecosystem, phosphorus is removed and a gradient of decreasing P concentration is produced. In the Everglades Water Conservation Areas, that gradient typically ranges from > 100 ppb near inflow points to < 8 ppb in native marsh communities. The water-column P gradient is typically accompanied by decreasing gradients of P storage in vegetation and soils. Nearly three decades of monitoring and research by the South Florida Water Management District and other organizations have conclusively established that characteristics of the wetland ecosystems change dramatically along the gradient and that native communities are viable only at P concentrations < 10 ppb.

That same research and monitoring data have provided a basis for developing relatively simple mass-balance models to support design and optimization of ~58,000 acres of Stormwater Treatment Areas (STA's) for removing P from marsh inflows and to simulate downstream marsh responses to variations in inflow P loads. This paper describes the evolution of those models from the steady-state STA design model (1995), the Everglades Phosphorus Gradient Model (EPGM, 1996), and Dynamic Model for Stormwater Treatment Areas (DMSTA, 2002). Applications to STA and marsh monitoring data collected through 2007 provide a basis for testing previous model calibrations and evaluating STA performance relative to long-term expectations.

While DMSTA was developed primarily a design tool, it can also be used as a diagnostic tool to facilitate interpretation of real-time monitoring data. Variations in measured STA outflow concentrations and loads reflect variations in inflow volumes, inflow P loads, water depths, climate, management, P cycling within wetland communities, measurement errors, and other random factors. It is difficult to evaluate the inherent P removal performance of the wetland community in the context of data variations induced by the other factors. DMSTA attempts to factor out the effects of management (inflow distribution, depth), hydrologic variations, and climatologic variations, so that the data provide a better signal of vegetation function and long-term performance relative to design simulations and management expectations.

Findings based upon data collected through 2007 include:

- Differences between observed and predicted STA outflow concentrations and loads were generally within uncertainty envelopes established in previous DMSTA calibrations.
- Performance of individual STAs cells was reasonably consistent with simulations of designated community types (emergent vs. submergent) when allowance is made for factors not considered by the model (startup, construction, maintenance).
- Applications to long-term marsh datasets demonstrate the feasibility of combining EPGM and DMSTA into a single dynamic model for simulating phosphorus storage in the water column, vegetation, and soils along gradients downstream of inflow points.

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Simplified Modeling of Surface Water Sulfate Dynamics in the A.R.M. Loxahatchee National Wildlife Refuge, Florida

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), a remnant of the historic soft-water Everglades, overlays Water Conservation Area 1 (WCA-1), in Palm Beach County, Florida, USA. Sulfate contamination has been identified as a serious environmental issue for the Everglades ecosystem including the Refuge. Studies have shown that even the most interior marsh in the Refuge has been affected by nutrient-laden canal water. Sulfate concentration in the Refuge perimeter canals are also elevated, and impact surface water in marsh areas near the canals, and to a lesser degree, more interior marsh.

High levels of sulfate entering Everglades marshes stimulate microbial sulfate reduction, the buildup of sulfide in porewater, and the production of methylmercury (MeHg, a neurotoxin to fish and other wildlife), change redox conditions in the underlying soil, and remobilize nutrients, thus affecting macrophyte growth and vegetation distribution. Studies of sulfate transport and transformation within the Refuge marsh have been constrained by our limited understanding of hydrology within the Refuge. The research reported here integrates simple hydrological and water quality models to support investigation of sulfate dynamics within the Refuge. This integration not only contributes to our understanding of sulfate dynamics in the Refuge, but also contributes to our understanding of the Refuge hydrodynamic.

In this research, we developed a water budget and a Completely Mixed Flow (CMF) water quality model for the Refuge that is implemented in Berkeley Madonna, a differential equation solver. We used the CMF model to examine the response of surface water sulfate in the Refuge to changes in sulfate loading and hydrological processes. In the model, the Refuge was divided into four compartments along a gradient from rim canal to marsh interior: canal, perimeter marsh, transitional marsh and interior marsh. The hydrologic, meteorological, and water quality data were primarily obtained from the South Florida Water Management District DBHYDRO online database. The CMF model calculates flow between the canal and marsh, groundwater recharge including levee seepage loss as well as evaporation and transpiration. Sulfate loss is modeled using a Monod relationship, in which the maximum sulfate disappearance (apparent setting) rate was obtained from model calibration process. Apparent settling of sulfate from the marsh water column is assumed to represent loss by sulfate reduction.

The model has been calibrated and validated using long-term monitoring data (1995-2006). Model results showed that the simple sulfate model is capable of capturing big-picture spatial, inter-annual, and seasonal variations in sulfate concentrations in the Refuge. Our simulations indicate that sulfate-elevated canal water intrusion into the marsh notably influences the surface water sulfate levels in the Refuge marsh areas.

Key findings relevant to restoration include:

- Sulfate contamination is a challenge to the Refuge's ecosystem health;
- Our simple modeling approach captures the big-picture sulfate dynamics in the Refuge and thus can be used to examine the effects of water management decisions on Refuge sulfate dynamics;
- As intrusion of sulfate-laden canal water into the Refuge marsh is a major driver of marsh sulfate levels, management attention should be paid to wet year and wet season conditions that may favor movement of high sulfate from the canal into the marsh.

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Isotopic Effects of Hydroperiod in Tree Islands

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A survey of foliar carbon and nitrogen isotope ratios of 18 tree islands in the Everglades National Park showed a distinct pattern where $\delta^{15}N$ of upland tree species for islands within the Shark Valley Slough (slough tree island) had higher values averaging +6.06±1.89 (±σ, n=10) than those for islands outside the slough (ridge tree island) averaging -1.58±1.53 (±σ, n=8). The variations in $\delta^{15}N$ values through season or between species are both very small compared to the differences among tree islands and are considered negligible. Slough and ridge tree islands have distinct hydroperiods, which seemed to be related to the $\delta^{15}N$ pattern we found. We proposed that $\delta^{15}N$ is tracing P limitation and that P limitation is determined by short hydroperiod induced water stress.

Previous studies have shown that in wetland ecosystems, foliar $\delta^{15}N$ values vary with P limitation. In this study we used $\delta^{15}N$ as a proxy of P availability. We found that average $\delta^{15}N$ is positively related to total soil P concentration of each tree island. Using seasonal variation of foliar $\delta^{13}C$ as an indicator of water stress, we found that hydroperiod affects plant water relations of tree islands. With longer hydroperiod inside the slough than outside, slough tree islands experience less water stress during dry season compared to ridge tree islands. This can be explained by marsh water existing in the slough during the dry season, which is available to tree island plants. We also found that this difference in water stress between slough and ridge tree islands is related to their foliar $\delta^{15}N$ values. Tree islands experiencing less water stress had higher $\delta^{15}N$ values, which indicated more available P for plants uptake. On the other hand, we found similar general pattern of foliar $\delta^{15}N$ in the lowland part of these tree islands and that foliar $\delta^{15}N$ between lowland and upland plants of each island was positively related, suggesting that marsh water inside the slough could also have higher P concentration than that outside the slough. Overall, our results suggest that tree island plants have the ability to harvest water from surrounding marshes, which also serves as a source for P uptake. Hydroperiod affects the amount of water tree island plants can harvest from the marshes as well as the long term P input of marsh water.

This study shows that hydrological factors such as hydroperiod and water flow can have major impact on nutrient distribution of tree islands in the Everglades. Since nutrient distribution is the key for tree island restoration, any change of hydrology by Everglades management or climate changes could lead to major changes of tree island plant communities. The connection between hydrology and nutrient status of tree islands shown here should be taken into account during future Everglades restoration plans.

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Vegetation Cover Decreases Evaporative Water Loss in a Wetland Ecosystem

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Analysis of oxygen and hydrogen isotope ratios of water is a useful tool for quantitative measurements of water evaporation. Water molecules with the lighter isotopes, $H_2{}^{16}O$, evaporate faster than $H_2{}^{18}O$ and $DH^{16}O$, leaving the residual water enriched in D and ^{18}O. Therefore, the greater the evaporation, the higher the ^{18}O and D values in the remaining water body. Here we used stable isotope analyses to study evaporative processes in a wetland water conservation area (Loxahatchee Wildlife Refuge, also known as WCA-1, South Florida Water Management District) where the primary purpose is to conserve regional water resources. Evaporation and transpiration are the two major pathways of water loss from the refuge. We collected water from 50 sampling stations located in the 145,920 acres of the refuge area for the months of August, September, and November 2006 and January 2007, covering from mid wet season to mid dry season. Water samples were analyzed for oxygen and hydrogen isotope ratios. The results confirm that the water in this area is enriched by evaporation since a plot of water D versus ^{18}O lies off the meteoric water line. However, the enrichment of ^{18}O and D within WCA-1 is not homogeneous, with differences in ^{18}O values between stations of up to 2‰. We GIS mapped the ^{18}O values of water for the entire area and found the isotopic enrichment pattern is consistent through time. This result suggests that water at different locations in the refuge has different evaporation rates. Possible factors that contribute to this evaporation pattern are: distance to the peripheral canal discharge station, water depth, and vegetation coverage. To find out which is (are) the determining factor(s) affecting water evaporation of the area, we mapped $\delta^{18}O$ values of water with elevation and vegetation type of the refuge and calculated average elevation and percentage of vegetation coverage of a $100m^2$ area around each sampling station. A multiple linear regression between $\delta^{18}O$ values of water and average distance from the discharge gates, elevation, and percentage coverage indicate that the observed evaporation pattern is not caused by water depth. Distance from the discharge gates and percentage vegetation coverage are both significantly correlated with $\delta^{18}O$ values of water. The effect of distance is related to the water turnover rate, i.e. the further the location is to a discharge station the greater the time the water at that location has been exposed to evaporation. In contrast, the higher the vegetation coverage the lower the loss of water through evaporation. In the future, we will determine if the effect of vegetation coverage in diminishing water loss by evaporation is annulled by the loss through transpiration.

The two major pathways of water loss, evaporation and transpiration, can have significantly different impact in the nutrient budget of the Loxahatchee Wildlife Refuge. Evaporation will lead to nutrient enrichment, while transpiration will lead to a nutrient depletion in the water column. In the future, we will model the nutrient budget of the refuge based on these two water loss pathways.

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A Loss-on-Ignition Method to Assess Soil Organic Carbon in Calcareous Everglades Wetlands

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Measurement of soil C is important for determining the effects of Everglades restoration projects on C cycling and transformations. Accurate measurement of soil organic C by automated CNS analysis may be confounded by the presence of $CaCO_3$ in Everglades wetlands. The objectives of this study were to compare a loss-on-ignition (LOI) method with CNS analysis for assessment of soil C across a diverse group of calcareous Everglades wetlands. Over 3168 samples were taken for three soil depths (floc, 0-10, 10-30 cm) in 14 wetlands and analyzed for LOI, total C, and total Ca. The LOI method compared favorably to CNS analysis for LOI contents ranging from 0-1000 g kg^{-1}, and for soil total Ca levels from 0-500 g Ca kg^{-1}. Total C measurement by CNS analysis was including TOC and inorganic C (IC). LOI was a good indicator of organic C. For all wetlands and soil depths, LOI was significantly related to total C (r^2=0.957). The ratio of TC/LOI was variable when LOI less than 400 g kg^{-1} due to CaCO3 present, but when LOI exceeded 400 g kg^{-1} the ration of TC/LOI was liner and the mean was 51%. In this case, TC measurement from CNS analyzer was equal or close to total organic carbon (TOC). Simple estimated TOC can use LOI multiple by factor 0.51. Multiple regression model of TC with LOI and Total Ca significantly improved (R^2=0.997) the prediction of total C only by LOI, special in soils with high total Ca (presence as $CaCO_3$) and low LOI. Estimates of total organic C by CNS analysis were obtained by accounting for IC associated with $CaCO_3$ by calculation, with results being similar to total organic C values obtained from LOI analysis. The proportion of C in organic matter measured by the LOI method (51%) was accurate and applicable across wetlands, soil depths, and total Ca levels, thus LOI was a suitable indicator of total organic C in Everglades wetlands.

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Reconstructing Primary Producer Communities in WCA-2A in Relation to Phosphorus and Hydroperiod

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The northern Everglades Water Conservation Areas have experienced recent ecological shifts in primary producer community structure involving marl periphyton mats and dense typha stands. Multiple investigations have identified phosphorus as a driver of primary producer community structure, but the effects of water impoundment beginning in the 1950s has also been identified as a concern. Unfortunately, long term monitoring data does not exist for the Everglades so primary producer community structure prior to 1950 is inconclusive. In an effort to understand pre-1950 primary producer community structure and identify timescales of community shifts since 1950, we measured paleolimnological proxies on three sediment cores collected in Water Conservation Area-2A (WCA-2A) along a phosphorus enrichment gradient. Photosynthetic pigments, total phosphorus, organic matter, total organic carbon and nitrogen were used to infer historic primary producer communities and phosphorus inputs. In addition, excess ^{210}Pb was used to establish historic dates for the sediment cores.

We inferred from paleolimnological proxy data that prior to 1950 the northern area of WCA-2A established a marl periphyton community circa 1920. This community shifted to typha dominance around 1950. The middle and southern areas of WCA-2A did not develop a marl periphyton community until the impoundment occurred in 1950. The middle of WCA-2A quickly developed the periphyton community within 5 to 10 years following the impoundment while the southern area of WCA-2A required nearly 20 years to develop marl periphyton. Recently, the middle of WCA-2A has developed a typha community while the southern area of WCA-2A has yet to develop typha dominance. Investigations into current typha communities in the Everglades have proposed that a concentration of 650 to 700 µg/kg of phosphorus in the sediments is needed to promote typha dominance. The results obtained from this research suggest that this concentration holds true throughout the past 100 years in WCA-2A. In both sediment cores collected from current typha-dominated areas, sediments inferred as typha-associated corresponded to total phosphorus concentrations at or above 700 µg/kg. It has been shown that the marl periphyton communities serve as a mechanism for removing water-column phosphorus and depositing it into the sediments. In addition, inorganic phosphorus is co-precipitated with the calcium carbonate associated with the marl. These increasing concentrations of sedimentary phosphorus and inorganic phosphorus provide optimal conditions for typha growth. As a result, the temporal and spatial differences occurring over the past 100 years indicate that the water-column phosphorus gradient is the primary driver of primary producer community structure in WCA-2A.

The establishment of the marl periphyton in the middle and southern areas of WCA-2A correspond to the impoundment period beginning in 1950. We infer from paleolimnological data that hydroperiod works as a secondary driver in determining primary producer community structure. Possible mechanisms could be increased delivery of water-column phosphorus, decreased dry periods that could desiccate and destroy primary producers and alterations to biogeochemical processes regulating sedimentary phosphorus concentrations. Nevertheless, these data confirm the historic significance of phosphorus and hydroperiod in regulating primary producer community structure in WCA-2A and support the need for future consideration in relation to management and restoration.

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Unmanned Aircraft Systems for Wading Bird Surveys in the Everglades

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Monitoring of wading bird (order Ciconiiformes) populations in the Everglades is considered essential to the evaluation of the Comprehensive Everglades Restoration Plan. While traditional aerial survey methods using manned aircraft are effective, they are also expensive, and exposing biologists and pilots to risks associated with manned air missions. However, there are many logistical questions associated with the use of UAS to detect colonies of wading birds. We evaluated the ability of a small (5kg, 2.5m wingspan) autonomous UAV to fly precision flight paths, and to take digital pictures that would allow observers to identify breeding colonies. The aircraft was custom built at University of Florida, is equipped with GPS autopilot, a high-resolution digital camera payload, and radio equipment for maintaining telemetry links with a ground control station. In May 2008, we flew the aircraft over a series wading bird colonies in tree islands in WCA 3. These colonies contained either breeding Great Egrets (*Ardea albus*) or similarly sized white decoys. Pictures of tree islands with and without wading birds or wading bird decoys were evaluated by 14 observers not associated with the field project. The average error in detecting all colonies (including those with only one or two nests) was 13.8% (s.d. 8.1%). When detecting colonies of greater than two nests, only one observer made a mistake.

- The UAS in its current configuration appears to deliver the most promising results at altitudes between 500 and 1000 feet, potentially complementing higher-altitude surveys.
- The ability to remain on course was measured at less than 50 m, or the level of accuracy of the onboard GPS unit. Improvements in GPS accuracy will improve this accuracy.
- The UAS shows excellent potential for repeatable survey routes and the ability to collect digital information that allows correct identification of wading bird colonies.

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Patterns of Peat Elevation in the Ridge-Slough Mosaic

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The ridge and slough mosaic is a major landscape component of the Everglades, described by stands of sawgrass (*Cladium jamaicense*) on elevated ridges interspersed among deeper water sloughs comprised of floating and emergent species as well as extensive periphyton. Autogenic feedbacks among depth and duration of inundation, plant community composition, net primary production, and peat accretion/decomposition are hypothesized to create and stabilize multiple ecosystem accretion equilibria. These stable states in ecosystem carbon budgets result in similar long term accretion rates in ridges and sloughs, despite strongly differential primary productivity. Our principle objective is to evaluate C budget equilibria; however, prior to detailed C budget measurements, we sought to better understand relationships among extant landscape patterns of peat elevation, the composition of plant communities, and recent hydrologic change. Current literature describes elevation differences (bimodality) between intact ridges and sloughs and the loss of these differences with hydrologic alteration. However, efforts to quantify those elevation differences in response to known hydrologic changes are not sufficiently developed to be diagnostic of regime shifts (from ridge-slough to a flattened landscape), nor can we predict transitions between ridge and slough. Moreover, we have limited quantitative information linking elevation differences to changes in the plant communities hypothesized to autogenically maintain the bi-modal ridge slough mosaic. To address these questions, we compared theoretical predictions and observations of the distribution of soil elevations across large (2 x 4 km) landscape blocks spanning a gradient of hydrologic impairment in the ridge-slough region of the central Everglades. We found

- strong evidence of alternative stable state maintenance in the best conserved ridge-slough mosaic in central WCA3A$_S$, with significant shifts away this bimodality under hydrologic alterations,
- corresponding shifts in slough communities and occurrences with drainage, and
- loss of anisotropy with impoundment, and loss of spatial autocorrelation with drainage.

Should the restoration of and maintenance for the ridge slough mosaic remain a priority, our results suggest that statistical descriptions of the distribution of elevation, particularly anisotropy and bimodality, can act as diagnostic measures of ridge-slough health. Further, these measures are sensitive and specific to the magnitude and direction of hydrologic alteration and may be useful for effective ecosystem monitoring.

Keywords: ridge-slough, peat, hydrologic modification

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Restoring Tree Islands in the Everglades: Experimental Studies of Tree Seedling Survival and Growth

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An experimental study of the survivorship and growth of seedlings of seven tree species found on tree islands in the central and northern Everglades was done at the A. R. Marshall Loxahatchee National Wildlife Refuge in South Florida in the Loxahatchee Impoundment Landscape Assessment (LILA) facility. In May 2004, 400 tree seedlings of each species were planted at different elevations along 5 transects on 8 newly constructed tree islands, four with and four without limestone cores. During the study, water levels were at or above the soil surface 23 to 30% at highest elevations and 82 to 87% at the lowest elevations along the transects. At the end of the study 30 seedlings of three species (*Annona glabra* L., *Chrysobalanus icaco* L., and *Ilex cassine* L.) were harvested.

Seedlings suffered between 40 and 85% mortality during the first 120 days, the period with the lowest water levels. *Ilex cassine*, *Salix caroliniana* Michx., *Chrysobalanus icaco*, and *Annona glabra* had the highest number of surviving seedlings, while *Magnolia virginiana* L., *Myrica cerifera* L., and *Acer rubrum* L. had the fewest. During the remainder of the study, water levels were mostly higher and sometimes covered the entire islands for months at a time. After 220 days, seedling survivorship of all species changed very little, however, nearly all seedlings of *M. virginiana* and *M. cerifera* had died. At the end of the study, seedlings of *I. cassine* and *A. glabra* had the highest survivorship rates, seedling biomass of *C. icaco* and *I. cassine* was greatest at the highest elevations along the transects, and seedlings of *A. glabra* had similar biomass across the entire transect. Seedling survivorship was not statistically different between islands with and without limestone cores; however, when seedlings of all species were combined, island core type was significantly different for above–ground biomass, seedling height, and canopy width. Because of the higher survivorship of their seedlings under both low and high water conditions, *A. glabra*, *I. cassine* and *S. caroliniana* are the most suitable species for establishing tree species on restored tree islands in the Everglades.

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Hurricane Wilma's Sediment Deposition Impacts on Mangrove Forest Soil Elevation and Changes within Constituent Soil Zones

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We assess the short term (one year post hurricane) impact of Hurricane Wilma's storm deposit on soil elevation at a mangrove forest location along the Shark River, in Everglades National Park. Using multiple depth surface elevation tables (SETs) and marker horizons we measured soil accretion, erosion, and shallow subsidence. We partitioned the effect of Hurricane Wilma's storm deposit to four constituent soil zones (surface (accretion) zone, shallow zone [0-0.35 m], middle zone [0.35-4 m], deep zone [4-6 m]) that comprise the entire soil profile. Hurricane Wilma deposited 37.03 (± 3.02 SE) mm of material; however, the absolute soil elevation change was + 42.85 mm due to expansion in the shallow soil zone. Erosion and shallow subsidence both played an important role at the six month post-disturbance sampling. One year post-hurricane, the soil profile lost 10.02 mm in soil elevation, with 8.53 mm of the lost due to erosion, while the remaining soil elevation loss was due to compaction from below ground subsidence. We found prolific growth of new live fine roots in the storm deposited material layer at the one year post hurricane sampling, suggesting that the material residing at the site may become more stable in the near future (i.e. erosion rate will decrease). The findings thus far indicate that the soil elevation has made substantial gains compared to site specific relative sea-level rise. However, caution is warranted. It has been reported that large amounts of above ground tree mortality may lead to substantial subsidence in mangrove forest. So the long term ecological outcome from Hurricane Wilma will depend on the beneficial gains from the storm deposit on soil elevation and the deleterious impacts from hurricane induced tree mortality.

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Everglades Rainfall Driven Operations – The Evolution of a New Paradigm for Operating the South Florida System

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The south Florida water conveyance infrastructure has long been operated through a series of traditional calendar based regulation schedules which managed the primary water storage areas of the system (Lake Okeechobee and the Water Conservation Areas) under a predominantly flood control paradigm (moving water downstream if water levels rise above the regulation schedule). The goal of the Everglades Rainfall Driven Operations (RDO) project is to provide a set of operational protocols for a current or projected system infrastructure that are aimed at achieving pre-drainage conditions in a post-drainage, managed hydrologic system. The nature of the project planning process, from computer modeling aided conceptualization and design through benefit and assurances quantifications to detailed design and the development of operating manuals, dictates that proposed RDO implementations must go through a series of development steps, both in modeling and real-world applications.

Historically, the South Florida Water Management Model (SFWMM) has been used in a number of State, Federal and partnership endeavors to demonstrate the viability of the RDO concept in combination with the construction or modification of south Florida system infrastructure and storage features including the Comprehensive Everglades Restoration Plan (CERP). Traditionally, stage based targets for specific locations in the Everglades have been initially derived by using depth time-series data from the Natural System Model (NSM) in combination with current topography. Investigations into NSM-based flow targets have also taken place, most recently in the Combined Structural & Operational Plan development effort in which flows across Tamiami Trail into Everglades National Park (ENP) were determined using an operational strategy (nicknamed RDO-lite) that considered a flow-based Rainfall Driven Formula.

A recent example of RDO implementation in a planning effort can be found by examining the SFWMM computer-modeling results used in support of the Everglades Agricultural Area (EAA) Phase 1 Reservoir Project Implementation Report development. The modeling utilized RDO to make environmental deliveries from the EAA Reservoir via Stormwater Treatment Area 3+4 to downstream natural areas. In order to balance competing objectives of the project (including spatial inconsistencies for performance targets within the remnant Everglades and desire to retain reservoir storage for drier conditions) and in recognition of the fact that subsidence in Water Conservation Area-3A (WCA-3A) has affected the natural topography gradient that contributed to pre-drainage sheet flow, initial NSM based targets were transformed in a number of ways based on feedback from the project team and evaluators. Transformations included offsetting WCA-3A targets higher in order to send additional flows toward ENP, applying an overall maximum depth target (truncation) to help prevent the reservoir from discharging during wetter periods thereby retaining water for drier conditions and introducing a drought screening criteria based on the Palmer Drought Severity Index that ensured an environmental need be recognized by the RDO scheme during drought conditions.

While project planning of RDO schemes in computer modeling applications has progressed and been refined over time, concurrent efforts have been undertaken by the SFWMD to provide, in real time, an estimate of the NSM-based natural system need represented at several gauge locations throughout the Everglades system. This has been achieved through the development of the stage based Rainfall Driven Formula, which provides a real time nonlinear autoregressive prediction model of the targets on a weekly basis. The generic structure of the Rainfall Driven Formula estimates these targets for the next time step given a number of observed rain and evapotranspiration values (weighted both spatially and temporally over a number of lag weeks). The predicted targets are then potentially subject to adjustments similar to those applied in the modeling world.

Despite the progress on developing real-time "NSM-based" targets, in order to develop a practical operational protocol that will dictate system releases such that the release timing and quantity are consistent with the estimated and refined restoration targets, an optimization scheme that appropriately balances the goals of Everglades restoration must be derived. The goals are primarily defined in terms of performance measures (environmental, water supply, and flood control) and, in some cases, failure thresholds to meet such measures. The consideration of the performance measures with the appropriate weight and priority (e.g. developing a spatially consistent and agreed upon restoration vision) is essential for the successful implementation of RDO. Fortunately, the flexible nature of the RDO development scheme will allow for a gradual transition toward more natural conditions as expedited and regular CERP and non-CERP projects come online and as performance goals evolve over time.

Key Findings:

- Rainfall Driven Operations will provide a new operating paradigm for the south Florida system as changes are made to system infrastructure and storage.
- Techniques used to simulate RDO in computer modeling efforts in support of project planning continue to be improved.
- The ability to implement a real-world version of RDO has made significant progress with the development of real-time NSM-based stage and flow target formulas, but still faces technical and objective-related challenges.

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Response of Wetlands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge to Hydrologic Changes: Anthropogenic and Climate Impacts

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Tree islands are a key feature of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and have been designated as a performance measure to assess system responses to Everglades restoration efforts. Changes in the spatial distribution of tree islands, especially the loss of tree islands in areas where water depths are too great for too long (primarily in the south end of the Refuge), have been documented during the last few decades. There is evidence that tree islands in the north end, where it is drier than it was historically, are being invaded by shrubs, particularly along the edges and may be experiencing severe fires at a frequency greater than occurred pre-development. To examine historic wetland conditions and determine whether human-derived changes are greater than those due to natural climate variability, pollen assemblages were analyzed from a series of sediment cores. Data from cores collected on strand tree islands, pop-up islands, and adjacent marshes were used to reconstruct patterns of vegetational composition over the last few hundred years throughout the Refuge. These records provide clear evidence for vegetational response to hydrologic changes resulting from water management practices that began early in the 20th century and document long-term patterns of hydrologic and vegetational fluctuations prior to significant human influences.

Sites in the northern and central transects generally indicate that shrubs and weedy species became more abundant in the latter half of the 20th century. Plant community composition on tree islands also changed during this period, although specific responses varied with location in the Refuge and type of tree island. Pollen assemblages from sites in the southern transect indicate a shift from moderate to long hydroperiods in the mid-20th century. At all sites, the greatest changes in community composition occurred during the last half of the 20th century, and they exceeded the variability exhibited during the previous few centuries.

By correlating observed changes in plant communities with documented water management changes, we can compare ecosystem responses to altered hydroperiod over the last century with baseline levels of variability prior to significant anthropogenic change. Temporal resolution in the sediment cores is sufficient to reconstruct vegetational distribution and past hydroperiods at several time intervals. This will provide important insights into the amount of variability inherent to the pre-drainage Refuge wetlands, be used to evaluate impacts of past water management practices, and predict future changes in response to alternative strategies tied to Everglades restoration and the Comprehensive Everglades Restoration Plan.

- Tree-island and wetland plant communities in the Refuge exhibit significant changes in composition during the latter half of the 20th century.
- In the northern and central parts of the Refuge, vegetation changes in the late 20th century indicate a shift to shorter hydroperiods related to water management.
- In the southern Refuge, waterlilies and plants indicative of long hydroperiods became more abundant late in the 20th century, consistent with observed ponding of water during the last few decades.

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Vegetation and Hydrologic History of Everglades' Marl Prairies: Paleoecological Evidence from Big Cypress National Preserve

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Marl prairies presently occur on sites flanking Shark River Slough in the southern Everglades. Maintenance of the diverse floral and faunal assemblages characteristic of marl prairies is one of the restoration goals in the Comprehensive Everglades Restoration Plan, and this study was designed to assess the long-term stability of this habitat. Specific questions center on reconstruction of past vegetation, hydroperiod, and substrate characteristics at several time intervals throughout the region to understand the impacts of both natural climate fluctuations and recent water management practices on marl prairie communities and their distribution.

Sediment cores have been collected to bedrock in sites that currently accumulate both marl and peat in Big Cypress National Preserve (BCP). Core samples were analyzed for pollen, plant macrofossils, and geochronology. At three sites, peats are overlain by marl; age models based on radiocarbon and cesium-137 indicate that marl accumulation began in the early part of the 20th century. Pollen indicates occurrence of sawgrass marshes and moderate hydroperiods during peat accumulation prior to 1900 AD. During subsequent marl accumulation, grasses, weedy species, and shrubs became more abundant, indicating shortening of hydroperiods, probably related to water-management practices in the early 20th century. Cores from modern peat-accumulating sites consist entirely of peat deposited in sawgrass marshes and sloughs. Pollen and plant macrofossil assemblages from a core collected in sawgrass indicate a shift from *Nymphaea* dominance to greater abundance of *Cladium* and weedy species in the early 1900's. In the slough site, post-drainage (post-1900) changes to pollen and macrofossil assemblages are more subtle, with decreased abundance of *Cladium* and other marsh taxa coinciding with greater abundances of *Eleocharis* and shrubs. These data indicate that water management of the 20th century reduced freshwater flow to BCP sufficiently to alter vegetation at all sites and change sediment characteristics at some sites.

Expanding the spatial coverage of sediment core sites into eastern marl prairies will broaden our understanding of marl prairie habitat distribution and the processes governing their formation. The expanded coverage will include sites presumed to have been marl prairies before the onset of water management. The resulting data will form the basis for reconstruction of natural (pre-1900 AD) vegetation and hydrologic patterns on the flanks of Shark River Slough. Such information is necessary for resource managers and modelers to improve landscape models and their ability to predict ecosystem response to specific management changes.

- Pollen and plant macrofossil records from marl prairies, sawgrass marshes, and sloughs in eastern Big Cypress National Preserve indicate that hydroperiods became shorter after onset of water management practices early in the 20th century.
- At some sites, 20th century hydroperiods were shortened sufficiently to shift the system from peat- to marl-accumulating environments.
- Pollen evidence indicates that grasses and other plants characteristic of modern marl prairies have occupied these sites since the early 20th century; prior to that, sawgrass marshes occupied the sites.

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Benthic Foraminiferal Assemblages in Biscayne Bay: Implications of Natural and Anthropogenic Change in South Florida Marine and Marine-Margin Ecosystems

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A series of modern sediment samples from seven sites and five core samples in central and southern Biscayne Bay were analyzed for benthic foraminifers. The goal of the research was to determine important benthic foraminiferal assemblages in the modern environment, and use these data to assess the distributions of marine ecosystems in the past 100-400 years. Two of the cores are from localities in the mid-bay, whereas three represent near-shore sites. The latter cores were collected under the supposition that near-shore sites may be more sensitive to recent ecosystem change that may not be so readily apparent at the mid-bay sites.

Statistical data from the Biscayne Bay samples were compiled and processed using PRIMER. Similarity matrices of Bray-Curtis similarity were completed to develop hierarchical cluster analyses and Non-Metric Multi-Dimensional Scaling was used to determine relative relationships among the data in the ecospace. Seven assemblages were identified from these data that appear robust enough to be recognized at the regional level in Biscayne Bay. Further analyses of sub-sets of the data were used to isolate more specific data from the mid-bay cores, the near-shore cores and the individual near-shore core sites.

The identified assemblages identify a range of haline environments in Biscayne Bay both presently and in the recent past. None of the assemblages is typical of a continental shelf assemblage after, say, Rose and Lidz (1977), but the conditions within Biscayne Bay include assemblages indicative of polyhaline-euhaline restricted circulation environments and mesohaline brackish environments. One of the assemblages is indicative of mesohaline conditions (5-18 ppt), one is at the boundary between mesohaline and polyhaline conditions, two are indicative of polyhaline environments (18-30 ppt), and the remaining three are euhaline assemblages.

The *AE* assemblage reveals environmental conditions that are mesohaline and this assemblage was only observed in historical samples from the near-shore cores. This is the lowest haline assemblage and is dominated by *Ammonia parkinsoniana* and *Elphidium discoidale*. These also represent genera that may be found in stressed environments that are unfavorable to species that are not as adaptable (Holt 2005).

The *AEQ* is a transitional assemblage which is still dominated by *Ammonia* and *Elphidium*, but contributions to similarity and overall abundance of *Quinqueloculina* and other miliolids is >20%. The *EA* assemblage continues to have strong contributions from *Ammonia* and *Elphidium*, but miliolids increase between 20-50% of abundance and contribution to similarity in the assemblage. The increase of genera such as *Quinqueloculina*, *Triloculina* and *Miliolinella* indicate salinity in the polyhaline range of 18-25 ppt and greater occurrence of sea grass, particularly *Thalassia*. These assemblages are found historically in the near-shore cores and occur presently at the Black Point North site.

The *TEQ* assemblage is representative of 25-30 ppt polyhaline conditions and includes important contributions from *Triloculina*, *Elphidium* and *Quinqueloculina*. This assemblage is found historically at Middle Key and in the modern environment at Chicken Key. It is also observed in the modern samples which were dominantly mesohaline-polyhaline throughout the annual cycle of collection.

The *QEM*, *QMT* and *ERB* assemblages are all euhaline in nature. These are dominated by miliolids. The modern samples and cores from the mid-bay include these assemblages, and recent increases in more continental shelf genera such as *Articulina* and *Archaias* in the past 50-60 years show that marine circulation has increased in central Biscayne Bay with more stable euhaline conditions and thus reduced freshwater influence in this part of the bay.

The near-shore cores reveal a pattern of assemblages indicative of increasing salinity. There is clearly a natural component of the ongoing Holocene marine transgression. Present sea-level rise in South Florida translates to significant lateral changes to and translation of entire ecosystems. However, there are key data which show sudden increases in salinity via rapid changes to the benthic foraminiferal assemblages. The most significant findings at Middle Key reveal a salinity increase near the timing of the construction of the Key West Extension of the Florida East Coast Railway and more marine species increasing at the top of the core, corroborating the findings of Ishman et al. (1998) from a core in Manatee Bay. The foraminiferal assemblages near the top of the cores at Black Point North and at Chicken Key show a shift toward higher salinity conditions. Ostracode and mollusk data in Wingard et al. (2004) reveal an increase of genera that are tolerant of wide ranges of salinity. This manner of salinity fluctuations is not correlative to any patterns observed historically in any of the cores from Biscayne Bay. The timing of these changes is within the decade following the completion of the Central and South Florida project, which completed the modern network of drainage canals, and which also had the impact of ceasing the flow of documented groundwater springs which had flowed into Biscayne Bay (Kohout and Koplinski 1967).

Recent changes to the marine ecosystems in Biscayne Bay reflect both natural and anthropogenic changes. It is necessary to determine appropriate restoration of natural sheet and groundwater flows to Biscayne Bay as part of the ongoing Everglades restoration to reduce the high stress of salinity fluctuations that are a recent alteration to the natural ecosystems in Biscayne Bay.

- Benthic foraminifer assemblages identify present and former ecosystems in Biscayne Bay
- Natural sea-level rise and lateral ecosystem translation is an ongoing process impacting marine-margin ecosystems, and must be a consideration for all restoration efforts
- Salinity increases at near-shore sites can be tied to anthropogenic alterations to mainland physiographic and hydrologic systems and their associated ecosystems
- Mid-bay sites are increasingly influenced by continental shelf species of foraminifers which indicates an increase of marine circulation in the past 50-60 years
- Rapid salinity fluctuation has greatly increased in near-shore environments in the past 30 years, and is a fundamental and unique shift in the ecosystem history of Biscayne Bay

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Small and Medium Sized Mammal Inventory of Everglades National Park and Big Cypress National Preserve

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Small and medium sized mammals are ecologically critical as a food base, as predators, as vectors for disease and seed distribution, and provide numerous other connections in the natural system. Despite their importance, these taxa have not been systematically inventoried in South Florida since the mid 1950's. To fill this void, we inventoried upland, wetland, and coastal habitats in Everglades National Park and Big Cypress National Preserve. Methods utilized included standard live trapping techniques, tracking, remote sensing cameras, visual encounters, python gut content analysis and owl pellet analysis. Our goal was to identify presence and absence of mammals occurring in various communities in both parks. In addition, we are evaluating the occurrence of mammals of specific interest (those listed as present in the parks, but not reported for decades). Geographic information system data layers are also being developed for each species, to be used for modeling, prescribed fire planning, and long term monitoring. To accomplish these goals, a species/habitat matrix was constructed from existing literature/documentation regarding occurrence of mammals within the two parks. Using this matrix, we conducted a systematic sampling effort within major habitats in each park using a Proportion Area Occupied (PAO) approach. This approach allows for estimation of detection probabilities of each species and provides the baseline for future monitoring. Twenty-one species of mammals were documented in each park during phase one of our project. Specialized survey techniques are being developed for species that remained undetected during systematic sampling. By understanding the current status of these species, we can ensure that they will be considered as key components in future restoration efforts.

Key findings relevant to restoration:

- A mammal inventory will provide a comprehensive list of expected mammalian species as well as distribution data on species of special concern (i.e. Big Cypress Fox Squirrel, Everglades Mink, Round-tailed Muskrat)
- A mammal inventory will provide baseline data for evaluation and assessment of ecosystem restoration projects
- A mammal inventory coupled with an analysis of gut contents of Burmese pythons is providing insight into the impacts of this invasive species on native fauna.

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Restoration and Sea-Level Rise: The Role of Paleoecologic Data in Incremental Adaptive Management Strategies

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Currently the predictions of sea-level rise of 18 cm to 59 cm by the year 2099 (IPCC Report 2007; excluding increased melting of Greenland or Antarctica) provide a measure of uncertainty for ecosystem restoration and the social infrastructure of south Florida. In an ecosystem based on the supply of freshwater, and a restoration plan based on "getting the water right", understanding potential impacts of sea-level rise is critical. Setting realistic restoration targets and performance measures that are attainable and sustainable has been a goal of the CERP project managers, but how should attainable and sustainable be defined in the face of global change? Given the range in predictions and the level of uncertainty, what tools do managers have to incorporate sea-level rise into restoration planning?

The primary source of data on long-term global change and sea-level rise is the geologic record. Paleoecologic assessment of cores from Biscayne Bay, Florida Bay, and the southwest coast have indicated increasing salinities in all the estuarine environments in south Florida during the 20th century. The critical question for restoration is how much of this is due to natural sea-level rise and how much is attributable to anthropogenic alteration of the freshwater supply to the estuaries. The subsurface geology of south Florida lengthens the temporal record and provides additional insights. The Florida peninsula has emerged and submerged repeatedly over at least the last five million years. The last interglacial (~125,000 years before present (yrBP)) left marine deposits over much of south Florida, and the Pleistocene reefs that now form the Florida Keys were built up during this period. During the maximum extent of the last Ice Age, ~21,000 yrBP, almost the entire continental shelf of Florida was exposed. Since that time sea-level has been rising in south Florida in a step-wise fashion, with hinge points representing changes in rates of rise (Savarese, 2004; Wanless et al. 1994). A significant hinge point occurred at about 3200 yrBP when the rate of sea-level rise in south Florida slowed significantly allowing shorelines to stabilize or expand with the growth of mangroves, mudbanks etc. (Wanless et al. 1994). This change in sea-level led to the development of the Everglades ecosystem that exists today.

A critical goal of restoration is preservation of habitats to maintain or preserve species. How can managers define success in terms of habitat and species preservation in the face of anticipated sea-level rise related to changing climate? In a natural system, species migrate and/or adapt as climate changes and their habitats are altered or shift spatially. Species that fail to migrate or adapt go extinct. Over the last 1 to 1.5 my, during the dramatic changes in climate and sea-level that occurred, the diversity and general composition of the benthic invertebrate fauna of south Florida has remained relatively stable. Thirty percent of marine mollusk species survived (Allmon et al. 1993) and many more species are represented by their direct descendents who filled the same ecological niches as their ancestors. A true perspective on the response of species and organisms to the changes in their environment can only be gained by examining the long-term evolutionary history of the ecosystem over geologic time.

New applications of paleoecologic data are being used to set performance measures and targets for restoration based on hindcasting of pre-anthropogenic environmental conditions. These same methods can be adapted to forecast potential sea-level rise conditions under different IPCC scenarios. The method (see Marshall abstract for details) involves coupling paleoecologic data from sediment cores to linear regression models based on instrumental data. Paleoecologic interpretations of the faunal and floral assemblages found in cores are based on known environmental tolerances of taxa derived from extensive monitoring of the modern environment. These data allow researchers to reconstruct salinity and other environmental parameters and to identify key biological responses to environmental change. For example, the presence of a clam, *Polymesoda caroliniana,* is restricted to the narrow ecotone where the salt and freshwater environments meet along the river systems of the southwest coast. The stratigraphic distribution of *Polymesoda* in cores illustrates spatial shifts over time, which can be compared to changes in other ecosystem parameters.

Linked paleoecologic and regression models provide a useful tool for incremental adaptive assessment. Once the paleoecologic data are analyzed and the modern calibration data sets developed, periodic assessments can be run incorporating the latest data or projected change scenarios to determine whether restoration targets need to be reassessed. In addition, continued monitoring of key indicator species associations determined from core analyses, will provide temporal perspective on the rates of change to the biotic components of the system.

Due to the great impacts of sea-level change on the Florida coast, likely scenarios of rates of rise must be incorporated into restoration planning. Given the uncertainty of projections on the rates of change, incremental adaptive management will be critical to continuously revaluate restoration targets as global change occurs. Consider the following:

- Sea-level has risen and fallen many times over geologic time and under natural conditions organisms and ecosystems migrate, adapt or go extinct – this is natural and expected – however, humans have altered the natural system
- Restoration goals need to incorporate projected change scenarios and restoration should not be considered a return to past conditions
- Paleoecologic data provide a means to examine long term biotic responses to associated environmental parameters
- Coupling paleoecologic data with regression models provides a means to hindcast and forecast conditions under different scenarios and provides an important tool in incremental adaptive assessment

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Using Hydrologic Monitoring as a Tool for Synthesis of the Greater Everglades and Southern Estuaries Modules of the Monitoring and Assessment Plan

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Increasing the quantity, quality, timing, and distribution of freshwater flows through Everglades National Park (ENP) is a primary goal of the Comprehensive Everglades Restoration Plan (CERP). Describing estuary salinity and residence time are important for describing a wide range of biological and chemical issues associated with the freshwater marsh/coastal mangrove transitional ecotone. The U.S. Geological Survey (USGS) has participated in studies that attempt to quantify the effects of water management on the hydrology of coastal areas in ENP. Through these efforts, the USGS has established an extensive network of monitoring stations at coastal creeks and rivers that discharge freshwater into northeastern Florida Bay and the southwestern coastal estuaries. The current network includes over 30 data collection platforms (DCP's), which measure flow, salinity, temperature, water-level and water quality data along transects that represent major flow paths from the Everglades wetlands to the southern estuaries. The network has provided data for hydrodynamic model development and calibration, as well as baseline information for other physical, biological, and chemical studies being conducted in the Everglades ecosystem. These studies are conducted as part of the USGS Greater Everglades Priority Ecosystems Science initiative (GEPES) and the CERP Monitoring and Assessment Plan (MAP).

The Coastal Gradients of Flow, Salinity, and Nutrients project was implemented under the Greater Everglades (GE) module of MAP in 2003. As part of the MAP revision process, the Coastal Gradients project has been identified as a key link (within MAP) between the GE module and Southern Estuaries (SE) module. Developing links between the monitoring data collected as part of Coastal Gradients/GE module to biological and physical studies being performed in the SE module has been identified as a priority for the MAP revision. Hydrologically connecting these two modules will help provide a more comprehensive synthesis within MAP.

Use of historical and real-time data collected by the USGS will benefit restoration in several ways:

1. Pre-CERP (baseline) hydrology can be compared to data collected during and after CERP modifications.
2. Current scientific investigations funded by MAP can utilize physical data rather than theoretical values in order to increase ecosystem understanding.
3. Historical and real-time data can be used to determine hydrologic responses from short and long-term climatic events, such as hurricanes and global climate change.

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Aerial and Field Monitoring of Selective Avifauna in Aquatic Refugia in Southwest Florida

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Aquatic refugia are integral features of the south Florida landscape and are vital to maintaining threatened and endangered wading bird population levels over time. Since wading bird species have varying foraging ranges, constraints, and strategies, their patterns of distribution can vary greatly depending upon local water levels, water quality and prey density variability. The purpose of this project was to determine the importance of refugia in the southwest Florida landscape, with special emphasis on the function of refugia as they relate to the survival and perpetuation of threatened and endangered species.

7,955 observations of wading birds were recorded during 56 aerial surveys. Each survey covered 19 sites within the project area, (12 in Picayune Strand State Forest (PSSF) and 7 in Fakahatchee Strand State Preserve (FSSP). Additionally 10 sites were surveyed outside of the project area; in Belle Meade, as well as ponds and mangrove creeks south of U.S. 41). Sites in PSSF included Willow Ponds (WP), Artificial Ponds (AP), and Canals (CA), while sites in FSSP consisted of Pop Ash Ponds (PP) and Tram Ditches (TD). These sites represent the distinctive biotopes, both biogenic (WP and PP) and anthropogenic (AP, CA, and TD). Data were summarized by grouping observations by site, biotope, and season. Monthly observations that were recorded during ground avifaunal surveys were included in the analysis to evaluate differences between aerial and ground survey methodologies.

There were no statistical differences between aerial and ground survey results, which seems to indicate comparable methodologies. However, the percent avifauna observed was higher at all of the sites within the project area during ground censuses with the exception of the Tram Ditches. Both aerial and ground survey methodologies have strengths and limitations. Aerial surveys emphasize a landscape approach, while ground surveys tend to capture a more detailed picture of a smaller area (particularly in areas with dense canopies) and allows for the use of audible cues.

Avian abundance was significantly higher in areas outside of the project area, particularly at sites south of U.S.41. This spatially geographic distribution is most likely an indication that species of wading birds surveyed during this project were finding more suitable foraging habitat south of U.S. 41 and possibly a preference for more open, natural estuarine environments. Within the project area, wading birds were more frequently observed during dry down periods. Overall, there seemed to be no preferences for biotopes in FSSP; however Pop Ash ponds were important foraging sites for wading birds at the end of the spring dry-down. In PSSF, slightly higher percentages of wading birds were found at the Willow Ponds than in other biotopes within PSSF, perhaps indicating a slight preference for more natural refugia than the man-made Artificial Ponds or Canal settings. Given that wading birds depend on refugia for foraging, the importance of restoring refugia for avifauna becomes paramount particularly during the dry season when other foraging areas dry out. A more complete understanding of the role of aquatic refugia in the south Florida ecosystem is critical to the recovery of wetland-dependent listed species.

Key Findings relevant to restoration:

- Systems such as FSSP, that had minimal hydrologic anthropogenic alteration, had greater avifaunal abundance than PSSF, which has been severely drained and disturbed through human actions.
- Restoration of PSSF will focus on restoring hydrologic parameters that historically existed by removing hydrologic impediments such as roads and filling man-made canals to re-establish natural sheetflow. Successful restoration should increase avian species diversity and abundance.
- Efforts to restore PSSF's historic habitats could increase the forage base for the endangered wood stork (*Mycteria americana)* and other threatened wading birds, particularly during the dry season when other sources of prey are unavailable.
- Avian species composition, abundance and distribution of wading birds should be included in post-restoration assessments, since avifaunal use is a reliable indicator of wetland restoration success.

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Understanding the Movement and Transformation of Nitrogen in the Southern Everglades

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The goal of this research project was to characterize and quantify nitrogen cycling dynamics in the southern Everglades. Through the implementation of the Comprehensive Everglades Restoration Plan (CERP) numerous upstream restoration interventions will have major implications on the timing and quality of freshwater flows to southern Everglades marshes. The C-111 canal underwent one such intervention in 1997 when the southern levee wall was removed and the historical north-south hydrological sheetflow was restored. This restoration allowed freshwater to flow across the marsh, through the mangrove-dominated estuarine transition zone, and ultimately to Florida Bay. Since this restoration effort the C-111 basin has been an excellent study site to gauge ecosystem response to hydrological restoration. However, nitrogen cycling dynamics in the C-111 basin have not been directly studied since levee removal.

In this research project, we compared ^{15}N natural abundances to N-cycling in mesocosms amended with ^{15}N tracer. The ^{15}N tracer technique allowed us to isolate the flows of nitrogen among various ecosystem components. These *in situ* mesocosm experiments ran for a period of 21 days with six mesocosms ($2m^2$) deployed at a near-canal and an interior marsh site. In addition to the ^{15}N tracer experiment, three varying loads of phosphorous (0.00, 6.66, and 66.6 mg P) were added to mesocosms to determine what, if any, effects phosphorus-load has on the rate of nitrogen cycling. By and large the results show that periphyton is most active in both rate and magnitude of ^{15}N tracer uptake, while increased phosphorus load limits the magnitude of ^{15}N tracer uptake but accelerates the rate of uptake in periphyton. The control P-load of 0.00mg P lead to a peak ^{15}N value of 307.45‰ occurring on day 3, while the 6.66mgP load lead to a peak ^{15}N value of 265.65‰ occurring one day earlier on day 2. Secondly, nitrogen natural abundance analyses from a landscape wide transect study have shown that ecosystem components sampled in the C-111 basin at a near canal site possess a heavier, more enriched ^{15}N signal (7.34‰± 2.27) than a downstream site which has acquired a lighter, more depleted signal (1.17‰± 1.24). The data suggest that these marshes are cycling DIN internally (downstream nitrogen spiraling), which is leading to depleted downstream nitrogen isotopic values.

<u>Relevant Findings for Everglades Restoration</u>:

- Of all ecosystem components sampled, periphyton is most active in both rate and magnitude of nitrogen uptake in the C-111 Basin.
- Increased phosphorus load limits the magnitude of N uptake for most ecosystem components, but accelerates the rate of N uptake by periphyton.
- Near-canal locations possess a heavier, more enriched ^{15}N signature, while more downstream locations possess lighter ^{15}N signatures.
- Marshes in the C-111 Basin are cycling DIN internally and are sinks for canal derived inorganic N.

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Catabolic Diversity of Periphyton and Detritus Microbial Communities in Water Conservation Area-2a of the Everglades

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The catabolic diversity of wetland microbial communities may be a sensitive indicator of nutrient loading or changes in environmental conditions. The objectives of this study were to assess the response of periphyton and microbial communities in Water Conservation Area-2a (WCA-2a) of the Everglades to additions of organic C-substrates and inorganic nutrients. Carbon dioxide and CH_4 production rates were measured using a 14-d incubation for periphyton, which typifies interior areas, and detritus, which is prevalent at P-impacted areas of WCA-2a. The wetland was characterized by decreasing P levels from peripheral to interior areas. Microbial biomass and N mineralization rates were higher for periphyton than detritus. Methane production rates were also higher for unamended periphyton (80 mg CH_4-C kg^{-1} d^{-1}) than detritus (22 mg CH_4-C kg^{-1} d^{-1}), even though the organic matter content was higher for detritus (80%) than periphyton (69%). Carbon dioxide production for unamended periphyton (222 mg CO_2-C kg^{-1} d^{-1}) was significantly greater than unamended detritus (84 mg CO_2-C kg^{-1} d^{-1}).

The response of the heterotrophic microbial community to added C-substrates was related to the nutrient status of the wetland, as substrate-induced respiration (SIR) was higher for detritus than periphyton. Amides and polysaccharides stimulated SIR more than other C-substrates, and methanogenesis was greater contributor to SIR for periphyton than detritus. Inorganic P addition stimulated CO_2 and CH_4 production for periphyton but not detritus, indicating a P limitation in the interior of WCA-2a. Continued nutrient loading into the interior of WCA-2a or enhanced internal nutrient cycling may stimulate organic matter decomposition and further contribute to undesirable changes to the Everglades ecosystem caused by nutrient enrichment.

Relevant findings to restoration

- The heterotrophic microbial community of detritus was more sensitive to organic C inputs than periphyton.
- Periphyton was more sensitive and responded more readily to inorganic nutrients than detritus.
- Continued nutrient loading or internal cycling from the periphery to the interior of WCA-2a may alter the catabolic diversity of the heterotrophic microbial community and stimulate organic matter decomposition.
- Increases in nutrient availability alter pathways of organic matter decomposition and may stimulate denitrification and SO_4 reduction at the expense of methanogenesis.
- The resulting regeneration of N and P to floodwater may further exacerbate the harmful effects of nutrient enrichment on the ecosystem which are currently observed in P-impacted areas.

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Patterns of Variability in the EDEN Digital Elevation Model in the A.R.M. Loxahatchee National Wildlife Refuge

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The digital elevation model (DEM) dataset created by the Everglades Depth Estimation Network (EDEN) is a critical dataset for Everglades restoration. Its development is an iterative process in which the feedbacks from diverse users are essential for its continual improvement. Recently, scientists at FAU found that the computed hydroperiods from EDEN data are more variable and patchy in the A.R.M. Loxahatchee National Wildlife Refuge (LOX) than other sub-regions, seemingly reflecting fine scale topographic variation from the many small tree islands in LOX. In an initial examination of the EDEN DEM and Digital Ortho Quarter Quads, it also appears that the hydroperiod and water depth differences might be related to the original elevation measurement and the interpolation processes and rules. The high variability in fine scale topography in LOX poses special problems for the interpolation of the DEM, because it is not clear how much of that variability should be smoothed to match the DEM in other areas and how much should be preserved, and thus reflect the unique character of LOX.

To provide a solid foundation for subsequent analyses of EDEN data, this study quantifies the variability patterns of the EDEN DEM within LOX. The EDEN DEM is compared with field elevation data, which include gage station elevation measured by field personnel, Aerial Height Finder elevation by the U.S. Geological Survey, and elevation datasets derived from the water depths measured by field personnel. These elevations are calculated as the EDEN water surface minus the field personnel water depths on the date when the water depth is measured. The statistical comparison techniques and indices are the Root Mean Square Error, correlation, and other statistics. A confidence index dataset for the DEM in LOX is produced following the general procedure for computing water surface confidence index by Pearlstine et al.

The significance of this study to restoration is that it:

- Compares scenarios for smoothing the topographic variability in LOX so that the resulting elevation data match the DEM in other areas and thus allow for comparisons across the entire system, while reflecting the unique character of LOX.
- Will enhance studies that rely on EDEN hydrology data across the entire ecosystem.

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Characterizing the Interactions between Trace Metal and Dissolved Organic Matter from the Florida Coastal Everglades

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Metal toxicity, bioavailability and mobility in the environment are controlled by their speciation. Dissolved organic matter (DOM) in aquatic environments can interact with metal ions to form organo-metal complex, thus, strongly affecting the metal speciation. Therefore, knowledge on the metal-DOM binding properties is necessary to better understand the biogeochemistry of metals. Such metal binding parameters of DOM have often been studied by fluorescence quenching methods. This technique traditionally used single excitation and emission wavelengths which are typical of humic-like fluorophores. During the 1990s, synchronous fluorescence spectra and excitation-emission matrix (EEM) fluorescence spectra have been widely used to characterize fluorescent DOM. Thus, a combination of such techniques and fluorescence quenching titration has allowed to evaluate the binding properties of different types of DOM fluorophores. However, since the synchronous fluorescence spectra and EEMs are often composed of various type of overlapping fluorophores, better resolution is required to obtain accurate binding parameters.

Recently, Stedmon and coworkers introduce parallel factor analysis (PARAFAC) to statistically decompose EEMs to their individual fluorescent components. As such, a combination of EEM and PARAFAC has been successively applied to characterize DOM in aquatic environments. PARAFAC results provide estimates of the relative fluorescence intensity of each fluorescent component. Thus, the combined technique of fluorescence quenching titration with EEM-PARAFAC is a potentially useful technique for characterization of interactions between trace metals and DOM. In the present study, we assess the binding parameters of DOM from the Florida Coastal Everglades to Cu(II) and Hg(II) using EEM-PARAFAC. Two binding parameters, i.e., conditional stability (K_M) and fraction of the initial fluorescence that corresponds to the binding fluorophores (f) were determined using the Ryan and Weber model.

The surface water samples containing the DOM were obtained from two slough systems, i.e., Shark River Slough (SRS) and Taylor Slough (TS), in the Florida Costal Everglades (FCE) during the wet season (June to October, 2007). Two of the four sampling sites were located in freshwater marshes dominated by peat (SRS) and marl (TS) soils and others were collected at mangrove dominated brackish sites. For PARAFAC modeling, the FCE-PARAFAC model was used for decompose the EEMs obtained from fluorescence quenching titration experiments. This model was obtained from a large database (n = 1108) collected from the FCE (including SRS, TS and Florida Bay). This FCE-PARAFAC model is composed of four terrestrial humic-like components, two microbial humic-like components, and two protein-like components.

Triplicate titration experiments used to test the accuracy of the method showed good reproducibility when assessing the interactions between six humic-like components with Cu(II), indicating that the combined technique of fluorescence quenching titration with EEM-PARAFAC is quantitatively applicable to evaluate fluorophore-specific interactions between trace metals and humic-like components in DOM in aquatic environments. On the other hand, the reproducibility of triplicate titrations of the two protein-like components was lower compared to that for the humic-like components. The reason of such large error in protein-like components is presently not clear.

Our data shows clear differences in metal-DOM interaction from samples of different DOM composition and between two metals. The calculated log*K* values of six humic-like components at all sampling sites ranged from 4.48 to 6.32 and from 3.92 to 6.76 for Cu(II) and Hg(II) titration experiments, respectively, and were similar range to those found in other aquatic environments using fluorescence quenching titration. It is interesting to note that the log*K* values of humic-like components with Hg(II) at an estuary mangrove site (SRS6) (4.14±0.15, n=5) were significantly lower than those at other sites (4.95±0.52, n = 17), but those with Cu(II) at SRS6 (5.26±0.63, n = 5) were similar to those at other sites (4.93±0.33, n = 16). Such differences could be explained by reduced complexation between Hg and DOM due to the enhanced effect on inorganic complexation between Hg(II) and Cl at this high salinity site (salinity = 23.8).

There were several interesting points on the spatial and inter-components differences in the *f* values. For example, the *f* values of three terrestrial humic-like components with Cu(II) were always higher than those with Hg (II), irrespective of differences in sampling sites. On the other hand, the *f* values for the another terrestrial humic-like component with Cu(II) was always lower than those with Hg(II). Such difference suggests that the binding sites, and thus the complexation processes, are different between former and later groups of humic-like components. While Cu(II)-DOM complexation has been mainly attributed to interactions with amino, carboxyl, or carbonyl functional groups, Hg(II) has been suggested to strongly interact with reduced organic sulfur. Thus, the difference in *f* values of humic-like components with Cu(II) and Hg(II) suggests that former humic-like group is relatively rich in amino, carboxyl, or carbonyl functional groups, but there is a substantial amount of reduced organic sulfur in later humic-like group.

Different from quenching of humic-like components with addition of Cu(II) and Hg(II), the enhancement of the fluorescence intensity after its initial decrease for the protein-like components with addition of additional Cu(II) was observed at mangrove dominated brackish sites, suggesting the release of protein-like components from interactions with other DOM components due to increased Cu(II) complexation to the former.

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Streamgauging Planning at Stormwater Treatment Area-1 West

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Stormwater Treatment Areas (STAs) play a vital role in the Everglades Forever Act passed by the US Congress in 1997. The STAs operated by South Florida Water Management District (District) are designed to remove pollutants such as phosphorus and nitrogen from the agricultural water before discharging them into the everglades. By the mandated regulation, pollutant removal rates of the STAs must be monitored to ensure continuous flow of good quality water to sustain ecosystems downstream. Flows in and out of these STAs are controlled by culverts, pumps, spillways and weirs. Accurate flow data collection, processing and archival of data from these hydraulic structures are essential elements of the mandatory permit compliance, development and management and evaluation of the efficiency of these STAs.

While it will seem to be a relatively simple task to measure flow (streamgauge) using an ADCP (Acoustic Doppler Current Profiler) or ADFM (Acoustic Doppler Flow Meter) at the STA structures whenever the opportunity presents itself, the actual need for streamgauging is dependent upon the operation of the STA. Therefore, performing streamgauging without taking into consideration the operational needs of the STA may lead to unnecessary repetitious measurements and an inadequacy of flow predictions in terms of the range of operational requirements for the water control structures. Thus a proposal for a framework and a methodology for capturing either from the operational plan or from historical operations the streamgauging needs and using those to develop an analytical framework for identifying appropriate streamgauging opportunities is necessary for effectively monitoring flow through STAs.

This paper focuses on providing the framework for these processes based on streamgauging measurements collected from STA-1 West and introduces new flow rating techniques applied to weir-box culverts at the STA. The result of such an exercise has provided for STA-1West: (1) An established region or range of need of flow measurements based on the operation of the STA; (2) Recommendations on future streamgauging measurements based on the rating developed and used for the flow type(s) in question; and (3) Recommendations on future streamgauging measurements based on the historical data and operational needs of the structure.

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Flow Rating for Interior Culverts in Stormwater Treatment Areas

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South Florida Water Management District (District) operates and maintains flow monitoring and rating development for six large stormwater treatment areas (STAs). These STAs are designed to remove pollutants including phosphorus and nitrogen from the agricultural water released from the Everglades Agricultural Area (EAA). Accurate flow rating of hydraulic structures in STAs is a key to water quality modeling and pollutants reduction assessment.

Currently, flow ratings at District hydraulic structures mainly rely on physically-based equations. However, parameter calibration needs good representative streamgauging measurements using high-tech acoustic flow meters: ADCP, ADFM or other instruments.

Due to budget and staff limitation, streamgauging is not equally conducted for all of existing hydraulic structures in the STAs. Flow measurements for exterior culverts in the STAs generally have higher priority than interior culverts because they are key structures for pollution control. To date, over 900 field measurement data are available for exterior structures, while only 9 measurements for interior culverts. However, accurate estimation of interior culverts is also critical in evaluating treatment cells' performance within STAs.

In this research, water budget combining with statistically-based rating methods are proposed to perform flow rating for the interior culverts. The culvert group G375 A-F in one treatment cell of STA-3/4 was used as a case study. In rating analysis of the interior culverts, daily and 15-minitue discharge time series were calculated after balancing the water budget for each treatment cell. Then, these time series were used to generate interior culvert rating equations by multivariable regression and artificial neural network (ANN), respectively. With this new approach, we are able to:

- produce quite reasonable predictions of flow time series;
- solve flow rating problems for interior culverts using existing measurements at exterior structures;
- maintain the balance of water budget in individual treatment cells;
- provide more rating options constrained to data conditions;
- apply the new approach to various interior culvert ratings of other STAs;
- support accurate assessment of ecologic restoration by means of STAs.

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Developing an Everglades Slough Vegetation Performance Measure: Integrating Slough Vegetation Hydrologic Optima from Scientific Literature, Experimentally Determined Plant Species Responses and Hydrologic Model Predictions

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Compartmentalization and changes in hydrology have altered the ridge and slough communities of the Everglades landscape causing the topography and vegetation to become more uniform (Sklar, 2000; Richards, 2008). These changes, mainly the result of altered water flow and hydropatterns caused by levees and canals interacting with managed changes in water depth and water level fluctuations, have had a detrimental effect on Everglades vegetation. One of the purposes of the Comprehensive Everglades Restoration Plan (CERP) is to restore the hydrologic conditions conducive to development and maintenance of a natural slough community.

White water lily (*Nymphaea odorata*) characterized a deep-water slough community in a quantitative analysis of plant associations across the Everglades (Stober et al., 2001, EPA REMAP 1999). Paleoecological studies indicate that native slough communities were once dominated by *N. odorata* in Northeast Shark River Slough prior to the use of artificial management and control structures (Saunders et al., 2007). Since *N. odorata* is considered representative of pre-drainage slough communities, hydrologic optima for *N. odorata* were used to build predictive performance measure tools to be used in restoration evaluations.

An extensive review of the scientific literature and mesocosm studies were performed to identify hydrologic optima for *N. odorata*. From Everglades field studies, slough communities with wet season water depths exceeding 90 cm were dominated by *N. odorata* (Powers, 2005; Volin, 2007; and Givinish, 2007). McVoy et al (in review) estimated that pre-drainage water depths in slough had a long term average depth of 60 cm (2 ft.), long term average annual maximum depth of 90 cm (3 ft.), and a long term average annual minimum depth of 30 cm (1 ft.). *N. odorata* and other species of slough vegetation (*Nymphoides aquatica* and *Eleochris elongata*) responses to variation in water depth and hydroperiod were experimentally determined by growing plants collected from WCA 3A outside on the Florida International University campus in nine 3410 L (900 gal) mesocosms. Root biomass from harvested cores (1.44 ± 0.18, 1.99 ± 0.13 and 1.87 ± 0.16 mg cm^{-3} , for 30, 60, and 90 cm depths, respectively) was significantly lower for plants in shallow water than deeper water, but biomass in medium and deep water was not significantly different. Lowering water levels from 30, 60, and 90 cm to 5, 35, and 65 cm, respectively, caused changes in growth, morphology and root biomass productivity of plants at each water depth; but these were especially dramatic in plants at the 5 cm depth, where plant shoots were exposed, and leaf morphology was miniaturized. In addition, for the shallow depth, a water level drawdown of 4 months reduced root productivity by 75% from control levels. For plants grown in deep water, this same drawdown reduced fine root productivity by 15%. This hydroperiod experiment provides evidence that extreme water level fluctuations only marginally affect *N. odorata* fine root productivity in deeper waters, while in shallow waters with the same drop in water levels, leaf and root productivity is significantly reduced.

Predictive performance measure tools, based on slough vegetation hydrologic optima and tolerances gathered from the scientific literature review and the *N. odorata* mesocosm studies, were developed and applied to evaluate CERP-related restoration alternatives. The Combined Structural and Operating Plan (CSOP) and the Tamiami Trail Limited Reevaluation Report (LRR) evaluations are presented as case study applications of how to compare restoration alternatives that maximize conditions necessary for slough vegetation using these predictive tools. Empirical return frequency curves for maximum continuous hydroperiod , continuous dry down events (depth <0.7 ft), wet season average depth, and dry season average depth were simulated from the Natural System Model (NSM) and the South Florida Water Management Model (SFWMM) output throughout the period of record (1965-2000) to evaluate CSOP restoration alternatives. Average wet season depth, total number of days water depths exceeds 2 ft., and total number of days water depth exceeds 3 ft. during a subset (August –October only) of the wet season were simulated from the USACE mass balance spreadsheet model (2007) throughout the period of record (1983-2007) to evaluate LRR restoration alternatives. Deviation from slough optima hydrologic targets was then examined to help compare restoration alternatives.

Development of the slough vegetation performance measure tools has led to the development of several key restoration findings that are presented below:

- Combing hydrologic optima information from the historical scientific literature and controlled mesocosm studies is an effective approach for developing slough vegetation performance measures.
- Hydrologic optima and tolerances can be used to select performance targets within predictive models for an evaluation.
- The CSOP and LRR case study examples showed that predictive slough vegetation performance measures can be used as a tool to evaluate CERP-related restoration alternatives.

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Temporal and Spatial Salinity Patterns in Joe Bay, Everglades National Park

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Joe Bay is the primary hydrologic connection between the southern Everglades and northeastern Florida Bay. Joe Bay is connected to Florida Bay through Trout Creek—the main contributor of flow to northeastern Florida Bay. Salinity measurements are collected by the USGS as part of ongoing Coastal Integrated Network monitoring efforts. Funding for continuous salinity monitoring within estuarine creeks flowing into Joe Bay was provided by the Everglades National Park (ENP) Critical Ecosystems Studies Initiative (CESI).

Salinity-based performance measures have been developed to assess the effects of Everglades restoration on the coastal areas of ENP. Multiple regression models have been developed that use independent variables to predict salinity at selected ENP Marine Monitoring Stations. The purpose of the current effort is to determine whether the salinities in Joe Bay are representative of salinity over larger areas. As part of this effort, ArcGIS is currently being utilized by the USGS to summarize salinity survey data collected by motor boat in conjunction with available ancillary salinity data collected from fixed monitoring locations in Joe Bay.

As part of the current effort, Joe Bay has been divided into four polygons that represent eastern, central, and western Joe Bay, and Snag Bay. The average salinity value of each polygon, determined from the salinity survey data, will be compared against the average salinity values at the fixed monitoring locations. Specifically, statistical tests will be used to determine whether the average salinities from the fixed monitoring stations and the average salinities for the polygons are analogous; if so, GIS could potentially be used to aerially extrapolate data from fixed monitoring stations.

The evaluation of temporal and spatial salinity patterns in Joe Bay will benefit restoration as follows:

- The analysis further addresses uncertainty in salinity measurements derived from models.
- The methods employed here can be utilized in other coastal areas.
- The results of this analysis may suggest that additional assessment tools such as GIS, regression models, and hydrodynamic models could be used together to evaluate whether a more natural hydrologic regime has been achieved for the coastal waters of ENP.

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Habitat, Hydrology, and Reproduction: Important Relationships and Their Implications for the Conservation of the Florida Snail Kite and Everglades Restoration

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The Florida snail kite (*Rostrhamus sociabilis*) is an excellent case study in examining the relationships between habitat quality and demographics. The snail kite is an endangered bird species that is endemic to the Everglades watershed. As with many organisms in dynamic environments, the kite's demography is tightly coupled to the seasonally fluctuating hydrology of the Everglades, making it an excellent indicator of wetland landscape health. One of the kites most critical breeding regions, Water Conservation Area 3A South (3AS), has experienced long-term vegetation community shifts from impoundment and water management, an effect reflected in the movement of kite nesting to higher areas within 3AS. Their population has also precipitously declined since severe drought in 2001 and reproductive success has not presently recovered to pre-drought rates. The main reason for this decline is the absence of the Florida apple snail (*Pomacea paludosa*), but we propose that changes made to foraging habitat quality reduce the rate at which the snail kite encounters the apple snail.

We initiated a long-term habitat monitoring program in 3AS in 2002 to assess current vegetation communities, track changes that may occur, and predict vegetation shifts with new restoration hydrologic regimes. Using detailed data from 2002-2006, we determined correlations between hydrology, vegetation community change, and kite nest success. Using 'temporally discrete hydrologies', we were able to ascertain the season and hydrologic time lags that are most correlated to community composition and nest success. Over the five years, plots trended towards deeper communities and densities of important emergent foraging vegetation species declined with nest success. We feel that our analysis will provide critical information for modeling the effects of restoration alternatives on the snail kite.

- Vegetation communities in 3AS are trending towards deeper communities in key Florida snail kite foraging habitat
- Densities of key emergent species are significantly declining
- Snail kite nest success is correlated to vegetation community composition in 3AS

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Effects of Sea-Level Rise on Saltwater Intrusion in Northern Broward County, Florida

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The coastal aquifers of Florida, such as the Biscayne aquifer, are particularly susceptible to sea-level rise and saltwater intrusion because of the flat topography, highly transmissive limestone aquifers, and shallow water table gradients in the region. Over the past century, inland freshwater levels have dropped by several meters due to the construction of a highly managed canal network designed to drain large portions of the Everglades. The transformation of these reclaimed lands from agriculture use, which provided artificial recharge through irrigation, to residential communities requiring additional canals to lower water levels, further weakened the freshwater gradient along the coast that helps to control saltwater intrusion. Consequently, the movement of the saltwater front has become increasingly sensitive to many natural hydrologic stresses, including rainfall and sea-level rise, as well as anthropogenic stresses, such as municipal well field withdrawals.

The USGS is developing a variable-density, ground-water flow and solute transport model for the Pompano Beach area of Broward County to identify the hydrologic stresses that have had the greatest effect on the historical movement of the saltwater front. The model is being calibrated to saltwater intrusion patterns and hydrologic conditions observed over the past century. Preliminary model results suggest that movement of the saltwater front is most sensitive to municipal withdrawals. Movement of the front, however, is also sensitive to the 24-cm sea-level increase that has occurred over the past century. Model results also suggest that the combined effects of hydrologic processes, such as well field withdrawals and sea-level rise, are nonlinear. Therefore, when individual stresses are paired, the combined effect can be a multiple of each individual stress. This finding and its potential consequences highlight the importance of investigating the effects of sea-level rise in coastal aquifers such as the Biscayne.

Development the model described herein benefits CERP in several ways:

1. The model can provide insight into the relative magnitude of natural and anthropogenic stresses on the historical movement of saltwater fronts in coastal aquifers.
2. A calibrated model can be used to run future water management scenarios to evaluate proposed water management strategies for threatened ground-water resources in the region.
3. The model can be used as a tool to gauge the consequences of future sea-level rise projections as well as prolonged droughts of varying severity.

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