2005 Florida Bay and Adjacent Marine Systems Science Conference

December 11-14, 2005

Hawk's Cay Resort
Duck Key, Florida, USA

PROGRAM AND ABSTRACT BOOK

UNIVERSITY OF FLORIDA
IFAS

Sea Grant
Florida

Project # 0521

Welcome to Florida Bay!

On behalf of the Florida Bay and Adjacent Marine Systems Program Management Committee (PMC), I welcome you to the sixth Florida Bay Science Conference. We are returning to our roots this year with a three-day conference highlighting the science themes in the Florida Bay Science Plan plus adding a half-day session highlighting science from adjacent ecosystems.

As you know, the purpose of this joint conference is to provide a forum for physical, biological, and social scientists to share their knowledge and research results regarding the Florida Bay and Adjacent Ecosystems. Furthermore, this conference is designed to bring these scientists together with engineers, managers and regulators who are actively involved in all aspects of restoration. I encourage everyone to take the opportunity meet new colleagues and learn about the entire ecosystem.

The following pages provide a background and overview of the science themes and the conference. Please take a few moments to review this information and familiarize yourself with what is in store throughout the next few days. We have an exciting combination of presentations and posters that span a wide variety of scientific disciplines. In addition to the poster reception Monday evening, the posters will be on display throughout the entire conference, so please take advantage of catching the authors during breaks to discuss their poster.

Finally, I thank Beth Miller-Tipton and her staff at the University of Florida/IFAS Office of Conferences and Institutes (OCI) for their tireless efforts to organize this conference and past Florida Bay conferences. The PMC appreciates their contribution immensely.

Again, welcome to the conference, and please let me or any member of the OCI staff know if you need our assistance.

John H. Hunt
Co-Chair
Florida Bay PMC

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Program Management Committee

The Program Management Committee (PMC) is the sponsor of this conference. The PMC's primary role is to establish direction and priorities for science activities in Florida Bay and ensure close coordination of science activities with adjacent marine systems. The PMC consists of scientific program managers from:

- **Florida Department of Environmental Protection**
- **Florida Fish and Wildlife Conservation Commission***
- **Miami-Dade Department of Environmental Resources Management**
- **National Oceanic and Atmospheric Administration***
- **National Park Service**
- **South Florida Water Management District**
- **U.S. Army Corps of Engineers**
- **U.S. Environmental Protection Agency**
- **U.S. Fish and Wildlife Service**
- **U.S. Geological Survey**

* Current PMC Co-Chairs

Organizing Committee

- **Program Management Committee (PMC)**
- **Florida Bay and Adjacent Marine Systems Science Program**
- **Florida Sea Grant College Program**
- **University of Florida/IFAS, Office of Conferences and Institutes (OCI)**

Scientific Oversight Panel

Independent expert review is an integral component of the Florida Bay and Adjacent Marine Systems Science Program. This need is served by a Science Oversight Panel (SOP) which participates in the conference by leading question and answer sessions and providing subsequent technical and management review of the quality of research, modeling and monitoring activities in Florida Bay and the scientific inferences from these activities. The SOP consists of six senior scientists with significant experience in major estuarine restoration programs. Its current memberships includes:

Dr. William C. Boicourt
Horn Point Laboratory, Cambridge, MD

Dr. Boicourt is a Professor of Physical Oceanography and specializes in physical oceanographic processes including circulation of the continental shelf and estuaries.

Dr. William C. Dennison
University of Maryland Center for Environmental Science, Cambridge, MD

Dr. Dennison is the Vice President for Science Applications at the University of Maryland, Center for Environmental Science. He is a marine ecologist with a specialty in ecophysiology of marine plants and has conducted coastal marine research in all of the world's oceans.

Dr. John E. Hobbie (Chair)
The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA

Dr. Hobbie is Co-Director of The Ecosystems Center and is a coastal microbial ecologist specializing in biogeochemical cycles of large coastal and wetlands systems.

Dr. Edward D. Houde
University of Maryland, Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD

Dr. Houde is a professor at the University of Maryland and specializes in fisheries science, larval fish ecology, and resource assessment and management.

Dr. Steven C. McCutcheon
Hydrologic & Environmental Engineering, Athens, GA

Dr. McCutcheon is a specialist in water quality issues, hydrodynamic modeling, sediment transport, and hazardous waste management.

Dr. Hans W. Paerl
Institute of Marine Sciences, University of North Carolina, Morehead City, NC

Dr. Paerl is Kenan Professor of Marine and Environmental Sciences and his research includes nutrient cycling and production dynamics of aquatic ecosystems, environmental controls of algal production, and assessing the causes and consequences of eutrophication.

Conference Themes

The PMC invites presentations that refine understanding and build predictive capability of critical linkages across the following conference themes: Applications and Restoration Targets, the Mangrove-Estuarine Transition Zone, Benthic Habitats, Water Quality, Physical Processes, Higher Trophic Levels, and Adjacent Systems.

Applications and Restoration Targets. At this point in time researchers are being called upon not only to continue to improve and enhance understanding of Florida Bay and the coastal systems with which it is connected, but also to contribute to the adaptive assessment process adopted by the Comprehensive Everglades Restoration Project (CERP). CERP is committed to a long-term, multi-decadal Monitoring and Assessment Plan (MAP), the regional component of which that is relevant to the Florida Bay and Adjacent Marine Systems Science (FBAMS) program is termed the Southern Estuaries. A formalized assessment process has been developed by CERP'S Integrated Assessment Team. The CERP assessment process will be implemented on the same sub-regional basis. In the Southern Estuaries domain it will be grounded upon the scientific understanding developed under the aegis of the FBAMS program. The same understanding has contributed to the specification of restoration targets as well as to mandated water management decisions. That said, the research community will need to remain engaged and involved in the process of CERP implementation to assure that it remains "science-based" and the promise of adaptive management is in fact fulfilled.

Mangrove-Estuarine Transition Zone. The Florida Bay mangrove-estuarine transition zone has many important ecological attributes, many of which have been affected by altered freshwater inflow from upstream water management practices. These sensitive attributes include plant and animal communities, nutrient processing and retention, and soil accretion or subsidence. Some of these will likely be affected by restoration activities and respond more quickly than the same attributes within Florida Bay.

Benthic Habitats. Seagrass and hardbottom habitats account for a large portion of primary production, provide food and/or shelter to many organisms, and are critical to the ecological function of Florida Bay. These habitats strongly influence water quality and have themselves been affected by freshwater inflow and water quality changes attributable to upstream water management practices. Research has yet to address critical metabolic and community responses to sediment characteristics, water temperature, salinity, and light levels.

Water Quality. Water quality has been shown to have substantial ecological consequence and be related to upstream water management and human development. The foremost need regarding water quality is to accurately predict the sensitivity of Florida Bay's nutrient regime and phytoplankton to changes in freshwater flow into the bay. For much of the bay, any factor that increases phosphorus availability either by increasing sources or decreasing removal would likely have substantial effects. The effects of increased nitrogen, potentially introduced as dissolved organic nitrogen from the Everglades, are uncertain. Alteration of contaminant exposures is also possible with changes in the sources of water introduced into the bay. In general, a more thorough understanding of the bay's nutrient cycles is critical to making predictions and evaluating restoration alternatives.

Physical Processes. To date, research and monitoring of physical processes has encompassed all major physical driving forces (i.e., winds and storms, precipitation, evaporation, surface water inflow, groundwater, sea level and tides, and boundary currents) and the hydrodynamic character of Florida Bay (i.e., varying salinity and circulation patterns, and exchanges with adjacent waters). Although considerable data exist on each of these processes, more work remains to fully characterize their relative importance and variability, particularly in the case of groundwater inputs and evaporation for which available estimates vary over a significant range of values. The degree to which these processes need to be better defined will be determined by the needs of the suite of hydrological and hydrodynamic models used to predict bay salinity and circulation patterns. The same can be said for improved measurements of such hydrodynamic characteristics as bathymetry and flow across the extensive mud banks that divide the inner portion of Florida Bay. The sufficiency of the physical models will have to be assessed in light of the requirements of the numeric and statistical water quality and ecological models and improved or modified if necessary. Furthermore, to the degree that predictions of rapid local sea level rise can be verified, the relationship between sea level and bay flushing processes will need to be better understood given the multi-decadal time span of the CERP implementation.

Higher Trophic Levels. Advances in understanding higher trophic level responses to restoration require an interdisciplinary approach with input from all the other science themes. For instance, the basic question of "how do changes in stressors affecting the bay affect pathways of higher trophic species' movement within and between adjacent systems" requires information from physical processes, water quality, benthic habitats and the mangrove-estuarine transition zone. As many higher trophic level species initially settle in seagrass, hardbottom and mangrove communities, we cannot predict the impact of various stressors on their recruitment without understanding the impact of stressors on juvenile habitat. These nursery areas need to be delineated so that the potential effect of water management changes on salinity patterns, nutrient inputs, seagrass community structure and other conditions in these areas can be predicted. Linking the higher trophic level theme to the other themes will require complete GIS integration data layers as they become available including salinity, fresh-water flows, benthic communities, and habitat structure and appropriate species distribution and abundance patterns.

Adjacent Systems. Adjacent to Florida Bay are Biscayne Bay, the waters of the Florida Keys National Marine Sanctuary, and other marine and upstream systems. This session will consist of a suite of presentations and posters on a wide-ranging suite of topics where the studies were conducted within these adjacent systems. Some presentations will emphasize connectivity to Florida Bay and others will be wholly contained within the adjacent system.

Program Agenda

Abstract page numbers are indicated at the end of listings when applicable [example: "…(p. 2)"]

Sunday, December 11, 2005

5:00pm–7:00pm Registration Office Open

5:00pm–7:00pm Poster Presenters to Set up Displays

7:00pm–9:00pm **Early Bird Social in Poster Display Area**

Monday, December 12, 2005

7:30am–5:00pm Registration Office Open

7:30am–8:15am **Early Morning Refreshments in Poster Display Area**

8:15am–8:30am **Welcome and Official Opening**

SESSION I – APPLICATIONS AND RESTORATION TARGETS

SESSION MODERATOR: *John Hunt,* Fish and Wildlife Commission (FWC), Marathon, FL

8:30am–8:50am **Synthesis and Analysis of Ecological Information to Determine Minimum Flows and Levels for Florida Bay — *David Rudnick*[1]*,*** *Melody Hunt*[1], *Christopher Madden*[1], *Robin Bennett*[1], *Amanda McDonald*[1] *and Joel VanArman*[2]; [1]Coastal Ecosystems Division, SFWMD, West Palm Beach, FL [2]Water Supply Department, SFWMD, West Palm Beach, FL .... (p. 3)

8.50am–9:10am **The Challenges of Setting Performance Measures for South Florida's Estuaries: Nearshore Transition Zones versus Middle to Outer Bay Zones — *G. Lynn Wingard*[1]** *and Joel W. Hudley*[1]; [1]U.S. Geological Survey, Reston, VA .... (p. 5)

9:10am–9:30am **The Environment of Florida Bay: Past. Present. Future? *Joseph C. Zieman,*** Department of Environmental Sciences, University of Virginia, Charlottesville, VA .... (p. 7)

9:30am–9:50am Session Recap and GROUP DISCUSSION

9:50am–10:20am **Refreshment Break & Networking in Poster Display Area**

SESSION II – MANGROVE TRANSITION ZONE

SESSION MODERATOR: *Steve Gilbert* – US Fish and Wildlife Service (USFWS), Vero Beach, FL

10:20am–10:30am **Opening Remarks and Session Overview by Moderator**

10:30am–10:50am **Marsh Ecosystem Nitrogen Dynamics of the C-111 Basin —** *Daniel L. Childers*[1] *and* ***Jeffrey R. Wozniak*[1]*;*** [1]Florida International University and Florida Coastal Everglades LTER, Miami, FL .... (p. 28)

Monday, December 12, 2005 (continued)

10:50am–11:10am **Terrestrial Brackish Groundwater Discharge – a Significant Flux of Phosphorus to the Mangrove-Estuarine Transition Zone of the Southern Everglades — *René M. Price*[1]**, *Peter K. Swart*[2] *and James W. Fourqurean*[3;] [1]Department of Earth Sciences and the Southeast Environmental Research Center, Florida International University, Miami, FL; [2]Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, FL; [3] Department of Biological Sciences and the Southeast Environmental Research Center, Florida International University, Miami, FL .... (p. 27)

11:10am–11:30am **Landscape-scale Spatial and Temporal Patterns of Aboveground Net Primary Productivity (ANPP) in Everglades National Park (2001-2004) — *Sharon M.L. Ewe*[1]**, *Evelyn E. Gaiser*[1], *Daniel L. Childers*[1], *Victor H. Rivera-Monroy*[2], *David Iwaniec*[1], *Jim Fourqurean*[1], *Robert R. Twilley*[2]; [1]Southeast Environmental Research Center and the Department of Biological Sciences, Florida International University, Miami, FL; [2]Wetland Biogeochemistry Institute, Department of Oceanography and Coastal Science, Louisiana State University, Baton Rouge, LA .... (p. 23)

11:30am–11:50am **Integrating Physical and Ecological Models to Assess Restoration Impacts on Fish, Roseate Spoonbills and American Crocodiles in Northeastern Florida Bay — *Jerome J. Lorenz*[1]**, *Jon C. Cline*[2], *Eric D. Swain*[3], *Donald L. DeAngelis*[4], *Valerie L. Chartier*[5], *Kevin Chartier*[5], *Mike Cherkiss*[5], *Leonard Pearlstine*[5], *Frank J. Mazzotti*[5]; [1]Audubon of Florida, Tavernier Science Center, Tavernier, FL; [2]Department of Biology, Case Western Reserve University Cleveland, OH; [3]USGS Center for Water and Restoration Science, Ft. Lauderdale, FL; [4]Departmwent of Biology, University of Miami, Coral Gables, FL; [5]Ft. Lauderdale Research and Education Center, University of Florida, Davie, FL .... (p. 25)

11:50am -12:10pm Session Recap and GROUP DISCUSSION

12:10pm–1:30pm **Group Luncheon** - The hotel guest rate includes a daily lunch ticket. If you will be commuting and will not be staying in the host hotel, lunch tickets can be purchased from the hostess each day.

SESSION III – BENTHIC HABITAT

SESSION MODERATOR: *Susan Markley* – Miami-Dade Environmental Resources Management, Miami, FL

1:30pm–1:40pm **Opening Remarks and Session Overview by Moderator**

1:40pm–2:00pm **Bay-Scale Changes in Florida Bay Macrophyte Cover: 1995 – 2004 — *J. Brooke Landry*[1]**, *Michael J. Durako*[1], *and Margaret O. Hall*[2]; [1]Center for Marine Science, University of North Carolina Wilmington, Wilmington, NC; [2]Fish & Wildlife Research Center, Florida Fish & Wildlife Conservation Commission, St. Petersburg, FL .... (p. 57)

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2:00pm–2:20pm	**Inorganic Phosphate Kinetics in Florida Bay Seagrass Ecosystems: ^{33}P Experiments and In Situ Chamber Studies —** *[1]**Ole Nielsen**, [1]M. Koch, [2]H.S. Jensen and [3]C.J. Madden;* [1]Aquatic Plant Ecology Lab, Biological Sciences Department, Florida Atlantic University, Boca Raton, FL; [2]Institute of Biology, University of Southern Denmark, Odense, Denmark; [3]South Florida Water Management District, Coastal Ecosystems Division, West Palm Beach, FL .... (p. 60)
2:20pm–2:40pm	**Diel Light Curves' Ability to Incorporate Temporal and Spatial Variation of Photosynthetic Characteristics of *Thalassia testudinum* in Florida Bay** — ***E. F. Belshe***[1], *M. J. Durako*[1]; [1]Center for Marine Science and Department of Biology and Marine Biology, University of North Carolina at Wilmington, Wilmington, NC .... (p. 53)
2:40pm–3:00pm	**Florida Bay Seagrass Seedling Responses to Hyposalinity and Ammonium Fluctuations: A Study of *Thalassia testudinum* Banks ex König — *Amanda E. Kahn***[1], *Michael J. Durako*[1], *and Marguerite S. Koch*[2]; [1]University of North Carolina Wilmington Center for Marine Science, Wilmington, NC; [2]Florida Atlantic University Aquatic Plant Ecology Lab, Boca Raton, FL .... (p. 55)
3:00pm–3:30pm	**Refreshment Break and Networking in Poster Display Area**

SESSION III – BENTHIC HABITAT (CONTINUED)

SESSION MODERATOR: *Susan Markley* – Miami-Dade Environmental Resources Management, Miami, FL

3:30pm–3:50pm	**High Salinity Event of 2004-2005 and Responses of the Seagrasses Community in Northeast Florida Bay — *Christian L. Avila***, *Stephen M. Blair, Christine D. Hopps, Susan K. Kemp, Omar Z. Abdelrahman, Maurice J. Pierre and Kathryn M, Skindzier;* Miami-Dade Department of Environmental Resources Management (DERM), Miami, FL .... (p. 51)
3:50pm–4:10pm	**A Conceptual Model for Seagrass Die-off in Florida Bay Based on Mesocosm and Field Experiments —** *[1]**Marguerite Koch,** [1]Stephanie Schopmeyer, [1]Claus Kyhn-Hansen, [1]Ole Nielsen and [2]Chris Madden;* [1]Aquatic Plant Ecology Lab, Biological Sciences Department, Florida Atlantic University, Boca Raton, FL; [2] South Florida Water Management District, Coastal Ecosystems Division, West Palm Beach, FL .... (p. 56)
4:10pm–4:30pm	**The Florida Bay Seagrass Model: Examination of Fresh Water Effects on Seagrass Ecological Processes, Community Dynamics and Seagrass Die-off — *Christopher J. Madden*** *and Amanda A. McDonald,* Coastal Ecosystems Division, South Florida Water Management District, West Palm Beach, FL .... (p. 58)
4:30pm–5:00pm	Session Recap and GROUP DISCUSSION
5:00pm–8:00pm	**POSTER SESSION & NETWORKING RECEPTION**

Tuesday, December 13, 2005

7:30am–5:00pm Registration Office Open

7:30am–8:30am Early Morning Refreshments

7:30am–5:00pm Posters on Display

SESSION IV – WATER QUALITY

SESSION MODERATOR: *David Rudnick* – South Florida Water Management District (SFWMD), West Palm Beach, FL

8:30am–8:40am **Opening Remarks and Session Overview by Moderator**

8:40am–9:00am **Sediment Phosphate Flux and Benthic Microalgal Communities in Florida Bay, USA — *Merrie Beth Neely*[1, 2]** *and Gabriel A. Vargo*[2]*;* [1]Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL; [2]University of South Florida, College of Marine Science, St. Petersburg, FL .... (p. 93)

9:00am–9:20am **Denitrification versus Dissimilatory Nitrate Reduction to Ammonium (DNRA) or Nitrite (DNRN) in Hypersaline Florida Bay Sediments in August 2004 and January 2005 — *Wayne S. Gardner*[1]** *and Mark J. McCarthy*[1]; [1]The University of Texas at Austin Marine Science Institute, Port Aransas, TX .... (p. 85)

9:20am–9:40am **Bioavailability of Dissolved Organic Nitrogen in Florida Bay — *Joseph N. Boyer*[1]***, Susan K. Dailey*[1]*, Patrick Gibson*[1]*, Nagamitsu Maie*[1,2] *and Rudolf Jaffé*[1,2]; [1]Southeast Environmental Research Center, [2]Department of Chemistry and Biochemistry, Florida International University, Miami, FL .... (p. 83)

9:40am–10:00am **Effects of Post-Hurricane Freshwater Imports from the Everglades on Bacterial Community Composition, Ectoenzyme Activities, and Nitrogen Cycling in Northern Florida Bay** — ***Frank J. Jochem***[1] *and Clayton J. Williams*[1]*;* [1] Marine Biology Program, Florida International University, North Miami, FL .... (p. 91)

10:00am–10:30am **Refreshment Break and Networking in Poster Display Area**

SESSION IV – WATER QUALITY (CONTINUED)

SESSION MODERATOR: *David Rudnick* – South Florida Water Management District (SFWMD), West Palm Beach, FL

10:30am–10:50am **Organic and Inorganic Nutrients, Rates of Phytoplankton Nutrient Uptake, and Their Relationship with Phytoplankton Community Composition in Florida Bay and in a Comparative Subtropical Ecosystem in Australia — *P. M. Glibert*[1]***, C.A. Heil*[2, 3]*, J. Alexander*[1]*, M. Revilla*[1]*, S. Murasko*[2]*, A. Hoare*[2]*, J. O'Neil*[1]*, W.C. Dennison*[1] *and D. Hollander*[2]; [1]University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, MD; [2]College of Marine Science, University of South Florida, St. Petersburg, FL; [3]Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL .... (p. 87)

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10:50am–11:10am **Nutrient Quality Drives Phytoplankton Community Composition on the Southwestern Florida Shelf Region, including Florida Bay —** ***Cynthia A. Heil***[1], *M. Revilla*[2], *P. M. Glibert*[2], *J. Alexander*[2], *S. Murasko*[3], *D. Hollander*[3], *and Ana Hoare*[3]; [1]Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL; [2] University of Maryland Center for Environmental Research, Horn Point Laboratory, Cambridge, MD; [3]College of Marine Science, University of South Florida, St. Petersburg, FL .... (p. 89)

11:10am–11:30am **Aquatic Ecological Risk Assessment: Florida Bay and South Biscayne Bay —** ***G.M. Rand***[1], *P.R. Gardinali*[1], *W.B. Perry*[2], *J.F. Carriger*[1], *M. Tompkins*[1], *and A Fernandez*[1]; [1]Southeast Environmental Research Center, Florida International University, Miami, FL; [2]Everglades National Park, Homestead, FL .... (p. 94)

11:30am–12 noon Session Recap and GROUP DISCUSSION

12 noon–1:30pm **Group Luncheon** - The hotel guest rate includes a daily lunch ticket. If you will be commuting and will not be staying in the host hotel, lunch tickets can be purchased from the hostess each day.

SESSION V – PHYSICAL PROCESSES

SESSION MODERATOR: ***Patrick Pitt*** **– US Fish & Wildlife Service (USFWS), Vero Beach, FL**

1:30pm–1:40pm **Opening Remarks and Session Overview by Moderator**

1:40pm–2:00pm **Sedimentation and Circulation Changes in Florida Bay as a Response to Climate Change —** ***Charles W. Holmes,*** Center for Coastal and Wetland Studies, U.S. Geological Survey, St. Petersburg, FL .... (p. 120)

2:00pm–2:20pm **Estimating Evaporation Rates in Time and Space across Florida Bay —** ***René M. Price***[1], *William K. Nuttle*[2], *Bernard J. Cosby*[3], *Peter K. Swart*[4]; [1]Department of Earth Sciences and the Southeast Environmental Research Center, Florida International University, Miami, FL; [2]Eco-Hydrology, Ottawa, Canada; [3]Department of Environmental Sciences, University of Virginia, Charlottesville, VA; [4]Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, FL .... (p. 126)

2:20pm–2:40pm **Atmospheric-Aqueous Exchange of Carbon Dioxide in Florida Bay —** ***Wade R McGillis***[1,2], *Peter A. Raymond*[3], *Susan K. Dailey*[4], *and Joseph N. Boyer*[4]; [1]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY; [2]Earth and Environmental Engineering, Columbia University, New York, NY; [3]Yale University, New Haven, CT; [4]Florida International University, Miami, FL .... (p. 125)

Tuesday, December 13, 2005 (continued)

2:40pm–3:00pm **On Florida Bay Hypersalinity and Water Exchange — *Thomas N. Lee*[1],** *Elizabeth Johns*[2], *Nelson Melo*[3], *Ryan Smith*[2], *Peter Ortner*[2], *Dewitt Smith*[4], *and Ned Smith*[5]; [1]Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; [2]NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, FL; [3]Cooperative Institute for Marine and Atmospheric Studies, University of Miami, Miami, FL; [4]ENP, Homestead, FL; [5]Harbor Branch Oceanographic Institute, Ft Pierce, FL .... (p. 123)

3:00pm–3:30pm **Refreshment Break & Networking in Poster Display Area**

SESSION V – PHYSICAL PROCESSES *(CONTINUED)*

SESSION MODERATOR: *Patrick Pitt* – US Fish & Wildlife Service (USFWS), Vero Beach, FL

3:30pm–3:50pm **Flows and Stages in the Southern Everglades and Along the Coastal Boundaries of Florida Bay – Calibration and Scenario Applications of the Time Model — *John D. Wang*[1]**, *Eric D. Swain*[2], *Melinda A. Wolfert*[2], *Christian D. Langevin*[2], *Dawn James*[2]; [1]Applied Marine Physics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; [2]U.S. Geological Survey Florida Integrated Science Center, Water and Restoration Studies, Fort Lauderdale, FL .... (p. 127)

3:50pm–4:10pm **The South Florida Hybrid Coordinate Ocean Model: An Integrated Approach for Florida Bay Modeling — *Villy Kourafalou*** *and Rolando Balotro,* Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL .... (p. 121)

4:10pm–4:30pm **Status of the Florida Bay Hydrodynamic Model — *J. M. Hamrick*[1]**, *M. Z. Moustafa*[2], *and D. Worth*[2]; [1]Tetra Tech, Inc., Fairfax, VA; [2]South Florida Water Management District, West Palm Beach, FL .... (p. 119)

4:30pm–5:00pm Session Recap and GROUP DISCUSSION

6:00pm–9:00pm **Poolside Networking Reception**

Wednesday, December 14, 2005

7:30am–5:00pm Registration Office Open

7:30am–8:30am Early Morning Refreshments in Poster Display Area

SESSION VI – HIGHER TROPHIC LEVELS

SESSION MODERATOR: *Peter Ortner* – National Oceanic and Atmospheric Administration (NOAA), Atlantic Oceanographic and Meteorological Laboratory (AOML) & Rosenstiel School of Marine and Atmospheric Science (RSMAS), University of Miami, Miami, FL

8:30am–8:40am Session Overview and Introduction

8:40am–9:00am **Examining Interactive Effects of Salinity and Seagrass Habitat on Higher Trophic Level Species for the Development of Florida Bay Minimum Flows and Levels Technical Criteria — *Robin Bennett*[1]**, *Darlene Johnson*[2], *Joan Browder*[3], *Amanda McDonald*[1], *Christopher Madden*[1], *David Rudnick*[1], *Michael Robblee*[4]; [1] Coastal Ecosystems Division, South Florida Water Management District, West Palm Beach, FL; [2] Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; [3] NOAA Fisheries Service, Southeast Fisheries Science Center, Miami, FL; [4] United States Geological Survey, Center for Water and Restoration Studies, Miami, FL .... (p. 156)

9:00am–9:20am **Transport of Pink Shrimp Postlarvae into Interior Florida Bay — *Joan A. Browder*[1],** *Maria M. Criales*[2], *Michael B. Robblee*[3], *John Wang*[2] *and Thomas Jackson*[1]; [1]NOAA Fisheries, Miami, FL; [2]RSMAS, University of Miami, Miami, Fl; [3]U.S. Geological Survey, Miami, FL .... (p. 160)

9:20am–9:40am **Cross-Shelf Larval Transport and Behavior of Pink Shrimp at the SW Florida Shelf — *Maria M. Criales*[1]**, *Joan A. Browder*[2], *Michael B. Robblee*[3] *and Christopher K. N. Mooers*[1] ; [1]RSMAS, University of Miami, Miami, FL; [2]NOAA Fisheries, Miami, FL; [3]U.S. Geological Survey, Miami, FL .... (p. 164)

9:40am–10:00am **Application of a Simulation Model of Pink Shrimp Growth and Survival — *Joan A. Browder*[1],** *Darlene R. Johnson*[2], *Robin Bennett*[3], *Frank Marshall*[4] *and John Wang*[5]; [1]NOAA Fisheries Service, Southeast Fisheries Science Center, Miami, FL; [2]Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; [3]South Florida Water Management District, West Palm Beach, FL; [4]Cetacean Logic Foundation, Inc., New Smyrna Beach, FL; [5]Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL .... (p. 158)

10:00am–10:30am **Refreshment Break & Networking in Poster Display Area**

Wednesday, December 14, 2005 (continued)

SESSION VI – HIGHER TROPHIC LEVELS (CONTINUED)

SESSION MODERATOR: *Peter Ortner* – NOAA/AOML & RSMAS/UM , Miami, FL

10:30am–10:50am **Physiological and Behavioral Responses of Estuarine Fish to Salinity Changes in Florida and Biscayne Bays — *Pamela Bachman*[1]** , *Gary M. Rand*[1] *and William B. Perry.*[2]*;* [1]Florida International University, North Miami, FL, [2]Everglades National Park, Homestead, FL .... (p. 155)

10:50am–11:10am **The Use of Otolith Microchemistry to Monitor and Evaluate the Movement of Coral Reef Fish in South Florida Waters — *Trika L. Gerard*[1]**, *Dave Jones*[2], *Monica Lara*[2]*;* [1]National Oceanic and Atmospheric Administration, NMFS SE Fisheries, Miami, FL; [2]U Miami, Cooperative Institute for Marine and Atmospheric Studies, Miami, FL .... (p. 166)

11:10am–11:30am **Hard-bottom Community Ecology in the Florida Keys with an Emphasis on Sponges —*Mark J. Butler, IV***, *Donald C. Behringer, and A. Kathryn Kauffman,* Department of Biological Sciences, Old Dominion University, Norfolk, VA .... (p. 162)

11:30am–12:00pm Session Recap and GROUP DISCUSSION

12 noon–1:30pm **Group Luncheon** - The hotel guest rate includes a daily lunch ticket. If you will be commuting and will not be staying in the host hotel, lunch tickets can be purchased from the hostess each day.

SESSION VII – ADJACENT SYSTEMS

SESSION MODERATOR: *Brian Keller* –Florida Keys National Marine Sanctuary (FKNMS), Marathon, FL

1:30pm–1:40pm **Opening Remarks and Session Overview by Moderator**

1:40pm–2:00pm **Biscayne Bay's Shallowest Habitats: Linking Seasonal Patterns in Benthic Community Structure with Salinity and Temperature Patterns — *Diego Lirman*[1]**, *Joe Serafy*[1, 2], *Greg DeAngelo*[3], *Amit Hazra*[1] *and Destiny Smith*[2]*;* [1]University of Miami, RSMAS, Miami, FL; [2]NOAA/National Marine Fisheries Service, Miami, Fl; [3]NOAA/National Geodetic Survey, Silver Spring, MD .... (p. 198)

2:00pm–2:20pm **Hindcasting Salinity in Biscayne Bay —** *Rick Alleman*[1] *and* ***D. Michael Parrish***[2]*;* [1]Coastal Ecosystems Division, South Florida Water Management District, West Palm Beach, FL; [2]BEM Systems, Inc., West Palm Beach, FL .... (p. 201)

2:20pm–2:40pm **The Role of Sponges in N Cycling and Total Respiration in Shallow Water Florida Keys Ecosystems — *Christopher S. Martens*[1]**, *Niels Lindquist*[2], *Melissa W. Southwell*[1], *Jeremy B. Weisz*[2], *James Hench*[3]*;* [1]Department of Marine Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC; [2]Institute of Marine Sciences, UNC–Chapel Hill, Morehead City, NC; [3]Department of Civil and Environmental Engineering, Stanford University, CA .... (p. 200)

Wednesday, December 14, 2005 (continued)

2:40pm–3:00pm **Nutrient Export from Florida Bay to the Florida Keys National Marine Sanctuary — *Patrick J. Gibson*[1]**, *Joseph N. Boyer*[1] *and Ned P. Smith*[2]; [1]Southeast Environmental Research Center, Florida International University, Miami, FL; [2]Harbor Branch Oceanographic Institution, Ft. Pierce, FL .... (p. 196)

3:00pm–3:30pm **Refreshment Break & Networking in Poster Display Area**

SESSION VII – ADJACENT SYSTEMS (CONTINUED)

SESSION MODERATOR: *Brian Keller* –Florida Keys National Marine Sanctuary (FKNMS), Marathon, FL

3:30pm–3:50pm **Transport Along and Across Hawk Channel: The Last Link in the Gulf-to-Atlantic Transport Pathway to the Reef Tract — *Ned P. Smith***, Harbor Branch Oceanographic Institution, Fort Pierce, FL ... (p. 204)

3:50pm–4:10pm **Decadal-Scale Ecological Shifts along the Florida Reef Tract: Understanding Cause and Effect — *William F. Precht*[1]**, *Steven L. Miller*[2]; [1]Ecological Sciences Program, PBS&J, Miami, FL; [2]Center for Marine Science and NOAA's National Undersea Research Center, University of North Carolina at Wilmington, Key Largo, FL .... (p. 203)

4:10pm–4:30pm **Initial Responses of Reef Fishes to Tortugas Ecological Reserves: Protecting Resources while Benefiting Fisheries —** *Jerald S. Ault*[2], ***James Bohnsack*[1]**, *Steven G. Smith*[2], *Jiangang Luo*[2], *Douglas E. Harper*[1] *and David B. McClellan*[1]; [1]NOAA Fisheries, Miami, FL; [2]RSMAS, University of Miami, Miami, FL .... (p. 195)

4:30pm–5:00pm Session Recap and GROUP DISCUSSION

5:00pm-5:15pm **Closing Remarks – *John Hunt,*** Fish and Wildlife Commission, Marathon, FL

5:15pm Conference Concludes

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Oral Abstracts

Applications and Restoration Targets

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Synthesis and Analysis of Ecological Information to Determine Minimum Flows and Levels for Florida Bay

***David Rudnick*[1]**, *Melody Hunt*[1], *Christopher Madden*[1], *Robin Bennett*[1], *Amanda McDonald*[1], and *Joel VanArman*[2]
[1]Coastal Ecosystems Division, SFWMD, West Palm Beach, FL
[2]Water Supply Department, SFWMD, West Palm Beach, FL

A comprehensive analysis of the effects of freshwater flow on the Florida Bay ecosystem and saline wetlands (transition zone) between the bay the Everglades has been completed in order to provide recommendations for Minimum Flows and Levels (MFL) criteria. Specification of MFL criteria for Florida water bodies follows Florida State law, where a MFL is defined as "the limit at which further withdrawals would be significantly harmful to the water resources". Significant harm is defined as the temporary loss of water resource functions (e.g. a species or habitat impairment) that result from a change in surface or ground water hydrology and that takes more than two years to recover. Florida Bay MFL analyses included literature reviews, data syntheses and simple statistical analyses, and the development and application of a mass-balance hydrologic model (ECT 2005), a dynamic seagrass community model, and statistical models of higher trophic level species (Johnson et al. 2005). From these analyses, a submerged aquatic vegetation (SAV) indicator species, *Ruppia maritima*, that occurs in the transition zone was proposed for defining Florida Bay MFL criteria. MFL criteria are being proposed in terms of freshwater flow and corresponding salinity levels required to protect SAV habitat in the transition zone from significant harm. Salinity and ecological conditions in northeastern Florida Bay that are coincident with recommended flow and salinity conditions in the transition zone were also determined to ensure that criteria that are protective of resources in the transition zone are also protective of resources in the bay.

Salinity was estimated for MFL analyses using a multiple linear regression approach for Taylor River (Marshall et al. 2004) in the transition zone and using FATHOM, a mass balance hydrologic model, for 41 basins within Florida Bay. The regression model and FATHOM estimated 33 year time series of monthly mean salinity (from 1970 through 2002) for the Taylor River and 41 basins in the bay, representing an historic "base case" that was used to assess flow-salinity relationships. This assessment indicated that water management practices in the eastern Everglades primarily influence salinity in the transition zone, eastern coastal embayments, and northeastern bay basins. In particular, the historic base case indicated that low flow and hypersalinity were more frequent, sustained, and extreme from 1970 to 1981 than in later years, despite rainfall levels that were similar over the entire base case period.

Ecological analyses focused on those regions that are most strongly influenced by water management – the transition zone, coastal embayments, and northeastern bay. Species that constitute SAV habitat in the transition zone were found to be sensitive to salinity, with loss of all major species occurring above 30 psu. *Ruppia*, the dominant vascular SAV of this region, is the most salinity tolerant of this assemblage – when this species disappears with high salinity, SAV habitat also disappears. The loss of this species near 30 psu is not only related to mortality of seedlings and adult plants, but also to inhibition of seed germination and reproductive success above this salinity level (Koch and Durako 2004).

SAV habitat in most coastal embayments and northeastern Florida Bay is dominated by two species, *Halodule wrightii* and *Thalassia testudinium*. These species are more salinity tolerant than *Ruppia* and under optimal laboratory conditions can tolerate extremely high salinity levels (near 60 psu). Empirical field data do not show clear salinity trends, but these data are limited to low and moderate salinity conditions; they are insufficient to assess hypersalinity effects. A dynamic simulation model of *Halodule* and *Thalassia* indicates strong salinity effects are likely to occur in the field because other factors are not optimal. In particular, the effects of salinity are probably due to indirect effects of competition between *Thalassia* and *Halodule* (e.g. for nutrients and light). Under hypersaline conditions (above 40 psu), *Thalassia* is predicted to become dominant, while under mesohaline conditions (less than 18 psu), *Halodule* is predicted to become dominant.

The quantitative and qualitative composition of SAV habitat appears to have an impact on many fish and invertebrate species of Florida Bay. A statistical analysis of a multi-decadal data set from Florida Bay demonstrated not only that salinity has a significant (though widely varying) effect on these fauna, but also that most fauna benefit from increased *Halodule* cover. Analyses indicate that increasing salinity from mesohaline toward marine and hypersaline conditions decreases the overall abundance of the forage base (prey for larger fish, particularly sport fish) in Florida Bay because of both direct salinity effects on these organisms and SAV habitat loss.

Translation of these hydrologic and ecological findings into specific recommendations for MFL criteria is in progress. The most sensitive ecological indicator of significant harm, that is a severe and multiyear disruption of ecological structure and function, appears to be *Ruppia* in the transition zone. Furthermore, protection of *Ruppia* in transition zone ponds would likely also protect the ecological resources of Florida Bay. Salinity levels of about 30 psu in the Taylor River ponds correspond to salinity levels of about 40 psu in Little Madeira Bay and the northeastern bay. Prevention of prolonged periods with salinity above 40 psu in these regions is likely to prevent a decrease in seagrass habitat diversity (with increased *Thalassia* dominance) and thus benefit higher trophic level species.

Prevention of significant harm via MFL specification and implementation does not constitute restoration for Florida Bay – it is only intended to protect the ecosystem from potentially severe impacts due to upstream consumption of water for human uses. However, insights gained from MFL analyses, as well as the models developed for this purpose, should help to facilitate the success of the Florida Bay and Florida Keys Feasibility Study and other restoration efforts.

References:

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The Challenges of Setting Performance Measures for South Florida's Estuaries: Nearshore Transition Zones versus Middle to Outer Bay Zones

G. Lynn Wingard and *Joel W. Hudley*
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The primary goal of the Comprehensive Everglades Restoration Plan (CERP) is to "deliver the right amount of water, of the right quality, to the right places, and at the right time" (http://www.evergladesplan.org) and a major feature of the CERP is to restore more natural flow into Florida Bay, Biscayne Bay, and the southwest coastal area. Setting performance measures and targets for salinity and other measures of water quality are a critical part of achieving restoration goals for the estuaries. The goal is for these performance measures to be sustainable and to accurately reflect the historical, pre-drainage condition of the estuaries. Determining what these target values should be, however, is not an easy task given the tremendous spatial and temporal variability that occurs within the bays.

An examination of recent (1993-2002) data illustrates the spatial variation in salinity that can occur (see table below). At water monitoring and stream gauging stations located in the transition zones of Florida Bay and Biscayne Bay, salinities have ranged from minimums of <1 to 6.9 ppt to maximums of 32 to 38 ppt. During the recent hurricane Katrina, salinity at Manatee Bay dropped 26.6 ppt in a 24 hour period, from 29.1 ppt at 8:30 pm on August 25, 2005 to 2.5 ppt at 8:30 pm on August 26, 2005. At Trout Creek, salinity did not drop quite so rapidly, but still declined nearly 22 ppt over a 5-day period, from 29.25 ppt at 7:30 am on August 26, 2005 to 7.3 ppt at 7:30 am on August 31, 2005. (Hurricane data retrieved from http://waterdata.usgs.gov /fl/nwis/rt on 9/1/2005). Bob Allen Bank water monitoring station, located in central Florida Bay, shows slightly less variation than the nearshore sites, with a range of 24 ppt recorded over a 5 ½ year period, but here the minimum values are 22 ppt and the maximums range into hypersalinity at 46 ppt. Peterson Key, located in the Atlantic Transition Zone of Florida Bay shows the least variability. The critical question when considering spatial variation within the estuaries is how much of what we see in recent years is due to anthropogenic alteration of flow? Would nearshore areas have shown such a wide range of variability prior to alteration of flow?

	Southern Biscayne Bay System		Florida Bay			
	Middle Key[1]	Manatee[1]	Joe Bay[1]	L. Madeira[1]	Bob Allen[2]	Peterson Key[2]
Data Time frame	7/93 to 1/00	8/93 to 1/02	7/93 to 1/95	8/93 to 3/02	9/97 to 4/03	8/93 to 4/03
Mean (ppt)	25.0253	8.6963	11.0274	19.9598	33.1534	34.6168
Stand. Deviation	5.7128	9.4150	8.8044	6.7347	5.0712	3.2016
Sample Variance	32.6356	88.6426	77.5170	45.3563	25.7175	10.2504
Range	29.9000	37.8000	33.3700	31.6700	24.2900	16.9500
Minimum	7.3700	0.0300	0.2900	6.8700	21.9900	26.5700
Maximum	37.2700	37.8300	33.6600	38.5400	46.2800	43.5200
# days measured	2590	2532	512	2703	1780	2321

([1]http://waterdata.usgs.gov/fl/nwis/nwis; [2]http://sofia.usgs.gov/exchange/halley/halleysalt.html)

Understanding historical patterns of change in the estuaries and how these patterns are related to natural and anthropogenic events is an essential component of setting sustainable and realistic performance measures. The temporal record of ecosystem change is preserved in sediment cores collected from Florida Bay and Biscayne Bay. In the nearshore transition zones at Taylor Creek, Joe Bay/Mud Creek, Middle Key and Manatee Bay, the cores generally record significant changes with declines in freshwater and increases in salinity occurring at those sites. Because upwelling of groundwater often "resets" the radiometric clock, we do not have precise age models for these nearshore cores. However, the presence of *Casaurina* pollen (a species introduced into south Florida around the turn of the century) provides a stratigraphic marker for pre- and post-20th century. Molluscan, ostracode, and foramifer (M-O-F) assemblage data from these nearshore cores indicate that in some locations long-term gradual trends towards increasing salinity began prior to the 20th century, but during the 20th century these trends were offset by shifts toward increasing average salinities.

Moving outward from the nearshore areas, M assemblage data from Whipray and Rankin (isolated basins in central Florida Bay) show a loss of low salinity and/or freshwater species in the lower portion of the cores and during the 20th century an increase in species tolerant of broad fluctuations in salinity. At Russell Bank and Bob Allen Bank in east central Florida Bay, the M-O assemblages have not changed dramatically over the 20th century, but there has been an increase in species tolerant of more extreme fluctuations in salinity in the latter half of the century. In the Biscayne Bay system, cores from Card Sound Bank, a barrier between the more restricted Barnes Sound to the south and the more open waters of Biscayne Bay to the north, indicate a shift around mid-20th century from M-O species tolerant of estuarine fluctuations to species more typical of stable, nearly marine salinities. In the more open bay setting near Black Ledge in Biscayne Bay, a shift from outer estuarine conditions to nearly marine conditions began to occur around 1920. M-O-F assemblages from Featherbed Bank in central Biscayne Bay have undergone a subtle shift toward slightly more marine species, but like Russell Bank and Bob Allen, these changes in assemblages have not been dramatic.

As we logically would predict, the results of our core analyses show that the nearshore areas have undergone more significant changes over the last century than the open bay areas, but the central isolated basins of Florida Bay also have undergone significant changes. This spatial variation makes the job of setting performance measures very complex. The temporal variation seen in the cores illustrate that in addition to anthropogenic changes, some long term natural trends and/or cycles are acting on south Florida's estuaries, and these changes may be outside the scope of restoration (e.g. climate change, sea-level rise). In order to be attainable and sustainable, the target salinity values need to consider the balance of forces at work – both anthropogenic and natural – because the existing ecosystem represents a combination of these factors. The key is to understand the natural range of variation that existed prior to significant human influence and to understand the natural trends or cycles of change. We propose that restoration should not be returning to the 19th century conditions, but rather the goal should be to determine where the system would be if the natural trends and/or cycles had continued uninterrupted and return the ecosystem to that intersect point. Our goal, in the ecosystem history research is to attempt to filter out the anthropogenic component of change, predict where the natural trends or cycles would have taken us, and use the intersect point to set the target values for restoration of the estuaries.

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The Environment of Florida Bay: Past. Present. Future?

Joseph C. Zieman
Department of Environmental Sciences, University of Virginia, Charlottesville VA

To people who were in south Florida years ago, the Florida Bay that is remembered fondly is the bay in the decade prior to the seagrass dieoff. This was a Florida Bay where much of the central and western bay possessed extremely clear water and the seagrasses, especially *Thalassia testudinum*, were dense and in near continuous monoculture.. But beginning in late 1987, Florida Bay experienced a large and unprecedented dieoff of *Thalassia testudinum*, culminating in the initial loss of over 20,000 ha of seagrasses, and significantly greater losses in the years following.

Early losses were relatively easy to quantify, as the majority of waters for Florida Bay remained as clear as they were in 1987. As the dieoff progressed over several years, turbidity from the unprotected sediments, and plankton blooms, generated by the nutrients released from the decomposing seagrasses and exposed sediments, increased also. Maximum seagrass losses were estimated to go as high as 40,000 ha, but these are only educated estimates, as the high turbidities precluded accurate surveys. As the dieoff and its downstream effects intensified, spreading well into the Florida Keys National Marine Sanctuary, so did the realizations that this was a very large-scale, regional problem, and that much of the cause and hence the solutions lay upstream of the FKNMS and Florida Bay, in the Everglades.

Another problem exists in defining what restoration is for Florida Bay.

Durbin Tabb was one of the first scientists to attempt to characterize earlier times in Florida Bay was Durbin Tabb. Tabb et al. (1962) noted that "under hypersaline conditions (above 45-59 ppt) the turtle grass, *Thalassia testudinum* is adversely affected. The blades of the "grass" die back and thus expose the bottom muds. If high salinity periods persist for periods of 3-5 months the turtle grass cover of Florida Bay becomes reduced by defoliation so that wind scour reaches the marl muds and turbidity increases markedly. Such turbidity conditions further limit the numbers of species that may be found in the region beyond that already reduced by hypersalinity."

Tabb et al (1962) also noted that with salinities in the range of the more moderate range of 30-40 ppt, "the seawater in western Florida Bay tended to become clearer, and that This would permit maximum growth and development of algae and marine grasses, which would further stabilize the bottom. Such conditions are favorable for angling and sightseeing, but are far different from the conditions that existed in the estuary prior to 1920, when the waters were stained by humic acids, organic particles and marl in suspension."

Other regional changes have affected the seawater entering florida Bay. Historically there was a large bed of *Thalassia* off the western Everglades which was estimated at 200 square miles in size. This contained what the US Fisheries Commission said was the largest clam bed in the US, and they actively encouraged its exploitation. Unfortunately *Thalassia* is highly sensitive to dredging of any sort, and in a relatively short time, the bed and clams were gone permanently. This large seagrass bed and its contained clams acted as an enormous filter for nutrients and particulate material traveling down the west coast of south Florida. The loss of this bed would have allowed this material to move further south and enter Florida Bay on flood tides.

Knowledge of the historical Florida Bay is critical to the restoration of a stable and persistent ecosystem. Attempts to recreate an aesthetically pleasing but historically unstable ecosystem is simply resetting the clock for another round to the dieoffs that occurred in the 1987-91 period. Numerous lines of evidence will be developed to attempt to reconstruct the historical Florida Bay.

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Poster Abstracts

Applications and Restoration Targets

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Selection of Vital Signs in Florida Bay for the National Park Service Inventory and Monitoring Program

Andrea Atkinson, *Matt Patterson, W. Jeff Miller, Brian Witcher* and *Kevin R. T. Whelan*
National Park Service Inventory and Monitoring Program, South Florida / Caribbean Network

The National Park Service Inventory and Monitoring Program divided the 270 park units in the United States and associated territories into 32 networks. Each network has the responsibility of selecting "vital signs", i.e. indicators of system integrity, and developing monitoring programs or coordinating with existing monitoring programs to effectively report the status, changes, and early warning of negative trends in these vital signs, for the purpose of assisting adaptive management of park resources. These vital signs can be physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park, known or hypothesized effects of stressors, or elements that have important human values.

The South Florida / Caribbean network includes four south Florida and three Caribbean parks including Everglades National Park, Big Cypress National Preserve, Biscayne National Park, Dry Tortugas National Park, Virgin Islands National Park, Buck Island Reef National Monument, and Salt River Bay National Historic Park and Ecological Reserve. The network has drafted conceptual models as a prelude to vital signs selection. Three conceptual models are of particular relevance to the Florida Bay: Florida Bay Ecological Zone; Mangroves, Beaches and Tidal Wetlands Ecological Zone, and Marine Benthic Communities Sub-Model. These conceptual models represent a problem analysis of the Florida Bay ecosystem by linking causes of change (i.e. physical system drivers and anthropogenic stressors) to the state of the ecosystem and to management activities. Figure 1 provides a simplified overview of the major physical system drivers and anthropogenic stressors affecting the Florida Bay Ecological Zone. (The Florida Bay Ecological Zone includes those portions of the Bay within NPS boundaries, not including the inter-tidal zone). Each of the components is discussed in greater detail in the draft model itself.

The National Park Service will be actively seeking input from interested local experts to improve the conceptual models and select and prioritize vital signs through a workshop process in winter 2005 and through an on-line web process.

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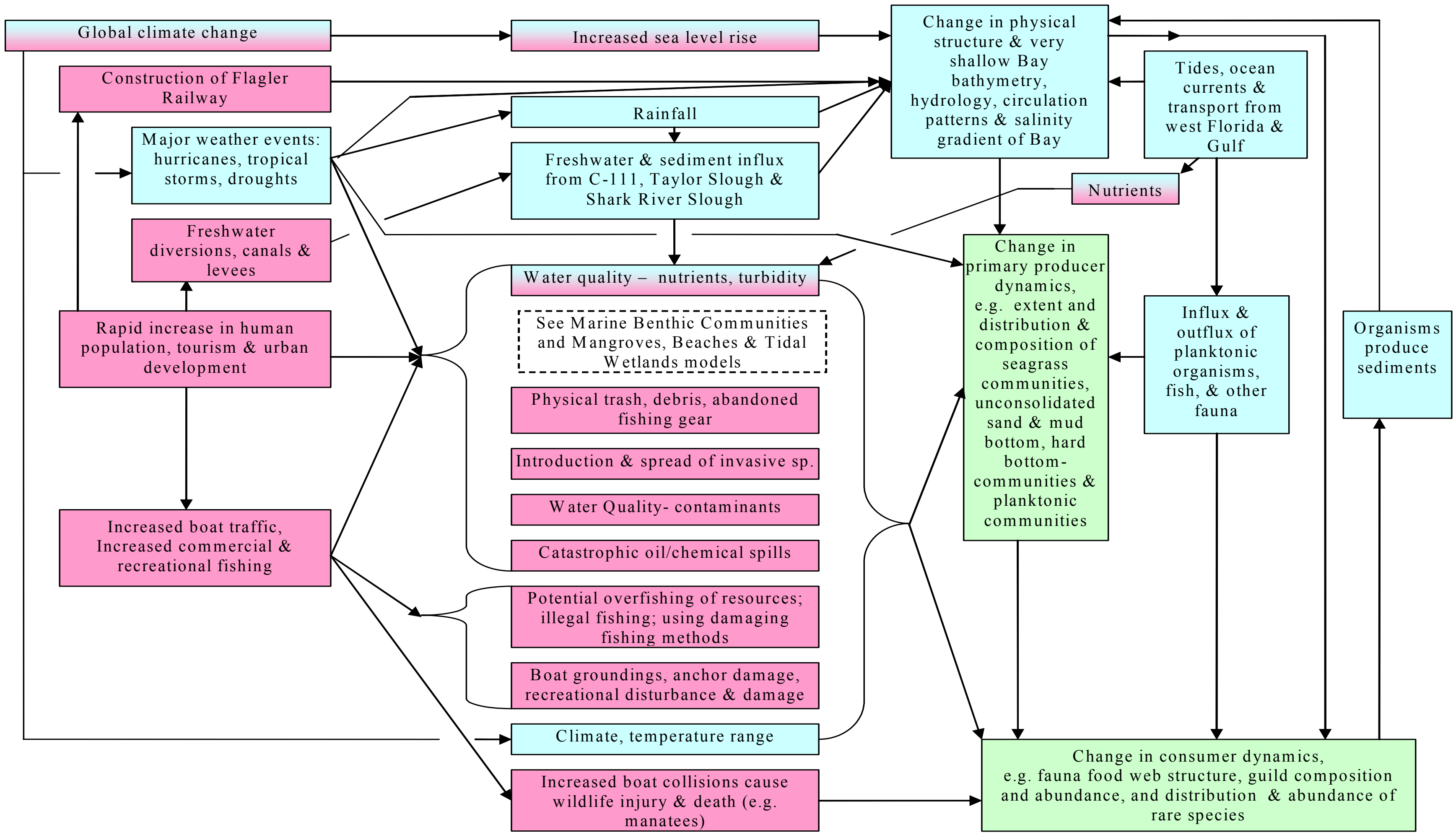

Figure 1. Florida Bay simplified conceptual model diagram showing relationship between physical system drivers, anthropogenic stressors and biological attributes to assist selection of Vital Signs.
System Driver Anthropogenic stressor Biological Attribute Driver/Stressor discussed together

Linking Greater Everglades Ecosystems with Florida Bay: Development of Metrics to Measure Restoration Success in the Face of Uncertainty

Andrew D. Gottlieb[1], *Thomas St. Clair*[1] and *Lisa Sterling*[1]
PBS&J, Jacksonville, FL, USA

It is critical to recognize the linkages between estuaries and upstream wetlands to understand the effects restoration will have on hydrology, water quality, and ecology. This presentation identifies the ecological models and associated Comprehensive Everglades Restoration Plan (CERP) system wide performance measures that link the Greater Everglades and Southern Estuaries. Current performance measures (PMs) for each region are described along with existing evaluation and assessment tools. Specific performance measures including the stressors and attributes are identified. Data gaps are identified along with potential mechanisms and tools to minimize uncertainty. Finally, the frame work/criteria for developing additional performance measures linking the Greater Everglades marshes to downstream estuaries and Florida Bay are offered. By linking the system, existing knowledge can be used as a driver to understand conditions in areas where more uncertainty exists.

The CERP was designed to eliminate or substantially moderate hydrologic and certain water quality stresses that have degraded the natural system (changes to the quantity, quality, timing, and distribution of water). The Plan was designed to increase the region's supply of fresh water, to improve how water is delivered to natural areas, and to provide for other water related needs. Changes associated with the Plan will ultimately affect flows to estuaries and Florida Bay. Restoration activities will also improve water quality. A series of CERP system wide performance measures has been developed by the Restoration Coordination and Verification (RECOVER) team to determine the regional effects of restoration projects on hydrology, water quality, and ecology. Evaluation activities will predict how the Plan will affect the ecosystem, and monitoring and assessment activities will document changes in the field and provide additional information to refine current hypothesis and conceptual models. Through monitoring and assessment, changes in the freshwater Everglades will be documented.

Conceptual Ecological Models (CEMs), developed through a collaborative effort by a multidisciplinary team of experts, describe the linkages between the GE wetlands and Florida Bay. The CERP system wide performance measures were developed based on the conceptual ecological models, which illustrate links among environmental stressors and ecological responses, and provide the basis for selecting and testing a set of hypotheses that best explain why natural systems in South Florida have been altered (Gentile et al. 2001). These models recommend attributes of natural systems that can serve as indicators of restoration program effectiveness in reducing or eliminating identified stressors.

Currently, RECOVER Greater Everglades and Southern Estuaries (SE) Subteam PMs are divided into three categories: hydrologic, water quality, and ecological. It is important to understand the upstream and downstream relationships and to document changes from current baseline conditions. Through evaluation and assessment feedback, current models and PMs will be continually revised in an effort to refine targets and minimize uncertainty. Additionally new models will need to be developed or existing models applied, in particular in the areas of water quality and ecology.

CERP's restoration efforts will affect fate, transport, and transformations along the flow path from the Greater Everglades (GE) wetlands to the estuaries and ultimately to Florida Bay and the Gulf of Mexico. Along with these changes will come additional uncertainties. One area which requires further research to reduce uncertainty is nutrient budgets for the GE and Florida Bay. Changes in phosphorus dynamics are well understood and will be tracked by existing monitoring networks. Nitrogen dynamics, on the other hand, are not as well understood and additional assessment activities will be needed to understand the effects of restoration on nitrogen. As changes in flow, water level, and water quality occur, changes in nitrogen dynamics can be expected. Continued experimentation is needed to document effects of changing P concentrations, water levels, and flows on nitrate reduction, denitrification, sedimentation, and dissolved organic matter (DOM). Additionally, understanding the effects of restoration on changes in vegetation and landscape structure will provide needed information on the quality and quantity of potential export material. It is through the recognition of uncertainty, identification of mechanisms to minimize uncertainty, and development of new predictive metrics and models linking freshwater and marine end members that a more complete system wide restoration can potentially be realized.

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Implications of Climate Change and Climate Variability upon South Florida Ecosystem Restoration and CERP

Peter B. Ortner
Atlantic Oceanographic & Meteorological Laboratory, Miami, FL

The Comprehensive Everglades Restoration Plan (the lynchpin of South Florida Ecosystem Restoration) is an ambitious attempt to re-engineer one of the most complex and expensive water management systems in the world. While turning back the clock is impossible, federal and state agencies are cooperating to, if not "restore an ecosystem" and "transform" the built environment at least put them on more sustainable trajectories. Because South Florida is sub-tropical and its' protected "natural" areas closely abut rapidly developing urban/suburban population centers (properties shared with major rapidly developing population centers in many other countries) SFER has received considerable attention as an internationally significant case study.

Given its geographic scope and multi-decadal planning and implementation horizons, the success or failure of CERP will to no small degree be determined by the degree to which management decisions are consistent with and adapt to not only global climate change (e.g., sea level rise, sea surface temperature change, atmospheric carbon-dioxide and large scale changes in precipitation patterns) but also inter-decadal climatic variability in the coupled ocean-atmosphere (e.g. the Atlantic Multi-decadal Oscillation, El Nino/La Nina, Sahel drought and tropical storm impacts). Local "climatically relevant" phenomena such as desertification and subsidence will not only complicate interpretation but will have to be specifically considered with regard to CERP assessments, evaluations and recommended management alternatives.

For good or ill SFER will not only be a case study with respect to political will and adaptive management but also with regard to regional climate prediction, the reliability of which will depend upon the assimilation of appropriate observational data into improved numerical models.

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Florida Bay – A Balanced Approach

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Water quality decline is often cited as the cause of habitat degradation in the Florida Bay, and linked to changes that have occurred in the last two decades, including algal blooms, seagrass die-offs, sponge mortality events and sea urchin population explosions. The assumption that these ecological changes are due to increased nutrient input from agricultural activity and other anthropogenic activities in Florida have been widely adopted and accepted by scientists, resource managers, politicians and the media. These arguments are effective because of their emotional appeal and simplicity, they are easy to understand. Some scientists publish work reporting findings with inflammatory language and little empirical data to substantiate their claims. The logic used is: if the cause of system decline is eutrophication, then a reversal of these conditions will return the ecosystem to its previous "pristine" state. As a result, the paradigm of nutrient pollution as the cause for seagrass and coral reef decline has dominated debate in Florida for over 15 years. Although compelling, these emotional and nonscientific approaches seldom leave room for alternate or complementary views.

There is a large body of scientific literature that elucidates a more nuanced and balanced picture of the complex system of the Florida Bay ecosystem, one which depicts the Florida Bay as a dynamic estuarine system influenced by upstream activities as well precipitation, inflow from the Gulf of Mexico, its own geological context as well as regional and global weather patterns. These results point to multiple actors leading to the current status of Florida Bay, and possible causes for the seagrass die-off of the late 1990s, rather than of the single source nutrients, specifically dissolved nitrogen, as described by some. Numerous types of data have been reviewed to give a full picture of the Florida Bay ecosystem, both past and present, and have been used to predict future conditions with the implementation of CERP.

The Everglades patchwork of wetland communities as it was encountered in the late 19^{th} century is a geologically recent system, originating ca. 5,000 years ago (Holling et al. 1994). Historically, the Kissimmee-Okeechobee watershed fed the Everglades throughout the year, but increased water flow during the rainy season accounted for ~76% of total rainfall into the system. As a result, pulses of freshwater were delivered to the Bay during the rainy season. These seasonal conditions influenced the Florida Bay estuarine conditions which would have also been variable throughout the year (more saline during the winter and less saline during the rainy season), depending on seasonal rain patterns and affects of annual weather. Many paleoecological studies have shown that salinity conditions in Florida Bay were naturally variable over time (Dwyer and Cronin 2001; Brewster-Wingard et al. 1998; Ishman et al 1998.) As seen in the paleorecord, changes in invertebrate population dynamics through time and space revealed natural salinity cycles over the past 300 years (Dwyer and Cronin 2001; Brewster-Wingard et al. 1998; Ishman et al 1998). Additional evidence in coral cores showed variation in levels of $\delta^{18}O$, also indicating changes in salinity before development (Swart et al. 1999).

Investigators have found evidence of changes in salinity and nutrient input at the turn of the century when significant modifications to the south Florida landscape began (Dwyer and Cronin 2001; Halley and Roulier, 1999; Brewster-Wingard et al. 1999; Brewster-Wingard et al. 1998; Ishman et al 1998, Orem et al. 1998). Changes in salinity were also recorded in coral skeleton isotope ratios (Halley et al. 1999; Swart et al. 1999; Swart et al. 1996; Smith et al. 1989). Fluorescence evidence showed a decrease in humic and fulvic acids from terrestrial sources in a scleractinian coral of Florida Bay during the twentieth century, suggesting a decrease in flow (Smith et al. 1989). With evidence of multiple authors with similar findings, and the knowledge that water delivery modifications significantly altered the Everglades, modified conditions in the Florida Bay environment are not surprising.

Global weather patterns including ENSO have a significant effect on precipitation and salinity patterns throughout the Bay over time, and continue to play a part in the water quality of Florida Bay (Cronin et al. 2002; Dwyer and Cronin 2001; Johns et al. 2001; Swart et al. 1999; Halley et al. 1994; Douglas and Engelhart 1981; Ropelewski and Halpert 1986; Montroy, 1987). These variables are uncontrollable and largely unpredictable in the context of ecosystem restoration. Further research on the effects of weather patterns on Bay salinity and nutrient dynamics would yield relevant information on the efficacy of water management decisions as related to the restoration of south Florida ecosystems, including the Florida Bay.

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The Florida Ocean and Coastal Resources Council

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The Florida Legislature in April 2005 created the Florida Oceans and Coastal Resources Council. This Council has three primary charges, creation of a Research Review, a Research Plan, and a Resource Assessment. These documents will be updated annually.

The Research Review and the Resource Assessment are intended to be used in developing the Research Plan. The Research Plan goes each year to the Legislature for the purposes of guiding its funding of Oceans and Coastal research. It can be anticipated that the priorities identified in the Research Plan may also affect decisions beyond those of the State Legislature.

Information on the Council and the status of the first editions of the three charges will be presented.

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Occurrence of C_{25} Highly Branched Isoprenoids in Florida Bay: Paleoenvironmental Indicators of Diatom-derived Organic Matter Inputs

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Highly branched isoprenoids (HBIs) with the C_{25} carbon skeleton are potentially valuable indicators of diatom-derived organic matter (OM) inputs to sediments. Although the occurrences of C_{25} HBIs have been widely observed in diatoms and recent environments, the investigations on those compounds in ancient sediments are rarely reported. In this work, a suite of C_{25} HBI monoenes and dienes were detected in a dated sediment core from Russell Key, central Florida Bay. Pt catalyzed hydrogenation proved all C_{25} HBIs to be acyclic alkenes with the same parent structure of 2, 6, 10, 14-tetramethyl-7-(3'-methylpentyl)pentadecane. The tentative double bond positions and geometries of three monoenes and one diene were established on the basis of comparisons of retention indices (RI) and mass spectra with those published for synthetic or isolated compounds.

Individual C_{25} alkene analyses showed significantly different depth profiles. Generally, the concentrations of dienes decreased rapidly with increasing depth and they were absent below 20cm, but this trend was not observed for the monoenes, suggesting that monoenes are more resistant to degradation. The highest concentration of total C_{25} HBIs was observed at mid depth in this core, reflecting strong historical inputs of diatom-derived sedimentary OM during that period. In fact, the depth profile of C_{25} HBIs reflected quite well historical variations in diatom abundance and variations in diatom species composition in central Florida Bay based on the results of fossil diatom species analysis by microscopy. A strong correlation coefficient was observed between the abundance of C_{25} HBIs and some species of diatoms. This study provides further evidence that some C_{25} HBIs can be applied as biomarkers for certain diatom inputs in paleoenvironmental studies.

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Applications of Molecular Markers in the Paleoenvironmental Reconstruction of Florida Bay

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The Everglades and Florida Bay are undergoing the world largest wetland restoration project with the aim of returning the system to hydrological conditions in place prior to anthropogenic modification. Therefore, it is essential to know what this original pristine condition was. In this study, molecular markers (biomarkers) were used in an attempt to assess historical environmental changes in Florida Bay. Two biomarkers of terrestrial plants, particularly mangroves (taraxerol and C_{29} *n*-alkane), combined with two seagrass proxies (*Paq* and C_{25}/C_{27} *n*-alkan-2-ones) revealed a sedimentary environmental shift from freshwater marshes to mangrove swamps and then to seagrass dominated environments, attributed to sea-level rise in Florida Bay since the Holocene. Generally, the data from the biomarkers showed maximum values for *Paq* and C_{25}/C_{27} *n*-alkan-2-ones in the upper parts of all cores, suggesting that the greatest abundant seagrass cover is a relatively recent rather than a historically long-term, bay-wide phenomenon. The greater oscillations in frequency and amplitude for the biomarkers were seen in the latter part of 20th century and potentially reflected an ecosystem under increasing anthropogenic stress. A sharp drop of *Paq* values in the upper part for two cores from the central bay may reflect an early seagrass die-off.. All algal biomarkers such as C_{20} HBIs, C_{25} HBIs and dinosterol indicative of cyanobacteria, diatoms and dinoflagellates respectively dramatically increased towards the surface and may be attributed to increased nutrient inputs to Florida Bay. The selected molecular markers seem adequate to evaluate environmental change in Florida Bay.

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Oral Abstracts

Mangrove-Estuarine Transition Zone

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Landscape-Scale Spatial and Temporal Patterns of Aboveground Net Primary Productivity (ANPP) in Everglades National Park (2001-2004)

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Aboveground net primary productivity (ANPP) is an important measure of ecosystem function as it provides insight into key ecological dynamics of an area. We present here a unique dataset representing four years (2001-2004) of data on the spatial and temporal patterns of ANPP in dominant primary producers (sawgrass, periphyton, mangroves and seagrasses) in the oligotrophic "upside-down" Florida Everglades coastal ecosystem. The 17 sites of the Florida Coastal Everglades Long Term Ecological Research (FCE LTER) program are located along fresh-estuarine gradients in Shark River Slough (SRS) and Taylor River/C-111 Basin (TS/Ph) that drain the western and southeastern Everglades respectively (Fig. 1). Trends and patterns of ANPP during the study period are influenced by freshwater inputs into the Everglades and mediated by global (e.g. El Nino) and regional (e.g. hurricanes) climatic factors that alter the rainfall patterns, hydrology, salinity, nutrient inputs and in the case of periphyton, community composition.

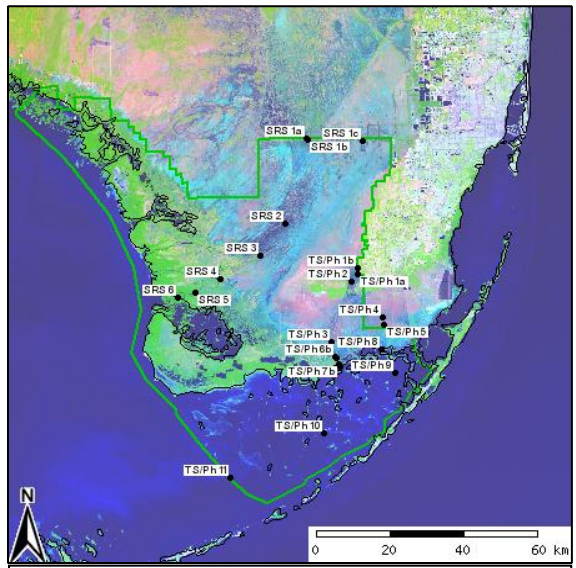

Figure 1. Location of LTER sites in ENP.

Interannual comparisons revealed that sawgrass ANPP at both basins and periphyton ANPP at SRS were lowest in 2003 (Table 1). This observation could have been influenced by rainfall during the dry season of 2003 which resulted in higher water levels in the sawgrass prairie. Childers et al. (in press) have shown sawgrass ANPP to be negatively related to annual water depth, hydroperiod and depth-days (i.e. annual flooding duration). The increased rainfall also resulted in lower than average salinity levels in the estuarine ecotones and in Florida Bay during the dry season that might have contributed to higher mangrove and seagrass ANPP in 2003. In 2004, a late wet season where rainfall did not begin until July, the drydown may have contributed to higher sawgrass ANPP at the SRS sites.

Table 1. The 2001-2004 average ANPP (± standard error) for each primary producer within each basin.

	Sawgrass (g $m^{-2}yr^{-1}$)		Periphyton (g C $m^{-2}yr^{-1}$)		Mangroves (g $m^{-2}yr^{-1}$)		Seagrass (g $m^{-2}yr^{-1}$)
	SRS	TS/Ph	SRS	TS/Ph	SRS	TS/Ph	TS/Ph
2001	464.4 ± 149.1	368.2 ± 43.8	18.93 ± 7.3	4621 ± 2688	1926 ± 348.1	323.7	76.3 ± 36.9
2002	486.0 ± 39.2	314.9 ± 24.0	64.6 ± 14.8	2361 ± 614.0	1779 ± 374.0	321.0	74.8 ± 40.1
2003	408.6 ± 122.6	287.4 ± 28.6	12.9 ± 2.0	2467 ± 1126	1858 ± 249.2	401.3	142.6 ± 90.7
2004	563.2 ± 176.0	334.3 ± 37.1	15.1 ± 9.8	1186 ± 264.0	1758 ± 345.3	249.0	53.6 ± 15.1

Intersite comparisons showed ANPP differed along the gradients from fresh-marine environment (Fig. 2). At the Shark River sites, ANPP generally increased with distance downstream while productivity peaks were observed at TS/Ph 3, 4 or 5 depending on producer type (Fig. 2). Increased ANPP with greater marine influence was also found in the seagrass *Thalassia* *testudinum* in Florida Bay. These results not only provide insight into the functional differences between these two major drainage systems but also reveal the importance of the mixing of fresh and marine inputs to ecosystem productivity in the terrestrial and shallow subtidal Everglades ecosystem.

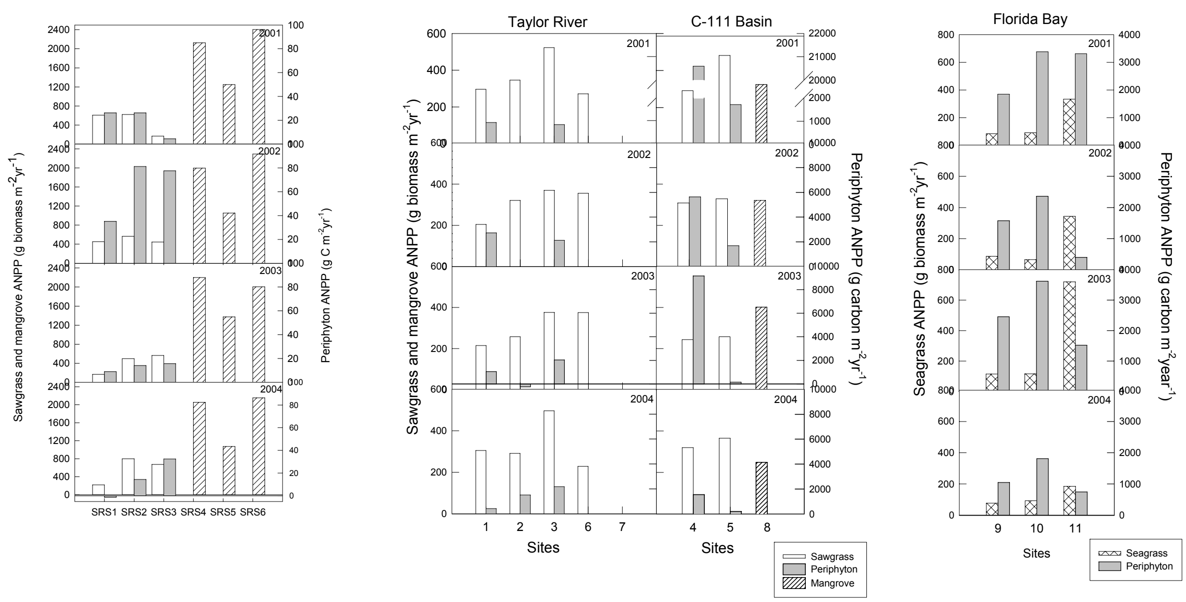

Figure 2. The 2001-2004 ANPP of sawgrass, periphyton, mangroves and seagrasses at the LTER sites located along Shark River Slough (SRS) and the Taylor River/C-111 Basin (TS/Ph).

The SRS and TS/Ph drainages are unique and differ in the relative contributions of their primary producer types (Fig. 2). Inter-basin comparisons revealed that sawgrass and mangrove ANPP were higher at Shark River Slough relative to Taylor River/C-111 Basin but the opposite pattern was found in periphyton ANPP (Table 1). At Taylor River/C-111 Basin, periphyton dominated ecosystem ANPP, accounting for most of the total productivity of the freshwater marshes. In the SRS marshes, deeper water and a different periphyton community composition relative to the TS/Ph sites most likely account for the lowered relative influence of periphyton on total ANPP.

Despite its oligotrophic nature, the Everglades is a highly productive system. Total productivity in the Everglades is comparable to other grassland and wetland ecosystems of the world. The Everglades is defined by high ecosystem productivity in marshes that are dependent on the maintenance of seasonal inputs of nutrient-poor freshwater. This ecosystem is also unique because of the high proportion of periphyton productivity in the southeast Everglades that has the potential to regulate other ecosystem attributes including soil formation, water quality and availability of fixed carbon to the rest of the food web.

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Integrating Physical and Ecological Models to Assess Restoration Impacts on Fish, Roseate Spoonbills and American Crocodiles in Northeastern Florida Bay

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Water management activities in southern Florida have altered hydrologic conditions throughout the region with declines in wading bird and crocodilian numbers linked to these changes. In particular, the Roseate Spoonbill (*Platelea ajaia*) and the American Crocodile (*Crocodylus acutus*) in northeastern Florida Bay exemplify the detrimental effect of water management practices on the Everglades landscape and have been identified as key indicator species for restoration of this estuarine ecosystem. In northeastern Florida Bay, these two species have overlapping nesting ranges, forage in the same habitat, and have similar hydrologic and hydrographic requirements. In addition, both species are dependent on the community of small, demersal fishes as the base of their respective food webs. This fish community has also been demonstrated to respond in a predictable manner to anthropogenic hydrologic and hydrographic changes. The Comprehensive Everglades Restoration Plan (CERP) seeks to restore and preserve South Florida's ecosystems by reestablishing more natural hydrological conditions in the remaining Everglades wetlands. Therefore, changes to the hydrologic regime that lead to the recovery and maintenance spoonbills, crocodiles and their prey base in Everglades National Park will indicate the success of CERP in meeting its restoration goals.

Recently, we have focused on developing interactive models that link hydrologic changes to hydrography, prey base production and success of spoonbills and crocodiles. The ultimate goal of this effort is to use output from the South Florida Water Management Model (SFWMM) and the Natural Systems Model (NSM) to predict hydrology and hydrography of the coastal wetlands, prey base fish abundance and availability, and measures of spoonbill and crocodile success under various hydrologic regimes. We believe that this will provide an invaluable tool in identifying water management practices that will be beneficial to Florida Bay under CERP activities.

The Southern Inland and Coastal System (SICS) model uses empirical data or SFWMM outputs as boundaries for a numerical model of flow and transport to estimate water levels and salinity in the estuarine areas of the mainland and Florida Bay. SICS utilizes a hydrodynamic surface-water model coupled to a three-dimensional ground-water model and a higher grid resolution than the SFWMM. This model produces estimates of salinity and water level on a daily time step for a 6 year period (1995-2001) and has a 305x305m grid size. Data generated by the SICS model using SFWMM boundaries will be validated by comparing model outputs to an empirical hydrologic data set collected within the mangrove habitat at four locations for the same time period.

Simulation output from SICS model is, in turn, used to drive the ALFISHES Model; an Across Trophic Levels System Simulator (ATLSS) model that predicts responses of functional fish groups in Everglades mangrove zone of Florida Bay. (ATLSS is a collection of ecological models designed to assess the impact of changes in hydrology on a suite of higher trophic level species of the southern Florida ecosystem.) Specifically, ALFISHES uses hydrologic inputs (empirical or simulated) to predict responses of prey bases fishes to changes in water level and salinity. The ALFISHES model covers the same spatial extent as the SICS model and predicts fish abundance (density and biomass) and availability on square meter basis for each grid cell on a five day time step. ALFISHES data output will be validated by comparing fish abundance and availability estimates to an empirical data set collected at four locations in mangrove wetlands for the same period as the model run.

A habitat suitability index (HSI) has been developed to model spoonbill nesting success in Florida Bay. The Spoonbill HSI model evaluates influence of hydrology on conditions for foraging by spoonbills in mangrove swamps adjacent to a portion of northeastern Florida Bay. The model is based on seventy years of spoonbill monitoring that included nesting success and foraging behavior. Model equations, supporting science, and validation and application of these models are documented. This model was used to create another ATLSS model (a landscape-level spatially-explicit species index or SESI model), that is designed to assess the relative potential for breeding and/or foraging success of the Roseate Spoonbill in northeastern Florida Bay. The inputs for this model are derived from SICS and ALFISHES outputs.

A habitat suitability model was also developed for the American crocodile to evaluate effects of restoration on this endangered species. The model is based on laboratory experiments and over 20 years of field data and includes components for hatchling survival (fall), crocodile foraging (spring), and nesting (summer). The crocodile suitability model uses output from hydrological models to determine salinity and water levels and uses rainfall data provided by NOAA and DOI. An additional ATLSS SESI model was developed based on the crocodile Habitat Suitability Model and was also based on SICS and ALFISHES outputs.

With development of restoration scenario capabilities in the SICS model, linking these complex models in an ecologically meaningful way will prove an effective and powerful tool for evaluating potential impact of water management policies on spoonbill and crocodile populations in Florida Bay and associated wetlands. In the future we plan to develop a decision-analytic framework to evaluate alternative management actions.

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Terrestrial Brackish Groundwater Discharge - a Significant Flux of Phosphorus to the Mangrove-Estuarine Transition Zone of the Southern Everglades

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We define a new phenomenon we call Terrestrial Brackish Groundwater Discharge (TBGD), which is related to submarine groundwater discharge (SGD), but occurs when seawater intrudes inland to force brackish groundwater to discharge to the coastal wetlands. A geochemical investigation of both the groundwater and surface water in the southern Everglades was conducted to investigate the occurrence of TBGD associated with seawater intrusion. A comparison of equivalent fresh-water head levels in brackish groundwater wells with the overlying surface water indicate the potential for discharge of brackish groundwater. During times of high water levels, the surface water chemistry remained fresh. Enhanced chloride, sodium, and calcium concentrations, indicative of brackish groundwater discharge, were observed in the surface water at times of low water levels. The brackish groundwater was distinguished from surface seawater in that it contained elevated concentrations of calcium and phosphorus. Brackish groundwaters of the southern Everglades contain 1 to 2.3 μM concentrations of total phosphorus. These concentrations exceed the expected values predicted by conservative mixing of local fresh groundwater and surface seawater, which both have phosphorus of less than 1 μM. The additional source of phosphorus may be from seawater sediments or result from the release from the aquifer matrix due to water-rock interactions (such as carbonate mineral dissolution and ion exchange reactions) induced by mixing fresh groundwater with intruding seawater. We propose that TBGD is a significant addition of phosphorus (the limiting nutrient) to the coastal wetlands of the southern Everglades.

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Marsh Ecosystem Nitrogen Dynamics of the C-111 Basin

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There is ongoing need for additional information and better understanding of the transformation, fate, and connectivity of nutrients in the Southern Florida Ecosystems. More specifically, research focusing on the manner in which Southern Everglades marshes process both nitrogen and phosphorus are of particular interest. This biogeochemical processing of nitrogen and phosphorus plays an important role in determining the amount and composition of nutrients being supplied to downstream coastal ecosystems like Florida Bay. The C-111 basin directly supplies freshwater, dissolved organic matter (DOM), impurities, and nutrients to northeastern Florida Bay. Through better understanding of nitrogen and phosphorus dynamics in this region managers and scientists will gain further elucidation of nutrient cycling in the Southern Everglades and its influence on the Florida Bay ecosystem.

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 into northeast Florida Bay. Since this restoration effort the C-111 basin has been an excellent study site to gauge ecosystem response to hydrological restoration (Parker *et al.* 2005 and Troxler Gann *et al.* 2005). However, nitrogen cycling dynamics in the C-111 basin have not been directly studied since levee removal. The objective of this experiment was to characterize and quantify nitrogen cycling processes in the Southern Everglades marsh ecosystem. To do this, 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 (FCE LTER site TS/Ph 4) and an interior marsh site (W-3). In addition to the ^{15}N tracer experiment, three varying loads of phosphorous (0.00, 6.66, and 66.6 g 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 0.00g P lead to a peak ^{15}N value of 307.45‰ occurring on day 3; meanwhile, the 6.66gP load lead to a peak ^{15}N value of 265.65‰ occurring one day earlier on day 2. In addition, it appears that in both P treatments ^{15}N values for periphyton reached equilibrium of 176.23‰ and 168.06‰, following the maximum peak values on days 3 and 2 respectively. These values could represent a nitrogen uptake threshold for periphyton in these marshes.

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 (TS/Ph-4) possess a heavier, more enriched ^{15}N signal (7.34‰± 2.27) than a downstream site (TS/PH-5) which has acquired a lighter, more depleted signal (1.17‰± 1.24). These data suggest that the marshes of the C-111 basin are acting as a sink for canal-borne dissolved inorganic nitrogen (DIN) and a source for “new” marsh derived DON to downstream ecosystems.

These findings illustrate both that phosphorus availability may be interconnected to nitrogen cycling rates and that the marsh is acting to transform and remove canal-borne nitrogen prior to export to Florida Bay. The combination of these findings with long term water nutrient data will result in a more complete picture of the concentration and composition of nitrogen exports to Florida Bay.

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Poster Abstracts

Mangrove-Estuarine Transition Zone

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Forecasting Responses of the Endangered American Crocodile to Alternatives for Restoration of Greater Everglades Ecosystems

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The American crocodile is an endangered species in an endangered ecosystem. The Everglades is the target of a multi-billion dollar effort to restore some of the hydrological and ecological functions of pre-drainage conditions. A key component of restoration is re-establishing freshwater flows to mangrove estuaries. The distribution and abundance of crocodiles in an estuary is strongly influenced by fresh water flow. A habitat suitability model was developed for the American crocodile to evaluate effects of restoration on this endangered species. The model is based on laboratory experiments and over 25 years of field data and includes components for hatchling survival (fall), crocodile foraging (spring), and nesting (summer). The crocodile suitability model uses output from the USGS SICS hydrological model to determine salinity and water levels and uses rainfall data provided by NOAA and DOI. Ecosystem restoration recommendations based on the model include: 1) restoring the amount of freshwater flow, 2) restoring location of freshwater flow through existing mangrove swamps and reducing point discharge of freshwater through canals, and 3) restoring timing of flow so that peak freshwater discharge occurs at thee end of the wet season into the dry season, and that water levels continue to recede during the dry season to concentrate prey for foraging. We hypothesize that re-establishing amount, location and timing of flow to Everglades estuaries will not only help conserve this endangered species, but also promote restoration of this endangered ecosystem.

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Linking Hydrologic Modeling and Ecologic Modeling: Application of Spatially-Explicit Species Index (SESI) Model for Adaptive Ecosystem Management in the Everglades Mangrove Zone of Florida Bay

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The Across Trophic Levels System Simulator (ATLSS) is a collection of ecological models designed to assess the impact of changes in hydrology on a suite of higher trophic level species of the southern Florida ecosystem. ATLSS requires hydrologic input to assess the effects of alternative proposed restoration scenarios on trophic structure. An ATLSS model (ALFISH) for functional fish groups in freshwater marshes in the Everglades of southern Florida has been extended to create a new model (ALFISHES) to evaluate the spatial and temporal patterns of fish density in the resident fish community of the Everglades mangrove zone of Florida Bay. 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 may be 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 other wading birds.
To facilitate linkage of hydrologic and ecological model components, we used a multi-modeling approach. We report on recent advances in the development of a generic multi-level modeling framework for ecological modeling. 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. An object model that includes support for open geospatial data standards for grid coverages and simple features is used to exchange model state information between model components and between the simulation server and a user-friendly GIS client.

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Assessing the Preservation of Organic Matter in the Mangrove-Dominated Estuary of Shark River Slough

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Mangrove forests are among the most productive coastal ecosystems in the world, and major primary producers in the estuaries of south Florida. Mangroves play a vital role in the carbon and nutrient cycles of these areas, contributing large amounts of organic matter in the form of autochthonous litter fall and acting as a trap for allochthonous organic, mineral, and nutrient inputs. Mangrove forests play a vital role in sustaining intertidal ecosystems; they fuel coastal food webs, provide shelter for a number different animal species, and their ability to trap and retain sediments allows these coastal habitats to maintain the elevation of the soil surface against sea level rise. With the Everglades restoration effort underway, it is now more important than ever to understand the impact that decreased freshwater input to this region over the last century has had on organic matter cycling and peat formation in order to predict how these processes will respond to the restoring of the altered hydrology.

For this study, mangrove peat soil cores from three estuarine sites along Shark River Slough were analyzed with the goals of (1) determining the major sources and potential historical changes of organic matter to the sediments, and (2) assessing the extent of preservation of organic matter within the peat soils down-core along a salinity/nutrient gradient. This was attempted using solid-state ^{13}C CP-MAS Nuclear Magnetic Resonance, geochemical proxies and biomass-specific lipid molecular markers. The relative degree of humification was also assessed down-core via UV-VIS spectroscopy of extracted humic acids. Lipid biomarker analyses revealed that mangroves have been the dominant vegetation at these sites, especially at the lower Shark River estuary, and that fungi and cyanobacteria are also contributors of organic matter to mangrove soils. The abundance of a series of ring-A-degraded triterpenoids in the peat extracts from all sites suggests microbial activity within the soil is high and that aromatization processes associated with the degradation of 3-oxy triterpenoids may in fact occur during early diagenesis, on a shorter geochemical timescale than previously assumed. Differences in the degree of soil humification between the upper and lower estuary, along the salinity/nutrient gradient, may be reflecting differences in below-ground primary production and root turnover times. Preliminary results from lignin phenol and ^{13}C-NMR analyses show that after surficial diagenetic processes occur the chemical signature of mangrove-derived organic matter is well preserved in the soils.

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Effects of an Abnormally Hypersaline Year (2004-05) on the Submerged Aquatic Vegetation in the Mangrove Ecotone of Northeastern Florida Bay

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In 1996 we established a routine submerged aquatic vegetation (SAV) monitoring project within the mangrove ecotone of northeastern Florida Bay. The objectives of this project are: 1) Characterize seasonal patterns of submerged vegetation community structure and distribution in the estuarine watersheds along the north shore of Florida Bay from Barnes Sound to Taylor River. 2) Determine any correlations between physical factors and plant distribution patterns. 3) Establish baseline data in order to assess the effectiveness of CERP activities in the future. 4) Provide collaborative and supporting data for other monitoring, experimental research and modeling efforts.

Surveying is conducted every six weeks at 4 sites: Taylor River (TR), Joe Bay (JB), Highway Creek (HC) and Barnes Sound (BS). At each site, 6 fixed stations along a salinity gradient, ending at Florida Bay are surveyed. Abundance estimates of SAV are assessed using a point intercept percent coverage method. Surface water salinity, temperature, water depth and water clarity are measured at each station on day of survey. Permanent hydrostations located at the uppermost surveying station at each site continuously monitor salinity, temperature, water level, pH, and dissolved oxygen.

During the June 2004 – May 2005 hydrologic year, surface water in the mangrove ecotone had the highest recorded maximum salinity, the longest duration of hypersalinity, and the shortest period of freshwater inundation than in any year for the past decade. Annual mean salinity for 2004-05 was nearly four times greater than the ten year average annual salinity recorded at our 4 sites. The highest annual standard deviations of salinity were also recorded at these sites over the same time period (Table 1).

Table 1. Annual mean salinity ± annual standard deviation of salinity over the past decade at 4 SAV monitoring stations.

	Joe Bay	Highway Creek	Taylor River	Barnes Sound
95-96	2.98 ± 4.89	3.64 ± 5.34	2.43 ± 4.65	11.51 ± 8.35
96-97	6.40 ± 9.95	5.76 ± 7.32	4.85 ± 8.33	18.49 ± 9.05
97-98	1.54 ± 5.22	1.30 ± 2.96	1.79 ± 4.84	12.44 ± 6.27
98-99	8.58 ± 12.90	6.84 ± 8.96	6.85 ± 10.06	20.11 ± 10.62
99-00	5.70 ± 10.25	5.12 ± 6.83	3.45 ± 6.57	16.20 ± 10.50
00-01	6.87 ± 9.16	8.29 ± 10.25	9.84 ± 11.25	20.86 ± 8.17
01-02	8.47 ± 11.78	10.49 ± 13.50	9.14 ± 13.45	21.99 ± 14.34
02-03	5.92 ± 8.02	6.40 ± 7.81	3.17 ± 6.05	20.82 ± 11.36
03-04	5.07 ± 8.62	5.76 ± 8.82	3.11 ± 6.92	18.51 ± 11.62
04-05	20.59 ± 16.81	21.27 ± 15.74	18.95 ± 17.32	32.75 ± 10.47

Monitoring stations located in ponds and streams upstream from Florida Bay all experienced significant declines in SAV abundance in concurrence with the increased and highly variable

salinity of 2004-05. At respective sites, the decrease in total SAV abundance from the previous year was: 80.3%(JB), 62%(HC), 80.2%(TR), 33%(BS).
Percent coverage of plants was substantially lower during 2004-05 than recorded in the past ten years at these upstream stations. No plant growth at all was observed at two stations where in previous years plant growth was abundant.

Along with extremely low abundance, a shift in species composition was also noted at upstream stations during 2004-05. Freshwater marsh plants *Utricularia spp.* were absent from five stations where they have previously been abundant each wet season. 2004-05
was also the first year *Chara hornemanii* and *Najas marina* were absent or in very low abundance at a number of stations. At the same time, a number of marine plant and algae species were observed for the first time at these stations. These included: *Halodule wrightii, Acetabularia crenulata, Laurencia spp., and Polysiphonia spp.*.

Downstream stations at all sites that are near or in Florida Bay did not experience the same severe declines in abundance. These stations have historically consisted of mixed beds of *Halodule* and *Ruppia maritima*. However, throughout 2004-05, *Ruppia* declined in abundance and had completely died off by the end of the hydrologic year. Furthermore, highest densities of marine algae including *Acetabularia*, *Laurencia* and *Polysiphonia* were observed at these downstream sites.

These analyses indicate that increased salinity and salinity variation during 2004-05 were detrimental to fresh/brackish water submerged macrophytes living in the mangrove ecotone and a shift towards more salt tolerant species may be occurring.

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Trends in the Density of *Eleocharis cellulosa* in Relation to Salinity and Hydroperiod in the Coastal Wetlands of Northeastern Florida Bay

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The coastal wetlands of northeastern Florida Bay form an ecotone between the freshwater Everglades and marine environment of Florida Bay. This relatively narrow band (≈5km) of coastal mangrove forest is influenced by both freshwater and marine systems and has the capacity to reflect ambient conditions in both major ecosystems. The hydrology of this area varies greatly on a seasonal and annual basis and is influenced by local weather conditions, rainfall, and water management practices. Construction and operation of a network of canals and water control structures known as the South Dade Conveyance System has reduced the pressure of the freshwater head in these wetlands. This, in conjunction with rising sea levels has led to more frequent and sustained saltwater encroachment into this area. In response to this advancement of marine and brackish waters, a steady landward increase of dwarf red mangrove (*Rhizophora mangle*) is supplanting historic freshwater sawgrass (*Cladium jamaicense*) marshes. Spikerush (*Eleocharis cellulosa*) is another major component of the emergent vegetation community of the ecotonal wetlands and is found in both freshwater environments and saline mangrove environments near the coast. In the spring of 1996, a project was established to monitor abundance of *E. cellulosa* in the coastal wetlands of northeastern Florida Bay. The goals of this project are: 1) Evaluate long term density patterns of *E. cellulosa*. 2) Determine seasonal and annual hydrologic effects on density. 3) Establish baseline data in order to assess the effectiveness of CERP related activities.

Surveying was conducted at three sites, located just north of Florida Bay at the terminus of the Taylor Slough/C-111 drainage area. From east to west these sites are: Highway Creek (HC) located on a tributary west of Highway Creek, Joe Bay (JB) located north of the eastern end of Joe Bay, Taylor River (TR) located north of Little Madeira Bay on Taylor River. At each site, five 0.5m^2 quadrats were permanently placed in the wetlands where *E. cellulosa* was originally (spring of 96) present in varying densities. At each site, individual quadrats were located within 200 yards of each other. Sites were visited every six weeks and all emergent shoots and stems of *E. cellulosa* located within quadrats were counted. Canopy height, along with maximum stem length was also recorded for each quadrat. Hydrostations located at each site continuously monitored surface water level, salinity, and temperature. Pore water salinity was measured on day of surveys.

Surface water levels fluctuate an average range of 55cm throughout the course of a year. The wetlands were flooded most of the year, with periods of substrate exposure coinciding to each dry season. Periods of exposure ranged from a few days to several weeks. Surface water salinity ranged from freshwater (<1psu) to hypersaline (>36psu) and was extremely variable on both a seasonal and annual basis. Pore water salinity was significantly less variable seasonally but has steadily increased from a mean (3 sites combined) of 5psu in 1996 to 25psu in 2005. Density of *E. cellulosa* has declined at HC by approximately 75% since 1996 (from 80 stems/m^2 to 20 stems/m^2). At JB, stem density has also decreased over the study period, but at a much slower rate. Density has declined from 210 stems/m^2 to 150 stems/m^2 (28% decrease). These declines in density appear to be in relation to increased pore water salinity over the same time period. However, at TR *E. cellulosa* density has remained relatively stable since the study began, with a mean of just above 80 stems/m^2.

Seasonal variation of shoot and stem density were also apparent at all sites in relation to the wet/dry cycle. Increased salinity on the wetlands during the dry season correlated negatively with stem and shoot density. Stem density at both TR and HC varied approximately 50% between wet and dry seasons. On average, density at TR declined from 120 stems/m^2 in the wet season to 60 stems/m^2 in the dry season. Seasonal variation was less consistent at JB, however extreme die-back and re-growth events occurred on a number of occasions between wet and dry periods. During the 2004/05 hydrologic year, stem density declined from a high of 355 stems/m^2 during the wet season to a low of 43 stems/m^2 during the dry season.

Hydroperiod varied on an annual basis and was positively correlated with *E. cellulosa* density. Years that experienced extended periods of flooded, freshwater conditions resulted in the greatest densities of shoots and stems. Low water levels in conjunction with extended hypersaline conditions resulted in lowest densities. Shoot/Stem ratio and canopy height also increased during periods of freshwater. The mean shoot/stem ratio (all sites) was 1:2.64. This ratio on average increased in the wet season to 1:3.04 and decreased in the dry season to 1:2.17. Canopy height averaged 37.5cm during the wet season. During the dry season, shoots and stems went through a browning and wilting phase which culminated in the death of many shoots and a decline of canopy height to an average of 12.5cm. New stems typically emerged in late June/early July with the onset of elevated surface water levels and surface water salinities less than 5psu.

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Tracking Rates of Salt-Water Encroachment Using Fossil Mollusks in Coastal South Florida

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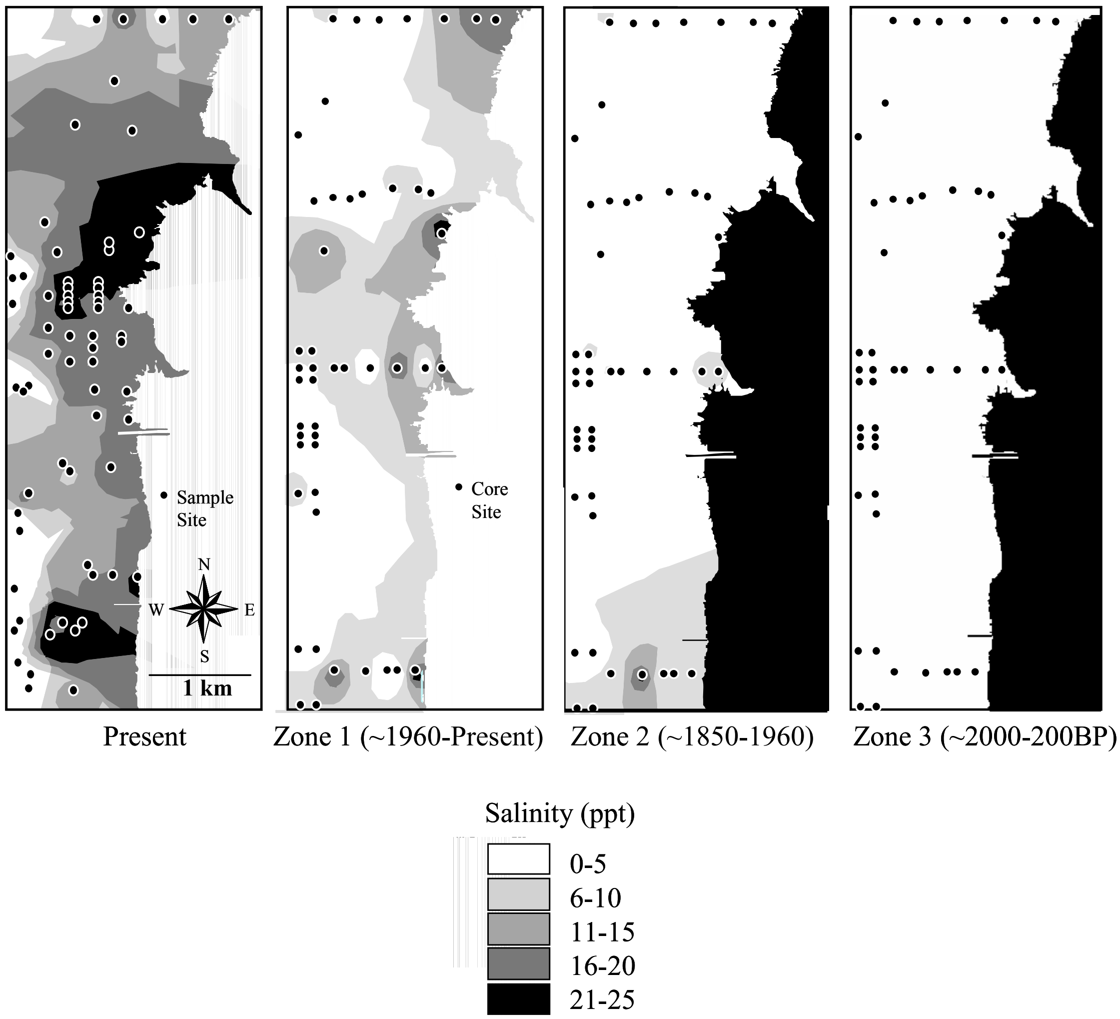
A combination of sea-level rise and diversion of natural tidal drainages has caused rapid salt-water encroachment into South Florida's coastal wetlands. We determined the rate of migration of coastal vegetation zones in response to salt-water encroachment through paleoecological analysis of mollusks in 36 sediment cores taken along transects perpendicular to the coast in a 5.5 km^2 band of coastal wetlands in southeast Florida. Transects from the interior to the coast intersected five ecotones between distinct vegetation zones: freshwater swamp forest, freshwater marsh, and dwarf, transitional and fringing mangrove forest. Vegetation composition, soil depth and organic matter content, porewater salinity and the contemporary mollusk community were determined at 226 sites to establish the salinity preferences of the regional mollusk fauna.

Resulting calibration models allowed accurate mollusk-based inference of salinity and vegetation type from fossil assemblages (R^2 = 0.79 and 0.67, respectively) in chronologically calibrated (^{210}Pb and ^{14}C) sediments. Most sediments were shallow (20-130 cm) and permitted inferences on a coarse temporal scale for three zones; an upper peat layer (zone 1) representing the last 30-70 years, an mixed peat-marl gyttja (zone 2) representing the previous ca. 150-250 years and a basal section (zone 3) of Holocene marl deposits with basal dates ranging from 310 to 2990 YBP. Modern peat accretion rates averaged 3.1 mm yr^{-1} while subsurface marl accreted more slowly at 0.8 mm yr^{-1}.

Mollusk-inferred pore-water salinity and vegetation type for zone 1 show a steep gradient with freshwater communities being confined west of a north-south drainage canal constructed in 1960 (Fig. 1). In contrast, inferences for zone 2 (pre-drainage) suggest that freshwater marshes and associated forest units covered 90 % of the area, with mangrove forests only present along the peripheral coastline. During the entire pre-drainage history, salinity in the entire area was maintained below a mean of 2 ppt and only small pockets of mangrove vegetation type were present; currently, salinity averages 13.2 ppt and mangroves occupy 95% of the wetland. Over 3 km^2 of freshwater wetland vegetation type have been lost from this basin due to lateral salt-water encroachment rates, calculated from the mollusk-inferred interior migration rate of freshwater vegetation type of 3.1 m yr^{-1} for the last 70 years (compared to 0.14 m yr^{-1} for the pre-drainage period). This rapid rate of encroachment is facilitated by sea-level rise and freshwater diversion. Plans for rehydrating these basins with freshwater will require high-magnitude re-diversion to counteract locally high rates of sea-level rise and a long-term perspective to restoration.

Figure 1. Contour maps of salinity based on weighted-averaging regression/calibration inferences from mollusk assemblage composition in surface material (present) and sediment zones 1, 2 and 3. Coring site locations are indicated.



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Sedimentologic and Geophysical Study of the Stratigraphy and Development of a Modern Carbonate Island, Cotton Key, Florida

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Cotton Key is a triangular shaped carbonate mud island of recent age in the Southeastern region of Florida Bay. Currently the periphery is covered in mangroves, and the island is dominated by a skeletal wackstones deposit, gray to grayish brown in color that is up to 2.5 meters thick. The wackstones overly limestone bedrock, Pleistocene in age. One of numerous carbonate islands dotting the southeastern boundary of the Everglades National Park, Cotton Key and analogous neighbors are classical interpreted in 2-dimesional geometry as comprised of sediments and mud banks representative of a single shallowing upward sequence related to Holocene sea level rise flooding over flat, hardened Pleistocene bedrock. However, under certain circumstances, two separate sequences may be preserved beneath Florida Bay Islands; an observation with serious implications for standard shallowing-upwards models of carbonate tidal flat deposits.

The purpose of this study is to reexamine the deposits beneath Cotton Key in Florida Bay using a combination of closely spaced sediment push cores and shallow geophysical imaging techniques. This study was the first of to test the feasibility of using ultra-shallow seismic on these types of deposits. Seven sediment cores were collected to evaluate the island stratigraphy and paleo environment chronology. Two seismic lines, at right angles were collected. The lines consisted of 15-centimeter spaced geophones and a near-source, nonelastic, seismic impulse source. The practical implementation of high-resolution seismic imaging at ultra-shallow depths may have the potential to complement ground-penetrating radar, chiefly in areas where materials exhibiting high electrical conductivity, such as clays or seawater saturated sediments, prevent the effective use of ground penetrating radar. Preliminary geophysical results indicate that varying acoustic-based geophysical devices were effective at shallow depths in modern carbonate environments. Ultra-shallow seismic, according to the results, has potential applications in modern carbonate environments.

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Habitat Suitability Index for Roseate Spoonbills Nesting in Northeastern Florida Bay

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The Roseate Spoonbill (*Platelea ajaia*) serves as one of the key indicator species for restoration of the estuarine ecosystems in South Florida. Water management activities have altered hydrologic conditions throughout the region with a 90% decline in the numbers of wading birds being one result. The reduction in wading bird numbers signals a general decline in the functioning of the region's ecosystems as a consequence of this hydrologic alteration. In particular, the case of spoonbills nesting in northeastern Florida Bay exemplifies the detrimental effect of water management practices on the Everglades landscape. The Comprehensive Everglades Restoration Plan (CERP) seeks to restore and preserve South Florida's ecosystems by reestablishing more natural hydrological conditions in the remaining Everglades wetlands. Therefore, changes to the hydrologic regime that lead to the recovery and maintenance of the numbers of spoonbills in Everglades National Park will indicate both the success of CERP in meeting its restoration goals and success by the Park in its mandate.

We will present a habitat suitability index (HSI) model for spoonbills that nest on islands in Florida Bay in Everglades National Park. Habitat suitability index models provide resource managers with a means to evaluate the benefits to spoonbills of changes to hydrologic conditions caused by changing the amount or timing of managed surface water flows into Everglades National Park. The HSI model described evaluates the influence of hydrology on conditions for foraging by spoonbills in the mangrove swamps adjacent to the northeast portion of Florida Bay. The model equations, the supporting science, and the validation and application of these models will be documented.

The HSI model described is conceived as an initial step toward building a general tool for ecological forecasting in this portion of the Park. The grid used for these calculations is designed to support the implementation of a suite of linked physical, water quality and ecological (population) models for forecasting ecological change in this region of the Park. The output from the HSI model can be used in the context of a decision-analytic framework to evaluate alternative management actions or restoration plans in relation to proposed manipulations of hydrology and salinity.

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Using Albino Mutations in Red Mangroves as an Indicator of Anthropogenic Stress and A Long-term Metric of Recovery following Restoration in Florida Bay

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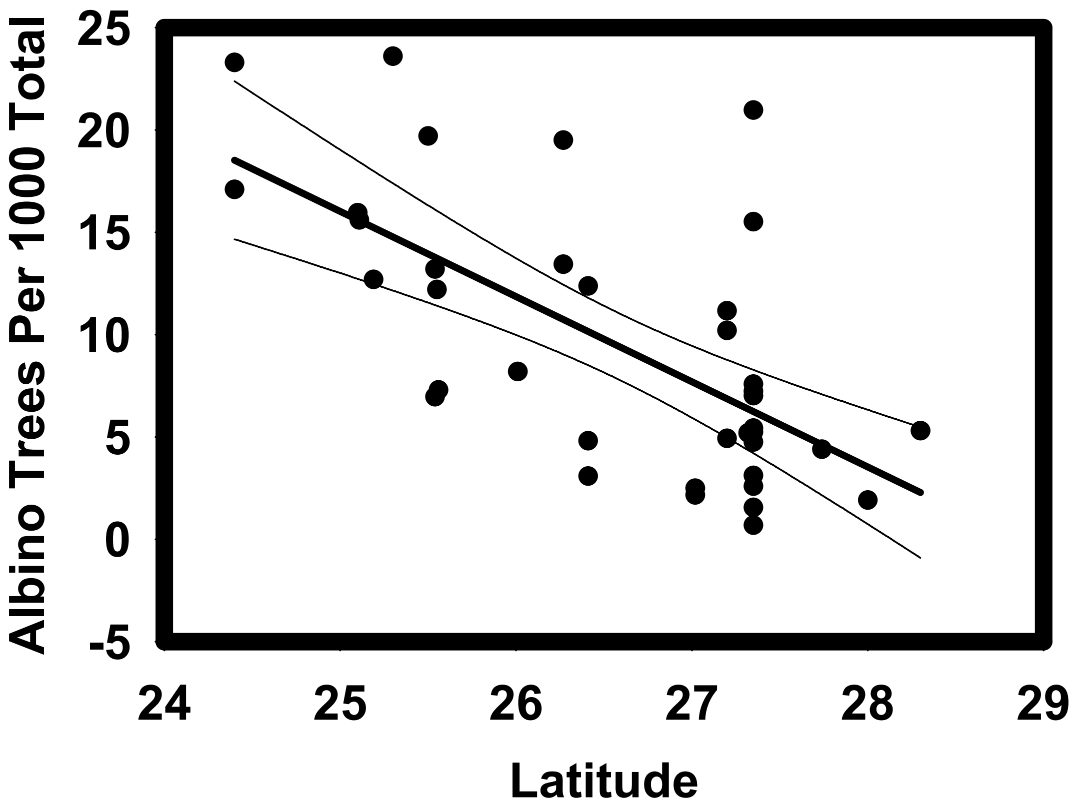
Mutation rates increase with contamination by mutagenic chemicals. We have recently shown how albino mutation rates of red mangroves measured by simple field survey techniques can distinguish between polluted and non-impacted sites in Tampa Bay (Wetlands 25:326-334). We present here preliminary data from 7 other Florida estuaries (n=38 total forests, 31,513 total reproducing trees, and 268 trees producing albino propagules). *Rhizophora mangle* mutation rates increased with decreasing latitude (Fig. 1). The shoreline of Florida Bay, as indicated by 5 sites in the Everglades National Park and Florida Keys, had significantly higher mutation rates than more northerly Florida estuaries (ANOVA, $P<0.005$, $R^2 =0.431$). Although tree size was positively correlated with mutation rate and negatively correlated with latitude, it was not a significant covariate in the ANOVA. Thus, surveys of more sites are required to determine presumptive causes of elevated incidence of mutations in the Florida Bay – Keys and Biscayne Bay estuaries.

Fig. 1. Frequency of occurrence of *R. mangle* trees expressing albinism in their propagules versus latitude in the state of Florida. Regression: R^2=0.43, $P<0.005$.



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Mapping Height and Biomass of Mangrove Forests in the Everglades National Park with Shuttle Radar Topography Mission Elevation Data

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We produced a landscape scale map of mean tree height in mangrove forests in Everglades National Park (ENP) using the Shuttle Radar Topography Mission (SRTM) elevation data. The SRTM data was calibrated using the USGS/SOFIA Digital Elevation Model as well as airborne LIDAR (Laser) data. The mangrove mean height map has a spatial resolution of 30m with a pixel mean tree height error of 2.0m. In addition, we used field data to derive a relation between mean stand height and biomass in order to map the spatial distribution of standing biomass of mangroves for the entire ENP (Figure 1). We show that most of the mangrove standing biomass in the ENP resides in intermediate-height mangrove stands around (~8m). We estimate the total mangrove standing biomass in ENP to be 6.1 Mtons.

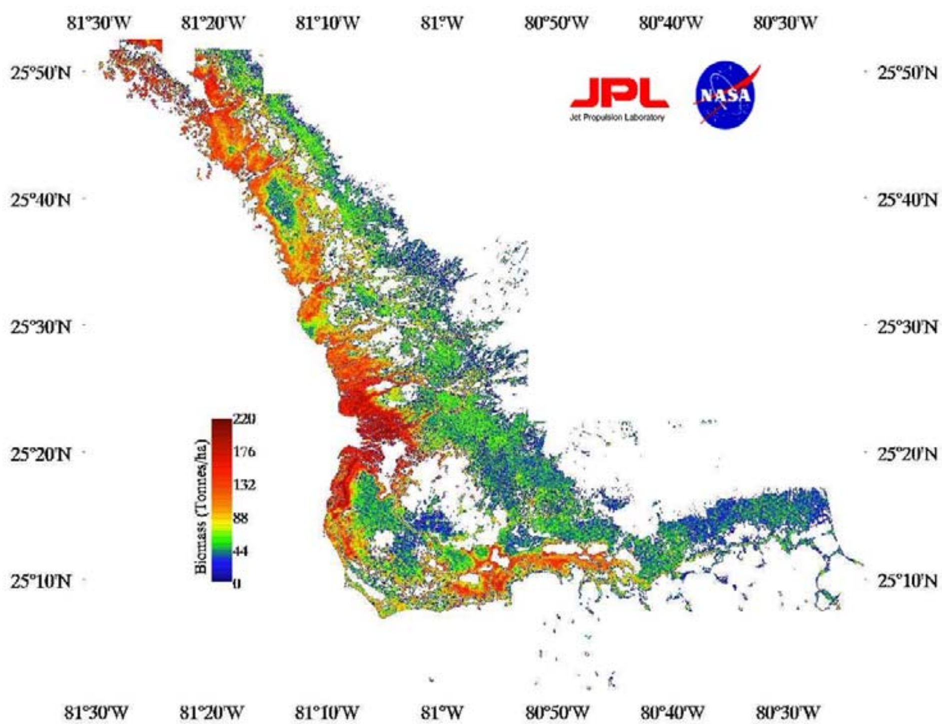

Figure 1: Map of standing biomass in mangrove forests of the Everglades National Park.

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Water-Delivery-Optimization Modeling for Restoration Performance Measures: Salinity in Florida Bay, Florida

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Restoration projects such as the Comprehensive Everglades Restoration Plan (CERP) utilize numerical models to simulate and evaluate restoration scenarios that have been developed to analyze the effects of water management on set “performance measures”. In general, these scenarios are developed intuitively rather than analytically, and they are evaluated experimentally. In lieu of using a “trial and error” method for satisfying performance measures, an optimization technique may be used to provide more precise results.

The U.S. Geological Survey’s numerical modeling of the coastal regions of Florida Bay and Everglades National Park has yielded an accurate representation of local surface-water and ground-water hydrology. The Southern Inland and Coastal System (SICS) model represents this area with a two-dimensional, hydrodynamic surface-water model and a three-dimensional ground-water model, coupled to represent the interaction of the two systems. Salinity transport has been incorporated into both flow regimes and salinity exchange between them is also accounted for. This is important at the coastal interface because the ecology of the system is extremely sensitive to salinity fluctuations. The SICS model is presently the most comprehensive tool available to predict the results of ecosystem restoration alternatives; however, determining which restoration alternative will produce the desired objectives is a more complex process. A common approach is to design water-delivery schemes intuitively, and then simulate them in a model. This trial-and-error approach, however, simply validates suggested schemes and does not necessarily yield optimal scenarios.

To use the SICS model as a design tool, some optimization-modeling techniques must be applied. This approach uses model response to approximate a functional relationship between the water-delivery scheme and a performance measure that defines an objective. The relationship is then used to modify the model input water-delivery scheme to better match the desired performance measure. The new model results are then used to improve the functional relationship, and the process repeats.

Optimization-modeling has been used for a variety of management issues such as traffic light timing and ground-water pumping rates. Different optimization codes are used to achieve a variety of objectives. These codes are applied to a wide range of ground-water flow management problems, such as determining optimal well-pumping rate solutions. General optimization packages can utilize a variety of global optimization methods. For example the Modular Ground-water Optimizer (MGO) code utilizes the genetic algorithm, simulated annealing and tabu search methods. These methods can identify the global or near global optima of highly nonlinear objective functions. Another method often used for optimizing ground-water systems is parameter estimation. The program UCODE was developed for this purpose, and is designed to function with a variety of numerical models.

The parameter optimization techniques used for the SICS model area implement UCODE. Although UCODE is designed to be a calibration and parameter estimation program, constraints in this instance are defined that specify allowable ranges of model parameters. The solution created by UCODE minimizes (or maximizes) the objective function in terms of the constraints.

Subsequently, UCODE creates parameters that define input for the SICS model based on SICS model output statistics.

To apply a water-delivery-optimization technique to the SICS model area, it is necessary to define the modifications to the water-delivery scheme and the target criteria. Optimization-type simulations are often applied to steady-state models using constant inputs. The SICS model is an unsteady simulation, however, which makes defining input variations substantially more complex. In order to produce a meaningful result, modifications to surface-water inflows must remain within realistic limits. The total inflow is not allowed to exceed the sum of existing inflow and excess water upstream, or to be negative (that is, flow cannot occur in an upstream direction). Because it is very impractical to define flow modifications for each model timestep, flow multipliers are defined for periods of above- and below-average flowrates. Several flow multiplier schemes were developed. The six-parameter method defines multipliers for each of the surface-water inflow locations separately for high and low flows. The two-parameter method defines high- and low-flow multipliers only for the largest inflow location, and the remaining available flow is apportioned to the other inflow locations based on the flow distribution in the original data.

The target criteria are based on the performance measures defined in the Florida Bay Florida Keys Feasibility Study (FBFKFS). The performance-measure objectives in this study were defined for delineated regions in the bay and coastal subembayments. The performance measure specifies a salinity range and the objective of reducing rapid changes in salinity. To create a target salinity timeseries for a particular location, the base-case salinity timeseries is scaled to be within the FBFKFS-defined range, and a moving average technique is used to smooth the data. This smoothing reduces the rapid changes in salinity.

Preliminary results illustrate the ability of the model to effectively improve salinity values within a target area (Figure 1). The optimized inflows typically exhibit decreased wet-season peak flows, and increased dry season flows. Future model runs will include additional target areas for performance measures and longer simulation periods.

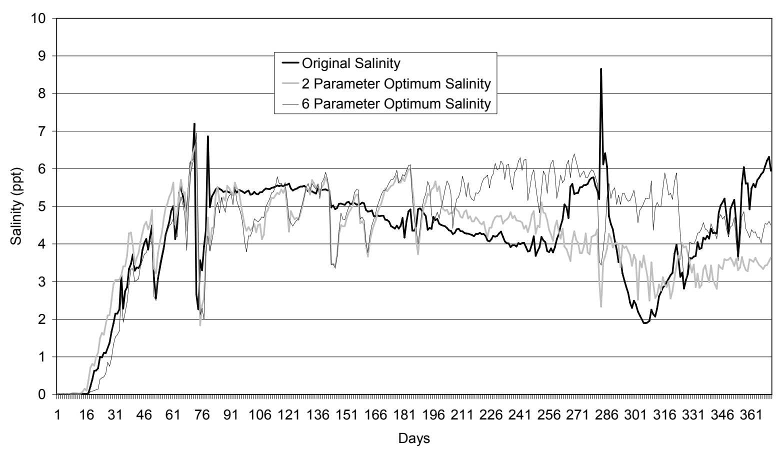

Figure 1. Water-Delivery-Optimized salinities.

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Developing Shallow-Water Acoustic Telemetry Methods for Juvenile Snapper Habitat Studies in the Florida Keys National Marine Sanctuary

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The recent availability of customized coded micro-transmitters for small/juvenile fish tagging may provide useful tools in determining the early life history habitat requirements of commercially valuable snapper species within and outside marine protected areas. This pilot study utilizes micro-acoustic tags (dry wt. = 0.65g; excess mass = 0.39g.; 417 kHz) and standard acoustic telemetry methodologies developed by Battelle and NOAA Fisheries for juvenile salmon survivorship studies to investigate questions of habitat use patterns of juvenile snappers in Florida Keys National Marine Sanctuary's reserve areas. We apply these methodologies to examine specific physical, environmental, and biological factors with the goal of optimizing telemetry instrumentation and field techniques for this application. Optimization requires trade-offs between limitations imposed by biological constraints and factors influencing the propagation, detection, and decoding of transmitted acoustic signals in estuarine/marine environments. Important physical factors are operating frequency, encoded pulse length, and vegetation density in mangrove-seagrass-reef habitats in 1.5m to 6m depths. Environmental factors include determining tracking baseline configuration within the geometry of distinct habitat patches and effects of dense mangrove roots on propagation of encoded acoustic signals. Biological factors include tag effects on survivorship of juvenile snappers and short-term movement patterns within habitat patches. We will present initial data from shallow-water testing of acoustic reception at 417 kHz in obstruction-rich environments, compare juvenile salmon and snapper tag implantation survivorship, and range-testing strategies for shallow salt water.

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Oral Abstracts
Benthic Habitats

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

High Salinity Event of 2004-2005 and Responses of the Seagrasses Community in Northeast Florida Bay

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The Miami-Dade DERM has conducted submerged aquatic vegetation and water quality monitoring in northeast Florida Bay since 1995. The program assesses 10 coastal basins in northeast Florida Bay, from Little Madeira Bay east to Little Blackwater Sound, as well as Card and Barnes Sound. The program utilizes the Braun-Blanquet Cover Abundance method and general water quality characteristics to assess SAV status, on a bi-monthly basis.

During May of 2004 the initiation of a high salinity event initiated was documented. Above normal salinity concentrations persisted through May 2005, with numerous basins setting new monthly maxima for salinity during that period. Record high salinities for the period of record (1995 to 2003) were recorded in 11 of the12 basins in July, 2004, and in 9 of 12 basins during May of 2005 (Table 1). On average (all months, all basins), salinity was 15 psu above normal from July 2004 to May 2005. Salinities in the individual basins ranged between 5.7 to 35.6 psu above average (Table 1). During the high salinity event, the basins' average temperatures generally did not show exceptional variations, and were within historic ranges. However, in January and March of 2005 the basins were elevated above their respective means for the month. In addition Highway Creek tied a the record high in March (27.8°C) and Joe Bay exceed the basin's previous record high for March by 0.3°C (29.0°C).

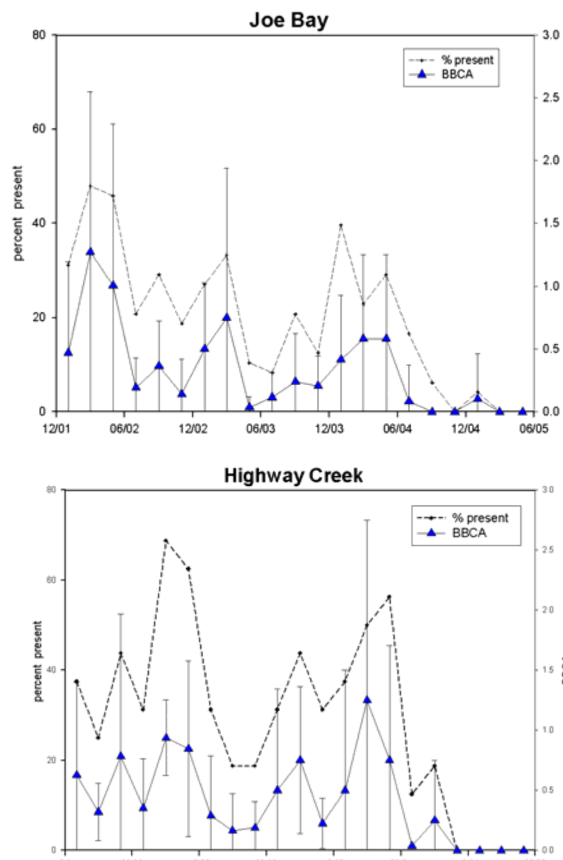

Figure 1. *R. Maritima* BBCA and % presence in Highway Creek and Joe Bay. Jan 2002-May 2005.

Changes in the seagrass populations were also documented. For example, the presence and abundance of *Ruppia maritima* in Joe Bay and Highway Creek had been relatively stable in recent past (i.e., 2002 & 2003). However, a sharp decline in BBCA value and percent presence (% of sample quadrats containing *R. maritima*) started in July 2004. This species remained absent or at abundance levels below previous years, through May 2005 (Fig. 1). The BBCA value for *R. maritima* decreased 93% in Joe Bay when compared to the 2002-2003 period (e.g., from 0.46 to 0.03) and it's presence decreased 83% (e.g., from 26.5% to 4.5%). In Highway Creek, *R. maritima* BBCA decreased 92% (e.g., from 0.57 to 0.05) and presence decreased 87% (e.g., from 39.2% to 5.2%). This level of change is not unprecedented for Joe Bay as this species was absent from this basin during most of 1996-1997. However, the absence of *R. maritima* from Highway Creek noted since July 2004 was the first such occurrence during the ten year period of this project .Changes in *Halodule wrightii* populations were also documented. Annual mean BBCA value for *H. wrightii* in Joe Bay increased from 1.10 (≈ 3% cover) in 2003 to 1.50 (≈ 4 % cover) in 2004, and presently is 1.88 (≈ 5% cover). Annual *H. wrightii* in Highway Creek, however, did not show an equivalent response. BBCA values increased from 0.95 (≈ 3% cover) in 2003 to 1.35 (≈ 3.5-4% cover) in 2004, but have subsequently decreased to 0.89 (≈. 3% cover) in 2005. A consistent response 'signature' for *Thalassia testudinum* was not identified. Of the ten basins that support *T. testudinum*, six basins showed BBCA values consistent with past values however; four basins (e.g., Manatee Bay, Little Madeira Bay, Little Blackwater Sound, and Blackwater Sound showed at least three successive months of below average BBCA values and a period-of-record low monthly mean BBCA value during the event period.

Table 1. Basin average salinities (averaged of all stations sampled within each basin)

Average Salinity in the basins assessed.

	2003						2004						2005			
BASIN	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul
Alligator Bay	19.8	24.7	25.7	19.1	15.0	14.3	20.5	23.2	33.8*	41.5**	34.1*	32.1*	35.0*	40.0*	45.9**	30.7
Barnes Sound	29.4	32.0*	32.1*	29.7	28.7	26.3	26.7	28.8	35.8*	41.5**	38.7*	35.1*	36.1*	37.9*	39.2*	34.8
Blackwater Sound	29.7	31.6*	31.3*	31.8*	28.8	26.7	26.5	29.6	35.2*	41.7**	40.1*	37.0*	37.1*	38.9*	40.5*	35.6
Davis Cove	21.4	26.3	25.8	22.0	17.5	15.1	21.4	24.8	34.3*	40.9**	35.4*	33.4*	36.3*	39.9*	45.6**	27.2
Eagle Key Basin	23.8	29.1	26.8	18.1	17.9	15.5	19.3	22.0	31.1*	40.9**	38.5*	33.3*	36.5*	42.5**	47.3**	32.6
Highway Creek	16.2	26.0	12.4	3.6	8.5	9.4	15.1	22.4	35.1*	42.0**	17.6	26.8	27.1	34.9*	39.4*	5.3
Joe Bay	12.3	24.2	13.8	3.2	0.7	0.7	5.7	16.1	27.5	39.1*	11.1	15.6	30.4*	34.7*	44.0**	8.8
Little Blackwater Snd	24.8	28.8	29.6	18.2	16.9	17.0	22.0	26.6	32.9*	40.8**	32.1*	29.1	35.2*	38.3*	42.7**	19.6
Little Madeira Bay	15.2	23.7	20.4	9.4	10.8	5.1	11.1	16.4	31.4*	40.8**	31.8*	25.3	29.0	37.4*	46.1**	24.9
Long Sound	20.5	27.0	23.2	12.4	10.3	11.0	19.9	24.2	33.6*	40.2**	25.9	30.1*	31.1*	35.9*	41.6**	12.8
Manatee Bay	27.8	29.7	28.9	24.0	26.8	23.6	24.3	25.8	36.2*	42.5**	36.4*	33.8*	34.4*	36.9*	40.7*	27.1
Trout Cove	24.7	28.4	27.3	21.4	21.8	23.8	23.0	25.1	34.1*	40.7**	37.8*	38.1*	36.7*	39.3*	44.8**	33.9

* = record high monthly maximum salinity for the basin

** = Record high basin maximum average salinity

Difference between average basin salinity readings and period-of-record monthly averages for each basin

	2003						2004						2005			
BASIN	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul
Alligator Bay	2.5	2.8	-3.2	-2.8	-2.8	-3.4	3.1	1.3	5.0	19.5	16.3	14.4	17.6	18.0	17.0	8.8
Barnes Sound	3.3	3.2	-1.4	-1.9	-1.3	0.7	0.7	0.0	2.3	9.9	8.8	9.5	10.0	9.1	5.7	3.2
Blackwater Sound	4.5	3.3	-0.8	2.1	0.9	1.7	1.2	1.4	3.2	11.9	12.2	12.0	11.8	10.6	8.5	5.8
Davis Cove	2.7	3.3	-3.8	0.1	-0.7	-2.9	2.7	1.8	4.8	19.0	17.2	15.4	17.6	16.9	16.1	5.3
Eagle Key Basin	4.3	6.4	-1.1	-6.5	-4.0	-2.1	-0.2	-0.8	3.3	16.3	16.6	15.7	17.0	18.8	19.4	8.0
Highway Creek	6.0	6.4	-12.4	-2.5	5.2	-0.7	4.9	2.7	10.4	35.9	14.3	16.8	16.9	15.2	14.6	-0.8
Joe Bay	4.7	9.2	-9.9	-8.1	-3.6	-4.7	-1.9	1.1	3.8	27.8	6.9	10.2	22.9	19.7	20.3	-2.5
Little Blackwater Snd	5.3	5.3	0.5	-2.5	-1.8	-0.9	2.5	3.2	3.8	20.1	13.4	11.2	15.7	14.9	13.6	-1.1
Little Madeira Bay	2.3	4.8	-4.9	-7.5	-2.2	-7.1	-1.7	-2.5	6.1	24.0	18.8	13.0	16.2	18.5	20.8	8.1
Long Sound	3.8	5.7	-4.5	-5.0	-1.1	-2.5	3.2	2.9	5.9	22.9	14.6	16.5	14.4	14.7	13.9	-4.6
Manatee Bay	3.9	3.7	-2.8	-3.1	1.3	1.2	0.4	-0.3	4.5	15.3	10.9	11.4	10.5	10.8	9.0	0.0
Trout Cove	3.1	3.5	-3.0	-1.3	-0.2	1.8	1.3	0.3	3.8	18.0	15.8	16.1	15.0	14.5	14.6	11.3

The high salinity event ended in June 2005, following excessive regional monthly rainfall (14 to 20 inches). Additionally, Hurricane Katrina affected the study area in August 2005. Initial post-Katrina assessments have documented low dissolved oxygen (>1.0 mg/l) in multiple basins, and sponge mortality in Blackwater Sound and Barnes Sound.

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Diel Light Curves' Ability to Incorporate Temporal and Spatial Variation of Photosynthetic Characteristics of *Thalassia testudinum* in Florida Bay

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Fluorescence, photochemical quenching and non-photochemical quenching exhibit diurnal variation. The magnitude of diurnal fluctuations are dependent on a multitude of factors that are specific to the organism, environment and time. When using Pulse-Amplitude Modulated (PAM) fluorometry to measure landscape-scale photosynthetic characteristics of *Thalassia testudinum* these natural variations can obscure the physiological signal and must be accounted for. In order to incorporate the entire temporal and spatial scale of sampling in Florida Bay two photophysiological techniques, Diel Yield and Diel Rapid Light Curve (RLC) methods, were investigated. Photosynthesis irradiance (P-E) curves were calculating using both methods and the ability of each to accurately predict the relationship between electron transport and irradiance was assessed. Neither method was able to provide consistent estimates of photosynthetic efficiency or capacity. The Diel Yield method frequently produced unrealistic predictions of photosynthetic capacity (rETRmax) and saturation irradiance (I_k). The Diel RLC method produced more reasonable predictions of rETRmax and I_k, but this method was unable to accurately predict photosynthetic efficiency (alpha) when ambient irradiances were continuously high throughout the day ($>I_k$, Figure1). We believe that with sampling modifications or further calculations the Diel RLC method can provide an estimate of photosynthetic efficiency and offers a method to reasonably approximate photosynthetic characteristics at the landscape-level. Both the Diel Yield and Diel RLC methods use data generated from RLCs, which vary depending on previous light history; thus, diurnal variations do affect estimates of electron transport rates. Therefore, the Diel RLC method does not negate diurnal variation but it produces a curve that incorporates the changing ambient light environment.

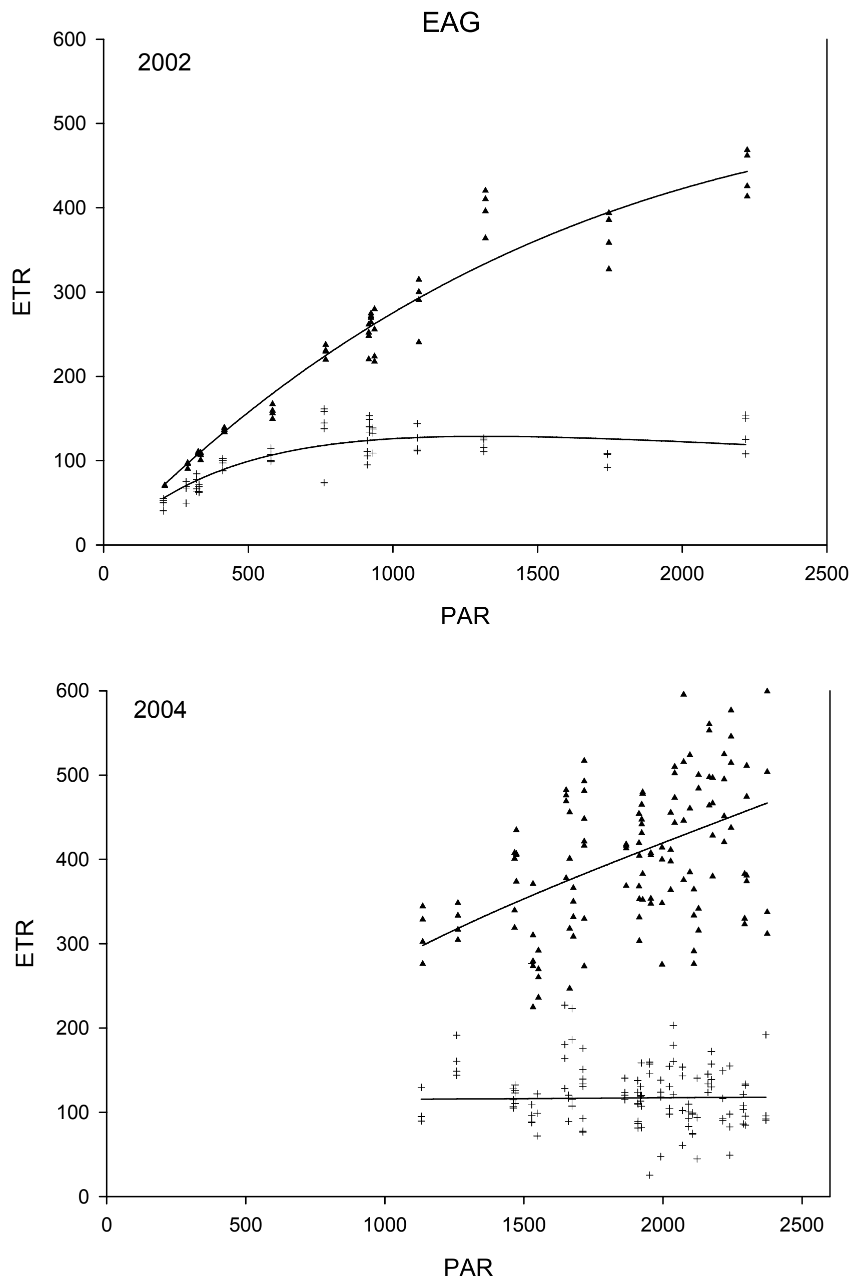

Figure 1. Diel Yield (▲) calculated rETR vs. irradiance (PAR μmol photon $m^{-2}s^{-1}$) and Diel RLC (+) interpolated rETR vs. irradiance (PAR) for Eagle Key (EAG) in 2002 and 2004.

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Florida Bay Seagrass Seedling Responses to Hyposalinity and Ammonium Fluctuations: A Study of *Thalassia testudinum* Banks ex König

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Many studies have examined the impact of environmental stressors on mature *Thalassia testudinum*. The goal of this study was to examine possible effects of proposed water flow alterations into Florida Bay on *T. testudinum* seedling survival. As the proposed changes would influence the amount of freshwater entering the system, salinity and ammonium were manipulated in a series of mesocosm experiments. One experimental series examined direct introduction into hyposaline conditions, from 30 to 0, 10 and 20 PSU. A second series of experiments examined seedling responses to slow acclimation to reduced salinity (2 PSU every 3 days), coincident with depleted and elevated levels of ammonium (0, 10 and 20 μM NH_4^+). The responses observed included growth (total leaf area over the course of the experiment), photosynthetic rates (as measured with PAM fluorometry) and tissue osmolality.

In the direct introduction treatments, the plants at 0 and 10 PSU had the greatest mortality. These plants also had the lowest number of blades and total leaf area. Growth was greatest at 30 PSU, followed by the plants at 20 PSU. Quantum yields after one month at treatment salinities were significantly greater for plants at 20 and 30 PSU than 0 PSU. For the acclimation treatments, the plants at 20 and 30 PSU had significantly greater total leaf area than those at the low salinities for all three ammonium treatments. At 0 and 10 PSU, blade widths and total leaf area were significantly less in the 20μM ammonium treatments than the 10 or 0μM treatments. Blade widths decreased at the lower salinities at all ammonium levels. Photosynthetic capacities ($RETR_{max}$) for 20 and 30 PSU treatment plants were significantly greater than those of the 0 and 10 PSU treatment seedlings. Across all salinities, $RETR_{max}$ was significantly greater in the 0μM than the 20μM ammonium treatments. In both sets of experiments, tissue osmolality increased significantly with increased salinity and tissue remained consistently hyperosmotic to the media.

To manage the physiological changes and energy required for internal ion balance, the productivity of the plant may be reduced. In this study, growth and survival were the best indicators of tolerance. At lower salinities, increasing ammonium negatively impacted growth suggesting that were the input of fresh water into Florida Bay to contain higher levels of nitrogen, this would more negatively impact *T. testudinum* seedlings than would reduced salinity alone.

This study was funded by Florida Atlantic University (#URD51) under prime contract #C-12430 from the South Florida Water Management District.

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A Conceptual Model for Seagrass Die-off in Florida Bay Based on Mesocosm and Field Experiments

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Seagrass "die-off" has been observed in Florida Bay, as well as other regions of the world. Various factors have been put forth as causative agents for loss of seagrass meadows in Florida Bay based on field observations. We took an experimental approach to individually test these various hypotheses using three dominant seagrass species in the Bay. We examined seagrass tolerance to hypersalinity, high temperature, hypoxia, and sulfide exposure, and the interaction of these stressors in a series of four large-scale mesocosm experiments. We field validated mesocosm results at five sites in Florida Bay from July 2004 to July 2005 during which high temperatures (>31^{o}C), high salinity (>50 PSU), and high porewater sulfides (>5 mM) were encountered at the sites. During this field experiment, we also had die-off events at two of the five sites. Mesocosm experiments consistently showed all three species tolerated hypersalinity and high temperatures with an upper threshold of approximately 60PSU and 32^{o}C. While we did not find these factors to be primary causes of seagrass shoot decline, they contributed to higher plant and microbial respiratory rates. Belowground exposure to the phytotoxin, hydrogen sulfide, also appears to be a secondary stressor and not a direct cause of die-off events, with the caveat that sulfides do not diffuse across the sediment-water interface. We present a model of cascading events that result in an oxygen imbalance within the seagrass meadow which we hypothesize, based on our mesocosm and field experiments, leads to seagrass "die-off" events in Florida Bay.

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Bay-Scale Changes in Florida Bay Macrophyte Cover: 1995 – 2004

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Benthic macrophyte cover and distribution data have been collected using the Braun-Blanquet abundance/cover technique in ten basins within Florida Bay as part of the Florida Bay Fisheries Habitat Assessment Program (FHAP). Weighted averages for the most prevalent macrophytes observed during each sampling event since spring 1995 were calculated. Results indicate that the three most common seagrasses in Florida Bay, *Thalassia testudinum, Halodule wrightii,* and *Syringodium filiforme*, have increased in distribution since 1995. *Halodule wrightii* and *Syringodium filiforme* exhibited an increase in both frequency and cover at the bay-scale, an occurrence driven by their dramatic increases in the western-most FHAP study basins: Johnson and Rabbit Key Basins. *Acetabularia*, *Batophora*, *Halimeda*, *Penicillus*, and drift Rhodophytes also increased in both frequency and cover since spring 1995. *Batophora* is the most ubiquitous macroalgae throughout Florida Bay and *Acetabularia* and the drift Rhodophytes exhibited the strongest seasonal fluctuations; they were both much more abundant and widespread during spring samplings.

Spearman rank order correlation analysis of the Braun-Blanquet data showed that *Thalassia* abundance was generally negatively correlated to all other macrophytes, while *Halodule*, *Halophila*, and *Syringodium* were positively correlated to one another on most occasions. These seagrasses fluctuated between positive and negative correlations with the macroalgae, and as a group, the macroalgae were positively correlated with one another on most occasions, although exceptions did apply.

Non-metric multidimensional scaling was used to create ordination plots of the ~ 315 sample stations. Density overlays were used in conjunction with these ordination plots, and together these showed that total seagrass cover and total macroalgal cover were generally mutually exclusive in space. Spearman rank order correlation analysis was further used to determine if this spatial separation of the two macrophyte groups was statistically significant, and it was found that 11 of the 18 bi-annual sampling events yielded a statistically significant negative correlation between total seagrass cover and total macroalgae cover.

Canonical Correspondence Analysis (CCA) was used to determine which, if any, of the environmental/physical variables, collected as part of the FHAP data set, had a significant effect on macrophyte distribution within Florida Bay. Significance of these effects was determined using Monte Carlo Permutation Tests. CCA indicated that depth and visibility were the initial driving forces in macrophyte distribution. During fall 2000, however, a spike in salinity was observed and by spring 2001 this became the most significant variable affecting macrophyte distribution, and it remained so, along with depth, throughout the duration of FHAP.

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The Florida Bay Seagrass Model: Examination of Fresh Water Effects on Seagrass Ecological Processes, Community Dynamics and Seagrass Die-off

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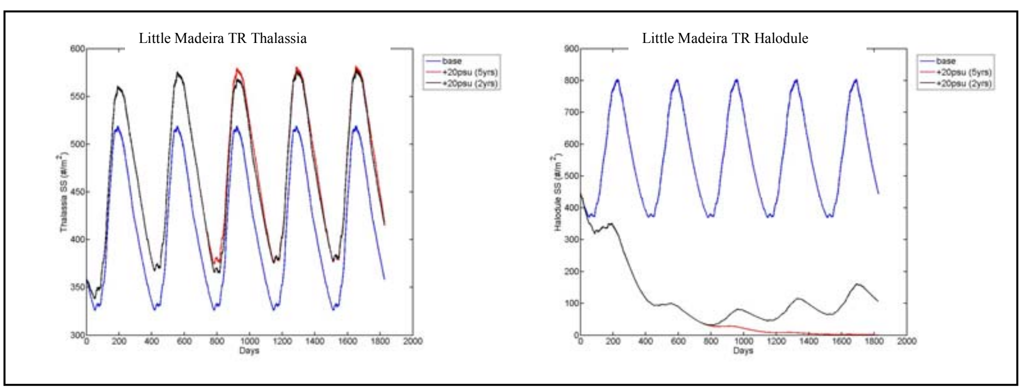
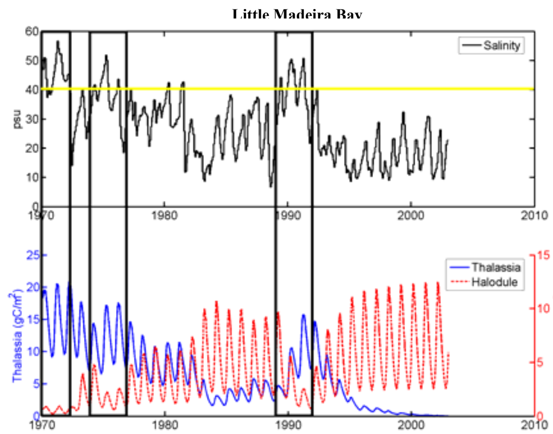
A seagrass model developed for Florida Bay is used to examine ecological processes and community dynamics to increase understanding of seagrass ecology and to improve the health of Florida Bay. The Florida Bay seagrass model is a spatially averaged, mechanistic unit model that is based on physiological responses of *Thalassia testudinum* and *Halodule wrightii* to salinity, inorganic nutrients, temperature, light and sediment sulfide concentrations, incorporating the effects of interspecific competitive interactions. The model tracks units of carbon biomass per unit area, calculates nutrient flows from variable stoichiometric relationships and considers response variables of per cent cover, biomass and species composition for 1 m^2 sections of Florida Bay bottom with a 3 h timestep. The model is parameterized and calibrated for seven basins throughout Florida Bay to encompass a range of conditions and representative community types. Salinity and temperature relationships for each species are from mesocosm studies by Koch and Durako (2004) and salinity inputs are from the FATHOM hydrological model (Nuttle et al. 2005). Internally derived variables include light regime and concentrations of sediment organic matter, nutrients and hydrogen sulfide.

The model was used to investigate the effects of salinity variation on seagrass community dynamics by systematically changing the salinity corresponding to potential low and high inflow regimes for target sites in a transitional bay and the open bay. Five-year simulations from 1996-2001 for an area influenced by Everglades input (Little Madeira Bay near the mouth of Taylor River and Eagle Key Basin in Florida Bay) were used for a response-recovery analysis. Baseline salinity inputs were increased daily by 20 psu, yielding a minimum of about 20 psu and a maximum salinity of about 50 psu, approximating salinity observed at Little Madeira Bay during severe drought years. Resulting runs show that *Halodule* was severely impaired after two years and eliminated within 5 years of persistent hypersalinity. The salinity response curve was not the cause of this result, as the decline occurred only occurred in the presence of *Thalassia,*



whose biomass increased by about 20%. Application of recovery scenarios that returned salinity to baseline levels after differing periods permitted assessment of the ability of the SAV community to recover and reflected long-term effects. Recovery of *Halodule* following relaxation of a two-year salinity stress was minimal and did not approach the pre-stress biomass level even after three “normal” salinity years. This result conforms to field observations that *Halodule* virtually disappeared from its common range in 1989-1994 following a hypersalinity event in the late 1980s despite a return to more normal salinity conditions in the early 1990s.



A 30- year retrospective simulation of SAV trends enabled the evaluation of the long term effects of droughts and other low flow conditions on the SAV community beginning in 1970. The analysis produces an estimate of seagrass community response to historical salinity conditions and shows that salinity plays a key role in the dynamics of the two species. Abundance and dominance of each species responds to periods of differing salinity extremes, with mixed beds occurring during polyhaline to marine conditions. Recent data (Borum et al. 2005) show how anoxia in surficial sediments can destroy *Thalassia* meristem tissue resulting in plant death, which may be exacerbated by *Thalassia* “overbuilding” during hypersaline conditions. The Florida Bay seagrass model projects several critical points at which low oxygen can potentially cause widespread die-off under different salinity conditions and biomass levels and calculates the additional nutrient load that is made available by die-off. If this load is released directly to the water column it potentially leads to widespread phytoplankton blooms, creating a change in state of Florida Bay from a benthic to a planktonic ecosystem.

The model demonstrates that salinity regime influences community dynamics and species composition of seagrasses in Florida Bay. Estuarine salinities of 20-40 psu support a healthy mixed community while hypersaline conditions longer than two years can impair the community by eliminating *Halodule* and favoring *Thalassia*, requiring recovery times up to ten years. Selective enhancement of *Thalassia* by high salinity promote “overbuilding” a high-biomass and low-diversity, destabilizing the population, community and ecosystem. Demise of benthic vegetation can affect nutrient cycles by reducing uptake capacity, releasing sequestered nutrients to the water column, and shift Florida Bay from benthic to water column autotrophy.

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Inorganic Phosphate Kinetics in Florida Bay Seagrass Ecosystems: ^{33}P Experiments and In Situ Chamber Studies

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Florida Bay carbonate sediments have a high affinity for inorganic phosphorus (P*i*) resulting in extremely low P*i* concentrations (<0.05 µM) in the water column and porewaters of the Bay. These low P*i* levels result in benthic and water column autotrophic production being P-limited in the Bay in contrast to most temperate estuaries which tend to be N-limited. In order to model primary production in the Bay as well as P-cycling for water quality and ecosystem models, the kinetics of P cycling needs to be elucidated. We have been investigating P*i* uptake kinetics of the main components of the Florida Bay ecosystem for the last three years using a two-fold approach: (1) We developed a methodology for investigating extremely low level uptake kinetics of P*i* by seagrass (*Thalassia testudinum*) roots and leaves using a radiotracer technique (^{33}P*i*). This methodology was then applied to ascertain the P*i* uptake kinetic parameters of *T. testudinum* from an eastern low nutrient status site and a western high nutrient status site in the Bay. In addition, we determined the minimum levels of P*i* where uptake is still positive (S_{min}) and compared this threshold level to the P*i* adsorptive-desorptive crossover concentration of the sediment. (2) In addition to this experimental work, we acquire seasonal P*i* kinetics in situ from the sediment, water column, and entire system (sediment + *T. testudinum* + water column) at our eastern and western Bay field sites by following P*i* disappearance from benthic chambers after low level P*i* amendments (~1.0 µM).

Our radiotracer results show that at P*i* levels characteristic of Florida Bay (≤0.26 µmol L^{-1}), *T. testudinum* is able to take up P*i* through both leaves and roots as a linear function of increasing P*i* concentrations. The slope of this linear function or affinity (α) was similar for both leaves and roots (0.12-0.30 and 0.10-0.20 µmol g dry wt^{-1} h^{-1}). Although *T. testudinum* was able to take up P*i* through its leaves at nanomolar levels (S_{min} values 0.002 to 0.009 µmol L^{-1}), the uptake rates at average water column P*i* levels were insufficient to meet plant P requirements, indicating that sediment pools or transient fluxes of P to the water column must sustain high seagrass production rates in the Bay. The sediment adsorption-desorption experiment showed a 10-fold lower equilibrium cross-over concentration for P*i* in the eastern (0.017 µM) versus western Bay sites (0.292 µM). These concentrations meet ≤ 10% and > 87% of the P demand for *T. testudinum*, respectively, a result that might account for the reported P-limitation of seagrass biomass and production in eastern Florida Bay.

Similar to plant uptake kinetics, P*i* disappearance from the benthic chambers over time exhibited an exponential decreasing pattern, indicating that at low in situ P*i* levels uptake is a linear function of the P*i*-concentration. This pattern was consistent for all three components of the ecosystem examined and across seasons and sites. The affinity of the individual components decreased in the order: water column>leaves>sediment indicating that all components of the system contribute to P*i* sequestration in the water column; however, the water column has the highest affinity. These results suggest that the pelagic biotic and abiotic components of the system are the main scavengers of P*i* in the Bay.

The P*i* concentration where no net P*i* uptake occurred (S_0) was always low and comparable to the ambient surface water P*i* levels, probably accounting for the ubiquitous low P*i* level in surface waters throughout the Bay. There was a tendency however towards lower average S_0 at the less P-loaded Eagle Key site compared to Green Mangrove Key with high P inputs from the Gulf of Mexico. S_0 also decreased in the order of system<sediment+water column<water column, therefore the benthic-pelagic coupling also accounts for the extremely low P*i* in surface waters of the Bay.

As applied to the modeling efforts currently ongoing in Florida Bay, our kinetic work clearly shows that P*i* uptake follows first order kinetics as a function of P*i* concentration at low in situ concentrations characteristic of the Bay. Therefore modeling should focus on the parameters alpha and S_o rather than V_{max} and K_m for both plant and system uptake of P. The turnover and transient flux of P*i* in the system will be important to quantify because of the highly efficient nature of the system to take up P*i* when available, even at P enriched sites. While the water column biotic and abiotic processes probably control the P*i* in surface waters of the Bay, the sediments are likely to compete with the plants for porewater P in the Eastern Bay, a fact that may account for P-limitation in the Eastern compared to Western part of the Bay.

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Poster Abstracts

Benthic Habitats

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Channel/Bank Systems and Linkage among Bioregions of the South Florida Ecosystem

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Surveys of bank systems and associated channels on the northern side of the Florida Keys and eastern edge of Biscayne Bay reveal complex physical and hydrodynamic environments that foster development of diverse benthic communities and associated nekton. The location of extensive channel/bank systems in areas considered to represent ecotones suggest they play an important role in physical and biological exchange between bioregions. Strategically located channel/bank systems link both Florida Bay and Biscayne Bay, respectively, with the coastal ocean and may provide migration pathways and filters for a variety of marine fauna, flora and materials. Channel/bank systems are likely to impact surrounding habitats as, like coral reefs, they provide shelter to high densities of fishes and crustaceans that forage in the surrounding open landscape. The degradation of these systems, primarily due to boat groundings, in ongoing and likely to intensify. The unique nature and strategic location of channel/bank systems suggest that plans to protect these potentially critical habitats be considered and research focused on their contribution to linkage between and definition of bioregions continue.

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Large-scale Remotely Sensed Submerged Aquatic Vegetation Monitoring in Florida Bay and Biscayne Bay: a Progress Report

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This report summarizes progress for the RECOVER Monitoring and Assessment Plan (MAP) Element 3.2.3.4: Large Scale Remotely Sensed SAV Monitoring in Florida Bay and Biscayne Bay.

This project is a joint effort of the South Florida Water Management District and the Florida Fish and Wildlife Conservation Commission, and it serves as a complement to MAP element 3.2.3.3. South Florida Habitat Assessment Program. The goals for this program are to 1) assess and map the distribution and abundance of SAV at the present time for the entire region from Florida Bay Bay to Biscayne Bay 2) test the utility of landscape metrics to describe spatial patterns of SAV beds in Florida Bay and Biscayne Bay, 3) to compare past, present, and future changes in seagrass distribution within Florida Bay and Biscayne Bay using aerial photography and landscape metrics.

To collect a baseline dataset against which future changes in seagrass distribution can be measured, aerial photography was flown in spring 2004 and 2005. Florida Bay SAV aerial photography was flown in April 2004 at a scale of 1:24,000 using natural-color film. Negatives were scanned at 0.5 m resolution, rectified and georeferenced. Seagrass maps are currently being made from the 2004 photography, and we hope to display a draft product at the conference. Weather conditions and contractor scheduling problems prevented acquisition of Biscayne Bay imagery until spring 2005. Digital natural-color and color-infrared imagery were acquired at a resolution of 0.5 m. Changes in Florida Bay seagrass cover in 1987, 1994, and 2004 will be discussed, although water clarity, varying scales, and classification issues in some data limit the analysis of historical trends. We are also analyzing a set of 1945 aerial photography which we hope will allow us to hindcast seagrass distribution and patchiness for much of Florida Bay.

Landscape metrics offer a promising technique for monitoring future changes in spatial patterns of SAV in northern Florida Bay in response to changes in the timing and quantity of freshwater delivery to the system. Seagrass patches were delineated in scanned aerial photographs for several study areas in Florida Bay using a supervised classification procedure in Erdas Imagine. Several landscape characteristics of SAV patches were then analyzed using Fragstats. Using periodic aerial photography of both Bay systems and more frequent analysis of landscape metrics in northern Florida Bay and western Biscayne Bay, we expect to visualize and measure quantitatively changes in SAV abundance and spatial patterns resulting from management actions.

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Monthly Variability in Florida Bay Benthic Foraminifera Community Structure

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Florida Bay is a shallow subtropical estuary, which experiences highly variable environmental fluctuations due to natural forces (hurricanes, climatic variations and sea level rise) and anthropogenic influences (agricultural activity, water management and urbanization). Study of short time-scale variability in benthic community population structure and synchronous environmental change is essential to understanding forcing relationships between environment and its effects on population. Benthic foraminifera assemblage variability is an excellent indicator of environmental change in estuarine and coastal areas because populations may respond relatively quickly on spatial and temporal scales (Alve, 1995). Temporal resolution is enhanced because foraminifera may reproduce as often as 3 months to one year (Murray, 1991).

Monthly population sampling from 15 stations throughout Florida Bay is being conducted in a multi-year program begun in January 2004. This includes collection of sediment samples containing benthic foraminifera as well as site measurement of environmental parameters (salinity, temperature, suspended particulate matter, chlorophyll, nutrients, and dissolved organic matter). The objectives of the current study are to examine sites in Florida Bay with enhanced temporal resolution and determine (1) monthly variability in benthic foraminifera species composition, diversity, dominance and abundance; and (2) provide data on the relationship between water quality parameters and these measures of benthic foraminifera community structure.

In northeastern Florida Bay (station 1), preliminary results from monthly sampling indicate a temporal inverse relationship between the relative abundance of particular species and increasing salinity to hyper saline (40 o/oo) conditions. The benthic foraminifera community is predominately *Ammonia sp.*, *Elphidium sps.* and *Peneroplis sps.* (greater than 60%). *Quinqueloculina sps.* and *Triloculina sps.* contribute 40% or less to the total population during each month sampled. Over a twelve month interval an inverse relationship is evident between *Peneropolis sps.* and *Ammonia sp. Peneroplis* sps.are more abundant under normal marine conditions, while *Ammonia* sp. is dominant during low and hyper saline conditions. *Elphidium sps.* decreased with increasing salinity.

Sample collection during 2005, foraminifera enumeration, and data processing is in progress and benthic foraminifera population characteristics are being compared with environmental parameters. These data sets will provide a fundamental baseline from which to evaluate long-term environmental change in Florida Bay and facilitate utilization of benthic foraminifera as proxies of environmental change.

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Loss and Restoration of Seagrass in South Florida

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Where sufficient substrate has been removed, natural recovery of the seagrass *Thalassia testudinum* (turtle grass) is small or nonexistent. Scars left by boat propellers and vessel groundings in *Thalassia* dominated seagrass beds persist for many years and local fishermen have been known to use these as landmarks to locate fishing holes. The inability of *Thalassia* to re-colonize a deep trench or depression created by these injuries is due to the geometry of vegetative reproduction of the severed rhizomes. Vegetative growth of *Thalassia* occurs by the creeping of rhizomal meristems buried in the sediment. These rhizomes give off erect, lateral, leaf-bearing branches. These long shoot rhizomes grow out horizontally, with the vertical plant shoots extending only upwards from the rhizome apical. If no sediment is present where the rhizome extends, the rhizome stops growing, failing to reorient. In some cases, these physical disturbances become ecologically permanent features.

In restoration experiments, it has been found that faster-growing, early-successional seagrasses, such as shoal grass (*Halodule*), can be substituted for turtle grass. It is a cost-effective method for rehabilitating vast areas of damaged *Thalassia*, but doesn't return the sea grass bed to its original condition. 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. In this case, that means restoring turtle grass habitats back to turtle grass.

Our data indicates that failure to replace major losses in sediment resulting from man-induced disturbances will result in a protracted natural recovery that will extend over a temporal scale of multiple decades or longer. We believe that replacing the lost sediment in these depressional areas are the keys for success in seagrass restoration programs dominated by turtle grass. 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 should further accelerate recovery of restored sites. Understanding and establishing realistic natural recovery rates will allow for the development of ecologically-based criteria for *Thalassia* restoration.

Contrary to long-held beliefs, it's now evident that steps can be taken to stem the loss of ecologically important turtle grass. Moreover, doing so in incremental fashion does not have to be expensive. What this means is that stewards of our marine resources now have a valuable tool to use in managing the preservation of critical seagrass habitats. However, it's a tool that cannot succeed by itself. Reducing groundings and propeller and anchor damage must also become an imperative for those creating public policy.

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Marine/Estuarine Site Prioritization Framework for Florida, Implications for Florida Bay

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Conservation, like any business endeavor, requires a focused, well-thought out approach to maximize success. Where resource managers and conservation practitioners work is likely as important as the activities undertaken. While resource management and conservation activities are likely taking place currently in many of the most ecologically important and sensitive locations, we are confident that not all of the most important areas to be working have been identified. Our recently completed marine/estuarine site prioritization framework for Florida can assist resource managers, scientists and conservation practitioners with the identification of priority areas for resource management and conservation activities (Geselbracht et al., 2005). Furthermore, our framework may assist in the identification of the types of resource management and conservation activities that should take place in specific areas to aid long-term resource protection. In this report, we describe some possible applications for the recently completed statewide site prioritization framework in Florida Bay and surrounding areas.

Proponents of the Florida Keys National Marine Sanctuary and Florida's aquatic preserves undoubtedly took into account resource distribution and representation in the context of other sites within their respective networks at the time of site proposal. However, this may not have been done in an objective, explicit and readily repeatable manner. The Florida marine site prioritization framework provides a mechanism to explicitly represent selected ecological features in network sites utilizing objective criteria. This framework consists of a collection of geospatial marine/estuarine habitat and species information, geospatial information on human uses of Florida's marine and estuarine systems, and the MARXAN site selection tool. The framework is flexible enough to allow for modification of the ecological features and criteria utilized to select a set of network sites. Furthermore, datasets contained in the framework can be readily updated and expanded.

The model results derived through this framework are not intended to replace expert knowledge of marine and estuarine systems and species, but to serve as a tool to help objectively evaluate and fine-tune expert knowledge. The framework is based on a site prioritization process that uses a site optimization algorithm known as MARXAN (Possingham et al 2000). MARXAN identifies priority areas which are defined as a set of areas that efficiently represent the selected amount of each ecological feature (13 major habitat and 36 species distributions/ aggregations) at the scale of analysis. To use this decision support tool, we selected a planning area, stratified it into subregions, selected planning units appropriate for the scale of the analysis (1500 hectare hexagons), identified the ecological features to represent (habitats and species distributions/ aggregations), the levels at which to represent these features in the model results, and chose an appropriate level of site cohesiveness.

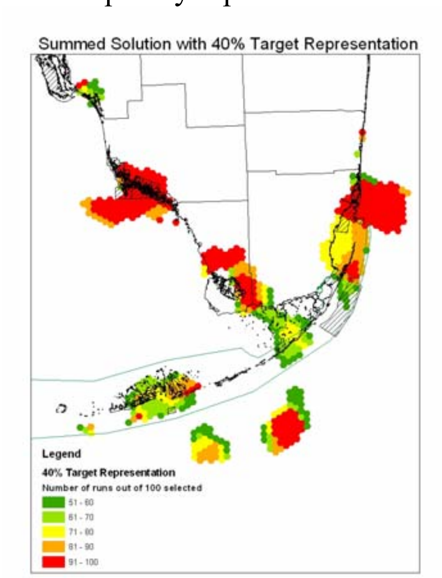
The Marxan model seeks to minimize the following objective function:

$$Total\ Cost = \sum_i Cost\ site\, i \quad + \quad \sum_j Penalty\ \cos t\ \ for\ element\ j \quad + \quad w_b \sum boundary\ length$$

Marxan begins by selecting a random set of planning units, then iteratively explores improvements to this portfolio of sites by randomly adding or subtracting planning units. At each iteration, the new portfolio is compared with the previous portfolio and the better one is selected.

Marxan uses a method called simulated annealing to reject sub-optimal portfolios, thus greatly increasing the probability of converging on the most efficient portfolio. In our applications, we ran the model 100 times with each model run consisting of 10 million iterations to obtain the optimal solution. The figure below depicts the number of model runs out of 100 that each planning unit was selected. Only planning units selected more than 50 out of 100 times are depicted. Also depicted with hatched lines are existing managed areas. The Florida Keys National Marine Sanctuary boundary is shown as a green line.

Although portions of the planning areas selected in more than 50 of the MARXAN runs currently fall within specially managed areas, there is a considerable number of these planning units falling outside of these areas. The framework provided here could serve as a tool to inform resource management decisions involving where to place and/or expand managed areas. The existing framework may also be used to identify ecological attributes (habitat or species) that are not adequately represented in existing managed areas on a regional basis.



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FHAP South Florida - A New, Improved Fisheries Habitat Assessment Program

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Seagrasses are the dominant benthic communities in the south Florida coastal waters likely to be affected by the Comprehensive Everglades Restoration Plan (CERP), and they provide the majority of the fisheries habitat in this region. One of the main goals of CERP is to improve fisheries habitat by increasing the species diversity and areal extent of seagrass communities. An effective way to determine if this goal is being met is to establish a comprehensive seagrass monitoring program in the south Florida region.

The Florida Bay Fisheries Habitat Assessment Program (FHAP-FB) has provided detailed information on the status and trends of Florida Bay seagrass and macroalgal species for more than a decade. However, a more spatially comprehensive monitoring program will be required to assess seagrass changes that may occur in response CERP implementation. The newly established, South Florida Fisheries Habitat Assessment Program (FHAP-SF) has increased the geographic scope of FHAP from ten sampling locations in Florida Bay, to a total of twenty-three locations extending from Lostman's River to Biscayne Bay (Figure 1). In addition, FHAP protocols have been expanded to provide process-oriented data for *Thalassia testudinum* such as photosynthetic quantum yields, reproductive status, and epiphyte loads. As part of the REstoration, COordination and VERification (RECOVER) program, FHAP-SF will provide quantitative metrics to assess the effects of CERP activities on south Florida ecosystems. These baseline data will also enable resource managers to monitor seagrass community responses to anthropogenic impacts, as well as to natural events such as the recent passage of Hurricane Katrina through South Florida.

The first FHAP-SF monitoring survey was conducted in May 2005. Stations were determined using the systematic-random sampling design employed in FHAP-FB. The cover/abundance of seagrass and macroalgal species was visually estimated at 691 stations (approximately 30 stations/location) using a modified Braun-Blanquet procedure. Macrophyte species were quantified within twelve, haphazardly-placed 0.25 m^2 quadrats at each station. In addition to macrophyte cover, the occurrence of seagrass flowers and fruits was noted for each quadrat.

Changes in water quality associated with increased freshwater inflow may lead to higher levels of water column nutrients and increased seagrass epiphyte loads. At sites where *Thalassia testudinum* was present, ten short-shoots were collected to determine leaf epiphyte biomass (g dry wt. epiphyte g^{-1} dry wt. leaves). Shoots collected for epiphyte biomass were also used to obtain seagrass morphometric data.

Chlorophyll fluorescence techniques, especially pulse-amplitude modulated (PAM) fluorescence, are quick, non-destructive, and quantitative procedures to investigate photosynthetic characteristics of seagrasses. Photosynthetic efficiency may prove to be a sensitive indicator of photosynthetic stress in seagrasses. Quantum yields and photosynthetic efficiencies were measured for *Thalassia testudinum* at each station where it was observed. These data will be used to determine if PAM fluorometry can be used to rapidly assess the physiological condition of *Thalassia*.

The samples and data collected during the May 2005 FHAP-SF monitoring survey are currently being analyzed. Maps of seagrass distribution and abundance, and changes in abundance will be produced using a contouring and 3D mapping program (ArcGIS). The geostatistical gridding method of kriging will be used to express trends in the monitoring data. Contour plots will also be created to illustrate trends in other performance measures (e.g. epiphyte biomass).

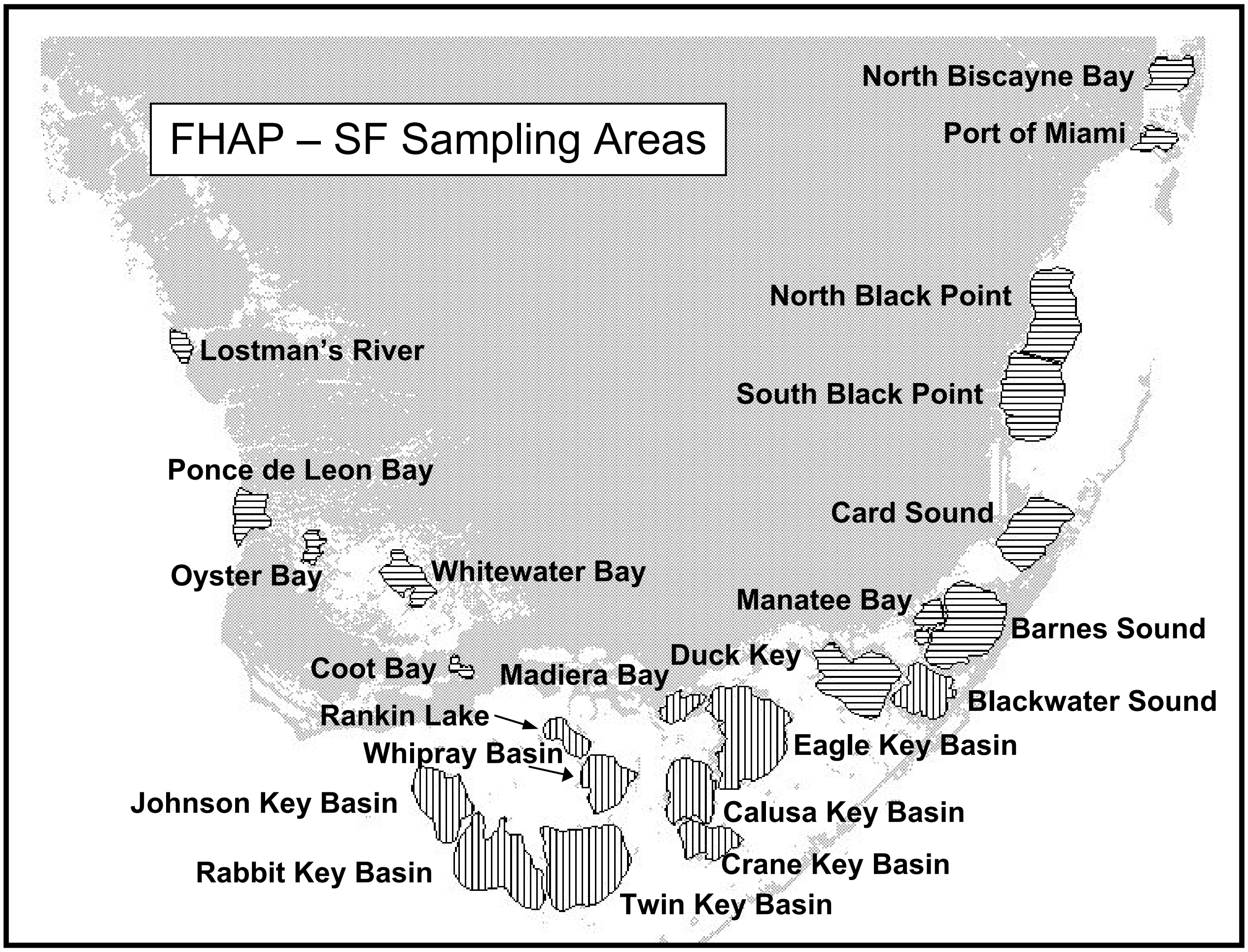

Figure 1. Ongoing and new FHAP-SF sampling locations. Vertical bars indicate current FHAP sampling locations, and horizontal bars indicate new FHAP-SF sampling locations.

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Community Structure in Sediment Bacteria along the Florida Everglades Marsh, Mangrove, and Florida Bay Ecotone: Estimation by PCR-DGGE and Sequence Analyses

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The coastal Everglades landscape may be viewed as an oligotrophic gradient of P limitation in the wetlands to N limitation at the marine boundary of the estuaries. Our Florida Coastal Everglades LTER consists of two watersheds: Shark Slough in the west which drains extensive sawgrass marsh and mangrove forests to the Gulf of Mexico, and Taylor Slough which drains a small watershed in the east and empties into eastern Florida Bay. Since sediments are known to play an important role to nutrient cycling, we investigated the change in sediment bacterial community structure (BCS) along theses gradients using PCR-DGGE.

Many different types of bacteria inhabited the soils and sediments along the gradient (50-60 bands). Cluster analysis showed that BCS first divided into two clusters: an estuarine Florida Bay group and a terrestrial wetland group. The Florida Bay cluster was further subdivided into Eastern and Central Bay group and a Western Bay group. The wetland cluster was also subdivided into a freshwater marsh group and a mangrove forest group. These results suggest that habitat types along with nutrient conditions are important drivers in BCS in coastal wetlands, whereas, in the estuary, BCS is mostly affected by the strong nutrient gradient.

Sequence analysis of the DGGE bands indicated that the major bacteria associated with every region was *Actinobacteria*, which was retrieved from wide range of habitats. In addition, the bacteria associated with sulfur cycling were also detected in every region. *Chloroflexi*, *Verrucomocrobia*, and *Nitrospirae* were characteristic bacteria in Everglades (marsh and mangrove), while *Cyanobacteria*, *Cytophagales*, *Desulfobacteraceae*, and *Gamma-Proteobacteria* were that in Florida Bay. It suggested that different types of bacteria inhabited according to the different environmental conditions and played a significant role in nutrient cycling.

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Modeling Analysis of Florida Bay's Seagrass Community Composition: The Importance of Sediment Characteristics, Water Quality, and Salinity

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From east to west in Florida Bay, seagrass beds change in both density and species composition. Using a mechanistic simulation model of seagrass dynamics, an exploration of the causes of seagrass diversity in Florida Bay is possible, giving insight to how the benthic community might respond to increased fresh water flow. Fresh water input is expected to increase as Everglades and Florida Bay restoration proceeds, resulting in reduced salinity and changes in nutrient, particulates, organic matter and temperature in affected waters.

The Florida Bay Seagrass Model is a spatially averaged, numerical description of seagrass community dynamics, synthesizing research on seagrass physiology and ecology in Florida Bay. Physical drivers in the model are light, nutrient concentration, sediment sulfide concentration, water temperature, and salinity. At present, the model simulates two of the four bed-forming seagrass species in South Florida: *Thalassia testudinum* and *Halodule wrightii*. In the development, parameterization, and calibration of the model, many information sources were utilized, including published studies, research collaborations yielding targeted experiments on specific seagrass processes, extensive seagrass and water quality monitoring programs, and the mining of the existing knowledge and expertise available for the Florida Bay ecosystem.

The seagrass model was calibrated for seven locations in different basins representing a gradient of environmental conditions in Florida Bay. Three sites are in the northeast coastal zone, two are in the central bay, and two are in the Gulf-influenced western sites. These sites vary in physical characteristics such as water depth, sediment depth, and salinity, as well as in seagrass characteristics. The northeast coastal sites are characterized by lower and more variable salinities than the central or western bay, as well as a thinner sediment layer (sometimes 5 cm or less thick) overlying the limestone basement. The seagrass beds in this region are sparsely populated and do not attain the densities observed in the central and western bay. Modeled seagrass populations generally track this observed low standing stock due to nutrient limitation. Additionally, species composition patterns that are observed in nature are also successfully replicated by the model. Near Everglades inflows, *Halodule* is relatively more abundant than *Thalassia*, while farther away from fresh inflows, *Thalassia* beds predominate. It is hypothesized that the shift in species composition is due to the interaction of salinity stress and nutrient competition.

We tested this hypothesis using the model by varying nutrient availability and salinity across the ranges found in eastern Florida Bay. The model successfully recreates the growth of *Halodule* in areas of fresh inflow based on salinity tolerance curves, which were derived from mesocosm experiments. In hyposaline simulations, *Halodule* out-competed *Thalassia* due to its slightly better tolerance of lower salinity. Where salinities approach marine conditions in the model, a range that is optimal for both *Thalassia* and *Halodule,* the species co-exist as mixed beds. In eastern basins that experience hypersalinity, however, modeled *Thalassia* generally dominates, despite observations of *Halodule's* higher tolerance for hypersalinity in mesocosm measurements (Koch and Durako 2004). In the simulations, *Halodule* was eliminated in beds of the northeast bay sites when salinities consistently averaged above 40 psu. This pattern of *Halodule* disappearance in hypersaline conditions is also observed in nature in eastern Florida Bay. We hypothesize the following mechanism: the thin sediment layer of the eastern bay, where a smaller nutrient pool is available to the plants, *Thalassia* can persist because it cycles its biomass slowly relative to *Halodule*. *Halodule*'s much shorter turnover time and higher growth rate requires continuous access to nutrients, which may be more effectively withdrawn from sediment pools by the much larger below ground biomass infrastructure of *Thalassia*. The physiological salinity stress to *Halodule* coupled with low nutrient availability results in a competitive advantage for *Thalassia* in hypersaline environments in the eastern bay.

Central Florida Bay is characterized by heavy epiphytization, high sediment organic matter content, frequent hypersalinity, and densely packed mixed seagrass beds. The deeper sediments of this region allow for a larger volume of porewater and a greater nutrient pool which prevents *Thalassia* from out-competing *Halodule*, leading to mixed beds even in hypersaline conditions. The modeled *Halodule* population is also bolstered by the morphology of the plants, with *Thalassia* being more vulnerable to epiphytization and decreased light availability. Despite the lower light environment for *Thalassia*, higher modeled biomass results in this region compared to the northeast, consistent with empirical measurements of seagrass biomass.

The western bay sites have more stable marine salinities and sediments thickness as great as 1 m. Our model predicts high biomass of both species limited by light and sulfide concentrations due to increased organic matter in the sediments. Monitoring data suggests a persistence of mixed beds in this region with *Thalassia, Halodule,* as well as the marine seagrass *Syringodium filiforme*. Ongoing development of the model is incorporating a *Syringodium* module that allows for an analysis of competitive interactions of three major seagrass species in beds in the western region of Florida Bay.

Reference:

Koch, M. S., and M. J. Durako. 2004. High salinity and multiple stressor effects on seagrass communities of Northeast Florida Bay. 2nd Interim Report for SFWMD contract # 12430.

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Examination of Sulfated Phenolic Compounds in the Seagrass *Thalassia testudinum* Using a Radiotracer Experiment

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The seagrasses, being marine angiosperms, are exposed to and tolerate a high concentration of inorganic sulfur. Sulfate (SO_4^{2-}) is the third highest ion in concentration in seawater, and hydrogen sulfide (H_2S), a phytotoxin, is commonly found in anoxic marine sediment. It has been hypothesized that the seagrasses may acclimate to the presence of these potential stressors by preferentially conjugating inorganic sulfur with phenolic compounds. The presence of these compounds has been documented in many of the subtropical and temperate seagrasses. Aside from noting their presence, little other work has been done on the initial hypothesis. In the only study of its type, Nissen and Bensen (1964) found that 50% of the radiolabled sulfate fed to *Zostera marina* was recovered in the phenolic flavonoid fraction. The current work at hand intends to use a radiotracer experiment to examine the relationship between hydrogen sulfide intrusion and the presence of sulfated phenolic compounds in the seagrass *Thalassia testudinum*. Also, this study is characterizing the phenolic acid profile of the seagrass gathered from both low and high sediment sulfide conditions.

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Long Term Evaluation of Sponge Population Recovery Following a Widespread Mortality: Will We Ever Know When Recovery Has Occurred? Is Restoration Necessary?

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One of the most dramatic manifestations of the perceived deterioration of the Florida Bay ecosystem has been widespread sponge mortalities caused by cyanobacteria blooms. During 1992 and 1993, widespread sponge mortalities significantly impacted sponge population in the Florida Keys, U.S.A. The extent of the impacted area was estimated to be approximately 1,000 km^2. The work described here (initiated prior to the mortalities) documented a highly significant reduction (over 90%) in sponge community volumetric biomass. Sponge numerical abundance data has been collected annually since 1991, allowing for the development of a unique, truly long-term (1991-2004) picture of sponge population dynamics following the mortalities. One of the project goals was to determine if restoration of hard-bottom sponge communities would be necessary.

As the project has evolved into a long-term picture of sponge population recovery, it is now possible to sort out natural sponge population abundance variability. The data identified several sponge species that are short-lived, and that widely fluctuate in abundance (*Adocia* sp., *Cinachyra* sp., *Halichondria melanadocia*, *Haliclona molitiba*, *Hyrtios* sp., *Niphates erecta*, and *Tedania ignis*). In a sense, it may be impossible to conclude that these species have recovered because their abundance is probably constantly changing. On the other hand, the data indicate that there are several long-lived sponge species that show gradual consistent recruitment. These species dominate sponge community biomass in the study area. Two species, the loggerhead sponge (*Spheciospongia vesparia*) and vase sponge (*Ircinia campana*) represented 59% of sponge community biomass prior to the mortalities. It is apparent that only a few species, such as these are important from a resource management perspective because they constitute the bulk of sponge habitat and ability to filter water. If these long-lived species successfully recruit, then sponge population recovery can be considered complete, as the abundance of other short-lived species will continue to fluctuate.

After ten years there has been significant recovery of sponge populations. However, certain key species (in terms of biomass) have not recovered fully, but their reestablishment appears to have begun. In this case, recovery of the sponge community biomass, unaided by human intervention, appears to be a decades long process.

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Characterization of the Nearshore Hard-Bottom Habitat of the Florida Keys.

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In 2002, thirty-two permanent nearshore hard-bottom sites were selected for quarterly surveys throughout the Florida Keys. The first two surveys were conducted in the summers of 2002 and 2003. The surveys included abundance estimates of larger sessile invertebrates (i.e. sponges, corals, and octocorals) using four 2x25m belt transects. Sessile invertebrates were counted, and for some taxa, measured for height and width. In addition, small sessile invertebrates (<5cm) were counted in 16 one-meter-square quadrates (four quadrats per transect). Percent cover and patch sizes of major algae and vascular plants were added in 2003.

Beginning in fall 2003, quarterly surveys of motile invertebrates, fish, and seagrass/algae were conducted along the same four 2x25m transects. In addition, we conducted a 20-minute roving search for fish, as well as a 20-minute roving search for lobsters and other large motile invertebrates. Presence/absence of non-patch forming algae was also catalogued. These surveys were repeated in winter, spring and summer 2004.

The sessile invertebrate data, collected during the beginning this study, allowed us to calculate structure complexity and species richness indices based on the fixed (sessile) invertebrate community for each site. In addition, we determined the dominant taxa of sessile and motile invertebrates, fish, algae and seagrass, and their spatial distribution in the Florida Keys. We also explored the data for any seasonal changes in the community. We looked for taxa associations using several hierarchical cluster analyses and used these associations in multiple regression analyses to determine any factor interactions.

Sponges and octocorals dominated the sessile community. Octocorals were more common in oceanside sites (although shorter than elsewhere) and sponges were relatively most abundant in the lower Keys. Laurencia (a red algae) covered more of the hardbottom community during summer than winter. For the motile invertebrate community, hermit crabs were the most abundant crustaceans and the Star shell (*Astraea spp)* was the most abundant mollusk. Among the fishes, *Lagodon rhomboides* and *Haemulon plumieri* were the most abundant.

Analysis of the data is currently underway for associations and linkages between the sessile and motile communities. Patterns detected thus far are that some taxa of small fishes (less than five cm) exhibit a trend toward higher abundance with increased density of octocorals whereas some taxa of larger fishes tend to be more abundant with increased density of sponges. Additional results from multivariate analyses will be presented.

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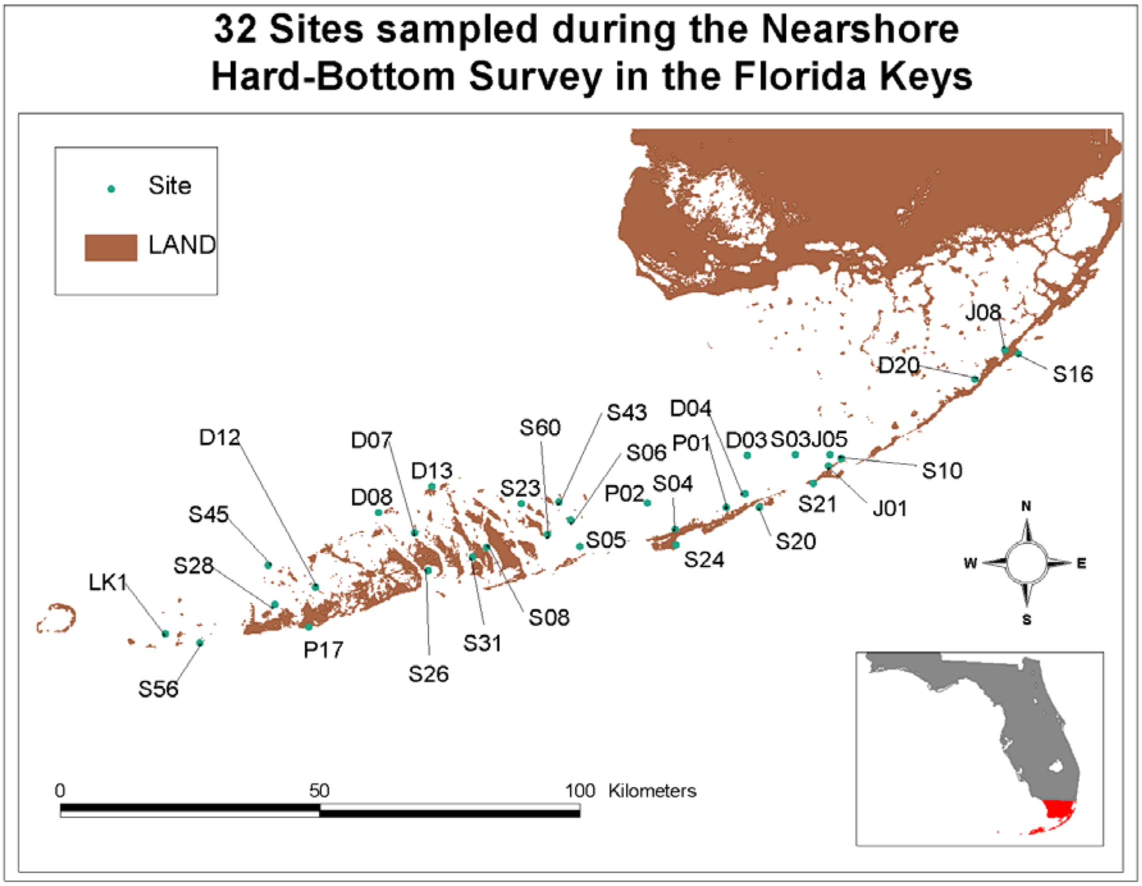
32 Sites sampled during the Nearshore
Hard-Bottom Survey in the Florida Keys
Site
LAND
J08
D20
S16
D12
D07
S60
S43
D04
D03
S03
J05
S10
D13
S06
P01
S23
P02
S04
S21
J01
D08
S45
S05
S20
S28
S24
LK1
S08
P17
S31
S26
S56
N
W
E
S
0
50
100
Kilometers

Oral Abstracts

Water Quality

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Bioavailability of Dissolved Organic Nitrogen in Florida Bay

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A better understanding of the biogeochemical cycling of nutrients entering Florida Bay is a key issue regarding the restoration of the Everglades. While we know that the Everglades marsh and mangroves deliver significant amounts of N to the Bay, the greatest portion (~90 %) of that total nitrogen pool (TN) is in the dissolved organic form (DON). Should this DON be readily available, any increased loading from changes in flows might have an impact on internal nutrient cycling and phytoplankton growth dynamics. To this end, assays of DON bioavailability (BDON) were conducted at 6 sites over 2 years (4 wet/dry seasons). Two sites were located in the freshwater Everglades marsh, 2 were in the fringing mangroves, and the others were located in Florida Bay proper.

Incubation experiments were established using ambient water (control) and water amended with glucose and PO_4^- (C+P). The C+P treatment was conducted in an effort to maximize DON degradation by provoking N limitation. Water was filtered through a 0.2 uM cartridge filter, dispensed into replicate 2 l bottles, before being inoculated with 10 ml of raw water from the corresponding collection site. Bottles were incubated in the dark at room temperature and sampled at 0, 1, 2, 3, 5, and 16 days. Samples were analyzed for heterotrophic bacteria production, bacteria counts, $Si(OH)_4$, TDP, TDN, NH_4^+, NO_3^-, NO_2^-, SRP and DOC. DIN was calculated as $NH_4^+ + NO_3^- + NO_2^-$. DON was calculated as TDN – DIN. BDON was calculated as percent loss of the DON pool over time.

There was a small, increase in bioavailability in DON with the addition of glucose and PO_4^-, but overall there was no significant effect (Fig. 1), therefore, data were grouped for further analysis. Overall DON bioavailability ranged from 1.8 – 50.8 % with a median of 23.2 %. Mangrove sites had significantly higher BDON (25.4 %) than either Florida Bay (19.8 %) or Everglades marsh sites (22.1 %). BDON in Florida Bay sites was significantly higher (23.2 %) during the wet season than dry (17.3 %, Fig. 1). No seasonal difference in BDON were discerned in marsh and mangrove sites.

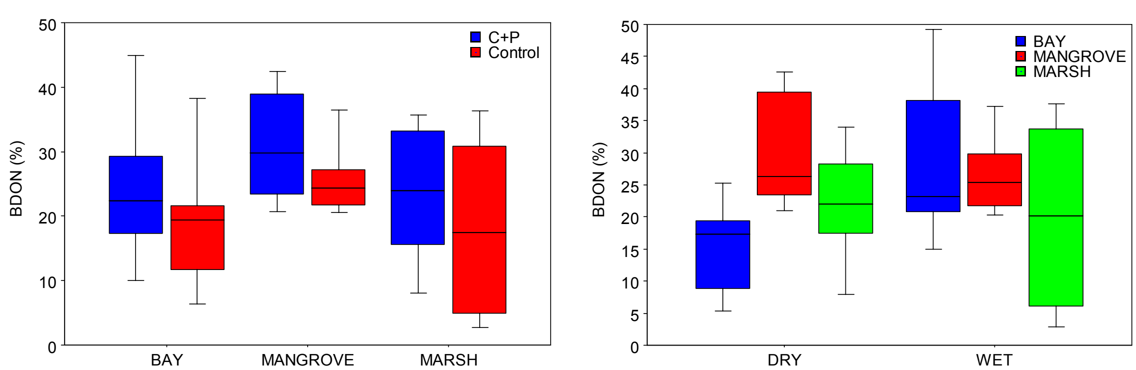

Figure 1: Bioavailability of DON in each community by treatment (left) and season (right) over the two year study period.

These assays provide a baseline for the bioavailability of organic nitrogen as controlled by heterotrophic bacteria in the system. That the BDON values were similar across community types was surprising and implies that source is not as important as chemical composition.

The BDON values reported here are on the low end in comparison to other estuaries, reflecting the oligotrophic nature of the terrestrial and aquatic sources. However, because DON is the dominant form of terrestrial N loading, the amount of recycled N provides a significant contribution to the inorganic N pool.

Previous estimates for Taylor Slough/C-111 panhandle loading are on the order of 290 metric tons yr^{-1}. If 90 % of TN loading is in the form of DON and 25 % of that is bioavailable, then 65 tons of this DON is potentially recycled back to inorganic forms and/or incorporated into biological biomass. This being the case, recycling of DON may account for much of the elevated DIN observed oftimes in eastern Florida Bay.

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Denitrification versus Dissimilatory Nitrate Reduction to Ammonium (DNRA) or Nitrite (DNRN) in Hypersaline Florida Bay Sediments in August 2004 and January 2005

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Nitrogen (N) conversions are dynamic at the sediment-water interface in shallow coastal environments, such as Florida Bay, due to: high biological productivity, rapid changes in redox potential with sediment depth, and demand for this nutrient by coastal organisms. Bacteria and other organisms mediate N transformations, such as N-fixation ($N_2 \rightarrow$ organic N), organic matter mineralization (organic N $\rightarrow NH_4^+$), nitrification ($NH_4^+ \rightarrow NO_3^-$), denitrification ($NO_3^- \rightarrow N_2$), and dissimilatory nitrate reduction to ammonium (DNRA; $NO_3^- \rightarrow NH_4^+$). Florida Bay differs from many coastal and estuarine ecosystems in that phosphorus, rather than N, often limits biological production in parts of the bay. Reduced forms of available N, such as NH_4^+ and NO_2^-, often are more prevalent than NO_3^- in this system.

An important biogeochemical question in Florida Bay is “What mechanisms keep bioavailable N in reduced forms rather than removing it quantitatively as N_2 via denitrification?” We hypothesized that DNRA is an important mechanism for retaining reduced forms of available N in Florida Bay. This hypothesis was examined in four regions in Florida Bay (north-central, Rankin Key; north-eastern, Duck Key; north-western, Murray Key; and central, Rabbit Key) in August 2004 and January 2005. Site water was passed continuously over intact sediment cores and concentrations of NH_4^+, NO_3^-, NO_2^-, O_2, and N_2 were measured in inflow and outflow waters under steady-state conditions to determine nutrient fluxes, oxygen consumption (SOC) rates, and net denitrification rates at the sediment-water interface. Excess $^{15}NO_3^-$ was added to inflow waters, and changes in nutrient-, O_2-, and N_2-fluxes, and the isotopic forms of N_2 (by membrane inlet mass spectrometry) and NH_4^+ (by HPLC) were measured to assess the importance of denitrification, DNRA, and N_2-fixation in determining the fate of available N. Salinities ranged from 37 to 41 in August and 33 to 45 in January. SOC rates (mmol O_2 m^2 h^{-1}) ranged from 1.25 at Rabbit to 3.80 at Rankin in August and from 1.03 at Rabbit to 1.90 at Duck in January. Net denitrification rates (µmol N m^2 h^{-1}), before $^{15}NO_3^-$ enrichment, ranged from 25 to 43 in August and 107 to 313 in January. Potential DNRA rates (µmol N m^2 h^{-1}) ranged from 43 at Rabbit to 157 at Rankin in August and from 11 at Rabbit to 82 at Duck in January. Ratios of total denitrification (after enrichment) to DNRA were lower than one (0.3 to 0.8) in August but higher (5 to 10) in January. Thus, DNRA was the dominant mechanism affecting the fate of NO_3^- in Florida Bay in August, but denitrification was dominant in January. Isotopic data indicated that N_2 from denitrification was derived from a combination of added $^{15}NO_3^-$ and NO_3^- from coupled nitrification/denitrification, except at Rankin, where 100% of produced N_2 was derived from the latter process. N-fixation was not measurable at any of the stations during August or January.

Nitrite is a key component of N-dynamics at the sediment-water interface. It is an intermediate of several processes, including nitrification, denitrification, and DNRA, but NO_2^- concentrations are low relative to NO_3^- in most aquatic environments. Nitrite concentrations and fluxes in Florida Bay were compared to data from a variety of shallow, nutrient-enriched ecosystems (Texas coastal waters; Florida Bay; Old Woman Creek Estuary, Lake Erie; and Lake Taihu, China). In contrast to results from other systems, NO_2^- was the *dominant* N ion occurring in hypersaline Florida Bay waters in August (and at two sites in January), and NO_2^- production rates increased in the presence of added ^{15}N-labeled NO_3^-. The sediment-water production of NO_2^- thus appeared to relate to DNRA, a process often ignored in aquatic sediments. These data indicate that dissimilatory NO_3^- reduction to NO_2^- (DNRN) is an important process associated with DNRA, in warm, organic-rich sediments, under high-salinity conditions, as occur in Florida Bay during summer.

The above results suggest the importance of DNRA and DNRN in Florida Bay and indicate that an understanding of internal N-dynamics is crucial to determining factors regulating nutrient-food web interactions during different seasons.

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Organic and Inorganic Nutrients, Rates of Phytoplankton Nutrient Uptake, and Their Relationship with Phytoplankton Community Composition in Florida Bay and in a Comparative Subtropical Ecosystem in Australia

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The stoichiometric proportions of nutrient availability, and the proportions in which phytoplankton utilize those nutrients have been found to be useful in determining potential limitation of plankton productivity and biomass in coastal ecosystems. The forms of nutrients limiting production and biomass in Florida Bay are of direct management interest. The alterations in the forms, sources, and ratios of nutrient inputs to Florida Bay that will likely result from the proposed Everglades Restoration project provide further justification for an assessment of the current status of nutrient loading and stoichiometric relationships. As part of a NOAA-funded program, we have addressed the dissolved and particulate nutrient composition, rates of uptake of various inorganic and organic nutrients and their relationship with bacterial and phytoplankton biomass and phytoplankton community structure at 6 representative sites within Florida Bay over several years. In a previous study conducted in Moreton Bay, Australia, similar parameters were measured with the same techniques, thereby permitting a comparative seasonal analysis of these subtropical, seagrass dominated ecosystems.

We have previously shown for Florida Bay that organic nitrogen and phosphorus play an important role in plankton dynamics during one season in which a major cyanobacterial bloom occurred. This relationship can now be extended across seasons. High organic nitrogen and phosphorus inputs are generally associated with Shark River Slough, whereas a higher proportion of inorganic nitrogen loading occurs in the eastern Florida Bay region. One component of the organic nitrogen fraction, urea, is not only elevated in the Shark River Slough area, but the proportion of uptake of urea relative to other nitrogen forms has also been found to be related to the proportion of cyanobacteria in the phytoplankton community, based on pigment analyses. The rate of inorganic nitrogen relative to other nitrogen forms, on the other hand, is related to the fraction of diatoms in the plankton community.

The relationship between nutrient and plankton dynamics between Florida Bay and Moreton Bay, Australia, lend insight into the interaction of nutrient limitation with other environmental factors in shaping plankton communities. Both are shallow, subtropical estuaries at equivalent latitudes lying adjacent to major metropolitan areas (i.e. Miami and Brisbane) and are subject to increasing eutrophication and outbreaks of harmful algae. The major differences in nutrient regulation of phytoplankton in these two shallow subtropical ecosystems are primarily related to the impacts of watershed differences (on the form and types of nutrient supplied) as well as differing hydrology (i.e. influence of depth on benthic-pelagic coupling). Whereas Florida Bay has significant loading of dissolved organic nitrogen, Moreton Bay has proportionately higher organic phosphorus and inorganic nitrogen loads. Florida Bay shows a gradient in phosphorus to nitrogen limitation east to west, while Moreton Bay is a nitrogen limited system throughout. In both systems, increases in the contribution of organic nitrogen to total phytoplankton nitrogen uptake are related to outbreaks of major harmful species, although this relationship holds for dinoflagellates in Moreton Bay and for cyanobacteria in Florida Bay. In both systems, inorganic nitrogen uptake is related to the proportion of diatoms. Higher overall nutrient uptake rates, as well as greater seasonality, were found in Moreton Bay compared to Florida Bay. Within Moreton Bay, seasonal riverine inputs of suspended sediments impacted productivity via phosphorus and light attenuation, while in Florida Bay, episodic wind related sediment suspension events contributed to significant benthic-pelagic coupling. In both systems, controlling eutrophication will require control of the organic as well as the inorganic nutrient sources.

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Nutrient Quality drives Phytoplankton Community Composition on the Southwestern Florida Shelf Region, including Florida Bay

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The southwestern Florida coastal shelf region, including Florida Bay, receives nutrient inputs from a variety of riverine sources which differ greatly in their watershed usage and flow regimes, and thus vary in the form, frequency and magnitude of their inorganic and organic nutrient inputs to the region. This region is the site of frequent and persistent algal blooms, including those of the toxic dinoflagellate *Karenia brevis* over the entire region, large scale diatom blooms commonly referred to as 'blackwater' or 'darkwater' in the Ten Thousand Island area and cyanoabacterial blooms in Florida Bay (e.g. *Synechococcus* spp.) as well as on the inner shelf (e.g. *Trichodesmium* spp.). Little is known about the comparative influence of these differing riverine sources and nutrient inputs regimes on downstream phytoplankton communities however, including these differing algal blooms.

During May 2003, 58 stations from the entrance of Tampa Bay to the Florida Keys and from nearshore out to the 30 m isobath were synoptically sampled over a 5 day period for inorganic, organic and particulate nutrients and phytoplankton community composition. A more limited suite of stations (19 total) covering the same areal extent were sampled for determination of nutritional and physiological status of the phytoplankton assemblages (as urease and alkaline phosphatase activities). Nutrient addition bioassays (2 L, 24 hr) were also conducted with natural plankton assemblages from the mouths of the Peace, Caloosahatchee, and Shark Rivers as well as in western Florida Bay. Large differences were observed in the distributional pattern between inorganic and organic nutrients and between N and P. Inorganic N concentrations were low throughout the region, while DON distributions were characterized by an onshore gradient, from 9.0 μM offshore to 30.0 μM nearshore over the entire region. DON concentrations within Florida Bay over this period ranged from 7.6 μM in eastern Florida Bay to 62.6 μM in Little Madiera Bay, adjacent to the Everglades. Areas of elevated urea concentrations were localized within two regions offshore of the Ten Thousand Island area to the west of the Everglades. Conversely, DIP and DOP concentrations were high only in northern coastal areas adjacent to outflows from the Charlotte Harbor and Tampa Bay estuaries, suggesting that coastal sources dominate the input of P to the shelf system, even during the dry season.

The north-south gradient in the availability of nutrients fall into three distinct zones (Fig. 9), herein termed I, II and III. Zone I, the mouths of the Peace and Caloosahatchee Rivers, was characterized by a particulate community that was seemingly N limited, as the stoichiometric proportions of the particulate matter were consistently <8 and the highest phytoplankton responses were found in bioassays enriched with N. This region had the highest abundance of peridinin –containing dinoflagellates, including *K. brevis*, concentrated at the mouth. Zone II, the Ten thousand Islands regions, and Shark River mouth, was characterized by a particulate stoichiometric ratio close to Redfield proportion, 8-24, and an increasing abundance of zeaxanthin-containing cyanobacteria and fucoxanthin-containing diatoms. Although smaller than in the Peace and Caloosahatchee, the phytoplankton in this region showed modest response in bioassays enriched in N, and an even smaller, but still positive, response to enrichments with P. Lastly, Zone III, western Florida Bay and the western Florida Keys had the highest proportion of diatoms, as indicated by the fucoxanthin: chlorophyll a ratio. The particulate material of this region was also characterized by the highest N:P ratio, >24, and thus was apparently the most P limited. This latter conclusion is somewhat at odds with the bioassay responses, which showed enhancement to N additions, but which also suggested a slight response to P as well.

These coastal regions reflect the differing riverine inputs to each river, which in turn are influenced by the major landscape shifts that occur in southwest Florida. A high phosphorus input region to the north is superimposed upon a north-south gradient in dominant form of nitrogen inputs, from DON in the north, to NH_4 and urea in the central region to NO_3 in the southern region. Collectively these patterns of nutrient distribution and phytoplankton physiology suggest that terrestrial nutrient inputs are large, even during minimal flow, and its relative availability leads to both differential nutrient limitation in different regions of the shelf as well as to the development of a varying plankton community composition. These results also strongly indicate that organic nutrients are an important contributor to the nutrient dynamics of the shelf.

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Effects of Post-Hurricane Freshwater Imports from the Everglades on Bacterial Community Composition, Ectoenzyme Activities, and Nitrogen Cycling in Northern Florida Bay

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Episodic storm events can alter trophic interactions in coastal pelagic microbial systems by increasing sediment resuspension and terrestrial runoff. This may, in turn, change nutrient availability, organic matter (OM) composition, and food web structures. In Florida Bay, Everglades runoff after tropical cyclones can introduce the majority of annual freshwater import into the bay within as little as a few weeks. These freshwater imports may also carry >50% of annual total nitrogen and phosphorus inputs into the bay, the majority being in organic form. Bacteria communities react rapidly on OM imports, but since organic materials >600 Da are not directly accessible, bacteria produce various ectoenzymes either attached to the outer cell wall or freely released into the water column that hydrolyze poly- and oligomers into directly usable compounds. Bacterial abundance, productivity, community composition, and ectoenzyme activities were recorded at 4 stations in northern Florida Bay from the Everglades mangrove fringe southwards (Little Madeira Bay mangrove fringe, Little Madeira Bay mouth, Park Basin, Manatee Basin) from May 2004 to January 2005. Particularly, the effects of freshwater runoff following a sequence of three hurricanes (Charley, Frances, Jeanne; August 13 – September 26, 2004) were addressed.

The early wet season of 2004 was exceptionally dry, resulting in salinities of up to 47‰. Freshwater release through the South Florida canal system and Taylor Slough in preparation for and during the hurricanes lowered salinities to 10.8‰ at the mangrove fringe and ~31‰ south of Little Madeira Bay, but this freshwater import did not initially solicit increases in inorganic nutrients. However, concomitant import of OM triggered an increase in bacterial production, which appeared balanced by microbial grazing pressure and did not result in increased bacterial stocks, and aminopeptidase (AM) activity. Bacterial conversion of labile dissolved organic nitrogen (DON) by AM activity and increased bacterial production balanced by grazing losses enhanced NH_4^+ regeneration and increased ambient NH_4^+ concentrations. As DON was transported southwards by continued freshwater flow through Taylor Slough, microbial communities further from the mangrove fringe reacted in similar ways while AM activity decreased at the mangrove fringe, perhaps linked to increased NH_4^+ concentrations. Effects of freshwater and DON import dissipated quickly once water flow was restricted again by water management and towards the south, never reaching the central bay (Manatee Basin). Microbial communities in the central bay remained relying on autochthonous production of dissolved OM and sediment resuspension by the storms. Quantitative real-time PCR with group-specific 16S rDNA primers and genetic community profiling by denaturing gradient gel electrophoresis (DGGE) of the variable region 3 of the 16S rDNA gene revealed α-proteobacteria of the *Roseobacter*- and *Rhodobacter*-groups and members of the *Cytophaga/Flavobacter* clade as the dominant members of bacterioplankton. DGGE analysis also revealed that changes in microbial activities upon increased freshwater and OM input were related to changes in community composition. From a limited, preliminary data set, temporal differences appeared more significant than regional differences. Comparison of genetic community profiles (16S rDNA DGGE) with "activity" profiles (16S rRNA DGGE) also revealed that most abundant genotypes were not always the most active bacteria. Bacterial production remaining elevated above pre-storm levels throughout the late wet season and early dry season 2004/2005 suggest that tropical cyclones can have long-lasting effects, and fall heterotrophy might be an important process in removing excess carbon import from the estuarine system.

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Sediment Phosphate Flux and Benthic Microalgal Communities in Florida Bay, USA

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In situ phosphate (P) flux between the sediment and the water column, oxygen production and benthic chlorophyll were measured in three regions of Florida Bay. Differences in the ratio of inorganic to organic phosphate flux were found between the three regions in relation to the amount of phosphate measured in the water column. Sediment porosity, tidal range and current conditions differed between the three sites. However, benthic chlorophyll content differed little.

P flux was not related to tidal cycle or season. *In situ* benthic chlorophyll values ranged from 1.1 - 42.9 mg m^{-2}. Certain nutrient addition regimes (N only, P only, and N and P) to the sediment within microcosms stimulated both benthic and water column chlorophyll concentrations. Benthic microalgal standing stock has patchy distribution but exceeds that of the water column by an order of magnitude during non-bloom conditions and is an important component of primary production in Florida Bay. Soluble reactive phosphate (SRP) values were frequently near the limits of detection, yet differences between light and dark chambers and afternoon vs. morning incubations indicate benthic microalgae could be mediating P flux from the sediment. Laboratory experiments using ^{33}P indicate that the presence of a benthic microalgal layer affects the release of phosphorus from the sediment to the overlying water column. Based upon the results from this study, P flux from the sediment can be an important contribution to the P budget of pelagic phytoplankton blooms in Florida Bay, accounting for 6.5 - 41% of demand.

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Aquatic Ecological Risk Assessment: Florida Bay and South Biscayne Bay

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A probabilistic aquatic ecological risk assessment (ERA) was conducted for Florida Bay and South Biscayne Bay based on pesticide and trace metal data obtained from historical data and a recent three-year monitoring program. The ERA approach followed the current U.S.EPA framework. The 90th percentile exposure concentration estimates for chlorpyrifos and endosulfan in surface water were higher in Joe Bay than other estuarine sites. Based on joint probability curves the potential risk was higher for arthropods exposed to chlorpyrifos in 1999 than in 2000. Potential risks for arthropods exposed to endosulfan were higher in 2000 than in 1999. Potential risks were also higher at all estuarine sites for endosulfan and arthropods than for chlorpyrifos and arthropods. Risks were lower for fish than arthropods. In addition, risks increased from single to multiple exposures. For metals, Florida Bay had a higher Hazard Index (HI) than Biscayne Bay. Arsenic was predominately responsible for the higher HI in Florida Bay. There were also potential acute and chronic risks of arsenic to arthropods in Florida Bay. Furthermore, there were low risks to arthropods in Biscayne Bay as a result of copper and arsenic. However, risks of copper and arsenic increased in Biscayne Bay when chronic exposures were considered.

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Poster Abstracts
Water Quality

Listed alphabetically by presenting author and abstract title.
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Water Quality and Sediment Chemistry and Toxicity in the Primary Canal System within Southern Miami-Dade County: 1996 versus 2001

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Miami-Dade County contains highly developed urbanized areas, as well as extensive agricultural regions in the southern portions of the county. Discharges of storm and drainage waters from Miami-Dade the associated pollutants, or contaminated sediments can affect Biscayne Bay, including Card and Barnes sound, as well a northeastern Florida Bay. To assess the status and trends of water and sediment quality within the primary canals in Miami-Dade County and Biscayne Bay, the County's Department of Environmental Resources Management (DERM) conducts long-term water quality monitoring of the surface water waters of the Bay and canals, as well as assesses canal sediment quality in the primary canals. The County's water quality monitoring initiated in 1979, and the sediment quality assessments have been conducted in 1995-6, and 2001-2, as part of the County's Municipal Separate Stormwater Sewer System (MS-4) National Pollution Discharge System (NPDES) permit. A total of 103 (52 Bay, and 51 canal) sites are visited monthly for the water quality program, and 55 'segments' within 23 canals are assessed once every 5 years for the canal sediment quality. The 'Southern Biscayne Bay' region is arbitrarily defined as the region south of the "Culter Drain" (C-100) Canal, including Card and Barnes Sound. Major canals assessed in the study, that discharge storm and drainage waters into Biscayne Bay in this region.(Culter Drain [C-100], Black Creek [C-1], Princeton [C-102], Military, Mowry [C-103], Florida City, C-111, L-31E). Additionally, the canals may have secondary or tertiary canals connecting to them. A total of 28 segments were evaluated in the 8 canals noted above.

Water samples were assessed for various parameters including, but not limited to: temperature, salinity, pH, dissolve oxygen, specific bacteria, nutrients, pesticides, hydrocarbons, volatile organic compounds, and metals (frequency of parameter assessment varies). Sediment quality was evaluated through assessment of sediment chemistry and toxicity. Chemical analysis included: at least the 14 trace elements, 23PAHs, 27 PCBs, and 41 pesticides. Analytical results was evaluated against the) TEL (Threshold Effects Limits) and PEL (Probably Effects Limits) as listed in the Florida Freshwater Sediment Quality Guidelines (McDonald et al., 2003) for each parameter in each sample. Sediment toxicity was evaluated through analysis of amphipod survival tests of pore water, and Microtox tests of solvent extracts. A classification scale of the overall sediment quality was developed, based on a "combined in a weight-of-evidence approach", which integrated the level of contamination in the soil, and the toxicity results. Categories were: "High Quality", "Slightly Degraded", "Moderately Degraded" and "Most Degraded" (Long et al., 2005). Water quality data for the 5 years prior to the sampling was summarized to allow assessment of relationships of the long-term water quality with the sediment quality results.

In general, the sediment quality in the canals showed little impact, with 80% of the 1996, and 100% of the 2001 show no or only slight degradation. The notable exception to this was Military canal. It should be noted, however, that a remediation program was conducted in Military canal in 2002, wherein the contaminated sediments within the canal were encapsulated, thereby greatly minimizing or eliminating the ability of the sediments to move into the adjacent Biscayne Bay waters. The sediment chemistry data suggest that lead, zinc, and chlordane were the chemicals of highest potential concern because they exceeded the Sediment Quality Guidelines in the most samples. The chemicals of least concern were arsenic, chromium, nickel, and pesticides other than chlordane and dichlorodiphenyltrichloroethane (DDT). The concentrations of most chemicals were similar in the two survey periods; however, the concentrations of some chemicals (notably pesticides and other organic compounds) may have decreased somewhat between periods.

The incidence of toxicity observed in Miami–Dade County canals was comparable to or lower than that recorded in the 1995–96 survey of adjoining Biscayne Bay, depending on the test performed. The incidence of toxicity was comparable to that of other southeastern U.S. areas that have been surveyed, but lower than in several national databases that included survey results from the more industrialized regions of the United States.

Table 1. Summary of canal sediment quality classification in 1996 and 2001

Year	Number Canals	Number Segments	No. Cat 1	No. Cat 2	No. Cat 3	No. Cat 4
1996	8	29	6	17	3	3
2001	8	27	3	24	0	0

Water quality parameters were summarized for the 5 years preceding each sampling event to allow for evaluation of relationships between sediment chemistry and overlying water quality. No consistent relationships were readily discernable. However, it is understood that many of the contaminants of concern have very low solubility, and the sediment quality at a particular station may be more representative of the transport of sediments from agricultural/industrialized regions, rather than settling or precipitation from the overlying water column.

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Interannual Variability in Carbon and Nitrogen Stable Isotopic Signatures of Size-Fractionated POM from the South Florida Coastal Zone

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Environmental conditions in South Florida coastal waters have been of local and national concern over the past 15 years. Attention has focused on the ecosystem impacts of salinity increases, seagrass die-off, increased algal bloom frequency, waste water influence, groundwater discharge, and exchange between Florida Bay, the Gulf of Mexico, and the Atlantic Ocean. Changes in water quality and productivity levels may be reflected in the isotopic signatures of coastal zone primary producers. Recent work with seagrasses in South Florida has demonstrated high seasonal and spatial variability in C and N isotopic signatures and decoupling between the two isotopic systems as they vary. To better understand the sources of seasonal and spatial fluctuation, size fractionated POM (particulate organic matter) samples have been collected on a quarterly basis since Sept. 2002. Fractions collected include >150µm, 50-150µm, and 0.1-50µm using Nitex mesh sieves and a portable pump system deployed from a small boat at 10 sites around the Florida Keys and Florida Bay. It was hypothesized that the planktonic groups respond more quickly to changes in water quality then seagrasses, and thus variations may be more clearly attributed to environmental parameters.

Significant spatial and temporal variability is evident both within site between size fractions and between sites. Seasonal oscillations of up to 4‰ were observed in N isotopic values and 6‰ in C isotopic values of the 50-150µm size fraction, which is dominated by diatoms and dinoflagellates. $\delta^{13}C$ values are depleted in the late winter/early spring sampling period possibly reflecting decreased productivity stress on available C pools. $\delta^{13}C$ depletion is generally coincident with $\delta^{15}N$ enrichment in the late winter/early spring, possibly demonstrating changes in DIN pools (NO_3^- and NH_4^+ concentrations) or changes in decomposition or denitrification rates. Broad groupings appear to separate Atlantic coral reef sites, interior Florida Bay sites, and western boundary Florida Bay/Florida Keys channel sites in isotopic signature and the magnitude of seasonal variation. Additionally, results utilizing flow cytometry in conjunction with isotopic analyses of the <50µm POM fraction from Florida Bay show a correlation between low DIN availability, cyanobacterial population abundance, and depleted $\delta^{15}N$ signatures, implicating N-fixation as a supplemental nutrient source, favoring N-fixing cyanobacterial blooms.

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Biogeochemical Relationship between the Everglades and Florida Bay Revealed Through Spatial and Temporal Variability of Nitrogen Isotopic Compositions of Dissolved Nutrients and Biologically-Derived Organic Components

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Identifying linkages between nutrient inputs from the Everglades and biogeochemical cycling processes in Florida Bay is critical to understanding the effects of hydrological restoration and changing nutrient regimes on water quality and ecosystem structure of Florida Bay. A stable isotopic approach affords an effective way of tracing the fate of varying nutrient sources and delineating the dominant biogeochemical processes and pathways governing nutrient cycling and assimilation in the bay. This study's main goals are to use stable isotopic analyses of C and N in dissolved and particulate materials to determine spatial and seasonal relationships between Everglades nutrient sources and their biological sinks in Florida Bay, examine the biogeochemical relationships among inorganic and organic components of the water column and benthos in Florida Bay and, assess future ecological response to changing nutrient inputs resulting from restoration efforts. Ten sites in Florida Bay and the Everglades were chosen to represent the 3 upland watersheds and the chemically and ecologically distinct regions in the bay. At each site, water, aquatic vegetation and surficial sediments were sampled for bulk stable isotopic analysis (C, N) and suite of biological, chemical and physical measurements were taken. Water samples were filtered and the dissolved components (DIC, DIN, DON, DOC) isolated for quantification and isotopic measurements.

Previous results from our research showed a distinct east-west spatial variation in the $\delta^{15}N$ of organic materials (particulate organic matter, sediment, submerged vegetation, and seagrass) from both Florida Bay and the Everglades. Large isotopic east-west (E-W) gradients of over 10‰ in $\delta^{15}N$ (from 4 to 14‰) clearly indicated that Everglades nutrient sources directly influence assimilation and recycling (i.e., denitrification) in the bay. To enhance the resolution of the isotopic trends, a bay wide survey of water, seagrass and sediment was conducted at 33 sites. Survey results confirmed that the E-W gradient reflects differing nutrient sources and dominant biogeochemical processes. Seasonal changes in hydrologic conditions from dry to wet influenced the $\delta^{15}N$ signals; however, the E-W isotopic gradient persisted. $\delta^{15}N$ of *T. testudinum* showed a progression toward more enriched values (typically 2‰ heavier) during the transition from the dry to the wet season. This directly correlated with an increase in dissolved N during times of higher freshwater flow from the Everglades into Florida Bay. The converse was observed for sediment, with more enriched values in the dry season, when freshwater flow from the Everglades is less and circulation is restricted in eastern Florida Bay. Long residence times for water in eastern Florida Bay, coupled with the shallowness of the system, are favorable for rapid recycling of nutrients through nitrification-denitrification processes in the sediment. In the wet season, when freshwater flow from the sloughs dramatically increases, allochthonous nitrogen sources, e.g. runoff from agricultural fields, may become incorporated into the isotopic signal thereby shifting to more depleted values.

To relate nitrogen nutrient sources to their biological sinks, the isotopic compositions of dissolved components were analyzed. High molecular weight dissolved organic matter (HMW

DOM, between 0.1μm and 1KDa) also displayed an E-W gradient. In the dry season, $\delta^{15}N$ values of DOM were up to 20‰ in the C-111 canal, compared with 2‰ in the western part of the bay. This E-W gradient of 18‰ directly overlapped with observed isotopic gradients in the POM, sediment and seagrass, supporting the hypothesis that differing Everglades nutrient sources support biomass production and significantly influence biogeochemical recycling in various regions in Florida Bay. More enriched values in the east suggest that waste water sources of N and the biogeochemical process of denitrification dominate in this region, while lower $\delta^{15}N$ values in the western bay suggest N sources from terrestrial runoff, and agricultural fertilizer, as well as atmospheric N for N_2- fixation. Seasonal changes in the size of the N-isotopic gradient appear to reflect changes in hydrologic flow from the Everglades watershed into the bay. Interestingly $\delta^{15}N$ of HMW DOM exhibited 2-3‰ enrichment baywide during the dry season suggesting that, as hydrological flow from the Everglades decreased, recycling processes of nitrification and denitrification and assimilation of DOM byproducts increased throughout the bay. Uptake and bioassay experiments confirm that DOM is readily assimilated by microbial autotrophs, supporting the interpretations from the stable isotopic data that DOM is an important source of N to phytoplankton and overall nitrogen cycling within Florida Bay.

Dissolved inorganic nitrogen (DIN) has traditionally been considered the more bioavailable form of dissolved N. While very low NO_3^- concentrations prohibited measurement, NH_4 concentrations in some parts of the bay were sufficient for isotopic analyses. Initial $\delta^{15}N$ measurements of NH_4 exhibit a 6‰ range from the Everglades watersheds with the lower values of 1-3‰ for Shark River and Taylor Sloughs and the most enriched value of 6.4 ‰ in the east for Canal C-111. While there is 1‰ enrichment in the Shark River Slough and Taylor Slough in the wet season, there is no significant shift for C-111 $\delta^{15}N$-NH_4. This E-W gradient in $\delta^{15}N$ of NH_4^+ is smaller but still consistent with those observed in organic materials and DOM. In Florida Bay the $\delta^{15}N$-NH_4 range is much larger (9‰) than in the Everglades, particularly in the dry season when values ranged by 9‰ with enriched values up to 12‰ in the east and relatively depleted values of 3‰ in the west. The size of this $\delta^{15}N$ gradient changes becoming larger in the dry and a smaller in the wet season. Larger gradients and more enriched values in the dry season infer that *in situ* recycling processes become critical for supporting photoautotrophic populations during times when freshwater input is dramatically reduced.

Stable nitrogen isotopic data of dissolved nutrients and biologically-derived organic components confirm the efficacy of the use of an isotopic approach to link nutrient sources in the Everglades to biological sinks in Florida Bay and to determine the dominant biogeochemical processes there. Spatial trends show that differing nutrient inputs from upstream watersheds impart distinct $\delta^{15}N$ signals and significantly influence nitrogen cycling in the bay. More enriched $\delta^{15}N$ values of nutrient pools and biological sinks during the dry season suggest some decoupling behavior in the biogeochemical relationship between the Everglades and Florida Bay when freshwater flow into the bay dramatically decreases and *in situ* processes dominate the isotopic signal.

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Remote Sensing of Water Quality Index and Connectivity in Florida Bay and Florida Keys: Some Recent Advances

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Traditional satellite ocean color data products for optically complex regions, such as Florida Bay (shallow, turbid) and Florida Keys (shallow), are subject to large uncertainties due to a number of reasons: 1) the standard 1-km resolution is often insufficient, and 2) it is difficult to differentiate phytoplankton pigments (chlorophyll) from colored dissolved organic matter (CDOM, or yellow substance), where the former can often be used as an index of eutrophication or an index of potential red tide. However, the medium resolution bands (250 and 500 m) and fluorescence bands available with the Moderate-resolution Imaging Spectroradiometer (MODIS), have shown great advantage in overcoming some of these problems.

We show examples of how to use these new data products to assess circulation patterns and phytoplankton biomass. Combined with other data products such as the spectral water-leaving radiance, they show unprecedented potential to enhance our understanding in water quality synoptic patterns and small- to large-scale connectivity. We also show our first effort to automatically integrate remote sensing data with *in situ* observations. Further, we present some preliminary data products from the 300-m resolution MERIS sensor, particularly for evaluation of its fluorescence products. Remaining issues and future directions will also be addressed.

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Sources of Variation in Florida Bay Water Quality

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Understanding the water quality environment of Florida Bay is of vital importance as the Comprehensive Everglades Restoration Plan (CERP) proceeds. Of utmost importance is the ability to predict how water quality parameters will change in response to changing physical forcing. Thus far, most of the long term water quality analyses have focused on the spatial and temporal distributions of water quality variables, as well as the correlations among water quality parameters (Boyer et al. 1999, Boyer et al. 1997, Fourqurean et al. 1993). There has been comparatively little examination of how physical forcing events (e.g. runoff, wind, precipitation/evaporation, storms) effect the water quality environment of Florida Bay (Lawrence et al. 2004). Furthermore, the studies that examined the effect of physical forcing on water quality did so only on short time and space scales.

Since 1996, we have taken 94 survey cruises sampling 40 discrete stations within Florida Bay for the following water quality parameters; dissolved inorganic nitrogen, dissolved inorganic phosphorous, silica, chlorophyll *a*, beam transmission (λ=660), light attenuation, total suspended solids, chromophoric dissolved organic matter and temperature. Some of the same parameters have been measured continuously along the track of these cruises (see Kelble et al. 2005). Our analysis of these data with respect to the relationship between specific physical forcing events and water quality will be presented and discussed. Relationships will be developed that can be used to parameterize and validate water quality models being developed for Florida Bay as well as in the evaluation of CERP alternatives with respect to their potential effect upon Florida Bay water quality.

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Fate of Everglades Dissolved Organic Matter in Florida Bay

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Restoration of the Everglades ecosystem is expected to increase freshwater flow toward Florida Bay. A key uncertainty in the restoration is how changing flow will change nutrient inputs and availability in the bay. Most of these inputs are in the form of dissolved organic matter (DOM). Experiments were conducted to determine decomposition rates and bioavailability of Everglades DOM and, specifically, dissolved organic nitrogen (DON) and carbon (DOC) in Florida Bay. The experiments tested three factors that may influence decomposition: DOM source (oligotrophic southeast Everglades vs. more nutrient-rich southwestern Everglades), phosphorus limitation, and sediment interactions (the presence or absence of sedimentary particles with associated microbes).

Experiments were conducted for two to three months in 2.5 L bottles and used 0_2 consumption in the dark to estimate DOM decomposition rates and the magnitude of labile (bioavailable) and refractory pools of DOM. Nitrogen and carbon mineralization rates were estimated from 0_2 fluxes based on DON and DOC measurements and stoichiometric assumptions. Surface water from Taylor Slough in the east and Shark River Slough in the west was filtered through a 0.2 micron filter and used as DOM sources. Salinity was adjusted in all bottles to 34 psu with NaCl. Bottles (four per treatment) were inoculated with microbes contained in either Florida Bay water (GF/F filtered) or this filtered water plus an aliquot of sediment (about 1 g wet weight/L). An artificial seawater sediment control was run to account for sedimentary consumption of 0_2, with consumption in control bottles subtracted from consumption in experimental bottles with sediment. Inorganic phosphorus was also added to half of the bottles to assess the effect of P limitation. Decay constants and the bioavailable carbon pool were calculated from natural logarithm transformed 0_2 uptake rates, using a single-pool model. A multi-pool model is under development to better estimate these decay parameters.

Results from two experiments in Taylor Slough (April-May 2004 and July-August 2005) show that an average of 17-25 % of the DOM appears to be bioavailable over these time periods and this bioavailable DOM has decay rates that are surprisingly fast (~ 1-5 % per day). The decay rates from July 2005 represent only the first 30 days of this ongoing experiment. They are significantly higher than in April 2004, at least partially a consequence of the ongoing experiment's shorter timespan. This difference may also reflect differences in the quality of the DOM.

The combination of P enrichment plus the presence of sediment particles significantly affected DOM decomposition, increasing the magnitude of cumulative 0_2 uptake rates and DOM loss (Figure 1). The loss of DOC and TDKN (calculated as the difference from initial to final concentration) confirm the trends in the oxygen uptake rates (Figure 2). These results point toward the importance of P for the decay of less labile DOM by sedimentary microbes. Preliminary results from the Shark River Slough site indicate equal or lower decay rates and lower bioavailablity of Shark River DOM than Taylor River DOM.

Table 1: Decay constants and bioavailability of Taylor Slough DOM

Taylor Slough	April 2004	April 2004	July 2005	July 2005
	Decay Constant k (d^{-1})	Minimum Bioavailable (mg C /l)	Decay Constant k (d^{-1})	Minimum Bioavailable (mg C /l)
No P, No Sed	0.017 ±0.002	2.76 ± 0.14	0.054 ±0.007	1.68 ± 0.24
No P, Plus Sed	0.020 ±0.004	3.11 ± 0.31	0.046 ±0.002	3.05 ± 0.17
Plus P, No Sed	0.012 ±0.002	4.16 ± 0.48	0.036 ±0.006	3.30 ± 0.35
Plus P, Plus Sed	0.016 ±0.001	4.42 ± 0.23	0.040 ±0.003	4.25 ± 0.32

Taylor Slough, April-May 2004

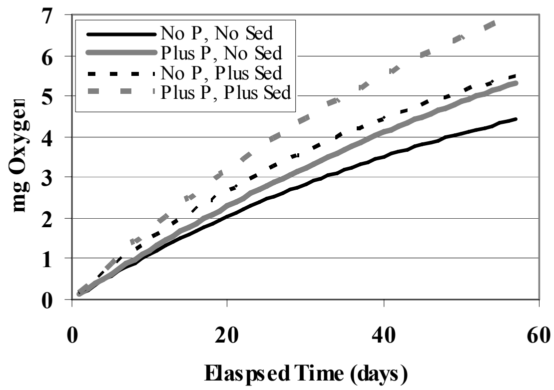

Figure 1: Cummulative 0_2 uptake

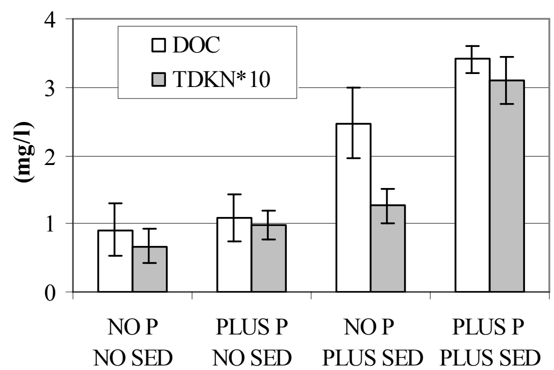

Figure 2: DOC and TDKN Loss

The results of these experiments indicate that oxygen consumption is a sensitive measure of decomposition, and can be readily translated into rates of DOC and DON decay and bioavailability. The development of a multi-pool model of decay should generate sound estimates of these factors.

In addition, results indicate that Everglades DOM decomposition may be more rapid at the sediment-water interface and during resuspension events than in clear Florida Bay waters, especially in central and western parts of the Bay where P levels are relatively high. The effects of changing fresh water flow on the Florida Bay ecosystem are likely to depend upon changes in DOM inputs, bioavailability, decay rates and water residence times in different regions of Florida Bay.

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Resuspended Sediments and Effects on Chemotaxonomy in North-Central and western Florida Bay

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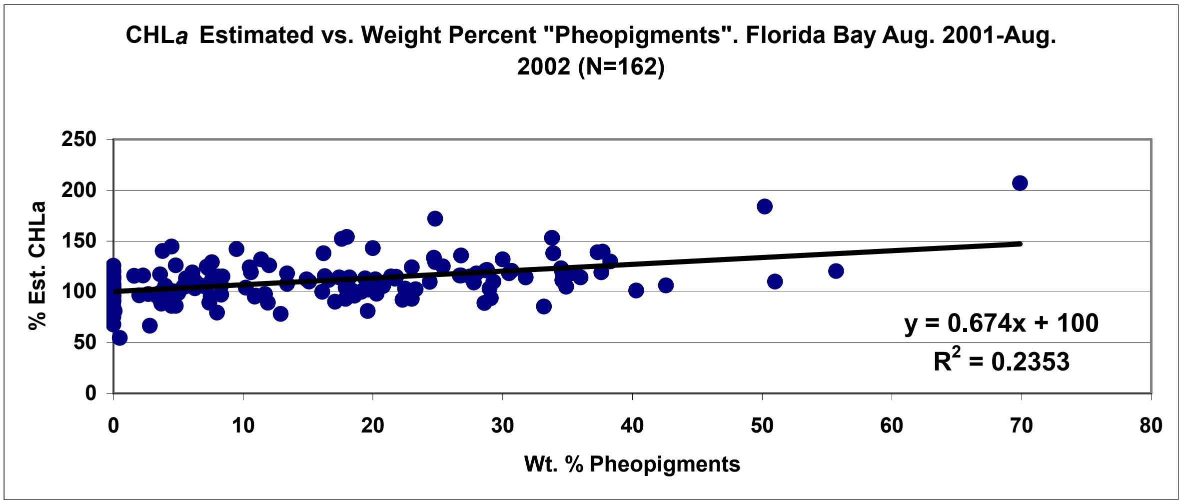
At the heart of pigment-based chemotaxonomy is the assumption or assertion that, once the overall pigment array has been dissected, the distribution of the primary (chlorophylls) and secondary / accessory (carotenoids, phycobiliproteins) photosynthetic pigments can be quantitatively deconvoluted in a way that yields the taxonomic makeup of the source community (Jeffrey *et al*., 1997; Millie *et al*., 1993). That is, specific biomarker pigments should be present in known ratios to a certain amount of primary pigment, namely chlorophyll-a (CHL*a*) in the case of oxygenic photoautotrophs. As an example, a number of diatom species have been studied by the author and many more are reported in the literature and these yield average chlorophyll-a -to- fucoxanthin molar ratios of $1.2 \pm 0.3 : 1$. Thus, the moles of diatom (or 'chrysophyte') contributed chlorophyll-a should be about 1.2 times the moles, or about 1.6 times the mass, of fucoxanthin found in a phytoplankton (seston) sample. Next, comparison of the 'diatom chlorophyll-a' to the chlorophyll-a similarly calculated for other taxa (e.g. divinyl-chlorophyll-a for the prochlorophytes; chlorophyll-b and/or lutein for chlorophytes; peridinin for dinoflagellates; 19'-hexanoyl-oxyfuxoxanthins and/or butanoyloxyfucoxanthins for prymnesiophytes /nanoflagellate chrysophytes; alloxanthin for cryptophytes; prasinoxanthin for prasinophytes; and zeaxanthin, echinenone and/or myxoxanthophyll for cyanobacteria should then allow the relative percentage of each taxon within the source community to be back calculated.

Chemotaxonomic descriptions of phytoplankton communities work reasonably well, especially when dealing with viable actively growing populations (*cf.* Louda 2002; Mackey *et al*., 1998). However, upon senescence, death and organic diagenesis, the photosynthetic pigments degrade at significantly different rates. Thus, even though we were able to show that the surficial flocs / mats in central Florida Bay were "a cyanobacterial diatom mat underlain with purple-S bacteria" (Louda *et al*., 2004), sediments buried but a few cm lacked the requisite diatom signal, namely fucoxanthin (FUCO). Thus, the cyanobacterial marker zeaxanthin (ZEA) dominated the 'biomarker' signal for pigment-based chemotaxonomy. Mg-free chlorophyll derivatives, the 'pheo-pigments' (PHEOs; pheophytin, pheophorbide *etc.*) were also rapidly formed from the parent chlorophylls (Louda *et al*., 2000). We have investigated the effect of senescence and death on the pigment distributions in various species and classes of phytoplankton and have found that, in general, the carotenoid diols, such as ZEA and lutein , remain intact much longer than more labile pigments such as FUCO and peridinin (*cf.* Louda *et al*., 1998, 2002).

In the main, chemotaxonomic estimation of the phytoplankton communities in Florida Bay were able to account for $100 \pm 13.6\%$ of the CHL*a* present when PHEOs are $\leq 7.5\%$ of CHL*a*+PHEOs. However, these methods overestimated CHL*a* as the percent pheopigments increased (Figure). That is, CHL*a* degrades rather rapidly to a variety of pheopigments upon senescence, death and/or predation and the presence of more stable carotenoids, especially the diol forms, lead to an overestimation of the 'expected' CHL*a*. The presence of resuspended sediments and microalgae debris then inserts a new degree of difficulty in the overall process. However, taking these facts into account will allow better estimations of community structures to be made. In spite of these difficulties, we have found that the order of community dominance (*e.g.*

cyanobacterial < or > diatom *etc.*) remained quite discernable and other divisions (*i.e.* Cryptophytes / alloxanthin), often unreported in other studies, were quantifiable as well.



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Spatial, Geomorphological, and Seasonal Variability of CDOM in the Florida Coastal Everglades.

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This paper provides long-term, seasonal, fluorescence based dissolved organic matter (DOM) data for highly compartmentalized estuarine regions of the Florida coastal Everglades (FCE) in an attempt to gain a better understanding of the dynamics (sources, transport and fate) of chromophoric dissolved organic matter (CDOM) in this sub-tropical ecosystem. For this purpose, water samples were collected monthly from a total of 73 sampling stations in the FCE estuaries during 2001 and 2002 and their fluorescence properties determined. Spatial and seasonal variability of CDOM characteristics were investigated for geomorphologically distinct sub-regions within Florida Bay (FB), the Ten Thousand Islands (TTI), and Whitewater Bay (WWB). Seasonal and spatial variations were observed, both in regards to quantity and quality of CDOM. TOC concentration ([TOC]) in FCE estuaries were generally higher during the wet season (June-October), reflecting a high freshwater loadings from the Everglades in TTI, and a high primary productivity of marine biomass in FB. Fluorescence parameters suggested that the CDOM in FB is mainly of marine/microbial origin, while for TTI and WWB a terrestrial, origin from Everglades marsh plants and mangroves was evident. CDOM quality variations seemed mainly controlled by tidal exchange/mixing of Everglades freshwater with Florida Shelf waters, tidal controlled release of CDOM from fringe mangroves, primary productivity of marine vegetation in FB and diagenetic processes such as photodegradation (particularly for WWB). The source and dynamics of DOM in these subtropical estuaries is complex and found to be influenced by many factors such as hydrology, geomorphology, vegetation cover, landuse and biogeochemical processes. Simple, easy to measure, high sample throughput fluorescence parameters for surface water samples can add valuable information on CDOM dynamics to long-term water quality studies which can not be obtained from quantitative determinations alone.

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Characterization of Dissolved Organic Nitrogen in an Oligotrophic Subtropical Coastal Ecosystem

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This paper describes detailed chemical characteristics of ultrafiltered high-molecular-weight dissolved organic nitrogen (UDON; < 0.7 µm, > 1 k Da) in an oligotrophic subtropical coastal ecosystem. Water samples were collected from rivers and estuarine environments within the Florida Coastal Everglades (FCE) ecosystem. The high-molecular-weight dissolved organic matter (UDOM) was obtained by tangential flow ultrafiltration. ^{15}N cross-polarization magic angle spinning nuclear magnetic resonance (CPMAS NMR) and X-ray photoelectron spectroscopy (XPS) were applied for the first time to the analysis of N species of UDOM of a coastal environment. Concentration and composition of total hydrolysable amino acids (THAA) of UDOM were analyzed to estimate its diagenetic state. Optical properties (UV-visible and fluorescence) and the stable isotope ratios of C ($\delta^{13}C$) and N ($\delta^{15}N$) were measured to assess the source and dynamics of UDOM. The two novel spectroscopic analyses consistently showed that the major species of UDON are in amide form, however, XPS-N1s showed a high concentration (21.7±2.7%) of aromatic N in the UDON. A relatively constant $\delta^{15}N$ value (3.4±0.1‰) and a relatively high THAA concentration (4±2 %UDOC or 27±4 %UDON) suggested that the UDON in the FCE has not apparently undergone an extensive diagenetic processing. The possible explanation for these observations is attributed to a low microbial activity and a continuous supply of fresh DON leached from plant biomass in this oligotrophic ecosystem. Although the Everglades UDON was not distinctly different from Florida Bay UDON, the overall molecular characteristics of the UDOM suggests a clearly autochthonous source for Florida Bay UDOM.

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Estimates of Nutrient Loads at West Highway Creek in Northeastern Florida Bay

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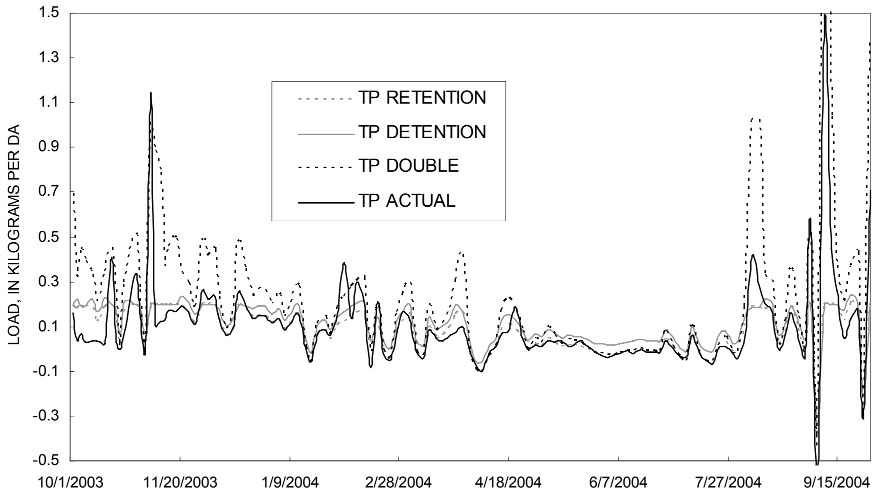
Coastal discharge, total phosphorus (TP) and total nitrogen (TKN) concentrations are continuously monitored by the U.S. Geological Survey (USGS) at West-Highway Creek in northeastern Florida Bay. Data are collected within the transition zone between upstream Everglades wetlands and downstream coastal estuaries, specifically, north of Long Sound near Key Largo. The product of net 3-day discharge and mean 3-day concentration sampling were used to compute TP and TKN loads between the wetlands and bay from the beginning of October 2003 through the end of September 2004 (water year 2004). Net loading was predominately from the wetlands into the bay (positive loading); the mean TP and TKN loads equaled about +0.1 and 8.0 kilograms per day (kg day^{-1}), respectively. As expected, wet season loads were larger than dry season loads because the loading signal mostly was explained by discharge and positive discharge increased during the wet season. An analysis also was made to determine the potential errors in total loading estimates if water-quality auto-samplers (collecting samples every 18 hours continuously) were replaced with grab samples collected at the end of each month**.** Although replacing the auto-samplers reduces costs, the errors in loading estimates were considerable. Specifically, monthly grab samples over and under-predicted the total annual TP and TKN loads by about 30% and -7%, respectively.

Regression-defined models were developed that predict TP and TKN loads solely as a function of discharge and time. The loading models were built for "gap-filling" so that annual loads could be estimated, and also for examining how loading will change under hypothetical water-management scenarios. The TP model reproduced about 80% of the actual load variability, with a mean absolute error of about 0.06 kg day^{-1}. The TKN model reproduced about 90% of the actual load variability, with a mean absolute error of about 2.6 kg day^{-1}. Upon gap-filling, estimated annual TP and TKN loads were about +38 and +3,127 kg, respectively, at West Highway Creek for the 2004 water year.

Loading changes were apparent under alternate water-management scenarios, specifically, retention, detention, and doubling the discharge from the wetlands into the Bay (Fig. 1A, B). The retention scenario captured net discharge greater than +40,000 cubic meters (m^3), resembling a case where excess runoff is captured for underground aquifer storage and recovery as part of the Comprehensive Everglades Restoration Plan. The detention scenario also captured net discharge greater than +40,000 m^3, but released the captured water at the later time so the total measured discharge was conserved. Doubling the positive coastal discharge from the wetlands into the Bay may resemble flow conditions upon the removal of upstream canals and levees, or construction of bridges that elevate roadways above upstream wetlands. Loading results from this scenario likely are less reliable than the results from the retention and detention scenarios, because doubling the positive discharge creates discharge values that are outside the range of values used for calibration.

A



B

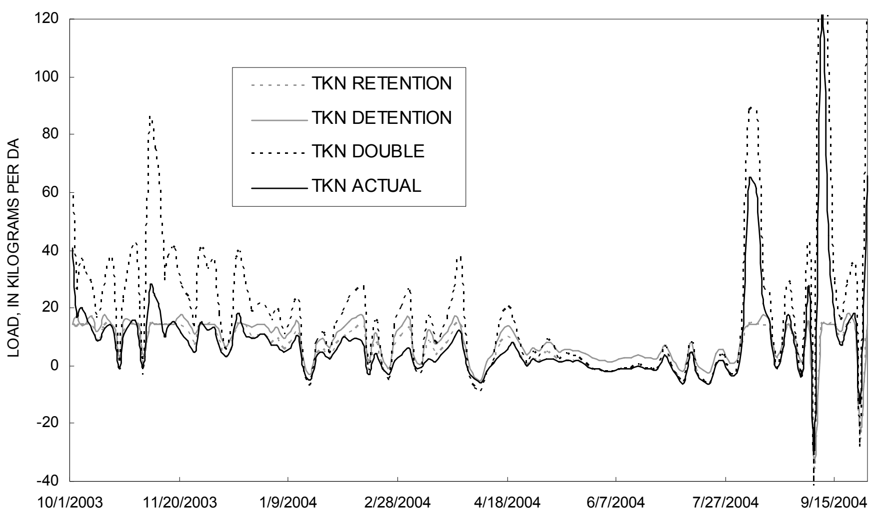


Figure 1. Actual and estimated (A) TP and (B) TKN loads from scenario testing.

Scenario testing results were compiled into duration curves so results could be reported with probabilities that acknowledge uncertainty. In the actual case (flow unaltered) at West Highway Creek, a TP load of +0.15 kg day^{-1} was exceeded 40% of the time. In the retention, detention, and doubling scenarios, the probability of exceeding a TP load of +0.15 kg day^{-1} was 31%, 45%, and 52%, respectively. For TKN loads in the actual case, a value of +9.0 kg day^{-1} was exceeded 51% of the time. In the retention, detention, and doubling scenarios, the probability of exceeding a TKN load of +9.0 kg day^{-1} was 40%, 53%, and 55%, respectively. Future plans include application of the methods at North River upstream of the cutoff near Flamingo, in southwestern Florida.

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The National Park Service Inventory and Monitoring Water Quality Assessment Program in Florida Bay

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National Park Service, Inventory and Monitoring, South Florida / Caribbean Network

The Vital Sign Indicator Selection and Prioritization for four South Florida and two Caribbean National Parks is currently underway. Vital Sign Monitoring Network provides a metric to determine the overall health (condition) of the park ecosystem. A strong water quality component has been identified as a critical element of the Vital Sign Network. The Vital Sign Network will provide consistent standards and protocols across the six National Parks. Water quality parameters will be archived in the STORET database (U.S. Environmental Protection Agency (EPA) database of ambient environmental data relating to Water Quality) at the regional data center (Atlanta, Georgia). The STORET database has open access to all researchers (as well as the general public). The Florida Bay water quality monitoring network maintained by Everglades National Park as well as auxiliary monitoring networks will be incorporated into the Vital Sign Network Water Quality data layer. Water Temperature (C°), Dissolved Oxygen (mg/L), pH, and Ionic strength expressed as conductivity and as salinity have already been identified as parameters of critical concern. Other environmental parameters of interest (Turbidity, etc.) will be considered.

The Vital Signs Monitoring Network is based on the evaluation of ecosystem models to determine important drivers and critical components of the ecosystem. These models are reviewed by park staff and interested researchers. These expert recommendations are then used to identify the highest priority vital signs to monitor. This is where you, as an active researcher in the Florida Bay program, can have the greatest impact in the Vital Sign Indicator Selection and Prioritization. Active participation by researchers in the monitoring prioritization and protocol establishment for not only the Water Quality Network but for the Florida Bay ecological zone conceptual model is critical for a successful program.

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Monitoring Regional Water Quality from Satellite in Florida Bay, USA

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In an effort to monitor resuspension and chlorophyll variability in south Florida we derived monthly mean imagery using the Sea-viewing Wide Field-of-view-Sensor (SeaWiFS) reflectance from the red band, as well as satellite derived chlorophyll concentrations. To assess how regional water quality varies spatially we divided the southwest Florida Shelf into nine different regions (Figure 1). The northern boundary was set at 25.83 degrees N, the latitude of Cape Romano, which has been used elsewhere to describe the northern extent of Florida Bay (Fourqurean and Robblee, 1999). The southern boundary was the northern extent of the reef track, along the two meter contour, nominally set at 24.58 degrees N. A boundary was drawn at the midpoint between the northern and southern bounds at 25.21 degrees N. A final horizontal boundary was added in the southern portion of the study site due to anomalous bathymetry features. The longitudinal divisions were set along bathymetry contours. The eastern most boundary was set at the two meter contour. The mid boundary was set at the twenty meter contour and the western most boundary was set at the forty meter contour.

The red reflectance (670 nanometers (nm)) and satellite chlorophyll concentrations were averaged for each of the regions. Red reflectance is an indicator of suspended sediments. Monthly, seasonal, and annual variability for each region was examined.

To assess change along the reef track a second analysis was performed. Regions were created from the keys extending to the thirty meter contour, at every other pixel from Biscayne Bay in the east to the Dry Tortugas in the west. In all 130 regions were examined covering a study area of 286 kilometers in the east west direction (Figure 2). We also created six different transects one kilometers wide (one pixel) extending from west of the Dry Tortugas to the mouth of Biscayne Bay (Figure 3). These transects run parallel to the reef track and are located at 1, 3, 5, 7, and 9 km off the Keys southward. In this manner we are able to assess change in a shore-parallel and shore-perpendicular fashion and show correlations between regions.

Figure 1

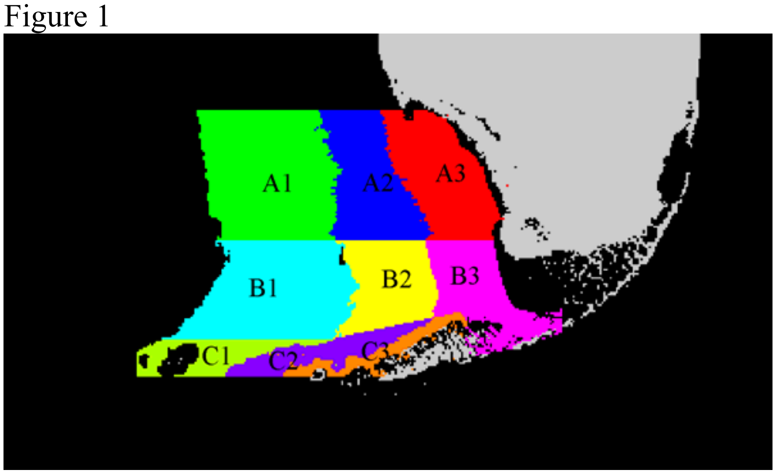


Figure 2.

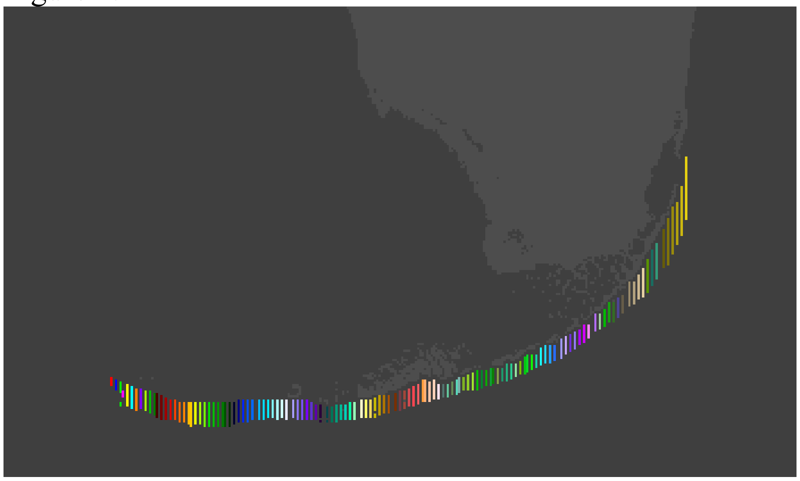
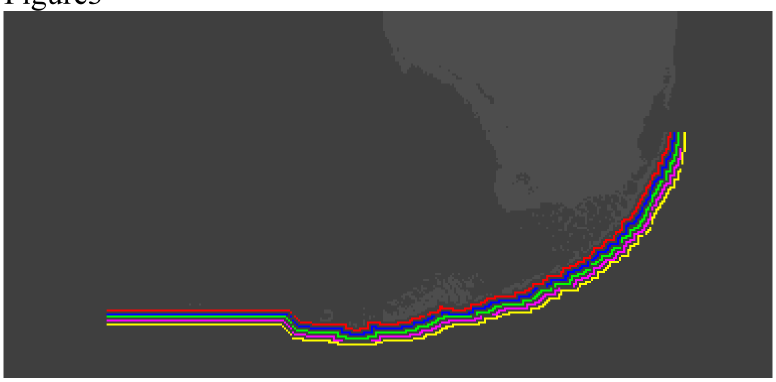


Figure3



Reference:

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Observations on Bottom Albedo in Florida Bay from Multiple Satellites

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Bottom albedo can be used as a proxy for seagrass coverage in shallow water ecosystems such as Florida Bay and the Keys. Seagrass beds absorb visible light and will appear to be dark in the satellite imagery. Using satellite imagery from 1985 through the present, from the Advanced Very High Resolution Radiometer (AVHRR) (1985-1997) and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) (1998-2004), we examine patterns in bottom albedo for south Florida. While SeaWiFS has six bands that detect visible light, the AVHRR has only one, in the red, so a comparable band from SeaWiFS is used for consistency. We devised a method to equate the SeaWiFS to AVHRR. The corrections that were used account for 84% of the variance between the two sensors (Wynne et al., submitted). Monthly means of red reflectance were created. Minimum reflectances over a season were used with gridded bathymetry to estimate the bottom albedo. Shifts in the bottom albedo were evident in between 1987 and 1995, consistent with seagrass losses. Additional changes have occurred in the last nine years, some indicating increased cover.

Reference:

Establishing a Continuous 20 Year Dataset Using Imagery from AVHRR and SeaWiFS. T.T. Wynne, R.P. Stumpf, V. Ransibrahmanakul. Submitted. International Journal of Remote Sensing.

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Spatial Variation of Sediment Characteristics with Respect to Sediment-Water Exchange of Phosphorus in Florida Bay

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Surface sediment samples from different regions of Florida Bay have been used to conduct the adsorption-desorption equilibrium experiments at ambient temperature and seawater salinity to determine the sediment characteristics with respect to sediment-water exchange of phosphorus in Florida Bay. In these experiments, sediments characteristics are quantified in term of relevant parameters, such as the zero equilibrium phosphate concentrations, and the distribution coefficients of phosphate in the sediment-seawater system, which is indicative of buffering intensity of sediments with respect to change in phosphorus loading in the system.

Preliminary results indicate that sediments from different regions of the bay behave differently with respect to the sediment-water exchange of phosphate. The zero equilibrium phosphate concentrations are found to increase with increasing exchangeable phosphate contents in the sediment samples that were previously determined by a sequential extraction method (Zhang et al., 2004). On the other hand, the distribution coefficients of phosphate in the sediment-seawater system are found to inversely correlate with the exchangeable phosphate concentration in the sediment samples. The higher reductant-soluble iron oxide content in eastern Bay sediments might contribute, to some extent, to greater values in the distribution coefficients observed in sediments with low exchangeable phosphate concentrations.

The higher distribution coefficients and lower zero equilibrium phosphate concentrations in eastern Bay sediments indicate that sediments in this region are of a potential to maintain a low water column phosphate concentration and a large buffering capacity with respect to external loading of water column phosphate. On the other hand, the higher zero equilibrium phosphate concentrations and lower distribution coefficients in northwestern corner of the bay indicate the sediments in this region is the source of dissolved phosphate to overlying water until it reaches a relatively high equilibrium phosphate concentration.

The effects of salinity and temperature on sediment-water partitioning of phosphorus are studied in sediment samples that cover both different sediment characteristics and geographic region of the bay. Priliminary results indicate that the zero equilibrium phosphate concentrations were positively correlated with the salinity of seawater, whereas the phosphate buffering intensity of sediments were increased with increasing ambient temperature. This study will provide a spatial distribution of sediment parameters relevant to P cycling as a function of salinity and temperature in Florida Bay. The zero equilibrium phosphate concentration, the distribution coefficient, and P buffering intensity of sediment are essential in water quality models for predicting the effect of increasing freshwater input, as proposed by the Comprehensive Everglades Restoration Plan, on the P cycle in Florida Bay.

Reference:

Zhang, Jia-Zhong, Charles J. Fischer, and Peter B. Ortner, (2004) Potential availability of sedimentary phosphorus to sediment resuspension in Florida Bay, *Global Biogeochemical Cycles*. 18(1):GB1038, doi: 10.1029/2004GB002255, 2004.

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Oral Abstracts

Physical Processes

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Status of the Florida Bay Hydrodynamic Model

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This presentation summarizes the status of the ongoing development of a Florida Bay Hydrodynamic model for assessing CERP impacts on the Bay. The Bay model is based on the Environmental Fluid Dynamics Code (EFDC) modeling system and is externally coupled to the TIME model of the South Florida wetlands which provides freshwater inflow, and the HYCOM ocean model of the Gulf of Mexico and Florida Straits which provides open boundary conditions for sub-tidal frequency sea level and transport. Results of the recently completed hydrodynamic and transport calibration and validation, spanning a seven-year simulation period between 1996 and 2002, will be presented. Model grid configuration, forcing functions and observed data used for model calibration and validation will be summarized. Model calibration and validation results will be presented for tidal and low-frequency sea level, currents, salinity and temperature. The model's overall performance will be evaluated by comparing the EFDC model's calibration and validation statistics with those obtained from other major modeling studies. A summary of the insights into the Bay's transport processes revealed by the model will also be presented and discussed.

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Sedimentation and Circulation Changes in Florida Bay as a Response to Climate Change

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Global warming and associated rise in sea level have affected and continue to influence coastal environments around the world. Effects of future sea-level rise may be determined by examining the consequences of previous sea-level rise. The geography of South Florida is ideally suited for this purpose. The slope of the shallow shelf and land surface is low and minor changes in sea level result in large-scale geographic effects. In addition, the South Florida ecosystem is diverse and has experienced substantial changes due to anthropogenic interference with the watershed. The South Florida restoration program, a multi-discipline, multi-agency effort, has produced a very large volume of high-quality data, which can be used to understand the cause-and-effect relation of environmental change better.

Over the past decade, short-lived isotopes (^{7}Be, ^{210}Pb, and ^{137}Cs) in sediment cores have been used widely to construct the historical record of changes over the last century. The most substantial change was a habitat transformation in the lakes and mud islands along the northern boundary of Florida Bay. Prior to ~1950, the lake floors were a hardbottom habitat, and the lake environments were oligohaline. After around 1950 and concurrent with decrease in freshwater flow, the environment changed to mesohaline and has since become normal marine. With this shift, marine carbonate sediment began to accumulate on the lake bottoms, resulting in the creation of a soft-bottom ecosystem. In the early 1970s, a major influx of carbonate sediment occurred in the former lakes. Much of this sediment was derived from erosion of the barriers that stretched across the lake mouths. In addition, the increasingly marine environments in the northern bay stimulated production of carbonate sediment, adding to sediment accretion in the basins. Carbonate production also enlarged the mud islands, extending tidal flats. As a result, passes between islands were closed, further restricting circulation.

In the central bay, the sediment record showed that accumulation was not affected by the change in hydrology but was controlled by variations in rate of progressive sea-level rise. The sea-level record as measured at Key West shows that sea level has been rising incrementally over the last century. Sea level was stable until about 1931. Between 1931 and 1950, sea level rose at a rate of ~ 5 mm/yr. After 1950, sea level remained stable until 1971, when it again began to rise, but at a rate of 3 mm/yr. On the leeward side of mud banks, these variations in rate of rise resulted in shifts in sediment- accumulation rates, with accretion increasing during rising sea level and decreasing during stable periods. Between late 1970 and early 1972, a sharp jump in sea-level rise occurred that was approximately 10 cm higher than the preceding period. This jump coincided with a strongly positive North Atlantic Oscillation (NAO), a la Niña (negative ENSO), and a negative Pacific Decadal Oscillation (PDO). Water driven northward into Florida Bay eroded banks along the northern coastline, increased sediment accumulation in the northern lakes, and increased accretion rates on the banks. This paradigm suggests, although anthropogenic hydrologic influences had an effect on the chemical environment in northern Florida Bay, climate forcing has played a major role in changing the geographic structure throughout the bay.

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The South Florida Hybrid Coordinate Ocean Model: An Integrated Approach for Florida Bay Modeling

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The SoFLA-HYCOM model (South Florida Hybrid Coordinate Ocean Model; (http://hycom.rsmas.miami.edu/overview/SoFLA_HYCOM.pdf)) is the Regional model for South Florida coastal seas. It has been developed specifically as a connection between South Florida's shallow coastal environments and the adjacent deep areas in the Straits of Florida and the Gulf of Mexico. A particular application of the SoFLA-HYCOM is to provide boundary conditions and atmospheric inputs for the Florida Bay model, developed by the South Florida Water Management District. To ensure proper connection with the Gulf of Mexico and the Straits of Florida (as well as the global circulation around them), the SoFLA-HYCOM is nested within the North Atlantic HYCOM that includes the Gulf of Mexico and the Caribbean, so that information on large scale flows enters through its boundaries. Therefore, the regional model acts as a crucial intermediate step from the large to the coastal scale.

The hybrid vertical coordinate system in the SoFLA-HYCOM makes the regional model particularly suited for the study area that involves transition from deep to shelf and shallow areas. The vertical layers can evolve from density-following (isopycnal) in the deep, stratified regions to bottom terrain-following (sigma-) layers on the shelf and to specific-depth (z-) layers in the mixed layer and other vertically homogeneous regions.

The performed numerical simulations have confirmed the data based hypothesis that Florida Bay is subject to intense interactions with the southwest Florida shelf and with the Florida Keys and Straits of Florida (through flows in the Keys passages).

Experiments with model tracers released in the Dry Tortugas area demonstrate that eddies provide an important mechanism for the retention of nutrients and larvae and for the subsequent release toward the Florida Keys Reef Tract, through eddy shredding upon interaction with the rough Keys topography. Pathways that reach Florida Bay through the Keys passages have been demonstrated.

Changes in salinity around Florida Bay have been simulated and associated with evaporation/precipitation and with changes in river flows (and associated buoyancy-driven circulation) from the neighboring rivers. An example is shown in Fig. 1, where the salinity of Florida Bay is influenced by the southwest Florida shelf rivers during periods of northerly winds, while light winds allow the riverine low salinity waters to escape toward north, bearing no influence on Florida Bay. Model results also address the influence of remote sources of low-salinity from as far as the Mississippi River.

The coupling between the SoFLA-HYCOM regional model and the Florida Bay coastal model forms the basis of a model system that can be used for the study of all hydrodynamic processes that affect the South Florida ecosystem dynamics. This system can be expanded for the study of larvae and nutrient transport, water quality issues and fisheries management. Preliminary tests on coupling with a larvae transport biological model have taken place.

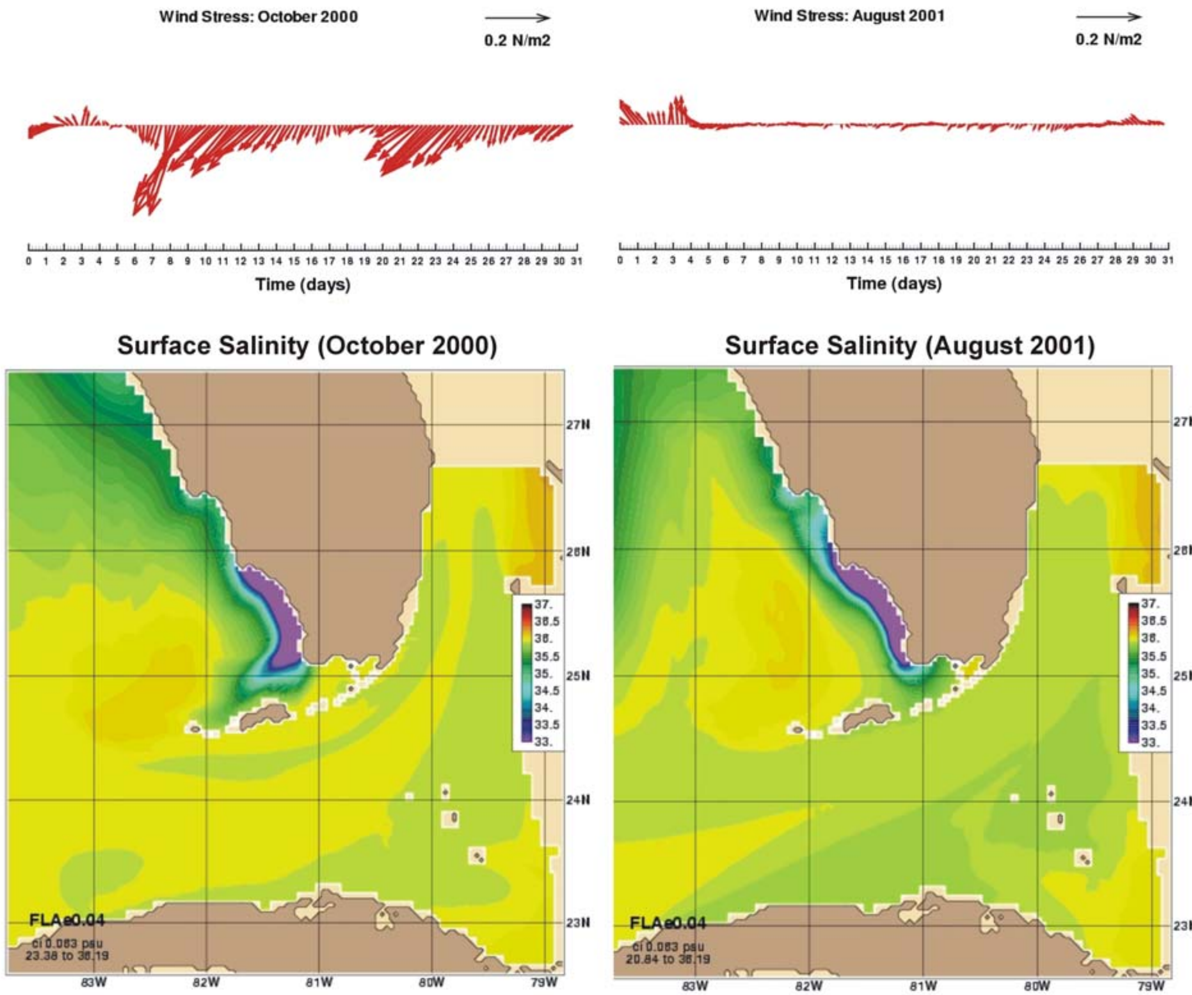

Figure 1: Six-hourly wind vectors (above) over Florida Bay and model computed near-surface salinity patterns during a period that circulation around Florida Bay is dominated by the wind (bottom left) and during a period that is dominated by remote rivers (bottom right). During periods of strong northerly winds (left), the low salinity waters from the southwest Florida shelf rivers influence salinity in Florida Bay, while during periods of very weak winds (right), the external low salinity waters are mostly advected away from Florida Bay.

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On 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 lying at the receiving end of the Everglades discharge between the Florida mainland and the Florida Keys. Alteration of Everglades flow has led to reduced water delivery to Florida Bay and elevated salinities, especially in the north-central region of Whipray basin where extreme hypersalinity can develop with concurrent sea grass die-off and water quality degradation and potential downstream impacts on Florida Keys coral reef ecosystems. We have recently conducted a series of observational studies of water exchange and salinity variability within the north-central, northeast and western regions of Florida Bay (Fig. 1) to better understand the important physical processes and to provide flow and salinity data to aid development and calibration of the bay hydrodynamic model. All studies took place over wet and dry seasons during 2001 for the north-central region; 2002 and 2003 for the northeast region and 2004 and 2005 for the western region. Measurement strategy was similar for all three regions and consisted of time series observations of flow, salinity and sea level variability in channels connecting the basins to surrounding regions, together with detailed salinity surveys and fresh water flux estimates to evaluate water and salt balances and estimate basin water renewal rates and residences times. Interior basin circulation was measured with shallow drifters. The north-central region study took place in Whipray basin where hypersalinity commonly occurs during dry seasons. Our findings indicate that water renewal of Whipray basin is strongly regulated by local wind forcing. Eastward winds from the passage of cold fronts during the winter/spring dry season resulted in a mean flow through Whipray of 11 m^3/s, with inflows over the wide western mud banks and outflows through eastern and southern channels. Westward and southwestward winds of the summer/fall wet season produced a mean through-flow of 3 m^3/s, with inflows through eastern channels and outflows over the western banks. The time required for complete renewal of Whipray basin waters is estimated at 6 to 12 months. Water balances are used to estimate a weak seasonal average ground water input to Whipray of 1.7 m^3/s during the dry season and a negative ground water outflow of -4.7 m^3/s for the wet season.

Fresh water discharge to Florida Bay occurs primarily in the northeast subregion from outflows through Trout Creek and Taylor Slough and prevents hypersalinity development except during extreme droughts. The resulting low salinity discharge plume tends to spread toward the south along the western boundary of the subregion, eventually mixing partially into the eastern side of Whipray basin in the vicinity of Twisty Channel. Water exchange is strongest in the southeast portion of the subregion in the vicinity of the intracoastal waterway and has significant wind and tidal influence. The western subregion of Florida Bay undergoes strong exchange with southwest Florida shelf waters which tend to be of lower salinity due to southward transport of discharge from Shark River and rivers of the west Florida coast. The benefit of this exchange is that the lower salinities of the western basins help to moderate the spread of hypersalinity waters from the north-central region. Hypersalinity development in the north-central region was found to be caused by the combination of reduced fresh water inputs during the dry season combined with weak basin water renewal rates. Hypersalinity development could be greatly reduced by diversion of fresh water to Whipray basin via McCormick Creek during dry seasons.

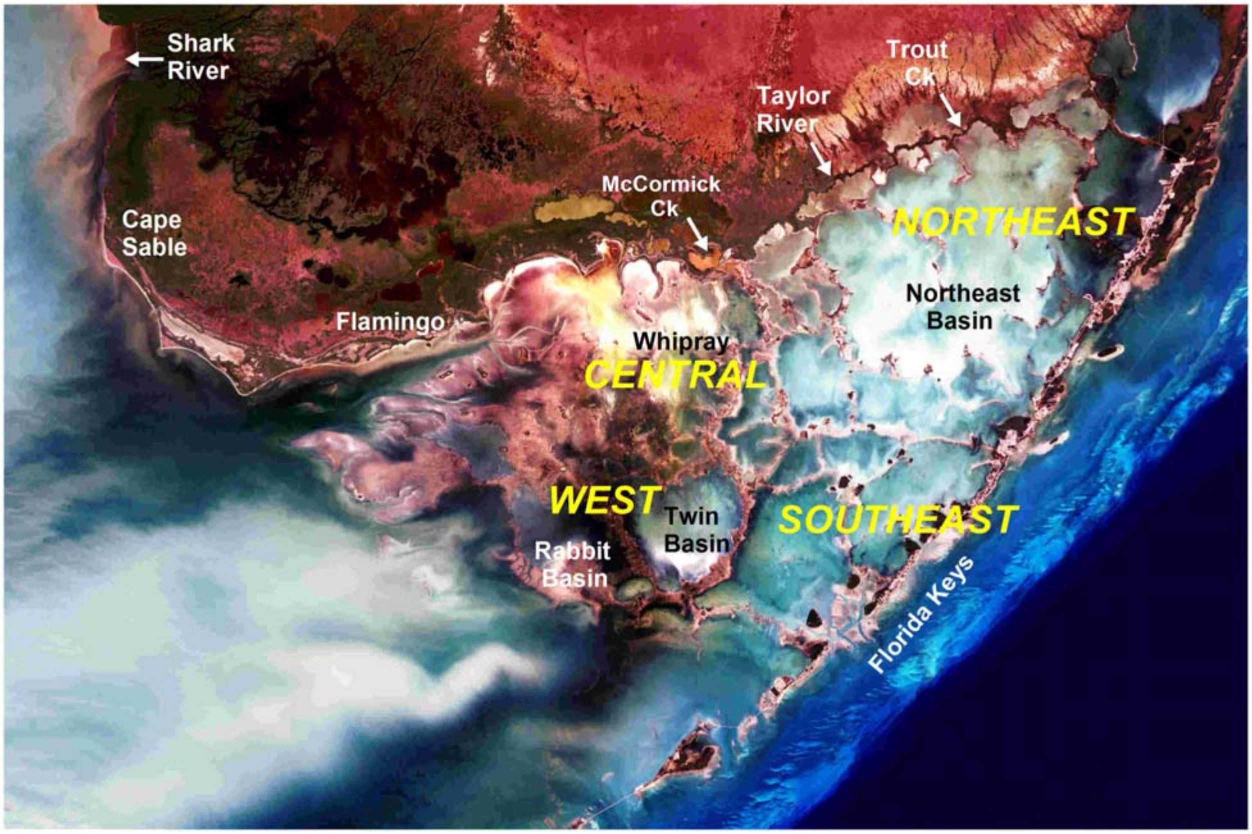

Fig. 1. Aerial view of Florida Bay (FB) and the southern Everglades showing the shallow mud banks (tan) and basins (blue and green) configuration. River discharge points are shown by arrows. The four major subregions of the bay, Central, Northeast, Southeast and West are identified. Our studies of basin water exchange have been conducted in Whipray basin in the Central region (2001), the Northeast region (2002-03) and in Rabbit and Twin Key basins of the Western region (2004-05).

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Atmospheric-Aqueous Exchange of Carbon Dioxide in Florida Bay

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The exchange of gases across the air-water interface affects the transport of most pollutants and biogeochemical constituents. Accurate estimates of the mass transport of these constituents across the atmosphere-aqueous interface are mitigated by the lack of ability to predict the gas transfer exchange velocity. Measurements of the gas transfer exchange velocity in Florida Bay were performed using seasonal carbon dioxide surveys and the flux-profile micrometeorological technique. In addition to the carbon dioxide flux and the gas transfer exchange velocity, measurements of wind speed, atmospheric stability, water surface turbulence, surface currents, and depth and wind were performed on a fine temporal scale. An immediate benefit of this effort will be estimates of gas transfer exchange velocities at then appropriate time step to determine the physical and biogeochemical forcing controlling atmosphere-aqueous carbon dioxide fluxes. Current estimates of gas exchange in any shallow water or estuarine system are hampered by a lack of accurate estimates of the gas transfer exchange velocity. This is particularly the case in complex ecosystems, where ambiguity associated with gas transfer rates results in a factor of 4 uncertainty in estimates of the gas flux, despite the potential importance of these systems as moderators of terrestrial and anthropogenic constituents before their discharge to the oceans. Data show the ability to map gas transfer exchange velocities, and the physical processes controlling this rate, at the small spatial and temporal scales necessary to map the variability gas fluxes in small aquatic systems. Turbulence and the processes contributing to turbulence in the aqueous surface boundary layer will be discussed. This relevance of this work on past and present oxygen and organic matter transport studies in Florida Bay will also be presented.

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Estimating Evaporation Rates in Time and Space across Florida Bay

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In this study we characterized the variation of evaporation in Florida Bay over time and between different locations in Florida Bay. We collected meteorological data needed to estimate evaporation over an 18-month period in 2001 and 2002 at Rabbit Key and Butternut Key within the bay. Evaporation was estimated from the data from these weather stations using both the Dalton Law and Priestly-Taylor methods. The results of the weather stations were then placed into a long-term temporal context of 33 years of temperature and rainfall data collected in South Florida at Flamingo, Royal Palm and Tavernier. Evaporation was also estimated using this long-term data based on an empirical formula for estimating evaporation from total solar radiation. Evaporation estimates from the platform data for the time period June 2001 to December 2002 ranged from 140 to 180 cm/yr with an average of 165 cm/yr. Errors in the estimation methods are comparable to the range of uncertainty in estimating this annual amount. There was no apparent variation in evaporation rate between the stations. Over the 33-year period, estimated annual evaporation ranged between 148 and 181 cm/yr with an average of 161 cm/yr. By comparison, estimated annual rainfall for the same period was uncorrelated with estimated evaporation and ranged between 83 and 179 cm/yr, with an average of 131 cm/yr. Therefore, Florida Bay is a net evaporative basin on average (-34 cm/year based on the 33-year period), but the fresh water deficit of evaporation in excess of rainfall varies widely from year to year.

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Flows and Stages in the Southern Everglades and along the Coastal Boundaries of Florida Bay – Calibration and Scenario Applications of the Time Model

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A numerical surface- and ground-water hydrodynamic and salt transport model of the southern Everglades, known as the TIME (Tides and Inflows in the Marshes of the Everglades) model was developed primarily to estimate the freshwater flows into Florida Bay and the Gulf along the western boundary of the Everglades, as well as to calculate the salinities in these coastal zones, and to evaluate how different Comprehensive Everglades Restoration Plan (CERP) restorations scenarios will affect Everglades National Park (ENP) and Florida Bay. TIME is an application of the Flow and Transport in a Linked Overland/Aquifer Density Dependent System (FTLOADDS) model code, which links a two-dimensional hydrodynamic surface water modeling code (SWFIFT2D) to a three-dimensional density dependent ground-water modeling code (SEAWAT). The domain of the TIME model includes Everglades National Park, and a small portion of Big Cypress National Preserve south of Tamiami Trail (US-41). The TIME model calculates surface-water flows, depths, and salinity based on the full two-dimensional horizontal flow equations, including drying and flooding algorithms. Surface elevations are obtained from a digital data base with approximately 400-m horizontal resolution and a few centimeters vertical resolution. River and creek topographies are added manually based on aerial drainage map coverage. Vegetation type and density are obtained from remotely sensed satellite imagery. The model uses forcing functions of rainfall, evapotranspiration, boundary discharges through control structures and culverts or bridges, flow exchange with the underlying aquifer, and wind and tidal exchange with the coastal marine waters. The ground-water model is based on three-dimensional density-dependent equations for saturated flow and has 10 vertical layers, each 7 m thick, to describe the hydrostratigraphy. The ground-water model calculates horizontal and vertical flows, salinity, and heads resulting from lateral general head boundary conditions, transpiration losses, and flow exchange with the above surface waters. The surface and ground-water models are coupled through leakage (flow exchange between surface water and aquifer), which is computed based on Darcy's law. Both models employ the same horizontal grid consisting of 194x174 square cells with 500-m spacing. The surface water model uses an alternating direction implicit method for the solution and a 10 minute time step. The ground-water model uses 1-day stress periods. The models are coupled once every stress period without iteration, and computed leakages are therefore based on ground-water stages that are lagged by one stress period. The TIME model is calibrated using stage data from more than 100 gages distributed over the entire domain and flow data from 10 major creeks and rivers. The calibration period spans 7 years from 1996 to 2002. The model's accuracy at representing the natural system is assessed for this period with computed mean bias and explained variance at each observation location.

To evaluate CERP scenarios, necessary boundary condition data are obtained from the South Florida Water Management Model operated by the South Florida Water Management district. This regional model predicts the effects of planned physical modifications and operational changes to the upstream system. The TIME model simulations predict changes in flows, stages and runoff to the coastal marine waters of Florida Bay and the southern gulf for the 1990 to 2000 period. The first year is discarded as a warm-up period, leaving a ten-year continuous period of flows and depths available for assessment of physical and biological performance measures. Three CERP scenarios will be evaluated using the TIME model: 1.) CERP0, which is the base case with planned changes, 2.) 2050 base, which delineates what conditions would be in 2050 if no changes are made to the system, and 3.) ALT7R5, which is one alternative scenario to CERP0 and includes numerous structural and operational changes.

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Poster Abstracts
Physical Processes

Listed alphabetically by presenting author and abstract title.
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Analysis of the Process Physics of Tributaries to Florida Bay Using Artificial Neural Networks and Three-Dimensional Response Surfaces

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New technologies in environmental monitoring have made it cost effective to acquire tremendous amounts of hydrologic and water-quality data. Although these data are a valuable resource for understanding environmental systems, often these data are under-interpreted and under-utilized. Data mining techniques, including artificial neural network (ANN) models, are being applied to the USGS data of five tributary creeks to Florida Bay (McCormick, Mud, Taylor, Trout, and West Highway Creek) to answer critical questions such as relative impacts of controlled freshwater releases, tidal dynamics, and meteorological forcing on streamflow, water level, and salinity.

Data mining is a powerful tool for converting large databases into a mechanism for understanding to solve problems that are otherwise imponderable because of the large numbers of explanatory variables or poorly understood process physics. Data mining methods come from different technical fields such as signal processing, statistics, artificial intelligence, and advanced visualization. It employs methods for maximizing the information content of data, determining which variables have the strongest correlations to the problems of interest, and developing models that predict future outcomes. This knowledge encompasses both the understanding of cause-effect relationships and predicting the consequences of alternative actions. The models used in analysis of the tributary creeks are empirical ANN models built directly from the data. An ANN model is a flexible mathematical structure capable of describing complex nonlinear relationships between input and output data sets (Roehl and others, 2003). ANN models can synthesize functions to fit high-dimension, non-linear multivariate data.

Chaos Theory provides a conceptual framework called “state space reconstruction” for representing dynamic relationships used by the authors in building ANN models. Data collected at a point in time can be organized as a vector of measurements; for example, element one of the vector might be the water level, element two the streamflow, and so on. A process evolves from one state to another in time and the vector of measurements, also referred to as a “state vector,” represents the process state at the moment the measurements were made. The state vector is a point in a “state space” having a number of dimensions equal to the number of elements in the vector. For example, eight vector elements equates to eight dimensions. Empirical modeling is the fitting of a multidimensional surface to the points arrayed in state space.

The ANN models of the tributaries are used to examine the impact of controlled releases, water levels, precipitation, wind speed and direction, on tributary salinity dynamics. Three-dimensional (3d) surfaces generated by an ANN model are a powerful way to discover the model’s representation of a process’ variable interaction and physics. For example, Figure 1a shows a 3d scatter plot of C-111 Canal flows and Trout Creek gage height and salinity in 3-space. Figure 1b shows a 3d response surface generated from an ANN model of the system by plotting two explanatory variables (gage height and controlled releases) with an output response variable (Trout Creek salinity). The data for the surface is computed by incrementing the “shown” (displayed) ANN model inputs across their historical ranges of the displayed input variables, while the “unshown” inputs (the ANN model has more than two variables) are set to a constant value, such a historical mid-range. The response surface is a representation of the dynamic history of the system. The response surface shows significant salinity response for all gage heights when the Canall-111 flows are below 500 ft^3/s. For higher gage heights (> 0.5 ft) significant salinity response occurs with flows up to 1,000 ft^3/s.

The salinity dynamics of the five tributary creeks are currently being analyzed. Response surface for the five tributary creeks and for various combinations of explanatory variables are used to evaluate system behavior at the five sites. Comparisons and differences in the process physics, as manifest by the response surface for each tributary, between tributaries will be presented.

Reference:

Roehl, E.A.,

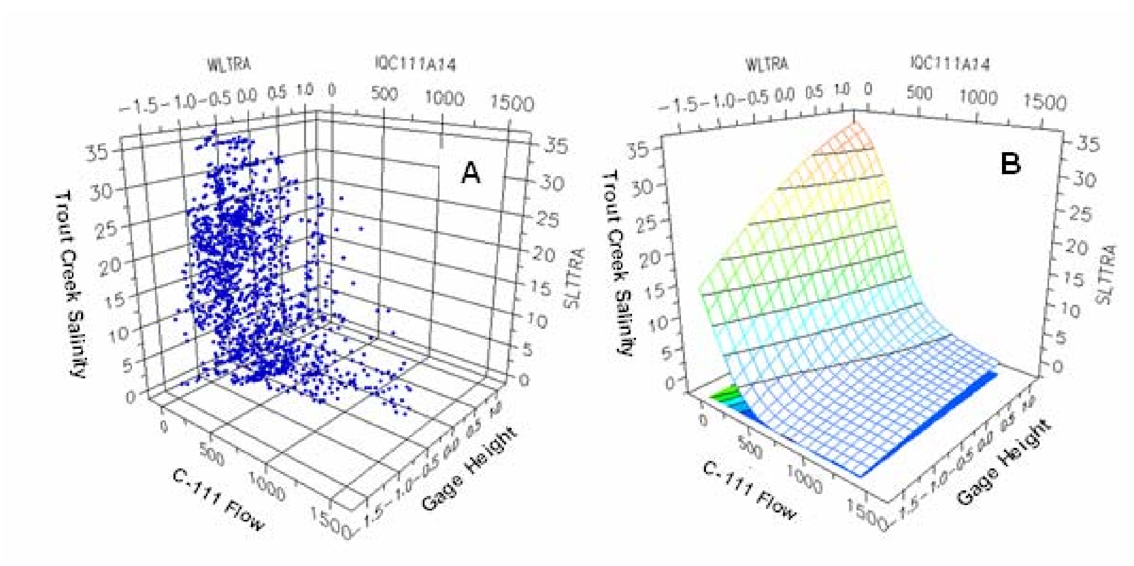

Figure 1. Three-dimensional scatter plot (A) of Canal 111 flow and Trout Creek gage height and salinity and three-dimensional response surface (B) generated by ANN model of the system.

Conrads, P.A., and Cook, J.B., 2003, “Discussion of Using Complex Permittivity and Artificial Neural Networks for Contaminant Prediction,” J. Env. Eng., Nov. 2003, pp. 1069-1071

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Real-time Oceanographic and Meteorological Observations in the Florida Keys National Marine Sanctuary

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A key element of any Coastal Ocean Observing System is a network of real-time in situ oceanographic and meteorological instruments. As part of NOAA's South Florida Program, several real-time moored oceanographic stations have recently been added to the existing array of meteorological and oceanographic sensors in the Florida Keys National Marine Sanctuary (FKNMS), and more are planned. Real-time data from the moored array are automatically posted on the project web site at: **www.aoml.noaa.gov/sfp/data.shtml**.

This poster presentation will focus primarily on recent observations from the real-time observing system elements located in the FKNMS, including meteorological data from the network of CMAN stations maintained by NOAA's National Data Buoy Center (NDBC).

The real-time moored array consists of several elements:

(1) A spar buoy located at Looe Key records current profiles over the water column as well as surface and bottom temperature and surface salinity. The location of the Looe Key station is ideal for monitoring the Florida Current as it meanders closer to the reef, and also for monitoring reverse (westward) flows associated with eddies and countercurrents. Extreme events such as the passages of tropical cyclones are also evident in the Looe Key record.

(2) A station at Moser Channel under the Seven-Mile Bridge records temperature, salinity, and water quality parameters such as light transmittance and chlorophyll fluorescence. This station is critical to monitoring any flows of southwest Florida shelf and/or Florida Bay waters as they move through the Keys passages toward the coral reefs of the FKNMS. When coupled with estimates of current direction and magnitude through the passages derived from sea level and wind data from nearby CMAN stations after calibration using current meter and shipboard data in the passages, a tool for monitoring these possibly harmful flows in real-time becomes a possibility. Another station similar to that located in Moser Channel will soon be placed in Long Key Channel and used to examine any significant differences between the flows through the two passages.

(3) In collaboration with NOAA's National Undersea Research Center (NURC) and the University of North Carolina at Wilmington (UNCW), the undersea laboratory "Aquarius" located in the coral reefs off Key Largo, Florida will soon be instrumented with temperature, salinity, water quality, dissolved oxygen, and current and directional wave sensors. Data from the Aquarius station will be made available to the numerous coral reef researchers who conduct studies in the area. The data will also be presented at an expanded web site which takes into consideration the needs and interests of the commercial and recreational fishing, diving and boating industries, educators, and the general public.

Real-time observations such as described herein are critically important not only for monitoring the often complex and inter-related oceanographic and meteorological events which occur in the south Florida marine ecosystems, but also for assisting with NOAA's goal of science-based resource management of the FKNMS.

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Salinity Variability in South Florida Coastal Waters, 1995 – 2005

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As part of NOAA's South Florida Program, ten years of shipboard observations of sea surface salinity and other oceanographic parameters have been obtained at an approximately bimonthly interval in the coastal waters of south Florida from Charlotte Harbor to Miami, including the Dry Tortugas and the Florida Keys. This time series shows that the surface salinity varies over a wide range of time and space scales in response to meteorological and climatological forcing, and demonstrates the inter-connectedness of the regional circulation.

The salinity data were collected using a flow-through thermosalinograph system aboard the University of Miami's research vessels the *R/V Calanus* (1995 – 1999) and the *R/V F. G. Walton Smith* (2000 – 2005). Nearly coincident data from Florida Bay and Biscayne Bay, collected using a similar flow-through system aboard the 25 ft research catamaran the *R/V Virginia K* at an approximately monthly interval, are combined with the larger-scale surveys for the purposes of generating contoured salinity fields. Data were obtained continuously along the cruise track shown in Figure 1.

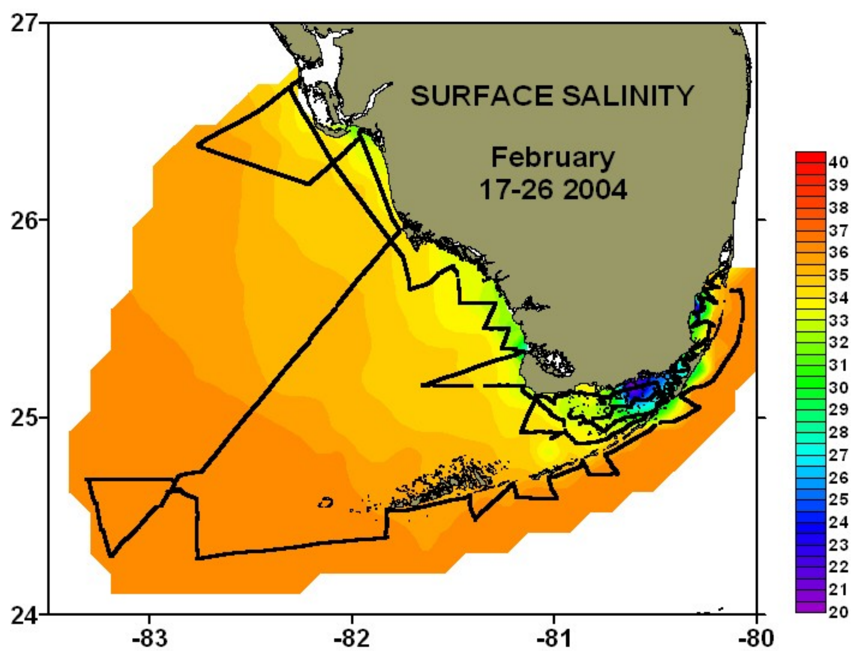

Figure 1. Representative map of sea surface salinity from surveys conducted during February 2004.

Figure 1 shows one example of surface salinity in the region. Highest salinities, around 36 psu, were found offshore in the Gulf of Mexico near the Dry Tortugas (near 24.5 N, 83 W) and on the Atlantic side of the Florida Keys. Lowest salinities, below 24 psu, were found in the northeast corner of Florida Bay (near 25 N, 80.5 W) and to a lesser extent in Biscayne Bay, western Florida Bay, and along the entire coastline of southwest Florida where numerous rivers provide a source of fresh water that disperses and acts to reduce the salinity over a large area.

Ten-year time series of salinity at a number of locations distributed along the standard cruise track were generated by objectively selecting data based on latitude/longitude criteria. The time series data were used to compute means and standard deviations, to examine seasonal and interannual variability, and to take a closer look at trends and anomalies in the data set. These data are interpreted in conjunction with precipitation data obtained from NOAA's National Climatic Data Center (NCDC) and standard meteorological data collected by the network of CMAN stations in the region operated by NOAA's National Data Buoy Center (NDBC).

The most obvious feature in both the salinity maps and the salinity time series is the seasonal pattern of higher salinity in the dry season (winter-spring) and lower salinity in the wet season (summer-fall). Superimposed on this seasonal pattern are salinity variations due to such phenomena as the very strong El Nino of winter 1997-1998 which caused the expected reversal of the normal wet/dry seasonal precipitation pattern, i.e. causing anomalously high winter precipitation and subsequently lower salinities across the region. This occurred to a lesser extent during the weaker El Nino of 2002-2003.

Unpredictable larger scale events can be seen in the salinity maps and time series, such as the occurrence of Mississippi River and other remote origin riverine waters, which were transported southward by an elongated Loop Current to the Tortugas and Gulf of Mexico areas during the summer of 1998 and again during the summer of 2004. Salinity can also be useful in understanding the causes and circulation pathways of other regional marine phenomena such as red tides (which occur on a nearly annual basis along the southwest Florida shelf) and more sporadic occurrences such as the "black water" event observed during the fall of 2003.

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Salinity Patterns of Florida Bay

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The salinity of Florida Bay has undergone dramatic changes over the past century in response to anthropogenic activities. Salinity values reached their most extreme, up to 70, in the late 1980's, concurrent with various other ecological shifts in Florida Bay including a mass seagrass die-off. In this study, surface salinity data was measured at approximately monthly intervals between 1998 and 2004. The survey data was standardized using the Kriging gridding process to remove any deviations in survey tracks. We gathered precipitation data from National Climate Data Center and calculated bulk flux estimates of evaporation using Seakeys and National Weather Service data. Runoff was measured at 6 creeks by the United States Geological survey using Acoustic Doppler Velocity Meters and estimates were made for 3 other creeks via correlation analyses to the directly measured flow data. The seven year data set was analyzed to quantify the effects of precipitation, runoff, evaporation, and climatic phenomena on salinity in Florida Bay.

Overall mean Bay-wide salinity for Florida Bay during this period varied from a low of 24.2 just after the passing of Hurricane Irene in October 1999 to a high of 41.8 near the end of a drought period in July 2001 (Fig. 1). The most dominant feature in this time series is the annual oscillation in salinity with high salinity in the early summer and low salinity in the winter. The mean Bay-wide salinity exhibited dramatic decreases (0.5 per day), whereas increases were slower (0.1 per day) indicating Florida Bay is capable of achieving estuarine conditions quickly, especially in response to large precipitation events such as tropical cyclones, but requires long periods (typically at least 8 months) of below average precipitation for hypersaline conditions to dominate. Furthermore, the highest salinities were observed in years when the onset of the rainy season was delayed enabling the high evaporation rates of the early summer months to escalate salinity. The net freshwater supply (precipitation plus runoff minus evaporation) for Florida Bay was calculated for each month and showed the expected inverse correlation with salinity (Fig. 1). The net freshwater supply was at a maximum of 36.3 cm in October 1999 due to Hurricane Irene and at a minimum of -16.1 in June 2004 when the onset of the rainy season was delayed, just prior to the second highest mean Bay-wide salinity observation of 41.7 in July of 2004.

The mean monthly values for precipitation, runoff, evaporation, net freshwater supply, and mean Bay-wide salinity were calculated to depict the typical annual cycle (Fig. 2). The mean direct annual runoff (21 cm yr^{-1}) was approximately 19% of mean annual precipitation (111 cm yr^{-1}). Mean annual evaporation was 157 cm yr^{-1} on average and thus the mean net freshwater supply was -25 cm yr^{-1}. However, the net freshwater supply showed a large degree of variation from -84.8 cm in 2004 to 18.1 cm in 1999. The mean annual cycles in precipitation and runoff were highly correlated with runoff lagging precipitation by one month. The annual salinity cycle was inversely related to the precipitation cycle with a lag of 2-4 months (highest precipitation in September, but lowest salinity in January). The net freshwater supply cycle was correlated with the salinity cycle; however, the values of net freshwater appear to have been underestimated. This underestimation is due to runoff occurring directly into Florida Bay at points other than those quantified in this study, the influence of indirect runoff along the southwest Florida coast on Florida Bay, and possible inaccuracies in our evaporation estimate.

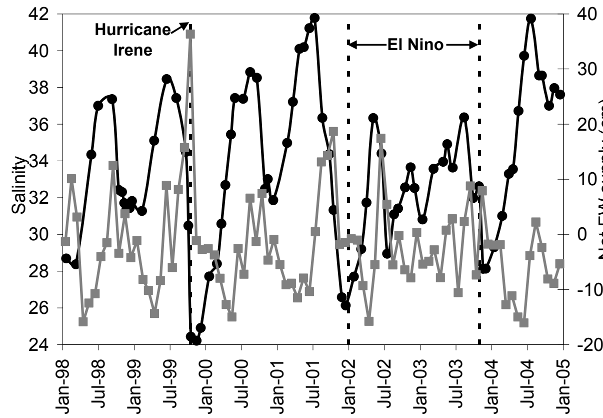

Fig. 1. Mean Bay-wide salinity for each survey cruise and net freshwater supply for each month.

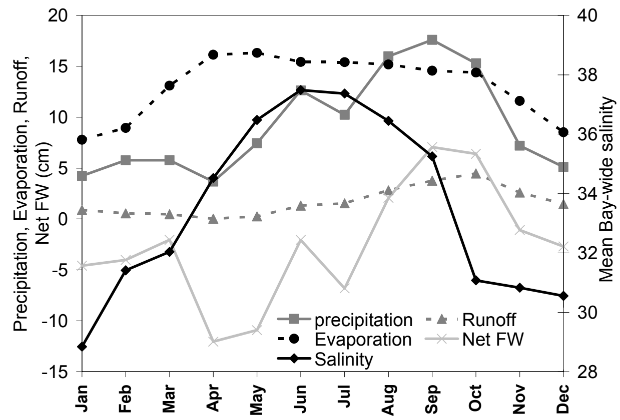

Fig. 2. Typical annual cycle of precipitation, runoff, evaporation, net freshwater supply, and mean Bay-wide salinity.

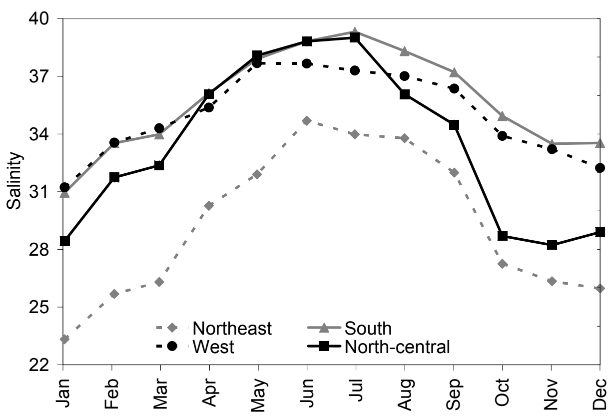

Fig. 3. Typical annual oscillation in salinity for the four sub-regions of Florida Bay.

There were distinct spatial salinity patterns in Florida Bay, and to examine these patterns the Bay was split into four sub-regions (northeast, north-central, west, and south) and their annual salinity cycles were plotted (Fig. 3). The west and south salinities were significantly more stable and closer to marine values than the other two sub-regions. The northeast consistently exhibited the lowest salinity and the north-central displayed the most dramatic changes in salinity. However, all regions had similar annual oscillations in salinity with highest salinities in the summer and lowest in the winter.

There was no long-term trend in salinity and it was determined that primarily local climatology (in particular precipitation and wet/dry seasonality) usually drives temporal salinity patterns; whereas runoff and bathymetry also had significant effects on the spatial salinity patterns. Furthermore, singular climatic phenomena have a significant effect on the salinity distribution as was observed by the dramatic drop in salinity following Hurricane Irene's passing in October 1999 and by the lack of the typical annual oscillation in salinity during the El Nino of 2002-2003.

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The Status of Statistical Model Development and Implementation for Salinity Performance Measures in Florida Bay and Along the Southwest Gulf Coast

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Multivariate linear regression (MLR) models have been developed and implemented for salinity at 17 locations in Florida Bay and along the southwest Florida coast using the Everglades National Park (ENP) Marine Monitoring Network (MMN) salinity data as the basis. An additional 15-17 statistical models are currently under development as part of a Critical Ecosystem Studies Initiative (CESI) for ENP. Continuous salinity data from the ENP MMN stations exist from the early 1990's. The dependent variables (predictors) in the MLR salinity models are water elevations in the Everglades, wind speed and direction, and sea surface elevation. Time series modeling methods (SARIMA) were adapted to a controlled step-wise regression process at a daily time step for model development. R^2 values for the developed models range from 0.56 to 0.86, with Nash-Sutcliffe Efficiency values from 0.66 to 0.92. Parameters were retained in the models only at the 0.999 or higher significance level. Comparisons of MLR estimates (monthly averages) to simulations made by the FATHOM model and to observed values for two representative locations are presented in Figures 1 and 2.

The conceptual basis for the use of correlative relationships for salinity models is a dynamic coastal aquifer physical model with upstream fresh water (surface and ground water) competing with denser salt water that is also being mixed locally within the interface zone by the wind. Within this dynamic framework each element is operating at a variety of characteristic frequencies that ultimately determine the daily average salinity composition at the fixed MMN monitoring stations in south Florida. Modeling these elements using SARIMA and multivariate regression time series procedures has produced evaluation tools that have been used for a number of tasks, including the evaluation of CERP freshwater delivery alternatives.

The MLR salinity models have been used with both observed stage values and stage as simulated by the South Florida Water Management Model, along with historic wind and sea elevation data to produce daily simulations of salinity for different periods of time. The salinity models have been used for the Interim Operations Program Congressional Report by ENP; for Florida Bay salinity performance measure development and to compare eight CERP water management scenarios by the RECOVER Southern Estuaries Sub-team; for the Interim Goals and Interim Targets CERP evaluations for the Restudy; and for the CSOP analysis by ENP. The MLR salinity models have been coupled with a pink shrimp ecological model by NOAA, and for a historical salinity recreation for the Florida Bay Minimum Flows and Levels program by SFWMD. The performance measure models (all 17) are currently available to all researchers through the Interagency Modeling Center.

The 2004 and 2005 CESI projects include a number of implementation tasks, some of which have been completed and some that are currently underway. For these projects, MLR salinity models will be used for historical reconstructions, flow regime development for several designated salinity regimes (including Florida Bay and Florida Keys Feasibility Study performance measures and paleo-ecological reconstructions), and coupling with the output from the USGS SICS/TIME model to ultimately evaluate CERP alternatives.

A number of the tasks for the current CESI projects will focus on the southwest Gulf coast estuarine area in the Cape Sable region and north along the Ten Thousand Islands area. The estuarine areas within the influence of the Shark River freshwater discharge have not been the primary focus in the previous CERP alternative analysis because salinity models have only recently been available for evaluations.

Figure 1. Comparison of salinity monthly simulations of salinity by MLR and FATHOM models with observed MMN and SERC values for Whipray Basin.

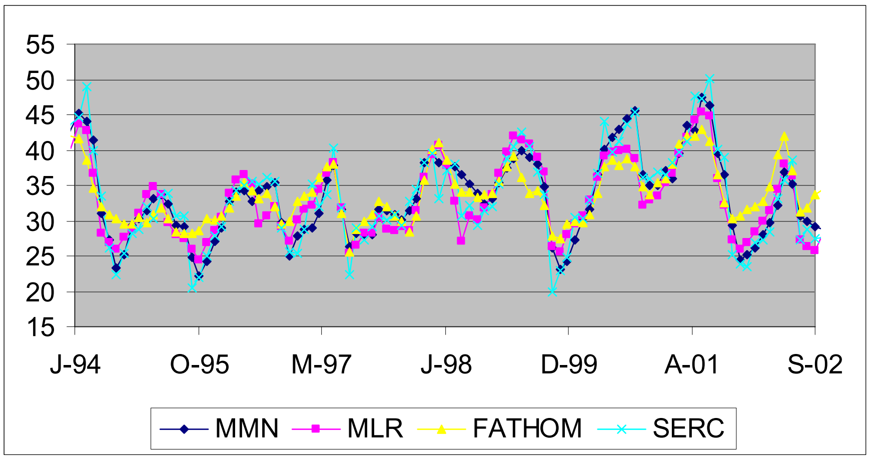
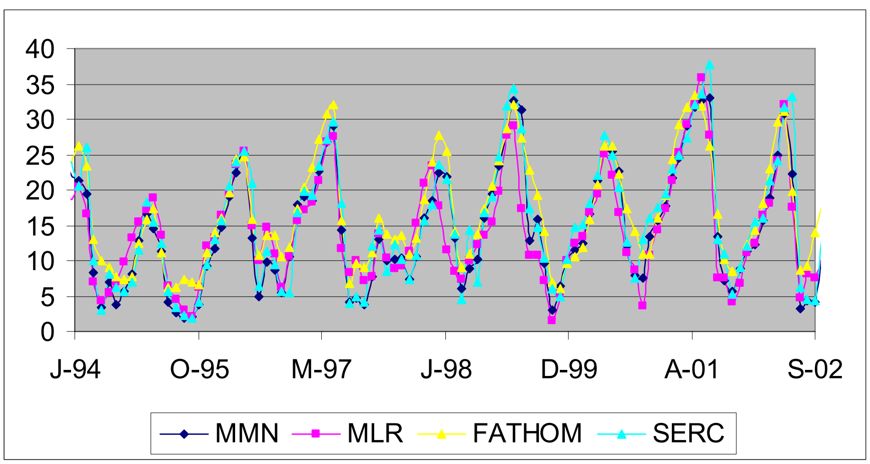


Figure 2. Comparison of salinity monthly simulations of salinity by MLR and FATHOM models with observed MMN and SERC values for Long Sound.



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Recent Measurements of Salinity, Flow and Sea Level Variability in Western Basins of Florida Bay – Rabbit and Twin Key Basins

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Rabbit Key and Twin Key basins consist of a pair of shallow water bodies adjacent to the western boundary of Florida Bay and enclosed by expansive mud banks that can be partially exposed at times of low water (Fig. 1). The basins are separated from the southwest Florida shelf waters by 9-Mile Bank to the west and from the southeast sub-region of Florida Bay by Twin Key Bank. To the north lies a broad bank region separating the basins from the north-central region of the bay where hypersalinity is commonly observed during dry seasons. These western basins serve as a transition zone for water exchange between the southwest shelf and more restricted, poorly flushed inner basins of Florida Bay. Exchange of western basin waters takes place through a series of flow channels through the shallow banks, as well as directly over the banks when water levels are sufficiently deep. As part of our collaborative effort to better understand circulation and exchange processes throughout Florida Bay we have recently made direct measurement of volume and salt transports through nine of the larger flow channels connecting the western basins to surrounding regions. Measurements took place over the June to November wet season of 2004 and the following December to June dry season of 2005. High resolution spatial salinity surveys were made at approximately 2 week intervals over the study period and sea level measurements were made continuously throughout both seasons. Interior basin circulation was observed with shallow drifters.

Initial results show a vigorous exchange between the western basins and the surrounding regions driven by tide and wind forced transports. The exchange of Rabbit Key basin waters with the southwest shelf caused considerable freshening of the western basins with Rabbit Key basin waters consistently fresher than waters of Twin Key basin (Fig. 2). Twin Key basin had significant exchange with Rabbit Key basin to the west and the southeast sub-region of Florida Bay to the east. Interestingly, all channels display significant mean outflows in both basins, which suggests there may have existed mean inflows over the broad banks to account for these outflows. Basin interior circulations were a mixed response to tide and wind forcing in Rabbit Key basin, but were primarily wind driven in Twin Key basin. This indicates strong frictional dampening of the semi-diurnal and diurnal tidal wave moving into the basins from the Gulf by the shallow Twin Key Bank separating the two basins. These results clearly show that shelf and oceanic transport of Shark River discharge and riverine inputs from the west Florida coast southward to the western Florida Bay region can have a considerable effect in moderating the development of hypersalinity in Florida Bay. These observations provide a comprehensive data set for use in calibration and validation of the Florida Bay hydrodynamic model.

Fig. 1. Location of Rabbit Key and Twin Key basins within the western sub-region of Florida Bay. Current and salinity time series were made during wet (Jun to Nov 2004) and dry (Dec 2004 to Jun 2005) seasons in channels connecting the basins to surrounding regions. Mooring locations are shown with solid triangles and squares. Shown with solid line is the vessel track of the bi-weekly salinity surveys.

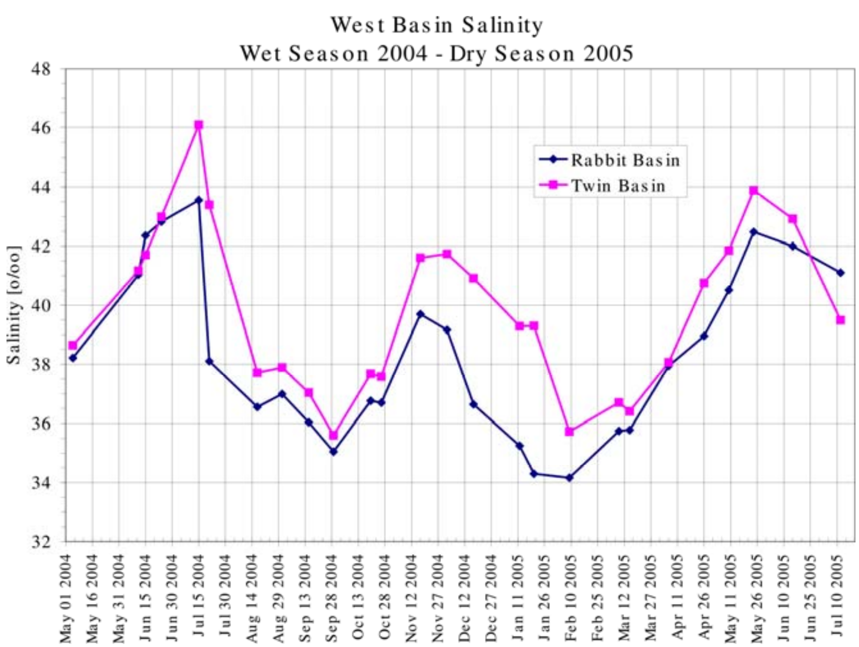

Fig. 2. Time series of basin average salinity from bi-weekly shipboard surveys of Rabbit and Twin Key basins.

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Flow Exchanges through Culverts along Everglades National Park Road

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The extension of Florida state route 9336 from the entrance of Everglades National Park near Homestead to Flamingo, Florida, follows the approximate basin boundary between Taylor and Shark River Sloughs in the southern Everglades. Flow exchanges through the park road are accommodated by two bridges at the headwaters of Taylor Slough and 178 two-foot-diameter culverts spaced at various intervals along the road between the park entrance and Coot Bay (Stewart and others, 2002). Historical insight offered by Craighead (1966), measured culvert flows in 1997 and 1998 reported by Tillis (2001), and data collected in 1997 by the National Park Service and summarized in Stewart and others (2002) suggest that the predominant flow exchange along the segment of road between Pa-hay-okee Overlook Road and Nine Mile Pond is from Taylor Slough into Shark River Slough. These conclusions were based primarily on synoptic observations and measurements. The objectives of this study are to collect continuous data for a full wet season to characterize the temporal flow exchanges and to analyze ancillary hydrologic data to assist in understanding the mechanisms that drive flow reversals.

Flow-velocity, salinity, and water-level data were collected in 2004-5 to investigate flow exchanges between Taylor and Shark River Sloughs through several park road culverts (fig. 1). Acoustic Doppler velocity profiling meters were installed in four northern culverts and point-velocity meters with conductivity sensors were installed at the outlets of three southern culverts. Water-level sensors also were installed on both sides of the road at two culverts where flow velocities were monitored. The data are providing insight into the temporal behavior of flow exchanges through the road. A sample of salinity and velocity data collected at culvert 89 (see fig. 1) is shown in figure 2. Although the predominant flow direction shown by the velocity data is westward (direction 270 degrees) from Taylor Slough into Shark River Slough, the data reveal shorter periods of eastward flow from Shark River Slough into Taylor Slough. Flow exchanges from Shark River Slough into Taylor Slough, accompanied by slight but measurable changes in salinity, are evident in the data recorded on August 5 to 10, August 31 to September 2, and September 4 to 8. Other hydrologic and meteorological data are being compiled and analyzed to determine the mechanisms that drive these flow reversals.

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Tillis, G.M., 2001, Measuring Taylor Slough boundary and internal flows, Everglades National Park, Florida, U.S. Geological Survey Open-File Report 01-225, 16 p.

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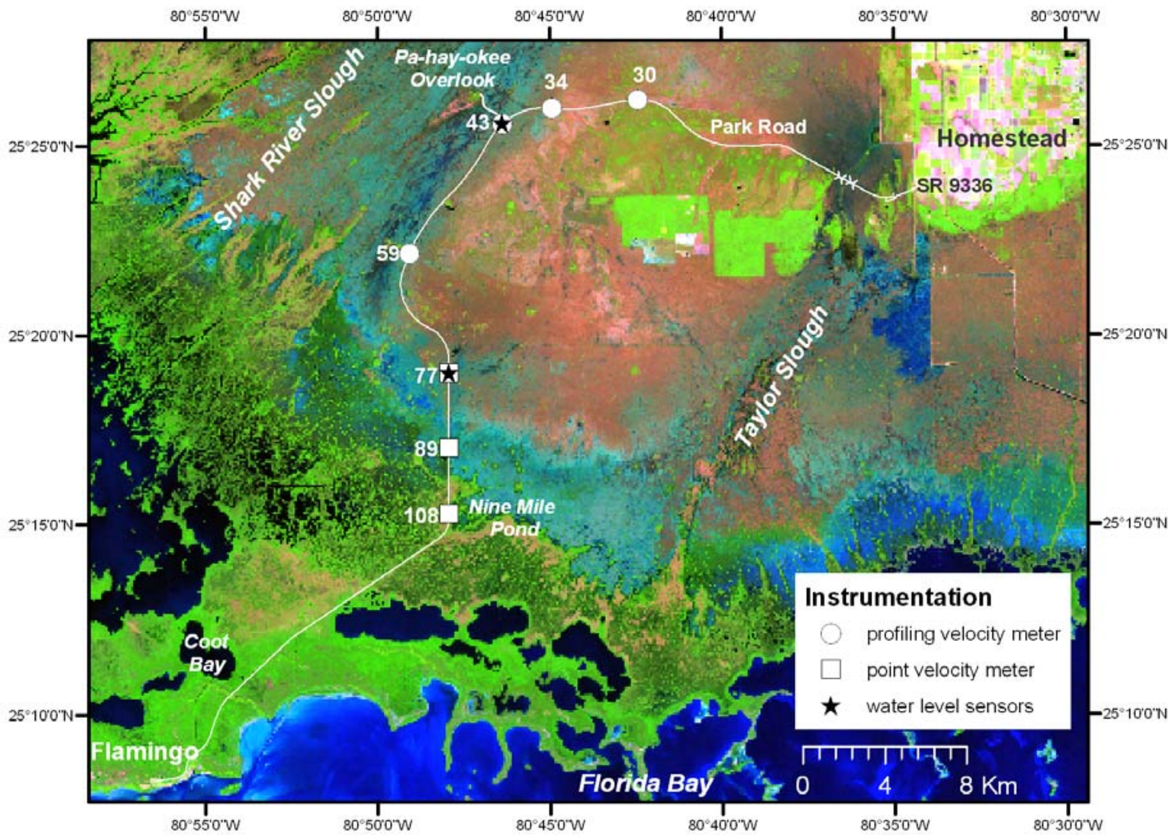

Figure 1. Satellite image of the Park Road showing locations of monitoring stations.

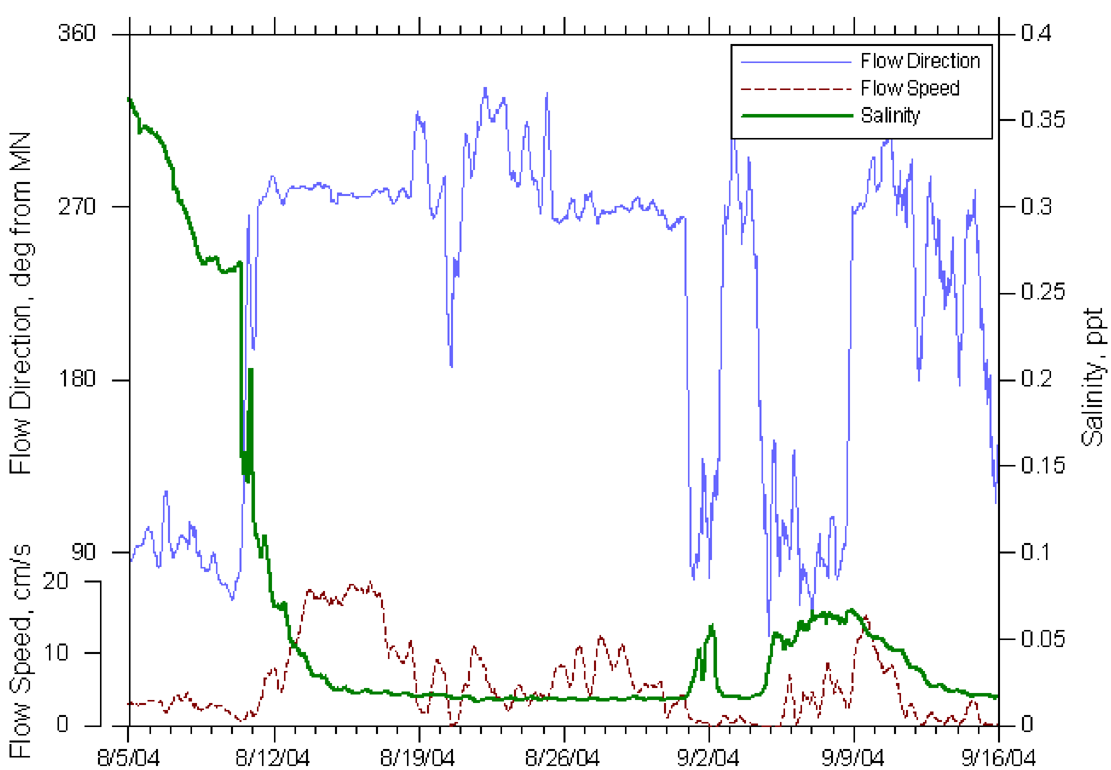

Figure 2. Flow speed, flow direction, and salinity measured at culvert 89, ENP Road.

Coastal Ocean Observing Systems: How SEACOOS and GCOOS are Facilitating Marine Systems Science in Florida

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Monitoring the pulse of the planet has never been more valued, as evidenced by the formation of the Global Earth Observing System of Systems (GEOSS). The United States' contribution to the ocean component of this initiative is the Integrated Ocean Observing System (IOOS). There are presently nine regional coastal ocean observing systems (COOS) ringing the coast of the United States; twelve including the Hawaiian Islands and Caribbean regions. Florida is unique in that it is the only state that overlaps boundaries with multiple regional systems-the SouthEast Atlantic COOS (SEACOOS), the Gulf of Mexico COOS (GCOOS), and the Caribbean COOS (IOCARIB).

Poised between distinct, yet interacting coastal ocean systems, Florida exemplifies the need for integrated, multi-disciplinary information to manage its resources. Florida Bay researchers, in particular, must consider influences from the Caribbean, Gulf of Mexico and waters from the Atlantic Ocean that connect through the tidal passes between the Florida Keys. Presented here is an overview of SEACOOS and GCOOS and an introduction to the variables presently measured by SEACOOS and GCOOS partners and affiliates. Examples of how ocean observing data are serving the critical and expanding needs of environmental protection, public health, education, research and recreation will also be provided.

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The Influence of Hurricane Katrina on Water Quality in Florida Bay and Surrounding Coastal Waters

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Prior to its devastating effects on Louisiana and Mississippi, Hurricane Katrina crossed south Florida as a category one hurricane in late August 2005. Synoptic events, such as the passage of tropical cyclones, can have a significant impact on water quality in areas where coastal waters are particularly shallow such as Florida Bay, the Southwest Florida Shelf, and the Florida Keys reef tract. Tropical storm and hurricane force winds affected south Florida and the surrounding coastal ocean from August 25th through the 27th (Figure 1). The rapid precipitation, runoff, and direct wind forcing associated with Katrina produced measurable changes in these waters.

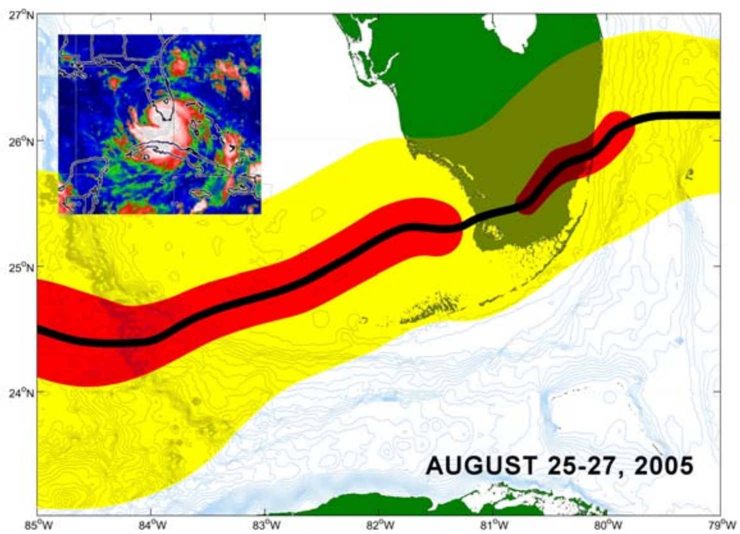

Figure 1. Tropical storm (yellow) and hurricane (red) strength winds affect south Florida and the surrounding coastal ocean in late August 2005.

As part of a long-term study funded by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Ocean Program (COP), scientists from NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML), the University of Miami's (UM) Rosenstiel School of Marine and Atmospheric Science (RSMAS), and the University of South Florida's (USF) College of Marine Science (CMS) monitor the physical, chemical, and biological properties of south Florida coastal waters on a regular basis. Scientists utilize bimonthly regional hydrographic surveys, monthly bay surveys (Florida and Biscayne), moored instrumentation, Lagrangian drifters, and remote sensing techniques to gain a more comprehensive understanding of how regional flow patterns and the resulting spatial distribution of water properties are influenced by the Gulf of Mexico, the Straits of Florida, and runoff from the south Florida watershed. These water properties (salinity, chlorophyll concentration, turbidity, dissolved organic matter, etc.) and their spatial distribution are a direct measure of the condition of south Florida coastal ecosystems.

Preceding Hurricane Katrina's passage through the region, routine hydrographic surveys collecting continuous flow-through measurements and discrete vertical station measurements of salinity, temperature, fluorescence, and transmittance were completed on the Southwest Florida Shelf, the Florida Keys reef tract, and in Florida and Biscayne Bays. During these surveys, moored instrumentation deployed about the region, including acoustic Doppler current profilers (ADCP), conductivity/temperature sensors (CT), fluorometers, and transmissometers, were recovered, refurbished, and redeployed. Additionally, the region was seeded with three Lagrangian shallow water surface drifters at Charlotte Harbor, Shark River, and the Dry Tortugas.

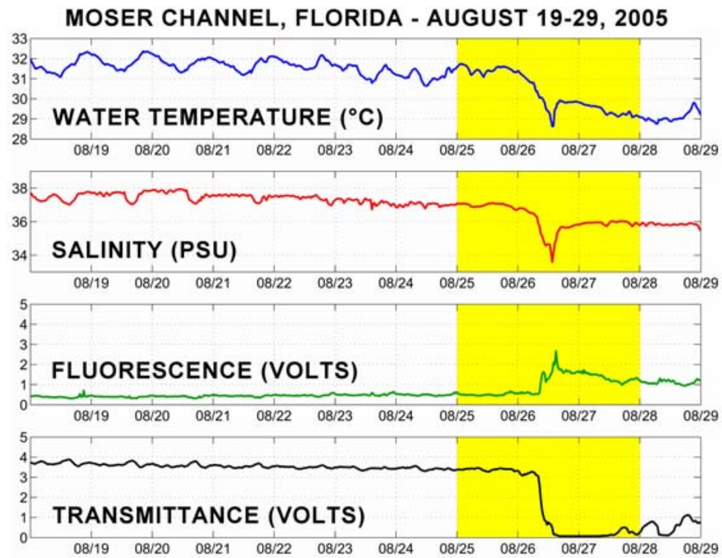

Figure 2. Moser Channel Oceanographic Monitoring Station records the passage of Hurricane Katrina (highlighted in yellow).

Following the storm, rapid response hydrographic surveys were conducted in Florida and Biscayne Bays. Preliminary results from these surveys show a marked decrease in salinity due to direct precipitation and extensive runoff through canals and rivers around the region. An increase in chlorophyll concentration and water turbidity (decreased transmittance) was also recorded, likely due to the resuspension of sediments and associated microphytes caused by wind driven mixing of the water column. These survey results agree with data recorded at real-time stations in the moored array. Shown in Figure 2, the influence of the tropical cyclone can be seen in the data logs from Moser Channel Real-Time Oceanographic Monitoring Station, located at the Seven-Mile Bridge in the Florida Keys (**http://www.aoml.noaa.gov/sfcoo/7MB/**). In addition, drifter trajectories during late August (not shown) emphasized the effects that tropical cyclones can have on the regional circulation, recording translations of up to 20 nautical miles in 24 hours (**http://www.aoml.noaa.gov/sfcoo/SFP_drifters/**). Moored non-real-time data covering the time period of this synoptic event will be compared with collected survey data, drifter trajectories, and moored real-time data following scheduled instrumentation recoveries in October 2005.

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Satellite-Tracked Surface Drifter Trajectories Reveal the Spatial and Temporal Current Variability of South Florida Coastal Waters

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Interdisciplinary hydrographic surveys of south Florida coastal waters are conducted on a bimonthly interval by researchers at NOAA's Atlantic Oceanographic and Meteorological Laboratory and the University of Miami's Rosenstiel School of Marine and Atmospheric Science as part of NOAA's South Florida Program (SFP). During these surveys, Lagrangian drifting buoys are deployed at three locations around the region: offshore Charlotte Harbor on the southwest Florida shelf, near the mouth of the Shark River in Everglades National Park, and in the Dry Tortugas at Riley's Hump. Shown in Figure 1, these buoys (CODE drifters) are intended for use in shallow depths typically found in coastal ocean environments. The drifters are tracked by satellite and trajectories are automatically posted on the NOAA SFP drifter website: **http://www.aoml.noaa.gov/sfcoo/SFP_drifters/**.

Figure 1. A shallow water CODE drifter.

The drifters are designed to track the motions of the surface currents, and since deployments began in 1994, their trajectories have shown a wide range of spatial and temporal variability in the regional circulation of south Florida coastal waters. Three seasonal patterns of flow on the southwest Florida shelf emerge from the collected trajectories. In the winter and spring, current flow towards the southeast transports drifters from the shelf through the middle Keys passages and into the Straits of Florida. In the summer, drifters generally track westward along the southwest Florida shelf and are eventually entrained in the Loop Current and carried into the Straits. In the fall, flow tends toward the southwest, moving drifters on the shelf towards the Dry Tortugas.

Drifters are often circulated through a semi-permanent cyclonic eddy located southeast of the Dry Tortugas known as the Tortugas Gyre. This can be seen in the drifter trajectories shown in Figure 2. Drifters were deployed during a December 2004 cruise at Charlotte Harbor, Shark River, and the Dry Tortugas (not shown). The Charlotte Harbor drifter entered the Straits of Florida via Loop Current entrainment and was caught up in the Tortugas Gyre making one full revolution around the center of the eddy. The Shark River drifter entered Hawk Channel through the Keys passages at Seven-Mile Bridge. Initially heading west in a coastal countercurrent, the drifter reached the Marquesas Keys before being carried back eastward, offshore from the countercurrent. South of Big Pine Key the drifter was influenced by the Gyre's cyclonic circulation and returned towards the west. Interestingly, these two drifters, after having been deployed quite a distance from one another, and having traveled two completely different routes, ended up at nearly the same location on January 27, 2005. This illustrates the combined effects of regionally varying wind fields and currents. Both drifters were subject to approximately the same wind forcing (as the wind varies over fairly large spatial scales in the region), but different current systems (Loop Current/Florida Current as opposed to along-Keys counter flows and eddies).

The drifter program, which has been ongoing for approximately ten years, has continued to provide information on the ranges of temporal variability, from episodic to interannual, as well as spatial variability, in the circulation of south Florida coastal waters.

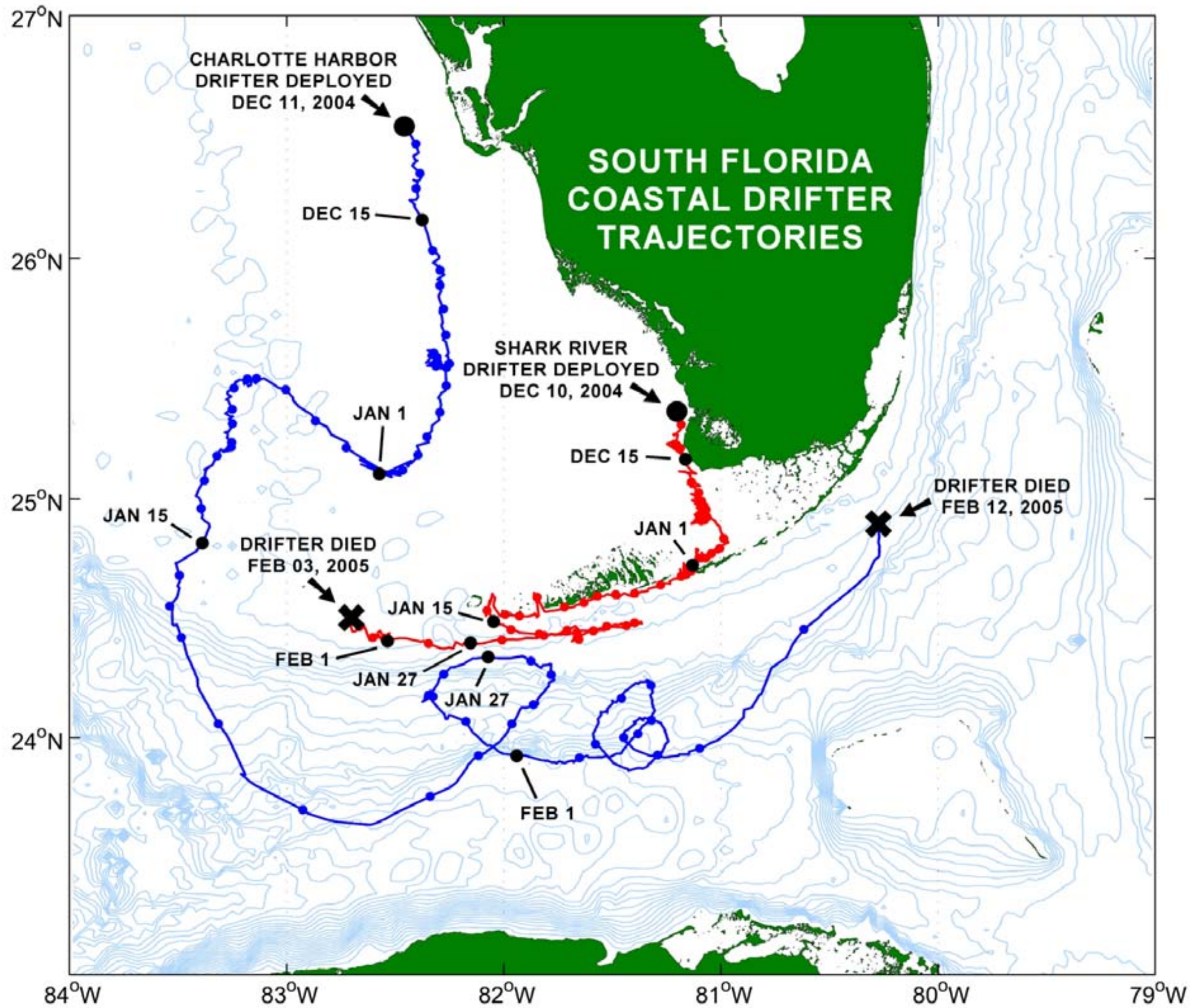

Figure 2. December 2004 Charlotte Harbor and Shark River drifter trajectories.

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Temporal Changes in the Delivery of Freshwater to Florida Bay: A Decade of Change

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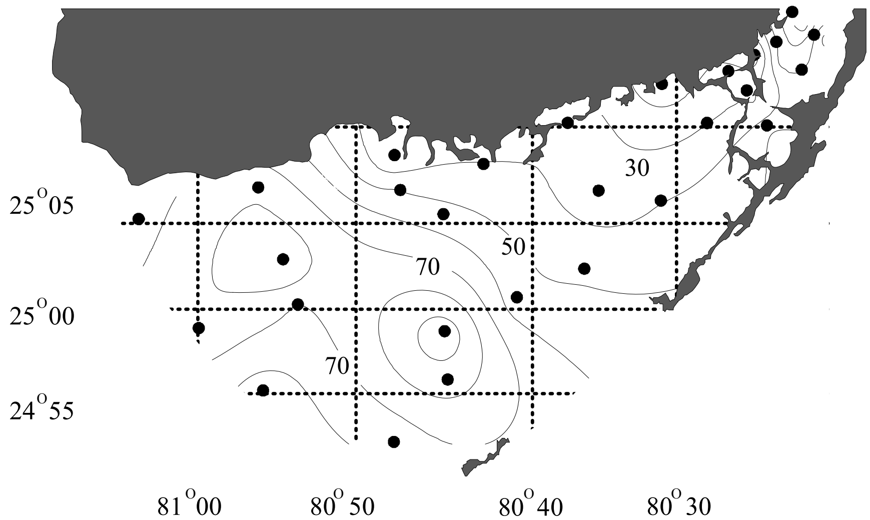

Figure 1: Contours show the percentage of freshwater derived from precipitation based on stable oxygen isotopes between 1993-1998 (Swart & Price, 2002). New data 1998-2005 suggests increased penetration of Taylor Slough water to the west.

Salinity variations within Florida Bay result from the mixing of seawater and freshwater derived from a combination of direct precipitation, runoff from the Everglades, evaporation, and possibly groundwater input. In order to distinguish the importance of these different sources to the freshwater balance in Florida Bay, we have developed a method using the stable isotopes of oxygen (^{18}O and ^{16}O) to separate runoff from direct precipitation. The premise behind this method is that while rainfall has an oxygen isotopic value of approximately -3 to -4‰, runoff has typical values of between 0 and +1‰. By calculating the intercept (at zero salinity) of relationships between salinity and the oxygen isotopic composition at the various locations throughout Florida Bay, it is possible over a specific time period to estimate the percentage of freshwater derived from these two sources (Figure 1). We have applied this method to oxygen isotope measurements made on samples collected on a monthly basis at the FIU sampling between October 1993 and December 2005. Our initial calculations made during the period 1993-1998 estimated that in the western portion of the Bay over 70% of the freshwater was derived from direct input from precipitation rather than from runoff. We have extended our approach into the temporal domain, in order to investigate changes in the water delivery between the period 1993-1998 and 1998-2003. Our results suggest a greater penetration of freshwater derived from Taylor Slough into the western portion of Florida Bay during the later period. These data provide the first direct evidence that changes in the water delivery in the C-111 canal area are impacting the salinity in the greater Florida Bay.

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A Bay-Estuarine Model to *S*imulate Hydrodynamics and Thermal, Salinity, Sediment, and Water Quality Transport in 3-Dimensions (BEST3D)

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This paper presents the development and application of a three-dimensional finite element model to simulate hydrodynamic and transport phenomena in bays, estuaries, and coastal waters. The hydrodynamic module of the model solves three-dimensional Navier-Stokes equations with or without the hydrostatic assumptions and salt and thermal transport equations to yield spatial-temporal distributions of tides, currents, salinity, and temperature. The Boussinesq approximation is employed to deal with the buoyancy force due to temperature and salinity variations. The moving free surface is directly dealt with by solving the kinematic boundary condition equation using a node-repositioning algorithm. The transport module solves a number of N_s sediment transport equations for N_s sediment size fractions and a system of M transformed equations governing the transport, fate, and reaction of M biogeochemical constituents. The Arbitrary Lagrangian-Eulerian (ALE) representation is adopted for all transport equations. The solution is obtained by finite element methods or a combination of finite element and Semi-Lagrangian (particle tracking) methods. The water quality module employs a general paradigm to transform the set of M biochemical constituents-transport equations into three subsets: component-variable transport, kinetic-variable transport, and mass action equations. The model can include any arbitrary number of fast/equilibrium and slow/kinetic reactions, and, more importantly, it enables the formulation and parameterization of kinetic reactions one by one. To demonstrate the flexibility and generality, the eutrophication model in WASP5, QUAL2E, and CE-QUAL-ICM are recast in the mode of reaction networks. This illustrates that the model embeds the most widely used water quality models as specific examples. Based on these three examples, the deficiencies of current practices in water quality modeling are discussed and the actions that must be taken to improve these practices are addressed. Finally, the model was applied to the Loxahatchee River estuary and was calibrated for tides and salinity reasonably well.

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Oral Abstracts

Higher Trophic Levels

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Physiological and Behavioral Responses of Estuarine Fish to Salinity Changes in Florida and Biscayne Bays

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Components of the Comprehensive Everglades Restoration Plan (CERP) such as the Biscayne Bay Coastal Wetlands Project, the C-111 Spreader Canal Project, and the Florida Bay Feasibility Project will act to restore more natural freshwater flows to northeastern Florida and Biscayne Bays, thus altering the present salinity regime in the area. Salinity is a limiting factor in the physiology and distribution of estuarine species.

The timing, volume, delivery and quality of freshwater to Florida and Biscayne Bays can affect the structure and functional aspects of the diverse fish communities in the bays. Coastal fish populations are an important food source for many of the Higher Trophic Level species (HTLs) of the bays that have been negatively affected by current water management practices. Variable and high salinity has been identified as an important stressor in Florida and Biscayne Bays.

Our studies focus on the following central theme and hypotheses: **Biological performance measures (i.e., growth, reproduction, survival) and behavior (i.e., habitat preference and locomotor behavior) of estuarine fish will be controlled by changes in salinity and water quality that will occur as a result of the restoration of freshwater flow to the bay.**

A series of acute and subchronic physiological toxicity studies were conducted to determine the effects of salinity changes on the life stages (embryo/larval, juvenile, adult) and fecundity of four native estuarine fish (*Cyprinodon variegatus, Floridichthys carpio, Poecilia latipinna, and Gambusia holbrooki*). Fish were exposed to a range of salinity concentrations (freshwater to hypersaline) based on salinity profiles in northeastern Florida Bay and adjacent Everglades areas. Growth (length, weight), abnormalities, survival and hematological endpoints (hematocrit, plasma osmolality) were measured after each salinity trial. Salinity trials included both rapid and gradual change events. Results show negative effects of acute, abrupt salinity changes on fish survival, development and reproductive success as a result of salinity stress. Our studies target reproduction and critical embryo-larval/neonate development as key areas for detecting long-term population effects of salinity change in Florida Bay.

Adults of each species were also examined for behavioral responses to pulsed and gradual salinity changes. These responses include changes in swimming performance, locomotor behavior and zone preference.

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Examining Interactive Effects of Salinity and Seagrass Habitat on Higher Trophic Level Species for the Development of Florida Bay Minimum Flows and Levels Technical Criteria

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As part of the development of Minimum Flows and Levels (MFL) technical criteria for Florida Bay, we examined the predicted response of the ecosystem to simulated changes in salinity examining responses in seagrass density, species composition and higher trophic levels. The coordinated application of two models represents a unique attempt to link simulations of hydrology to predictions of habitat and key consumers in Florida Bay.

Two kinds of models were used in conjunction in the scenario analysis of salinity, effects on SAV (submersed aquatic vegetation) and higher consumers that use SAV habitat. The SAV habitat was simulated under various salinity conditions using the Florida Bay Seagrass Model (Madden and McDonald 2005; McDonald and Madden 2005). The effects of salinity and corresponding seagrass habitat on 14 forage species (13 fish species and pink shrimp) in northeastern Florida Bay was then determined using species specific statistical models developed for Florida Bay (Johnson et al.2005a; Johnson et al. 2005b). A base case for the scenario analysis was established using an averaged salinity, temperature and nutrient dataset from the years 1996-2001 (the calibration period of the seagrass model) to produce a single "average year" base case input file for each of 2 seagrass model calibration stations in this region, Trout Cove and Little Madeira Bay. The scenarios repeated the averaged annual physical forcings for five consecutive years, with 11 variations to the salinity function from the base case input (one that decreased salinity, four that increased salinity, and six that incorporated a 30 day lagged salinity function). Seasonal "snapshots" of the seagrass model output (biomass converted to density) plus associated inputs of salinity and temperature (as monthly averages) were used as input for the higher trophic level (HTL) statistical models. Results from the scenarios were examined for each individual fish/invertebrate species and were aggregated to assess effects on the forage assemblage.

Simulated seagrass trended to a *Thalassia testudinum* monoculture when peak salinities were greater than 30 psu. In all months, predictions for the highest forage base abundance corresponded with lower salinities and higher *Halodule wrightii* densities. This relationship for the forage assemblage largely reflected the response of a subset of abundant species that showed declines at higher salinities. For some species, such as bay anchovy and two common killifishes (*Lucania parva* and *Floridichthys carpio*), salinity increases largely contributed to their decline. However, the salinity trend of the assemblage was also strongly influenced by declines in mojarras (*Euchinostomus sp.*), despite the expectation from the statistical model that this species should increase with higher salinity conditions. The observed salinity relationship for mojarras was instead driven by the decline in *Halodule* that occurred generally when salinity averaged above 40 psu.

Inter-annual trends in the model results point to the indirect effects of seagrass habitat on the forage assemblage. For each month, inputs of temperature and salinity to the HTL models were identical among years. If these variables alone determined forage fish assemblage density, no inter-annual variability would be evident. The inter-annual decrease in fauna can thus only be explained as an indirect salinity effect associated with *Halodule* loss. It is notable that during the modeled five year period, *Thalassia* density changed little; fauna were sensitive not only to the quantity (cover and density) of SAV habitat, but to the quality of this habitat. These results illustrate that salinity effects on fauna occur not only directly via physiological stress on the fauna, but also via habitat modification. This supports the validity of examining habitat variables in concert and of using submerged aquatic vegetation habitat as an ecosystem indicator for MFL development.

It is important to note that while the seagrass model incorporates dynamic feedbacks into its results as time-series outputs, the HTL models are independent of time and can present only static ("snapshot") results. Thus, the results should be viewed as conservative: these models do not reflect dynamic effects of population recruitment, predator/prey interactions or competition, or other life-history traits over time. Additional work that explores the interactive effects of salinity and benthic cover to the growth and survival of these and other Florida Bay fish species is needed to understand the mechanisms behind the trends herein described.

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Application of a Simulation Model of Pink Shrimp Growth and Survival

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A simulation model of growth and survival developed by Browder et al. (2002) to predict the response of pink shrimp to changing salinity and temperature was applied to several water management issues expected to change salinity patterns in South Florida estuaries: Florida Bay, Biscayne Bay, and Faka Union Bay in the Ten Thousand Islands. One or more of three response variables produced by the model were followed: average growth rate (or number of days to reach migration size), average survival during the first 121 days of the simulation (or survival rate) and potential harvests, which integrates both growth and survival. Each application revealed new information about the behavior of the model in terms of sensitivity to variation to conditions.

In one application, the model was used to evaluate the effect of redistributing flow to South Biscayne Bay from canals into a series of small creeks. The model output suggested that the redistribution scenario tested would have positive effects south of Black Creek Jetty and negative effects north of Black Creek Jetty. Salinity data were simulated by the TABS model (U.S. Army Corps of Engineers, Vicksburg, MS), and temperature data were provided from a Biscayne Bay fixed-platform recording station.

In one Florida Bay application to help establish minimum flows and levels, the model was used to evaluate the effect of different salinity regimes (from three representative rainfall years, wet, dry, and average) on the cohorts of each month of the year in four parts of Florida Bay: Whipray Basin, Rankin Lake, Snake Bight, and Palm Key Basin. Salinity input data were simulated by the FATHOM model, described by Cosby et al. (1999). Differences among scenarios and cohorts were more striking in Whipray Basin and Rankin Lake, where salinities were more extreme, than in Snake Bight and Palm Key Basin. Differences among cohorts and areas were more pronounced when temperatures were raised 3°C. Growth was enhanced in all years by the 3°C temperature increase but was depressed during the dry year compared to the other years. Depressed growth was more pronounced in Whipray, followed by Rankin. Survival was depressed for spring and summer cohorts during the dry year and during all years with a 3°C rise in temperature. Survival was lowest in Whipray, followed by Rankin.

In another Florida Bay application, the model was used in the first 5^{th}-yr Interim Goals and Interim Targets (IGIT) Evaluation of RECOVER (the science-based applied assessment component of the Comprehensive Everglades Restoration program) to predict indices of pink shrimp density and growth rates in north-central Florida Bay. The salinity predictions used as input to the shrimp model were by Frank Marshall using MLR models relating salinity in Whipray Basin to salinity in coastal embayments, predicted from “stage” predictions of the South Florida Water Management District hydrologic model. The IGIT protocol called for comparison of predictions for north-central Florida Bay to those for western Florida Bay, however daily salinity predictions under advancing stages of implementation of CERP projects were only available for north-central Florida Bay for the first 5^{th}-yr evaluation.

The predicted differences among years and scenarios were small. Density at 121 days from settlement was highest for the most number of years with the 2050 scenario. Growth rate was fastest for the most years in the 'NSM4.5' scenario.

In the Ten Thousand Islands application, the pink shrimp model was used to evaluate the effect on Faka Union Bay of several water management scenarios for the upstream Picayune Strand. Freshwater flows to Faka Union Bay had previously been radically changed in both timing and volume by a massage drainage project associated with a failed commercial development. Scenarios included four restoration alternatives, the 2000 and 2050 base cases, and a scenario approximating the flows from a hydrologically pristine basin. The model indicated increased recruits from pink shrimp recruited from Faka Union Bay under all restoration scenarios, compared to the 2000 or 2050 base. The highest potential harvest was with D3, which became the preferred alternative on the basis of expected benefits in both the upstream wetland and the estuary.

Simulation results provided representative views of possible spatial and temporal responses to water management alternatives. The Biscayne Bay application showed fine-scale spatial variation whereas one Florida Bay application showed detailed temporal variation and the possible effect on response to water management changes of an across-the-board 3°C increase in temperature as might occur with global warming. The other Florida Bay application showed only small differences in shrimp status under various scenarios through the fifth year of progress in CERP implementation. The Ten Thousand Islands application provided another spatial view of model capability.

The simulation model is based on relationships of survival and growth to salinity and temperature developed in laboratory trials with 2,000 shrimp from Florida Bay. The experimental data from Florida Bay suggested a growth optimum of 30 psu and a steep-sided survival plateau of 20-40 psu that narrowed with departure from optimal temperature (20-25°C). The relationship of potential harvests to salinity and temperature reflects interactions of survival and growth in reaction to changes in salinity and temperature.

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Transport of Pink Shrimp Postlarvae into Interior Florida Bay

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Research explored the null hypothesis that recruitment of pink shrimp postlarvae into Florida Bay is not related to distance from the western margin of the Bay or the prevailing amplitude of the tide. Tides are greatest at the bay's western boundary and attenuate with distance into the bay (Smith 1997). By exploring this hypothesis, we addressed the question of whether the abundance of pink shrimp juveniles in the interior of the bay is limited by the availability of favorable habitat, as defined by bottom vegetation and salinity in the water column, or by the supply of postlarvae reaching the area. The Bay's interior experiences extreme conditions of salinity with long periods of hypersalinity (>45 psu) punctuated by rare periods of relatively low salinity (<20 psu). Seagrasses decrease in abundance from west to east in Florida Bay. The extreme conditions and reduced seagrass habitat in central Florida Bay may depress the survival and growth of young pink shrimp, their abundance, and recruitment from this area to offshore adult populations. If so, then establishment of a more natural pattern of freshwater flow to the central Bay might lead to increased shrimp abundance. On the other hand, a sufficient supply of postlarvae may not reach the central bay to settle and contribute to juvenile density.

To test the hypothesis of a relationship of postlarval concentrations to tidal amplitude and distance into the bay from the Bay's western margin, we reallocated our sampling effort from the previous design (Browder 2002, Criales et al. 2005) to six stations along a transect that runs W-E from northwestern Florida Bay (Middle Ground channel) to central Florida Bay (Dump Keys) (Fig. 1). Our previous northwestern stations of Middle Ground (St. 1) and Conchie channel (St. 3) were retained and four new stations were added, Marker 6 (St. 2), channel east of Joe Kemp Key (Joe Kemp East) (St. 4), Buoy Key channel (St. 5), and Dump Key Channel (St. 6). Channel net sampling was conducted monthly at the six stations for three consecutive nights around the time of the new moon from July through November 2004 and 2005. In addition, hourly sampling for a 12-hr period was conducted in July and August 2005 at Joe Kemp channel and Marker 6 to compare tidal current regimes and postlarval supplies between these two sites.

Preliminary results for the period July through November 2004 indicate that the concentration of postlarvae increases from the exterior stations of Middle Ground and Marker 6 to the interior stations of Conchie and Joe Kemp channel, then decreases dramatically with further distance into the Bay (i.e., to Buoy and Dump) (Fig. 1). Contours of tidal amplitude from Smith (1997) and average postlarval concentrations at each sampling site was superimposed on the map of the Bay to show that the concentration of postlarvae is not highest at the westernmost stations, where the tidal amplitude is highest. Rather it is highest at Joe Kemp East in an area of relatively low tidal amplitude. Clearly, the relationship of larval supply to tidal amplitude or distance from the edge of the bay is not linear. The relationship of flow velocity to tidal amplitude or distance from the edge of the bay also is not linear. Flow velocity decreased sharply from Marker 6 to Buoy Key, then increased slightly from there to Dump Keys.

The 2004 results are mixed relative to the null hypothesis that the flux of postlarvae decreases with tidal amplitude and distance from the bay's western edge. The peak in postlarval concentrations in the station east of Joe Kemp Key, coupled with the decrease in concentrations at more easterly stations (Buoy and Dump), suggests an accumulation of postlarvae at a semi-permeable barrier or a leaky shoreline, with some penetration of the barrier. Wind conditions are critical and may strongly influence postlarval penetration of this barrier. In fact, a special hourly sampling effort in July 2005 revealed a large pulse of postlarvae reached Joe Kemp East on the first stage of the night flood tide following a period of strong winds. The relatively high flow velocity at Marker 6 may be due to convergence of several channels upstream of Marker 6. The decrease in flow velocity from Joe Kemp East to Buoy Key is consistent with the hypothesis of a decrease in flow into the interior Bay, and, coupled with the decrease in postlarval concentration east of the Joe Kemp East station, probably indicates a greatly decreased supply of postlarvae to the innermost stations (Buoy and Dump Keys) compared to more western locations.

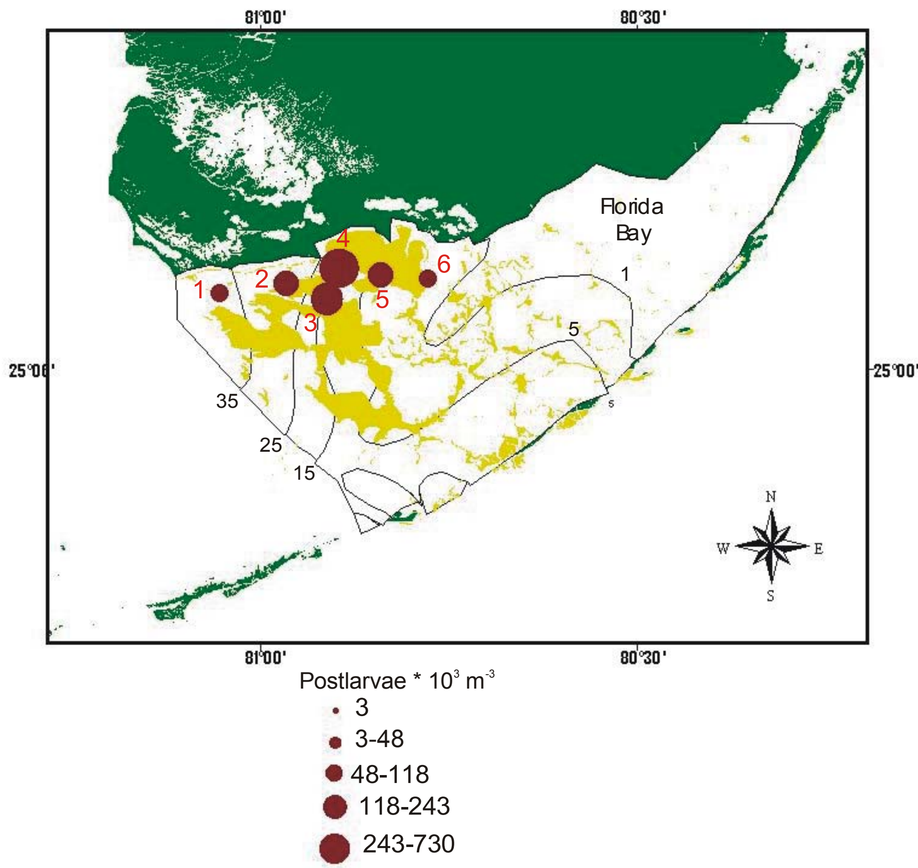

Figure 1. Tidal amplitude isopleths (cm) of the M_2 constituent in Florida Bay (Smith 1997) with superimposted average concentrations of pink shrimp postlarvae collected from July through November 2004 at six stations in Florida Bay. Station names are explained in the text.

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Hard-Bottom Community Ecology in the Florida Keys with an Emphasis on Sponges

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Shallow, hard-bottom habitat is a ubiquitous feature of the shallow waters within the Florida Keys marine ecosystem, and sponges are a prominent component of these communities. Yet, remarkably little is known about the structure, ecological function, or resilience of hard-bottom communities or about the population ecology of the large sponges that dwell there. Our poor understanding of these communities has been highlighted in recent years by questions about the possible impacts of ecosystem change and resource exploitation on hard-bottom habitat. For example, there are concerns about the possible ecological impacts of Everglades restoration (e.g., salinity change) and commercial sponge fishing on hard-bottom community structure and function. In the case of sponges, resolution of these issues has been hampered because so little is known about their biology and ecology. For example, there is no stock assessment, the most basic population dynamics for the pertinent sponge species is largely unstudied, their tolerance to changes in water quality has not been tested, their impact on planktonic communities is not well known, and the effect of the fishery on commercial sponges and allied species has never been examined.

There are several goals associated with our research on hard-bottom communities in the Florida Keys, one of the first of which was establishing a long-term monitoring program for hard-bottom in cooperation with FWCC-FMRI. In addition, we have conducted or are conducting a series of field and laboratory studies including:

- a field experiment to assess the potential factors that control recruitment of sessile hard-bottom species,
- observational field studies to determine the growth, reproduction, and natural mortality of commercial sponges,
- an experiment conducted with the assistance of sponge fishers to assess the impact of the sponge fishery on sponge communities, and
- field and laboratory experiments to determine if various species of sponge differ in their impact on planktonic community abundance or composition.
- spatially-explicit, individual-based modeling of changes in sponge, octocoral, and spiny lobster populations in response to various natural and anthropogenic stressors

Our hard-bottom monitoring program is of hard-bottom sites at depths of < 4m from Key Largo to the Lakes region west of Key West; extending on the oceanside south to the edge of Hawk Channel and on the bay-gulfside up to 15 km north of US 1. We currently survey the abundance and for some species, size structure, of > 60 species on each of 35 “permanent” sites once a year. Those sites were chosen from > 135 sites that we surveyed from Key Biscayne to the Marquesas in 2001 in a double-stratified, random sampling design. We are also monitoring recruitment on settlement plates at half of the permanent sites and at some we are also conducting experiments to examine the effect of local scour, microscale topography, and adult abundance on recruitment. Our current monitoring of hard-bottom habitat and select motile invertebrates is conducted in conjunction with FWCC-FMRI, who also periodically monitor the fish communities at these same sites. These surveys provide a spatio-temporal record of hard-bottom community structure that we use as a modeling framework and which may be used for commercial sponge population assessment and detection of habitat change.

Our results suggest that the common large sponges found in the Florida Keys (including species that are commercially fished) grow slowly (~3 cm dia/yr), their fecundity generally scales linearly with size, and they die when exposed to atypical salinities, although these responses vary among sponge species and among seasons. We estimate that natural sponge mortality of sublegal sized commercial sponges (< 5 inch diameter) to be approximately 7% of the population annually, with little difference among species. The fishery appears to operate legally (i.e., harvest only permitted species and sizes) with minimal impact on non-targeted species. We estimate that mortality of sublegal commercial sponges due to fishing activities to be approximately 3% of the populations annually, with that for most desirable species (sheepswool) being slightly higher overall on fished sites than that for yellow or glove sponges. Our estimates are in line with estimates of the fishers themselves (1 – 3%) based on their daily logbook records. We estimate that about 40% of the fishable area during our six-month study period was never visited or fished. In areas that were fished, fishers removed 33% of the legal sized sponges, 3% of the sublegal sponges, and virtually none of the non-commercial species. Undersized commercial sponges are not landed, but are thrown back into the sea to become “rollers”. We found that rollers grow at rates comparable to attached sponges and that the probability of reattachment varies with species and depth of sediment. We also found that rollers actually move little; the median distance moved after 6 months is ~ 1m.

Our field and laboratory experiments designed to assess the impact of sponges on the planktonic water column communities confirm that all seven species that we tested (golfball sponge, yellow sponge, sheepswool sponge, glove sponge, brown branching sponge, loggerhead sponge, vase sponge) consume primarily bacteria rather than larger planktonic size fractions. Completion of ongoing data analysis will yield information on possible differences in selectivity with season. These studies are detailed in an accompanying poster presentation (see Kauffman et al.).

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Cross-Shelf Larval Transport and Behavior of Pink Shrimp at the SW Florida Shelf

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We are investigating transport mechanisms of the pink shrimp (*Farfantepenaeus duorarum*) in South Florida to improve management of this commercially important species and to evaluate the impact of upstream water management changes on Florida Bay. Pink shrimp spawn offshore near the Dry Tortugas and larvae migrate to the nursery grounds in western Florida Bay, about 150 km to the east-northeast. We identified pathways and potential transport mechanisms by sampling with channel nets on both sides of the Bay. Results of 4 years of sampling indicated that the vast majority of postlarvae enter Florida Bay through its NW border, which connects the Bay with the SW Florida Shelf of the Gulf of Mexico. Larval transport mechanisms across the SW Florida Shelf were explored using a Lagrangian trajectory model (horizontal) coupled with larval behaviors (Criales et al. 2005, Criales et al. in press). The model showed that flood-tide transport, coupled with tidally-phased vertical movement by larvae, could move larvae up to 200 km eastward in 30 days, but whether early larvae can move vertically in phase with the tide to utilize flood tide transport is in question.

To clarify transport mechanisms and larval behaviors of pink shrimp during their cross-shelf migration, an oceanographic cruise was conducted 2-5 July 2004. Concurrent physical and biological measurements were collected at three stations positioned in an offshore-onshore transect between Dry Tortugas and Florida Bay. Plankton samples were collected with a 1-m^2 Tucker trawl (0.333 mm mesh) at three water depths. A 300 kHz ADCP was deployed at the bottom of stations, and a conductivity-temperature-depth meter (CTD) collected data every 2 hours for 24 continuous hours.

The water column was vertically stratified at the two offshore stations. Isotherms were close together at the Dry Tortugas station (30 m of depth) at depths between 15 and 20 m. Near the Marquesas (20 m of depth), the isotherms were uplifted near the surface. The sea surface temperature at Marquesas (nearshore) was about 2°C cooler than at Dry Tortugas. Winds from the southeast were weak and did not explain the uplifted isotherms. Periodic depressions of temperature, salinity, and density were observed at the shallow thermocline (Fig. 1). Simultaneously, changes in current direction coupled with increased current velocity occurred between 8-12 m and were accompanied by a strong density gradient. All these features are typical manifestations of internal tides and associated internal bores. Internal tides have not previously been reported for the SW Florida Shelf, but their presence is not surprising since they often result from the interaction between tidal currents and bottom topography in a stratified water column over continental shelves and slopes.

Pink shrimp larvae (myses and early postlarvae), rock shrimp (*Sicyonia* sp.) zoaea and myses, and lobster (*Scyllarides* sp.) phyllosoma were highly concentrated at the shallow thermocline at Marquesas. Concentrations of pink shrimp larvae at this station were about five times higher

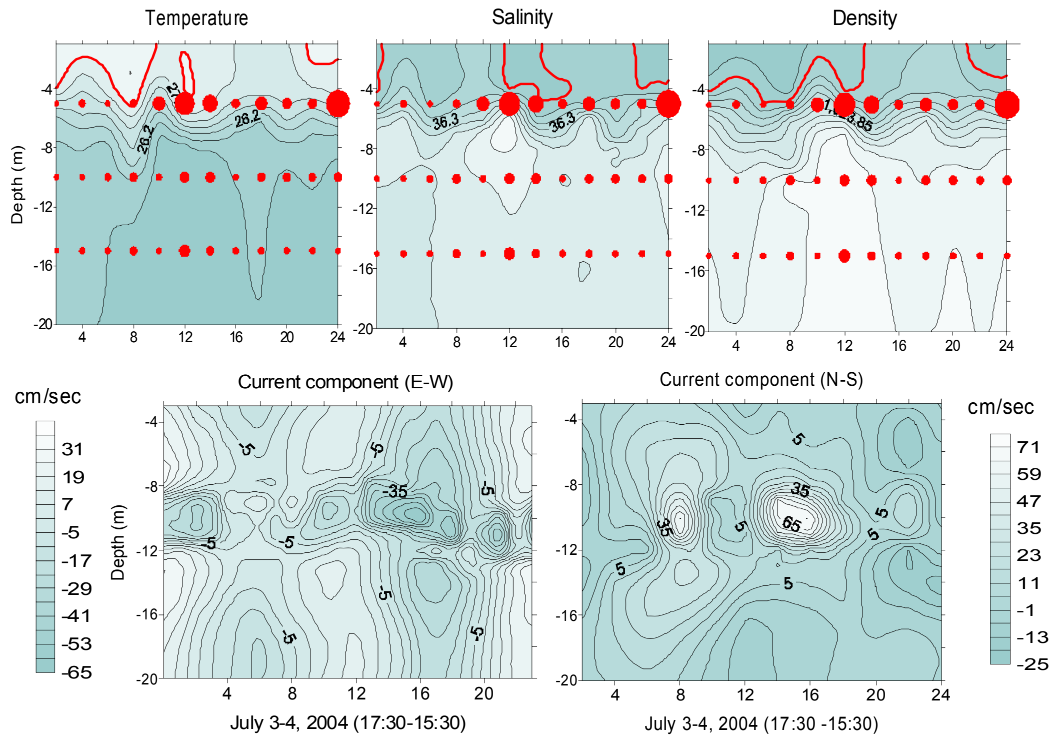

Figure 1. Vertical contours of temperature, salinity, density, and current components recorded near Marquesas for a 24-hour period on July 3-4, 2004. Concentrations of myses are superimposed on temperature, salinity, density contours and symbol sizes are proportional to concentrations. Isotherms, isohalines and isopycnals oscillated periodically intersecting at the sea surface (red and thicker lines). Cross-shelf (E= east +, W= west -) and alongshore (N= north +, S= south -) current components showed changes in current direction with increase of magnitude between 8 and 12 m.

than at the other two stations (near Florida Bay and near the Dry Tortugas), and lobster larvae were about three times higher than near the Dry Tortugas. Ontogenetic differences in vertical migrations of pink shrimp larvae were clearly observed. Protozoeae were located deeper than myses and postlarvae, and myses were deeper than postlarvae. However, evidence of day/night vertical migration cued by light was observed only for protozoeae. Myses and early postlarvae were concentrated near the surface in two large peaks of similar magnitude, one during the day and another at night, occurring at 12-h intervals (Fig.1).

Cruise results challenge previous findings about penaeid larval migration behavior, pink shrimp spawning locations, and southwest Florida shelf hydrodynamics. Follow-up work is needed to further expand our knowledge of these issues. More precise information about hydrodynamics and larval behavior will enable improvement of our transport models and a more comprehensive understanding of dispersal and connectivity.

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The Use of Otolith Microchemistry to Monitor and Evaluate the Movement of Coral Reef Fish in South Florida Waters

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Stable isotopic ratios of carbon and oxygen, embedded in the otolith of teleosts fish, have been well documented as useful tools for providing a wealth of information on environmental variations and stock structure of fish throughout their life history. Valuable data produced from stable isotope analyses include information about habitat temperature and salinity, migratory patterns and habitat use, diet and metabolic rates, and determination of the degree of stock mixing.

In this study, we are investigating spatial and temporal isotopic differences in fish from various sites within Florida Bay and between Florida Bay and adjacent waters. It is believed that snapper larvae settle and complete the juvenile phase of their life history in the sea grass beds and mangrove habitats of Florida Bay, before migrating to the reef tract as young adults. Thus, identifying isotopic trends in otoliths of fishes from Florida Bay will allow us to distinguish what portion of the Bay the juvenile phase of the fish was spent. Measurements of $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios in the sagittal otolith carbonate were obtained from juvenile gray snapper (*Lutjanus griseus)* collected in 2001-2004 from various locations within Florida Bay. Results indicated significant spatial variations between Florida Bay and other surrounding marine ecosystems (F= 210.0264; df=4; p<2.0000e^{-0004}). Temporal isotopic differences were also observed.

The data produced from this study will lead toward our mission of exploring migratory patterns and habitat use and how these patterns relate to the size-age structure of these fish. Future developments from this study will allow us to assess ontogenetic and environmental transitions. Ultimately, we are optimistic that we will afford fisheries managers with possible impacts of ecosystem change as a result of the Comprehensive Everglades Restoration Plan.

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Poster Abstracts

Higher Trophic Levels

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Fish Density, Diversity, and Composition of Fish Communities in Florida Bay: Results from Fisheries Independent Surveys

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A finfish sampling program using trawls and seines was conducted in Florida Bay from 1994 to 1997. Thirty fixed stations representative of the habitat types found in Florida Bay were sampled. The fixed station survey was designed to monitor the size structure of the fish component and seasonal changes in relative abundance of fish. Previous fish surveys conducted in Florida Bay have demonstrated that there are both regional and habitat differences in community composition and abundance of fish species within the bay and that the distribution of many species is closely linked to seagrass areas (Sogard et al., 1987; Matheson et al., 1999). These surveys have been used to make long-term comparisons of changes in fish abundance and composition in Florida Bay (Matheson et al., 1999; Thayer et al., 1999). Quantitative fish studies in Florida Bay have investigated the ichthyofauna of specific communities or individual habitat types, such as seagrasses and mud banks (Sogard et al., 1987; Matheson et al., 1999) However, the short duration of these studies; generally a year, precludes multi-year estimates of seasonal variation of community composition and abundance of fish species in Florida Bay. The purpose of this poster is to provide an overview of the relative abundance (catch-per-unit-effort) and composition of fishes and selected invertebrates collected from fixed station sampling conducted by FWRI's FIM program in Florida Bay from January 1994 to October 1997.

Consistent seasonal patterns of species density and richness among fish communities were observed in Florida Bay. Seasonal changes in environmental factors were, in some cases, strongly associated with species richness and abundance, which typically increased during the summer or fall and decreased during winter. Mean annual fish densities throughout Florida Bay were highest in 1994 and lowest in 1997 for both gear types (Figure 1a-b). In general, maximum abundances were observed during the summer (May- June) and fall (October-November) (Figure 2 a-b). The catches of strongly schooling pelagics, such as *Harengula jaguana* and *Opisthonema oglinum*, were highest from July through September representing 95.3% and 88.2% of the total of these species caught, respectively. Likewise, 61.4% and 62.6% of all *Cynoscion nebulosus* and *Floridichthys carpio*, respectively, were caught during July and August and nearly 80% of all *Penaeus* spp. and 68% of all *Eucinostomus* spp. were caught during August and September.

Overall, fish densities were found to be positively correlated with mean water temperature and dissolved oxygen and negatively correlated to salinity. Although there was a statistically significant seasonal cycle observed for all three variables, salinity stayed within marine levels throughout the year, and mean temperatures and dissolved oxygen levels stayed within moderate ranges that are well within the tolerance ranges for most marine fishes.

The species we collected in Florida Bay were similar to those collected from previous research in the Bay. The results presented in this study quantify seasonal variations in typical measures of Florida Bay fish communities based on a continuous collection of data from the FIM program and provide a comparable baseline for future investigations in Florida Bay.

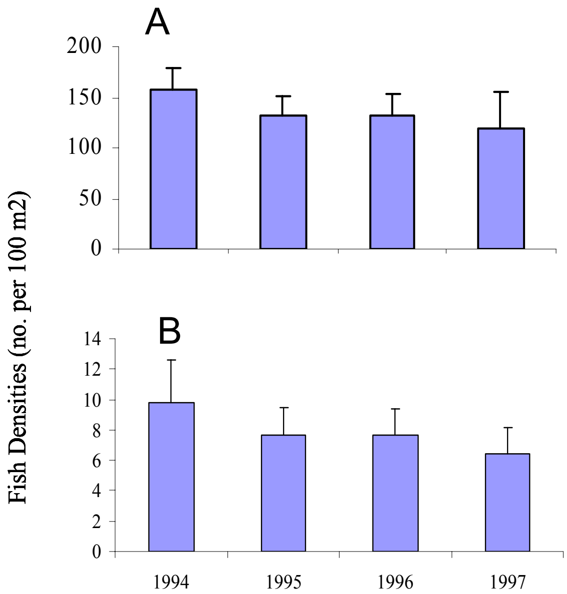

Figure 1. Annual variation in mean (+ SE) densities of fishes in Florida Bay. A=seine; B = trawl.

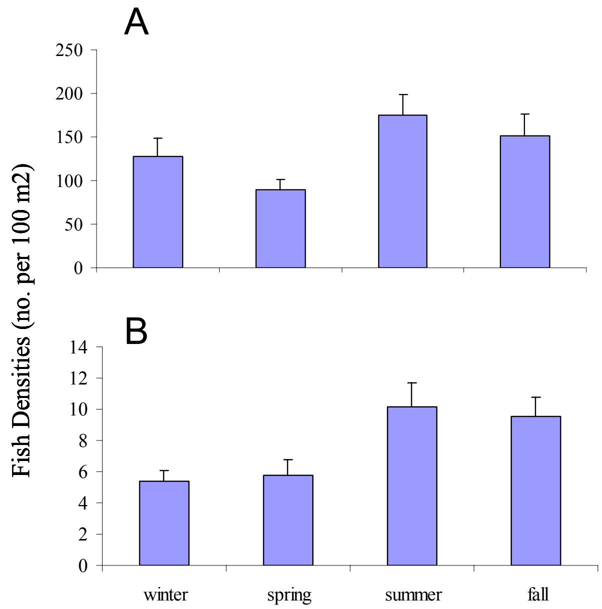

Figure 2. Seasonal variation in mean (+ SE) densities of fishes in Florida Bay. A=seine; B=trawl.

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A Pathogenic Viral Disease Infecting Juvenile Spiny Lobster in the Florida Keys

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In 2000, we discovered a lethal virus (HLV-PA) that infects Caribbean spiny lobster (*Panulirus argus*) in the Florida Keys. It is the first viral disease known for any lobster, and it alters the behavior and ecology of this species in fundamental ways. We have identified infected juvenile lobsters from sites throughout the Florida Keys, and from a few other locations in the Caribbean. The prevalence of infection varies with ontogeny; most infections are among the smallest size classes (16% infected). In contrast, < 1% of the more than 1500 adults sampled showed visual signs of HLV-PA infection.

The virus is highly pathogenic, with successful transmission (% infection) demonstrated via direct injection of hemolymph from infected donors (95%), oral ingestion of infected tissue (42%), and contact transmission among lobsters of varying size: < 25mm CL (63%), 30-40mm CL (33%) and 40-50mm CL (11%). Waterborne transmission is also likely over short distances of < 1m. In all cases, transmission declines with lobster size. None of the other decapods commonly found with P. argus (e.g., stone crab, *Menippi mercenaria;* spider crab, *Mithrax spinomosissimus*; spotted lobster, *P. guttatus*) acquired infections with HLV-PA after direct inoculations, so are unlikely carriers of the disease.

Field observations indicate that lobsters infected with HLV-PA are found alone in dens more often than uninfected lobsters. Laboratory experiments confirm this and show that that healthy individuals, which are normally social, detect and avoid diseased conspecifics - the first report of such behavior in any animal species in the wild. The evolution of this behavior may be an adaptation that thwarts transmission of disease in these social creatures and field experiments confirm that disease prevalence is independent of local population density.

We are continuing our studies of this disease on a number of fronts, including: (1) testing whether habitat change or alteration of individual condition alters susceptibility to infection, (2) developing immunological and genetic diagnostic tools to assess infection at earlier stages, and (3) spatially-explicit, individual-based modeling of disease transmission under varying scenarios of habitat structure, behavioral attributes, and fishing pressure to better understand disease dynamics and the evolution of traits to minimize transmission.

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Comparison of Gear for Sampling Epibenthic Communities in Biscayne Bay

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Historically, the epibenthic community in Biscayne Bay has been sampled with the same roller-frame trawl used in the commercial bait shrimp fishery, which has a low catch efficiency and cannot sample in extremely shallow waters. Recently two new gear have been applied to sampling the epibenthos in Biscayne Bay: the 1.5-m pull-net and the 1 m^2 throw-trap. The pull-net was developed to sample the extremely shallow waters of nearshore Biscayne Bay. The throw-trap was used since 1984 to sample the epibenthos in Florida Bay before expanding its use to Biscayne Bay and has been adopted by the monitoring and assessment program of the Comprehensive Everglades Restoration Project. Each of the other gear was compared to the throw trap in two respects. First, estimates of the density of a species (e.g., pink shrimp, *Farfantepenaeus duorarum*) were compared, seeking a conversion function. Second, species composition was compared among gear.

Concurrent data from the three gear collected within the period August 2002-October 2004 were compiled for analysis. For the single species comparison, corresponding (same site, same collection period) records from the three databases were merged into single records in two data files, one consisting of 212 throw-trap and trawl (TT-TR) records and the other consisting of 76 throw-trap/pull-net (TT-PN) records. Each throw-trap data element was an integer representing the number of pink shrimp in the 1-m^2 area that was sampled. This value ranged from 0 to 4 in the TT-TR data and from 0 to 8 in the TT-PN. Each corresponding trawl or pull-net data element was the 1-m^2 average of the number of pink shrimp caught in the area swept by the trawl or the pull-net, 1,101-m^2, on average, and 30 m^2, respectively.

Non-normal sample distributions and large differences in variances of faunal densities among the three datasets precluded the use of parametric methods on paired individual records to determine the relationship between throw-trap faunal density and density estimated with the other gear. Therefore, we modified a nonparametric regression approach, Kendall's robust line-fit method (Sokal and Rohlf 1998), to suit our data. This method provides the slope (b) and intercept (a) for a linear relationship. We used Kendall's rank correlation coefficient, equivalent to the ordering test (Sokal and Rohlf 1998), to determine the significance of the slope obtained from the robust line-fit method. In addition, corresponding densities from each data pair were compared graphically.

In 212 paired records of pink shrimp density for throw-trap and roller-frame trawl, throw-trap densities ranged from 0 to 4 per m^2 and trawl densities from 0 to 0.39 per m^2. The median of each group of trawl catches (no./m^2) corresponding to throw-trap catches of 0, 1, 2, 3, and 4 shrimp/m^2, respectively were input to the Kendall's robust line-fit method (Sokal and Rohlf 1998) to calculate the intercept and slope of the relationship between the throw-trap count data and the medians of the corresponding trawl catches. The intercept was greater than zero, probably reflecting the greater area sampled by the trawl, which makes a zero catch less likely. Because of this disparity in area sampled, on average, the trawl catch exceeds the throw-trap catch where the throw-trap catch is zero (i.e., 0.047 vs. 0). The throw- trap catch becomes larger than the trawl catch when the throw-trap catch reaches 1. By TT = 4, the throw-trap catch is over 31 times as great as the trawl catch, reflecting the greater efficiency of the throw-trap. The Kendall correlation test indicated that the slope of the fit was significant at $p \leq 0.1$.

There were 76 paired records for throw-trap and pull-net. The median of each group of pull-net catches (no./m^2) corresponding to throw-trap catches of 0 to 8 shrimp/m^2, respectively, were input to the Kendall's robust line-fit method. As was the case above, the intercept of the TT-PN comparison is greater than zero, again probably reflecting the differences in area sampled. The Kendall robust line-fit analysis indicated that, on average, the pull-net catch exceeds the throw-trap catch when the throw-trap catch is zero (i.e., 0.085 vs. 0). The throw-trap catch becomes larger than the pull-net catch when the throw-trap catch reaches 1. By TT = 8, the throw-trap catch is about 10 times greater the pull-net catch. The Kendall correlation test indicated that the slope of this fit was not significant, although the graphic analysis suggested a better fit than for the TT-TR comparison.

The fish fauna obtained from the three sampling gear were compiled for a comparison of the faunal assemblages collected by the three gear, and the resultant information is summarized in Table 1. The throw-trap collected more species per total area swept or total individuals caught, although it sampled the smallest area. The trawl caught the least species per unit area swept, but swept the largest area. The pull-net caught the fewest species per individuals caught.

Table 1. Comparison of the sampling characteristics of the three gear types.

Gear	Area swept	Individuals caught	Species caught	Individuals per species	Area per species
Throw-trap	696	4,545	45	101	15.5
Pull-net	8,550	6,197	34	182	251
Trawl	259,952	13,431	88	153	2,954

The throw-trap exhibited greater efficiency in sampling the species richness of the community. The roller-frame trawl and pull-net were restricted to largely separate parts of the study area operationally--the trawl sampling outside and the pull-net sampling inside the 3-ft (0.9 m) contour. In contrast, the throw-trap sampled all depths (< 1 ft to > 10 ft) present in the study area. However, this only partly explains its greater efficiency in terms of sampling species richness. The pull-net, operating only inside the contour, captured only 2 species unique to it. In contrast the roller-frame trawl, operating only outside the contour, captured 47 species not captured by the throw-trap or pull-net, and the throw-trap captured 14 species not caught by either the trawl or the pull-net. There was considerable overlap of species caught by the three gear types. Twenty-one species were caught by all three gears, 31 were caught by both the throw-trap and trawl, 22 were caught by both the throw-trap and pull-net, and 31 were caught by both the trawl and pull-net.

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Growth and Mortality Estimates to Support a Pink Shrimp Growth and Survival Model

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The pink shrimp, *Farfantepenaeus duorarum*, is an ecologically and economically valuable species that uses Florida Bay and other South Florida estuaries as nursery grounds. The pink shrimp is a prey species that links photosynthesizing organisms, plant detritus, and detritivores to higher consumers such as wading birds and game fish and is representative of other small epibenthic forage species. Offshore, it supports a multi-million dollar commercial fishery. Known spawning grounds lie on the southwest Florida shelf in an area bounded on the south by a line from the Marquesas to the Dry Tortugas. Pelagic early life stages immigrate to Florida Bay and nearby mangrove estuaries where they spend their juvenile stage. As subadults they return to southwest shelf waters to breed. Environmental conditions in the estuaries—especially temperature and salinity—influence growth and survival rates and subsequent recruitment to offshore spawning grounds and the fishery. The status of juvenile pink shrimp is representative of the ecological state of nursery grounds supporting forage species and their predators.

Time series of size-frequency distributions of young pink shrimp in Florida Bay and Biscayne Bay from fishery-independent datasets and three gear types were used to compare the characteristics of Florida Bay and Biscayne Bay stocks and obtain information that might be used to refine a simulation model of pink shrimp growth and survival as a function of salinity and temperature (Browder et al. 2002). In particular, this information is being used to evaluate the model function used to estimate survival from predation as a function of size. The Florida Bay dataset consisted of 25,197 individuals collected with a 1-m^2 throw-trap from Johnson Key Basin within the period 1984-2002 (Robblee et al. 1991). The Biscayne Bay datasets consisted of 15,451 shrimp collected bimonthly (August 2002-February 2004) with a roller-frame trawl in nearshore South Biscayne Bay outside, and 1,579 shrimp collected monthly (July 2003-October 2004) with a pull-net inside, the 3-ft (~0.9 m) depth contour.

We used two length-frequency methods, Shepherd's and ELEFAN, to estimate the growth constant (K) of the von Bertalanffy growth equation. We found the Shepherd method superior to the ELEFAN method based on scoring functions and the realism of growth estimates, so only estimates from the Shepherd's method are reported. The L_∞ used in all estimates was 40.1 mm carapace length (CL), based on Phares (1981). The annual growth constant calculated from each dataset is shown in Table 1. Estimates are based on the combined data of all available years. For Florida Bay, separately estimated K values for each of these years ranged 0.68-0.93 for fall cohorts and 0.73-1.01 for spring cohorts. Reported values are for both sexes because separating the data by sex caused a loss of the smaller individuals that could not be sexed, reducing both the number of individuals and the size range. The differences in K values cannot entirely be explained by differences in area or size range, and relative differences between fall and spring K values were not consistent among areas. The smallest shrimp were caught in Florida Bay with the throw-trap and produced the lowest K values. The smaller shrimp in Biscayne Bay were caught with the pull-net and produced the highest K value for fall. The trawl-caught shrimp produced the highest K value for spring. Nevertheless, the Biscayne Bay estimates support the

Florida Bay estimates as being “in the right ball park”. This is important because the Biscayne Bay samples were collected within a relatively short time period, and the shrimp in the trawl samples were almost as numerous as those in the Florida Bay samples, collected over a much longer time period. The size range in the pull-net data was intermediate to that in the Florida Bay throw-trap data.

Table 1. Estimated values of the growth constant (K) for the von Bertalanffy growth equation of pink shrimp in Florida and Biscayne bays.

Area	Gear	Fall	Spring	Size range (mm CL)
Florida Bay	Throw-trap	0.82	0.89	1.5 –17.5
Biscayne Bay	Roller-trawl	1.00	1.11	2.5 – 24.5
Biscayne Bay	Roller trawl	1.10	0.86	3.5 – 35.5

The estimated K values were used as input to estimates of instantaneous total mortality (Z) of pink shrimp in Florida Bay and Biscayne Bay. Alternative estimates were produced by the Ault and Ehrhardt (A-E) and Beverton Holt (B-H) methods. The fall and spring B-H Zs show a progression from higher to lower rates with increased size, although this is not evident in the A-E Zs. The lower Z from the trawl data with both methods is despite the fact that the roller-trawl sampled a fished population, so Z includes fishing as well as natural mortality. Regardless of which method is used, results suggest that the decrease in predation mortality with increased size may occur more rapidly in the model that in the field.

Table 2. Instantaneous total mortality estimates (Z) for pink shrimp in Florida and Biscayne Bay.

Method	Area	Gear	Fall Annual	Daily	Spring Annual	Daily	Size (mm CL)
A-E	Florida Bay	Throw-trap	4.50	0.0123	2.95	0.0081	1.5 –17.5
A-E	Biscayne Bay	Pull-net	4.50	0.0123	3.14	0.0086	2.5 – 24.5
A-E	Biscayne Bay	Roller trawl	3.52	0.0096	1.88	0.0053	3.5 – 35.5
B-H	Florida Bay	Throw-trap	5.43	0.0149	5.00	0.0137	1.5 –17.5
B-H	Biscayne Bay	Pull-net	4.92	0.0135	3.96	0.0108	2.5 – 24.5
B-H	Biscayne Bay	Roller-trawl	3.53	0.0097	3.32	0.0091	3.5 – 35.5

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Attributes of Florida Bay Contributing to High Mercury Concentrations in Fish

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Eastern Florida Bay has been identified as one of two "hotspots" for mercury in the Gulf of Mexico, the other being Lavaca Bay TX, an industrially contaminated superfund site. We investigated the attributes of eastern Florida Bay that contribute to the elevated concentrations in fish there despite the absence of an identified local source of mercury pollution. Comparison with the Lavaca Bay "hotspot" helps in identifying the critical attributes.

An estimated 75 metric tons of mercury were released into Lavaca Bay from industrial operations. The atmospheric and watershed inputs of mercury to Florida Bay are estimated at only 13 kg per year. As a result, total mercury concentrations in surface sediments are much higher in Lavaca Bay than in Florida Bay, by an order of magnitude. Subsurface concentrations of total mercury in Lavaca Bay are higher than surface sediments because of burial by cleaner sediments over time. Mercury concentrations in Florida Bay sediments are more uniformly distributed with depth because of wind resuspension in the Bays shallow waters, with highest concentrations usually found near the surface.

Despite the higher inputs and sediment concentrations of mercury in Lavaca Bay, fish in the 668 km^2 of eastern Florida Bay have generally higher mercury concentrations than the same species of fish in the ~10 km^2 of Lavaca Bay near the industrial source where mercury concentrations in sediments are highest. The spatial extent gamefish with wet weight mercury concentrations exceeding 0.5 $\mu g\ g^{-1}$ is much greater than in Lavaca Bay. This is likely due to more effective conversion of mercury to methylmercury and its efficient bioaccumulation in the respective food webs of the gamefish. Methylmercury concentrations in eastern Florida Bay sediments are about an order of magnitude lower than in Lavaca Bay sediments, but water column methylmercury concentrations are comparable. There must be more effective transfer mechanisms from the sediments to the water column in Florida Bay, and more effective retention mechanisms. One contributing factor is likely to be the differing nature of the sediments in the two bays. Lavaca Bay's sediments are mostly terrigenous aluminosilicates while Florida Bay's sediments are mostly biogenic calcium carbonate. The latter will bind both inorganic mercury and methylmercury less strongly than the former, the lower distribution coefficients favoring increased dissolved concentrations.

Analysis of stable isotopes of carbon, nitrogen, and sulfur suggest that the food web supporting gamefish in Florida Bay is benthic in origin, derived from benthic algae or the detritus of seagrasses and their epiphytes. The food web in Lavaca Bay depends more on phytoplankton and pelagic organisms in the water column. As a result, methylmercury released from its site of origin in the sediments in Florida Bay will be less vulnerable to flushing and dilution before entering the base of the food web. The flushing of water from eastern Florida Bay to the Gulf of Mexico is poor because of the Bay's shallowness and the imposition keys and mudbanks which impede water movement toward the Gulf of Mexico. Lavaca Bay is slightly deeper than Florida Bay with deep shipping channels traversing the bay and accelerating flushing.

Finally, the eastern third of Florida Bay has perhaps two to three times higher mercury concentrations in its fish than the western two thirds. Gamefish here move throughout the bay during their estuarine residence, but not so much as to average out the spatial concentrations of mercury in the eastern bay. In Lavaca Bay, some fish such as bay anchovies (*Anchoa mitchilli*) and spotted seatrout (*Cynoscion nebulosus*) move about enough so that they have limited temporal exposure to the most highly mercury contaminated area. These species have mercury concentrations, if captured in the most contaminated area, little different than fish captured outside the contaminated area and lower in concentration than the same species from eastern Florida Bay. In contrast, the red drum (*Sciaenops ocellatus*), has higher mercury concentrations in Lavaca Bay than in eastern Florida Bay. This species has high home fidelity and finds preferred habitat (deep channel refugia and isolated productive salt marsh) in the most contaminated area of Lavaca Bay that limits their migratory movements and permits long-term exposure to high methylmercury concentrations.

Our observations in Florida Bay suggest a question that begs for resolution: "are there other coastal habitats along the Gulf of Mexico and Atlantic coasts where mercury can attain high levels in gamefish despite the absence of point sources of mercury contamination?"

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Observations of Distribution and Abundance of Fishes Inhabiting Shallow, Near Shore Seagrass Beds in the Middle Florida Keys

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During 2003, we conducted a six-month, stratified-random designed pilot study using 21m seines on the Atlantic side of the middle Keys from June through November 2003 in order to determine the feasibility of collecting early life stages of snappers and other fishes in shallow near shore seagrass beds and to describe their abundance and distribution (Bartels and Ferguson, in press). Sampling sites were characterized by shallow (<1.3m deep) mixed-species seagrass beds consisting of *Halodule wrightii, Thalassia testudinum, Syringodium filiforme*, and mixed algae that were located adjacent to sandy beach fronts. All sites had a high percentage of seagrass cover (mean=94.1% $\pm$ 11.8). We were successful in collecting relatively high numbers of snappers (n=363) during 72 hauls. Approximately 85% (n=307) of the snappers collected were young juveniles ($\leq$100mm standard length (SL)) with a mean size of 36mm SL ($\pm$ 1.0mm SE). More than half of the snappers (n=200) were settlement-stage individuals ($\leq$ 40mm SL), including 69 new recruits ($\leq$ 20mm SL) and 131 early-stage juveniles (> 20mm to $\leq$ 40mm SL). The most abundant snapper collected was *Lutjanus griseus* (n=206), followed by *Lutjanus apodus* (n=66), *Lutjanus analis* (n=62), *Lutjanus synagris* (n=13), *Lutjanus* spp. (n=11), and *Ocyurus chrysurus* (n=5) (Figure 1). Snappers were consistently caught throughout the summer-fall sampling period. The lowest mean numbers of snappers were collected during July (1.3 $\pm$ 0.8 SE) and the highest during October (10.8 $\pm$ 6.5 SE). *Lutjanus griseus, L. apodus,* and *L. analis* were caught during every month of the survey; all five snapper species were collected during September and October (Figure 2). Results from this initial pilot study indicated that shallow, mixed-species seagrass beds near the shore, particularly along beachfronts, on the Atlantic side of the Keys may constitute an especially important, albeit limited, settlement habitat for early stages of snapper.

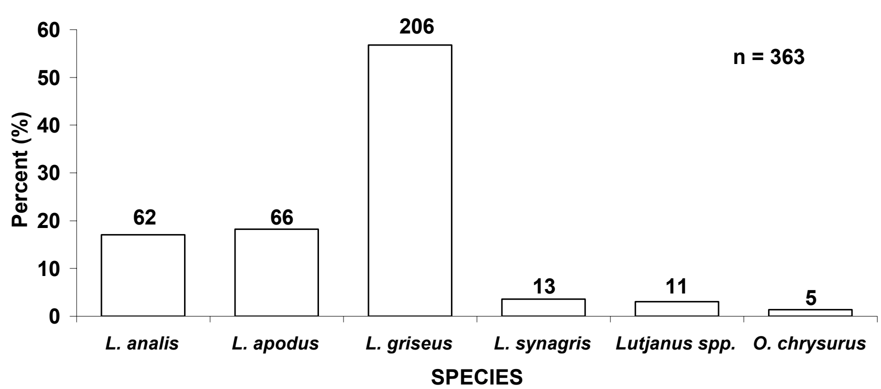

Figure 1. Percentage of the total snapper catch represented by each species during the 2003 six-month seine survey. Numbers above bars indicate total number of each species collected.

Due to the encouraging results obtained from our initial pilot study we are conducting a second stratified-random designed seine project in the middle Keys in order to expand on the habitat types previously surveyed and determine if shallow mixed-species seagrass beds adjacent to beach fronts are indeed preferred over alternate shallow water habitats along the Atlantic side of the middle Keys. The current seine survey is being conducted from May 2005 through April 2006 and includes year-round sampling of seagrass beds along all shore types found in the middle Keys. Mangrove and man-made shorelines and single-species seagrass beds are being sampled in addition to the mixed-species seagrass beds adjacent to sandy beach fronts that were sampled during the original pilot study. Our poster will present a comparison of the species distribution and abundance of fish collected during the 2003 six-month seine survey with those collected during the first six months of the 2005 seine survey. These data may be useful for providing baseline estimates of seasonal variations in fish communities occupying shallow, near-shore seagrass communities in the middle Florida Keys.

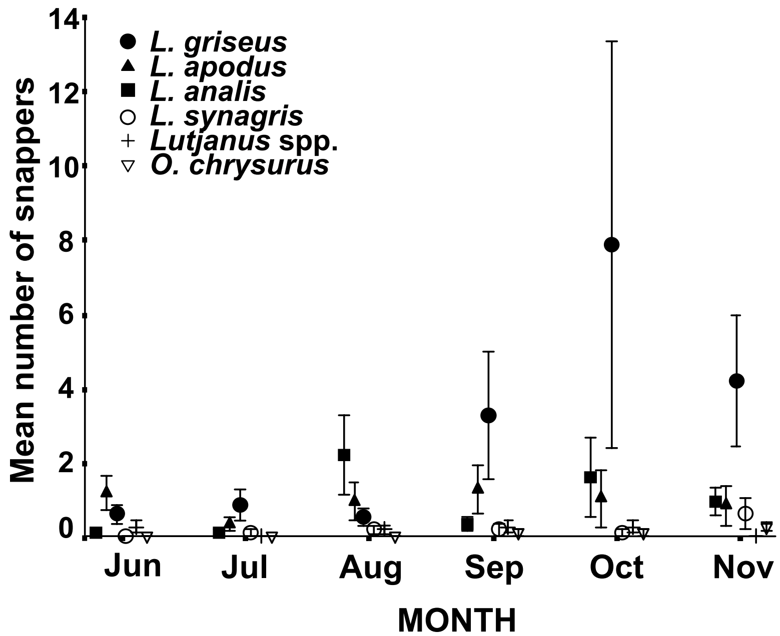

Figure 2. Monthly mean number of each snapper species collected during the 2003 six-month seine survey. Error bars indicate mean standard error.

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"Can't Get There from Here": Hydrological Connectivity Impacts Temporal and Spatial Patterns of Fish Community Structure

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Habitat complexity and connectivity affect the movement of fish across a landscape and can shape aquatic communities in a hydrologically variable environment. The role of connectivity in shaping wetland and estuarine fish communities has not been emphasized in past studies. We documented spatial and temporal patterns in fish community structure and standing crops along salinity and nutrient gradients in two sloughs of the Everglades National Park. Fifty-eight species of fish were collected from January 2000 to April 2004 at six sampling sites associated with the Florida Coastal Everglades Long-term Ecological Research (FCE-LTER) program. These sites span the oligohaline zone in the Shark River and Taylor Sloughs, Everglades National Park. We noted regional differences in species composition and total fish biomass through analysis of Bray-Curtis dissimilarity matrices. GIS-based percolation maps illustrate the differences in habitat connectivity both along the salinity gradients and among sloughs. We propose a conceptual model that relates fish biomass and an index of habitat connectivity to regional sites along the environmental gradients. The Florida Everglades is currently the focus of a major restoration effort that will alter freshwater flow to the oligohaline areas. Fish biomass is a vital link of energy transfer in the food web, and baseline data that links freshwater areas to mangrove regions are needed. Secondary production responses to changing habitat structure associated with water management practices must be understood if future management success is to be realized.

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Statistical Models of Florida Bay Fish and Shrimp for Minimum Flows and Levels Evaluation

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Statistical models using spline functions were used to predict the response of fish populations to changes in salinity and submergent vegetation (SAV) to help the South Florida Water Management District (SFWMD) determine the minimum flows and levels (MFL) that must be retained to avoid significant harm to the Florida Bay ecosystem. The models were used to predict fish and shrimp densities under scenarios of salinity and SAV related by other models to freshwater inflows of past wet, dry, and mean rainfall years. Relative abundance under the various scenarios will be used to indicate the ecological response of Florida Bay to water management changes as reflected by other models that relate salinity and bottom vegetation to freshwater flow.

Trawl/seine data collected by various agencies between 1973-1997 and throw trap data collected between 1984 and 2001 were combined into two files (one for trawl/seine and the other for throw-trap) and standardized and then were used to develop models for 17 trawl/seine species and eight throw-trap species. Five species were common to both gear types. All models were significant at $p \leq 0.0001$. Bootstrap validations of all full models were significant at $p \leq 0.05$. Models were also validated using external data not used in model development.

The most important variables in the throw-trap models were Julian date (5 species), habitat (3 species), *Halodule* standing crop (3 species), depth (3 species), and salinity (3 species), and in the seventeen trawl/seine models: region (9 species), *Syringodium* (9 species), depth (8 species), salinity (7 species), and *Thalassia* and *Halodule* (6 species each). S*yringodium* was unimportant in the throw-trap models. This is possibly because Syringodium was uncommon in throw-trap samples and it was removed from some models to enable convergence. The 'optimism' of the models, (bootstrap-adjusted r^2/unadjusted r^2) varied from 0.908 for *Syngnathus scovelli* (Gulf pipefish) to 0.996 for *Lucania parva* (rainwater killifish), higher values indicating the best models, least affected by over-fitting. The *Farfantepenaeus duorarum* (pink shrimp) model also had a high optimism index. The best throw-trap models in terms of r^2 were for *Farfantepenaeus*, followed by *Lucania.* The *Farfantepenaeus* model performed well most consistently, wet, average, and dry year--but it only did well the dry year when region was considered. The timing of highest predicted densities in model output, combined with minimum size data from the trawls, suggested that most species had protracted spawning, yet spawning was highest at certain times of the year. Small individuals of *Lucania, S. scovelli,* and *Gobiosoma robustum* (code goby)*,* were collected through much of the year.

Trawl models were run using region (Atlantic, Gulf, interior, and northeast) and habitat type (bank, basin, channel, island shoreline, and mainland shoreline) as categorical variables, and depth, Julian date, salinity, water temperature, *Thalassia* BB index, *Halodule* BB index, and *Syringodium* BB index as continuous variables. Braun-Blanquet values were used as indices of seagrass density in these models. Four trawl/seine species validated adequately for the dry year: *Farfantepenaeus, S. floridae, Microgobius microlepis* (banner goby)*,* and *Lutjanus griseus* (gray snapper) (Table 24). Ten species predicted adequately (with $r^2 \geq 0.1$ and $P \leq 0.1$) for the wet year, and nine species predicted adequately for the average year. Seven species performed adequately for two of the three validation years, and three species performed adequately for one validation year. Only two species performed adequately for all validation years: *Farfantepenaeus* and *Lutjanus*. There were five species models (*Anchoa mitchilli* [bay anchovy], *Atherinomorus stipes* [hardhead silverside], *Hippocampus zosterae* [dwarf seahorse], *Opisthonema oglinum* [Atlantic thread herring], and *Opsanus beta* [Gulf toadfish]) that did not validate with an $r^2 \geq 0.1$ for any of the validation years or predict the model data well. Three of these (*Anchoa, Atherinomorus*, and *Opisthonema*) are schooling species difficult to sample adequately as their occurrence is highly patchy *Hippocampus* and *Opsanus* have behavioral mechanisms that may reduce their rate of capture. All the trawl models had model optimism of ≥0.900, however the *Opistonema* model was marginal. Based on the p-values from ANOVA, the most important model variables as reflected in the top three ranked values were *Syringodium* (9 species), region (9 species), sampling depth (8 species), salinity (7 species), and the other two seagrasses, *Thalassia* and *Halodule* (6 species). The least important variables were temperature, Julian date, gear type (i.e., trawl vs. seine) and habitat type (i.e., bank, basin, island or mainland shoreline). Of the species models common to both gear, the *Farfantepenaeus* and *Opsanus* models based on throw-trap data had higher r2, suggesting they were stronger predictors of densities than the trawl/seine models. The trawl/seine models were stronger predictors of the densities of the fishes except *Opsanus beta.*

The throw-trap models predicted the validation data for the dry year better than the trawl/seine models for *Floridichthys* (goldspotted killifish), *Lucania,* and *Syngnathus.* The throw-trap models predicted the validation data for *Farfantepenaeus, Floridichthys*, and *Opsanus* better than the trawl/seine models. The throw-trap models predicted the validation data for the 1990's average years better than the trawl/seine models for all species but *Floridichthys*. Six of the eight throw-trap species (75%) predicted the validation set adequately ($r^2>0.1$) for the dry year, seven performed adequately for the wet year, and two species performed adequately for the average year. Only the *Farfantepenaeus* model performed adequately for the wet, dry, and two average year data sets. Four (24%) of the 17 trawl/seine species (*Farfantepenaeus, S. floridae, M. microlepis,* and *Lutjanus*) validated adequately for the dry year, ten species validated adequately (with an $r^2 \geq 0.1$) for the wet year, and nine species validated adequately for the average year. Only two trawl/seine species (*Farfantepenaeus* and *Lutjanus*) predicted the validation data set with an $r^2 \geq 0.1$ for all validation years. The throw-trap is a more precise gear and throw-trap samples were less variable; the throw-trap gear is superior for this reason. However, the broader coverage in time and space of samples in which the trawl/seine gear was used and the greater number of species (including juvenile sport fish) that it collected made models based on trawl/seine data better predictors over of a wider range of conditions. The use of data from both gears is vital to predicting the impact of salinity and SAV on the forage and juvenile fish community in Florida Bay. Combining data from several studies in a meta-analyses mode made it possible to extract more information than could be obtained by the data sets singly; but it was advantageous to analyze the throw trap and trawl/seine data separately.

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Variation in Otolith Microchemistry among Four Species of Juvenile Snappers

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The snappers (Family Lutjanidae) inhabiting South Florida's marine ecosystems are a commercially, recreationally, and ecologically important group of fishes that use seagrass and mangrove nursery habitats before migrating to the reef tract as young adults. Trace elements incorporated into the otoliths of a fish during growth will vary in composition and proportion depending on the environmental conditions to which the fish was previously exposed. Since the otolith material is not chemically or metabolically reworked during the life of the fish, the elements incorporated into the otolith's layers as it is formed are a permanent feature. Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) can be used to determine the microchemical constituents of fish otoliths—the composition and proportions of which define a distinct "elemental signature". These signatures can differ among fishes exposed to different water masses and environmental conditions allowing them to serve as natural tags for tracking fishes.

The trace elemental composition of otoliths extracted from four species of snapper (*Lutjanus apodus*, *L. chrysurus*, *L. griseus*, and *L. synagris*) collected within and around Florida Bay were examined in order to assess the extent of spatial, temporal, and taxonomic variability in elemental signatures. Juvenile snapper were collected between January 2001 and November 2004 across a range of habitats within five geographic regions within South Florida: Biscayne Bay, Florida Bay, Lower Florida Keys, Dry Tortugas, and Ten Thousand Islands. A total of 277 individuals were sampled from 14 sites within these regions. To avoid biases introduced by sampling a single cohort, a range of sizes of juveniles were collected over a range of dates across collection sites. All dissection, cleaning, and drying of the otoliths was conducted under class-100 clean room conditions using acid washed instruments. Otoliths were transported to the Laboratory for Isotope and Trace Element Research (LITER) at Old Dominion University in Norfolk, VA where they were decontaminated, weighted, and dissolved in acid. A Finnigan MAT Element 2 double focusing sector field ICP-MS was used to determine the concentration of trace elements occurring within the otoliths of juvenile snappers.

Because of the high resolving power of the Element 2 and the ability to select mass resolution we were able to avoid the problem of spectral interference apparent in previous studies and analyze a large number of elements simultaneously. A total of 32 trace elements occurred in otoliths of juvenile snapper from Florida waters within the detection limits of the instrument were targeted for analysis: Li, Mg, Mn, Rb, Y, Cd, Ba, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hg, Pb, Th, U, Na, P, Sc, Cr, Fe, Cu, Zn, and Sr. Elemental data were converted to molar concentration and expressed as ratios to Ca and ln-transformed to minimize the heterogeneity of variances among groups. Since most of the elemental ratio data were not normally distributed, even after transformation, non-parametric (permutation-based) statistical methods were used to

assess all significance levels. To account for the potential effects of variation among collection sites in fish size (and/or otolith weight) on otolith elemental ratios, ANCOVA was used to remove the effect of otolith weight. MANOVA was used to test for significant differences in multi-element otolith signatures of juvenile snapper within and among collection sites, times, and species. Canonical discriminant analysis (CDA) plots were used to reduce the multivariate elemental ratio data to two dimensions in order to visualize differences between collection sites and species identification. A stepwise variable selection procedure, implemented using redundancy analysis (RDA) and based on Akaike's information criterion (AIC), was used to find a subset of all the 32 elements examined that optimized the discrimination among sites and species. Quadratic discriminant function analysis and leave-one-out cross validation were used to assess the predictive ability of the discriminant functions and determine whether juvenile snapper from South Florida could be accurately classified to nursery region of origin and species identification based on multi-element otolith ratio signatures.

Our previous work examining otolith microchemistry of gray snapper (*L. griseus*) from South Florida has shown that juveniles can be classified to nursery region of origin with a high degree of accuracy. The high resolution of spatial separation found for this species in Florida Bay, on the order of 10 km, is indicative of the scale of migration occurring among populations of this species within nursery habitats. The present work attempts a similar assessment for three additional species of snapper (*L. apodus*, *L. chrysurus*, and *L. synagris*) which differ in life history trajectories.

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Sponge Feeding Selectivity across Seasons and Species in Florida Bay

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Sponges are conspicuous members of the Florida Bay hard-bottom community, both in their abundance and diversity. As filter feeders with high throughput and uptake mechanisms that can accommodate particles ranging over at least two orders of magnitude in diameter, from bacteria to microplankton, sponges have a direct effect on water column communities. Insight into the quantitative and qualitative feeding selectivity of the dominant sponges in Florida Bay is necessary to determine their role in modifying microbial community composition, and to assess the potential effects of perturbation in local sponge assemblages that might ensue, for example, from commercial harvest or environmental change such as Everglades restoration.

Our experimental approach was designed to facilitate comparisons of seasonal and species differences in rate and selectivity of particle removal. The seven species selected for study represent: large sponges that are the major structural features of hard-bottom habitat (vase sponge, *Ircinia campana*; loggerhead sponge, *Spheciospongia vesparium*), widespread and highly abundant sponges (golfball sponge, *Cinachyra sp.;* brown branching sponge, *Ircinia sp.*), and commercial sponges (yellow sponge, *Spongia barbara,* sheepswool sponge, *Hippospongia lachne;* glove sponge, *Spongia chereis*).

Particle removal was measured *in situ,* in field mesocosm enclosures, and in the laboratory. The i*n situ* study was conducted on up to five individuals of each available sponge species of interest at several sites in the Middle Keys. An excurrent water sample was collected directly from an osculum by syringe and an incurrent water sample was taken adjacent to the sponge. The mesocosm enclosure experiment was conducted near Bamboo Key with up to five individuals of each available sponge species of interest. Meshed PVC cages, $0.25m^2$ by 2m tall, were placed over individual sponges and water samples were collected by syringe at a height of 16cm above the substrate at 0, 20, 40, and 80 minutes. While changes in the number of bacteria over time were not detected in the field mesocosm experiment, the comparisons of excurrent and incurrent water samples collected *in situ* indicate significant removal of bacterioplankton by all sponge species during the summer. We conducted the laboratory experiment at Keys Marine Laboratory on Long Key during both spring and summer with water collected from Florida Bay. Sponges were held in 13-liter tanks without flow-through for the duration of the experiment and samples were collected at initiation and at 40 minutes. Samples were taken for viral, bacterial, and phytoplankton counts, as well as for denaturing gradient gel electrophoresis (DGGE). Use of DGGE fingerprinting will allow for comparison of selectivity within the bacterial fraction, both between seasons and among sponge species. Preliminary data indicate that all of the sponge species tested selected bacterioplankton over phytoplankton during the summer. The completed analyses will reveal whether their selectivity for different constituents of the planktonic community change with season.

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Experiments on Florida Bay Biota

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The South Florida ecosystem is currently undergoing a massive ecosystem restoration effort utilizing various private institutions, local, state, and federal government agencies. The restoration is coordinated by the Comprehensive Everglades Restoration Plan (CERP). The primary goal of the CERP is to restore a more natural freshwater flow through the south Florida ecosystem including quantity and timing of deliveries of freshwater into the system, and maintaining water quality within the overall system.

Determining the capacity and rate of chemical and physical change that the biota within these systems can withstand is essential before major changes are implemented. If additional changes are made to the ecosystem, whether in water quantity, timing or quality of r input, without a thorough understanding of the natural processes, the system will likely undergo further stress and potentially total collapse. As restoration continues, natural rates of change must be incorporated into restoration management decisions. Results of experimental studies conducted at the USGS Leetown Science Center (LSC) in Leetown, West Virginia, and advanced molecular analysis provide insights into the rate of change that can be tolerated by the biota within the south Florida estuaries.

In order to establish performance measures for restoration, it is critical to first determine how the system functioned historically. A true understanding of how human activities and natural cycles affect ecosystem change can be obtained by observing potential cause and effect relationships *in situ*, forming hypotheses, and then testing these hypotheses under closely controlled and monitored conditions. As long as laboratory conditions faithfully replicate natural *in situ* conditions, then the inverse becomes a valid approach; laboratory observations and experiments can generate new hypotheses that can be tested by field observations.

A system of large aquaria have been constructed at LSC in order to conduct experiments and accurately reproduce scenarios commonly found in the estuaries and marine ecosystems of South Florida (see figure). These aquaria allow us to test the effects of natural stressors on the fauna and flora of south Florida's estuaries, for example, salinity and temperature extremes.
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The first set of experiments in the Leetown mesocosms included eleven species of commonly found mollusks, both bivalves and gastropods, and six species of plants, including seagrasses and macroalgas. Results show that some species actually thrive in more extreme salinities and temperatures while others experience rapid die-off. Two of the gastropod species were able to not only survive, but reproduce in salinities at or above 55 parts per thousand (ppt) and temperatures at or above 58 degrees C. Species that are commonly found in more stable marine systems were much less tolerant of extremes in either temperature or salinity. No species that were tested were able to survive the low salinities (less than 15 ppt) for extended periods of time.

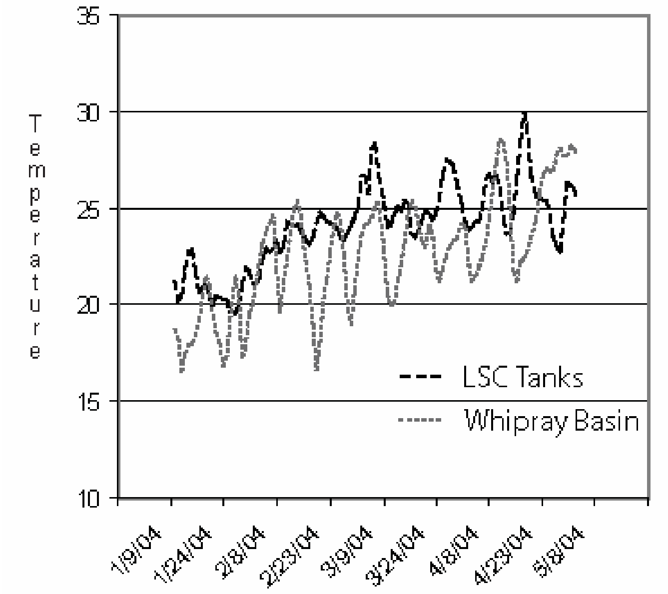

Figure: Comparison of water temperature (degrees C) at Leetown Science Center (LSC) in system A tanks and at Whipray Basin, in Florida Bay.

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Long-Term Patterns in Fish Community Structure in Johnson Key Basin, Western Florida Bay

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In western and central Florida Bay, a widespread die-off of turtle grass, *Thalassia testudinum*, the dominant seagrass, occurred between 1987 and 1991. The mortality event was followed by increasingly extensive and persistent turbidity and algal blooms (Fourqurean and Robblee 1999). In Johnson Key Basin, the cumulative effect of seagrass loss and recovery and reduced water clarity has been the shift from a turtle grass-dominated meadow to one exhibiting greater habitat heterogeneity. Here we describe and evaluate long-term (1984-2004) fish community patterns in response to habitat changes in Johnson Key Basin, western Florida Bay.

A 1-m^2 throw-trap was used to sample nine fixed stations in Johnson Key Basin between October 1984 and December 2004. Four replicate throw-trap samples were collected at each station at approximately six-week intervals for a total of 117 collections. Over the 20-year period-of-record, breaks in sampling occurred; however, sampling was continuous from October 1994 to December 2004. To evaluate the seagrass fish-community response to habitat changes in Johnson Key Basin, we compare results of collections made prior to seagrass die-off (1984-1987), during seagrass die-off and onset of algal blooms (1989-1991), and after seagrass die-off (post-1994) which included the decline of persistent turbidity/algal blooms (post-1994).

Fifteen species, of a total of 118 species collected were identified as being dominants (>0.05 fish/m^2) comprising over 96% of the fish community. Abundance of dominant fishes differed significantly ($p < 0.001$) among time periods, with overall fish density declining approximately 60% from a mean density of 19.7 fish/m^2 pre-seagrass die-off to a mean density of 7.7 fish/m^2 post-seagrass die-off (Figure 1). *Lucania parva*, rainwater killifish, *Gobiosoma robustum*, code goby, *Floridichthys carpio*, goldspotted killifish, and the gulf toadfish, *Opsanus beta*, were consistently the most abundant of the dominant species, accounting for > 90% of fish both pre-seagrass die-off (1984-1987) and during die-off events (1988-1991), and > 67% of fish post-seagrass die-off (1994-2004). *Lucania parva*, prior to seagrass die-off, was the most abundant fish observed in Johnson Key Basin comprising > 70% of the fish community. During seagrass die-off (1989-1991), the rainwater killifish declined in density and dominance to slightly less than 60% of the fish community. Concurrently, benthic species such as *Gobiosoma robustum* and *Opsanus beta* increased in density and relative abundance accounting for over 20% of the fish community. By 1994, persistent algal blooms characterized Johnson Key Basin, and the impact of seagrass die-off was evident in a loss of turtle grass, the presence of denuded bottom, and an increase of *Halodule wrightii*, shoal grass. Coincident with these changes fish community diversity had increased (Figure 1). *Lucania parva* had dramatically decreased in abundance to less than 1 fish/m^2 accounting for < 8 % of the fish community while the bay anchovy, *Anchoa mitchilli*, perhaps in response to the algal bloom, was now present and comprising 22 % of the fish community. Of the fifteen dominant fishes observed in Johnson Key Basin (1984-2004) four decreased in abundance, seven increased in abundance and four exhibited no statistical difference in a pre-seagrass die-off (1984-1987) and post-seagrass die-off comparison (1994-2004).

Long-term, the fish community in Johnson Key Basin appears to be recovering from the impact of seagrass die-off and subsequent turbidity/algal blooms (Figure 1). By 2004 diversity (H') is approaching levels present prior to seagrass die-off. Largely reflecting increases in *Lucania parva*, community dominance and evenness are also approaching pre-disturbance levels. Overall fish density remains low, possibly reflecting changes in seagrass habitat, the time required for the killifish population to recover, or other factors. The apparent recovery of the fish community in Johnson Key Basin coincides with similar improvements in water quality and seagrass conditions occurring broadly in Florida Bay (Boyer et al 2002; Zieman et al 1999).

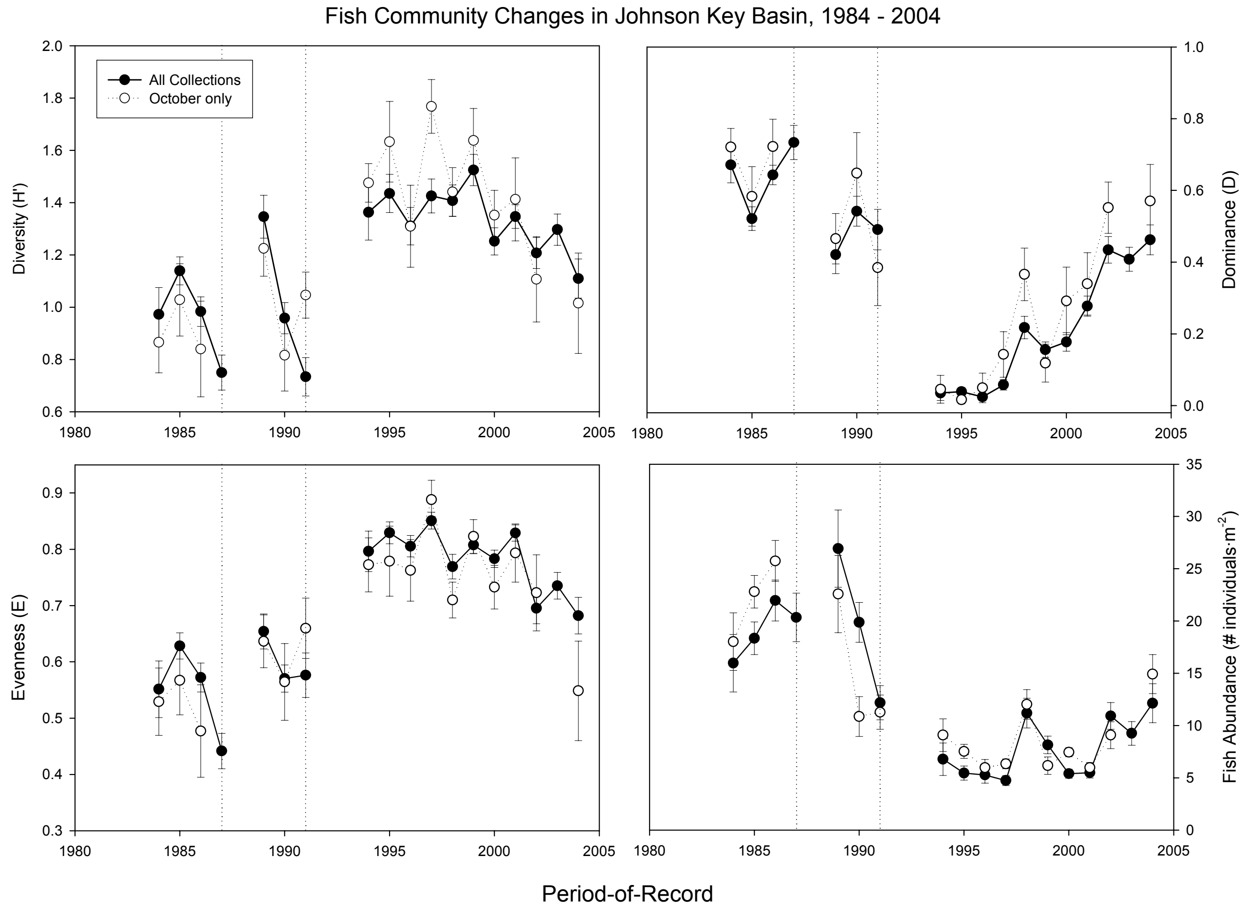

Figure 1. Fish Community Changes in Johnson Key Basin, 1984 – 2004. Mean Diversity (H'), Dominance (D), Evenness (E), and Fish Abundance are shown for all collections (●) and using data from only the October collections (○) to account for any differences due to seasonality. Error bars represent mean ± 1 SE.

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Elasmobranchs of Everglades National Park

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Few directed studies have been conducted on the elasmobranch fauna of Everglades National Park, so little is known of their importance in this area. Data on elasmobranchs captured during surveys for smalltooth sawfish in Everglades National Park were used to examine species occurrence, distribution and movement patterns. Surveys were conducted utilizing bottom set longlines, gillnets, seine nets and rod and reel from July 2000 to February 2005. A total of 1015 elasmobranchs of 12 species were identified within the Park (*Carcharhinus acronotus*, *C. isodon*, *C. leucas*, *C. limbatus*, *Dasyatis* spp., *Galeocerdo cuvier*, *Ginglymostoma cirratum*, *Negaprion brevirostris*, *Pristis pectinata*, *Rhizoprionodon terraenovae*, *Sphyrna mokarran* and *S. tiburo*). *Carcharhinus leucas* (n=302), *N. brevirostris* (n=239), *C. limbatus* (n=126) and *G. cirratum* (n=112) were encountered most frequently. Data from Mote Marine Laboratory's tag/recapture database showed that 20 *C. leucas*, three *C. limbatus*, eight *G. cirratum*, 16 *N. brevirostris* and two *S. tiburo* were tagged and/or recaptured within the park after periods at liberty of 1 to 1099 d. All 16 *N. brevirostris* were tagged and recaptured within the boundaries of the park (44 to 1061 d at liberty). *Carcharhinus leucas*, *C. limbatus* and *G. cirratum* were tagged or recaptured as far north as Tampa Bay on Florida's west coast. No recaptures were reported from Florida's east coast or south of the park boundary. The salinity, temperature and depth data were analyzed to determine any environmental preferences. The distribution, seasonal occurrence and size/frequency distribution of common shark species will also be presented.

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The Importance of South Florida Ecosystems to Smalltooth Sawfish (*Pristis pectinata*)

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The smalltooth sawfish (*Pristis pectinata*) was a common inhabitant of south Florida before hunting, bycatch in fishing gear and habitat modification resulted in a severe decline in the population. As a result of this population decline this species was added to the US Endangered Species List in April 2003, with the remnant population occurring mostly off south Florida. Ongoing research including collection of public encounter data, fishing surveys, acoustic tracking, acoustic monitoring and satellite tracking are examining the distribution, abundance and habitat use patterns of *P. pectinata* in southern Florida. Juvenile sawfish occur in coastal and estuarine areas in very shallow water. They have high levels of site fidelity and have close association with mangrove areas. Adults are distributed more widely, occurring from coastal habitats to deeper areas. During winter adults appear to move south into waters off the Florida Keys, including areas off the edge of the outer reef to depths of at least 100 m. The importance of south Florida ecosystems to conservation efforts will be discussed.

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Oral Abstracts

Adjacent Systems

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Initial Responses of Reef Fishes to Tortugas Ecological Reserves: Protecting Resources while Benefiting Fisheries

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The largest no-take marine reserve system in the U.S. was initiated in 2001 with the creation of 151 mi^2 Tortugas Ecological Reserves in the Florida Keys National Marine Sanctuary. An additional 46 mi^2 Research Natural Area planned for Dry Tortugas National Park. This reserve system potentially protects reef resources while supporting sustainable reef fisheries. We examined initial responses of reef fishes to the Tortugas reserve by comparing reef fish populations before and three years after the reserve was established. Synoptic cruises in 1999 and 2000 provide a baseline for comparison. In over 4000 dives, we recorded reef fish composition, sizes, and habitat characteristics at sites selected using a design-based approach with two stage random stratification. In 2004, after three years of protection, we detected significant domain-wide increases in abundance for several exploited and non-exploited species, but no declines. Significantly greater abundance and larger sizes were found in the Tortugas Ecological Reserve for black grouper, mutton snapper, and red grouper compared to the baseline. We did not detect any declines for exploited species in the Reserve, while non-exploited species showed both increases and declines. In fished areas on the Tortugas Bank, we detected either no change or declines in abundance for exploited species. Additional monitoring is necessary to ascertain whether observed patterns were due to potentially confounding influences of marine reserves, fishery regulations, Hurricane disturbances, or stochastic recruitment events.

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Nutrient Export from Florida Bay to the Florida Keys National Marine Sanctuary

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Florida Bay is the midpoint of the hydrological continuum of South Florida, connecting the systems of the freshwater Everglades to the north and the Florida Keys reef tract in the Atlantic to the south and east. Changes in the hydrologic regime and water quality parameters in upstream sections of this continuum may have direct or indirect impacts on downstream systems of Florida Bay and the reef tract (Lapointe & Barile 2004). Rapid development of both the mainland and island communities of South Florida have drastically altered naturally water transport processes of the area through the constructions of canals, levees, water control structures, and wastewater management practices. As the everglades are entering an era of ecosystem rehabilitation as part of the Comprehensive Everglades Restoration Plan (CERP), close attention must be paid to the downstream effects of restoration efforts with special attention of water flow, quality, and nutrient loading.

At the distal end of the South Florida hydrological continuum lies the Florida Keys reef tract. The coral reef community stretches discontinuously along the length of the Keys island chain between Hawk Channel and the Atlantic Ocean. Like many coral reef communities around the world, the Florida Keys reef tract has experienced a decline in health in the past few decades. Porter et al. (2001) report an overall loss of coral cover in the Keys of 38% from 1996 to 2000. Although likely the result of several environmental factors, some scientists speculated that outwelling of waters from Florida Bay might contribute to coral reef decline (Lapointe & Clark 1992). The tidal passes of the Keys island chain serve as a point of exchange for waters from Florida Bay, the Southwest Florida shelf and the Gulf of Mexico with the waters of the Atlantic coastal environment. One scenario is that bay waters may affect the reef by delivering relatively nutrient rich, hypersaline, turbid, hot, or cool waters to the offshore reef environment (Pitts 1994).

Nutrient mass flux through the Keys tidal channels has never been measured directly. The purpose of this study was to quantify the exchange of water and nutrients through one of the largest flow paths, Long Key Channel, using long-term, high resolution mass flow measurements combined with periodic tidal-scale collections of nutrient concentrations. Observations were made using an acoustic Doppler current meter coordinated with collections from an underwater autosampler engineered specifically for this project.

The results of this study describe a net annual export of nutrients from Florida Bay to the Florida Keys National Marine Sanctuary. The study found an estimated annual net flux through Long Key Channel of 3850 metric tons of TN and 63 metric tons of TP from Florida Bay to the Atlantic. Inorganic constituents accounted for 6% and 17% of the TN and TP pools, respectively. This export is driven principally by water transport, as flow accounted for about 90% of nutrient load. Nutrient concentration values varied seasonally but no significant difference was detected in the flow weighted mean concentration of inflowing or outflowing waters. If Long Key Channel is taken to represent 70% of Middle Keys outflows (Smith & Lee 2003), the results can by extrapolated to estimate net flux through all Middle Keys passes, such as Channel 5 and Channel 2, northeast of Long Key. Thus, the annual net flux from Florida Bay through the Middle Keys is approximately 5500 metric tons of N and 90 metric tons of P. Since studies have found that the passes of the Upper Keys show relatively little net transport (Lee & Smith 2002), and that passes west of Long Key Channel are outside the bounds of Florida Bay, the Middle Keys estimates can be taken as the total direct mass flux between Florida Bay and the Atlantic. These findings are about half of previous estimates of nutrient export from Florida Bay through the Keys passes by Rudnick et al. (1999) of 12000 MT TN and 180 MT TP.

Dispersal of bay waters in Hawks Channel and out into the greater Atlantic is likely strong enough to dilute outflowing nutrient concentrations to levels equivalent to that of the surrounding water column. The input of Florida Bay nutrients to the Keys coral reef community is minimal when compared to evidence of offshore tidal bores washing upon the reef. A recent study conducted by Leichter et al. (2003) in the upper keys produced evidence of relatively cool, nutrient rich subsurface waves upwelling onto the Keys reef tract. These waters contained an average of 4.0 µM NO_3^- and resulted in an estimated annual input of over 5000 metric tons of NO_3^- to reef tract waters. The estimated DIN export from Florida Bay through all the channels in the Middle Keys is only 330 metric tons; well under 10% of the NO_3^- input from offshore tidal bores. The results of this study indicate that if the coral reefs of the Florida Keys are suffering from nutrient eutrophication, Florida Bay waters are not the culprit.

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Biscayne Bay's Shallowest Habitats: Linking Seasonal Patterns in Benthic Community Structure with Salinity and Temperature Patterns

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The location of Biscayne Bay along a highly populated, rapidly growing urban center and directly downstream of CERP activities on the watershed makes this "national treasure" especially vulnerable to changes in water quality and flow. One of the most profound changes anticipated to occur with the implementation of CERP is the alteration of salinities within western Biscayne Bay. The areas most sensitive to the changes are shallow areas (< 1 m in depth) along the mainland shoreline, which are critical nursery habitats for pink shrimp and economically-valuable fishes such as gray snapper, hogfish, spotted seatrout and pinfish. Planned CERP activities will likely modify freshwater deliveries into western Biscayne Bay with unknown ecological effects on benthic and epibenthic organisms. Moreover, assessments of CERP performance are presently hampered by the lack of a spatially explicit and seasonally-resolved baseline of benthic community patterns; and the poor understanding of linkages between the hydrology and ecology of these areas.

Our CESI-funded project aims to fill these knowledge gaps by: (1) conducting video surveys of the nearshore environment with the Shallow Water Positioning System (**SWaPS**) to provide highly accurate, seasonally-resolved maps of the species composition, distribution, diversity, and abundance of seagrass, macroalgal and hardbottom organisms; and (2) relating the documented biological patterns to physical regimes via the deployment of miniature sensors that capture salinity and temperature dynamics in these shallow habitats. These data will form the basis for baseline benthic community characterizations against which future ecological responses to changes in freshwater flow can ultimately be assessed.

The shallow-water positioning system (**SWaPS**) is installed in a shallow-draft skiff, and uses a GPS receiver centered over a gimbaled digital camcorder that is suspended in a glass enclosure to provide a clear view of the bottom. A fixed-position base station receiver transmits real-time kinematic data to the boat by radio modem and the images obtained are superimposed with position, date and time, depth, heading, and pitch and roll. Post-processing the GPS data allows the user to recover the same position again with sub-meter accuracy. In 2005, dry and wet season surveys were conducted along nearshore environments of western Biscayne Bay (< 500 m from shore) between the Rickenbacker Cswy and Turkey Point to document community patterns along latitudinal and inshore-offshore gradients. The video collected during SWaPS surveys was post-processed by "grabbing" non-overlapping frames that were analyzed to determine: (1) spatial distribution of seagrasses, macroalgae, and hardbottom organisms; (2) species richness; and (3) abundance and percent cover.

In addition, salinity and temperature loggers were deployed between Black Point and Turkey Point at < 20 m from the mangrove shoreline to expand the spatial coverage of sensors deployed by Biscayne National Park and the Army Corps of Engineers into in the extreme shallows of Biscayne Bay.

While the data collected during 2005 are still being analyzed, these are some of the preliminary results of our efforts:

1. Seagrasses are the dominant benthic component of nearshore habitats of Biscayne Bay. Seventy-five percent of the sites surveyed had seagrass while forty-eight of these sites, located mainly in the northern section of our study area, were on dredged areas where depth is > 2 m and no SAV were detected

2. The distribution of seagrasses is clearly influenced by the inflow of freshwater from canals. Populations of *Halodule* and *Ruppia* were only abundant in areas close to canals. *Thalassia* was a dominant component of the seagrass community throughout the region but its abundance increased locally with increasing distance from the mouths of canals. Abundant populations of *Syringodium* are only found in the northern section of our study region in areas with open exchange with offshore water (i.e., across from the Safety Valve)

3. While canal outflow can influence seagrass and macroalgal distribution, areas in the vicinity of canals still support productive benthic communities. The occurrence of "dead zones" devoid of SAV appears to be restricted to a 50 -100 m buffer at the mouth of canals

4. Large areas of the nearshore environment support extensive and productive macroalgal communities dominated by drift macroalgal, especially *Laurencia*

5. A shift in the composition of macroalgal communities was detected at the onset of the wet season in areas in the vicinity of canals (e.g., Black Creek, Princeton Canal) were *Chara* and *Batophora*, two species commonly associated with freshwater, became dominant components

6. A field calibration exercise conducted to compare the data collected by divers with similar information collected using SWaPS showed no significant differences in the cover of any of the categories between methods (t tests, $p > 0.05$). These results indicate that SWaPS can be used effectively to document patterns of abundance and distribution of SAV in shallow environments and that the results obtained using SWaPS are fully comparable to the data collected by other regional SAV monitoring programs

7. Extreme nearshore environments (< 50 m from shore) experience wide daily fluctuations in temperature of up to 6° C that are directly associated with air temperature patterns

8. Salinity patterns are influenced by rainfall as well as outflow from canals. Salinity in the vicinity of canals can remain at low levels for prolonged periods even in the absence of rain due to the water management decisions to move water from other sources into Biscayne Bay

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The Role of Sponges in N Cycling and Total Respiration in Shallow Water Florida Keys Ecosystems

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Marine sponges are abundant in Florida Bay, nearshore patch reefs and outer reef tract sites in the Florida Keys. These sponges can be grouped based on their stable C and N isotopic composition and modes of nitrogen cycling. Approximately half of the Keys sponge species investigated can be classified as bacteriosponges that host large communities of microbes, up to 50% of their biomass. Significantly lower pumping rates by the bacteriosponges result in longer water residence times within their tissues plus preferential net export of DIN as dissolved nitrate. Higher nitrate/ammonium ratios in bacteriosponges provide evidence for efficient nitrification of ammonium generated from catabolism of filtered POM and DOM. These results suggest that differences in sponge tissue oxygenation may represent an important control on observed differences in N transformations including potential N_2 fixation, nitrification and denitrification. *In situ* measurements of oxygen concentrations in bacteriosponge and non-bacteriosponge tissues made with a submersible meter equipped with needle-style oxygen microsensors revealed extreme concentration gradients with hypoxic conditions generally occurring within a few mm depth in bacteriosponges. Non-bacteriosponge species generally feature patchy oxygenation ranging from hypoxic to near saturation concentrations.

In order to assess the importance of sponges in both N cycling and total respiration in Keys environments we have developed and applied new methods for measuring *in situ* N flux and respiration at both the individual sponge and control volume scales. For individual sponges we are measuring excurrent flows by dye injection-video or by Acoustic Doppler Velocimeter (ADV) while making continuous oxygen measurements with microsensors capable of better than five second time resolution. Nutrient samples for DIN and total DON species are collected periodically by syringe from individual sponges and by a novel *in situ* differential pressure system for DON and particulate N and for larger scale (20mX30m) control volume experiments. Control volume experiments conducted jointly with Stanford University scientists include collection of time-averaged water column nutrient samples while vertical water column oxygen concentrations and flow velocities are measured by AD Current Profilers (ADCPs) and chemical microsensors. Initial results with individual sponges consistently indicate that 5 to 30% of ambient oxygen concentration is consumed during sponge pumping.

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Hindcasting Salinity in Biscayne Bay

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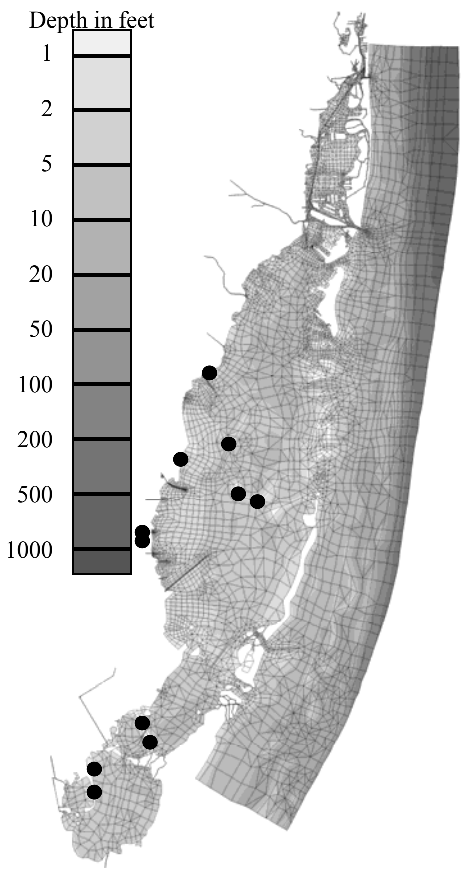
The Coastal Ecosystems Division (CED) of the South Florida Water Management District (District) has a general need for hindcasting salinity in Biscayne Bay (Bay), based on predevelopment flows, to provide an historic frame of reference for both existing and forthcoming proposed performance measures and criteria for processes such as setting minimum flows, reservation of water and evaluation of Comprehensive Everglades Restoration Plan (CERP) projects that may the Bay. Performance measures are indicators of the ecological health, hydrologic, and/or hydraulic behavior of the system. Performance criteria represent desired and/or mandated performance.

The period of interest is that of one hundred years ago, before the south central portion of the Bay came under the influence of the extensive drainage networks now present in south Florida. Almost no quantitative empirical data exists for this period; anecdotal information is also scarce. This paper therefore documents the simulation of salinity patterns in south central Biscayne Bay using a modified version of the TABS-MDS hydrodynamic and salinity model developed by Brown et al. (2003), which has generally performed well in reproducing modern salinity patterns (Brown et al., 2003; Parrish, 2005).

Modifications consist of new boundary conditions that represent a suite of model scenarios that have an historic basis and are anticipated to be of interest to policy makers. The suite of model scenarios is based upon the District's Natural Systems Model (NSM), which defines freshwater inflow. The NSM approximately simulates the hydrologic response of a pre-drained Everglades system to modern climatic conditions (1965 to 2000). Although one may wish to recreate the climatic conditions of the period of interest, the necessary data for such an action do not exist. Additionally, the use of recent hydrologic data allows for meaningful comparisons between the current managed system and the natural system under identical climatic conditions (adaptation of SFWMD, 2005).

Simulated overland flow data from NSM were selectively redirected in an effort to reconcile its coarsely integrated data with the relatively fine TABS-MDS mesh (Figure 1). Certain overland flows that are represented as occurring over the width of an NSM grid cell (2 miles) are recast as channelized flow in the TABS-MDS model, based upon visual inspection of aerial photographs (dated 1940) that show marked channels not simulated explicitly by NSM.

Results indicate that the TABS-MDS model, having boundary conditions that are based upon NSM output, are consistent with available paleoecological data that indicate pre-1900 salinity ranges. The paleoecological data are derived from the dating of core samples and the observation within those cores of estuarine fauna that are known to tolerate certain salinity ranges (Wingard et al., 2004) (Figure). The flow boundary conditions and simulated salinity patterns, taken together, form an historical context for the consideration of proposed performance measures and criteria.



TABS-MDS model mesh and bathymetry. Dots are locations of known paleoecological information.

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Decadal-Scale Ecological Shifts along the Florida Reef Tract: Understanding Cause and Effect

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Recent scientific papers and newspaper articles have admonished the U.S. Government for not doing enough to protect the valuable reef resources of the Florida reef tract. While we are all in agreement that Florida's coral reefs are threatened, we argue that understanding the main causes of their decline (and their recovery) are of paramount importance in devising science-based management and restoration strategies for these systems. The generally accepted model of coral reef decline is that the shift from a more desirable, coral-dominated state to a less desirable, macroalgae-dominated state was primarily a consequence of long-term overfishing and coastal eutrophication, making them more susceptible to other recent disturbances. This model, perpetuated in the literature by a series of affirmative *ad hoc* revisions, has retarded ecological discovery and confounded the direction of ecosystem management.

For Florida's coral reefs the implied lack of management is based on the hypothesis that the main causes of reef degradation are historical in nature and the woes that beset this system are local, man-induced, and reversible. While it is easy to take this view, evidence linking overfishing and coastal eutrophication to reef degradation in Florida remains elusive. Unfortunately, politicians, NGO's, managers and the public are receptive to such arguments because runoff from agricultural lands in the Everglades, sewage treatment, or overharvesting of finfish and shellfish are things that make intuitive sense and also have strong emotional appeal.

In the case of Florida, the catastrophic decline in coral cover (particularly for acroporid corals) started in the late 1970s and was empirically observed to be driven proximally by disease outbreaks, and more recently by ENSO-enhanced coral bleaching. Paleoecological and ecological data indicate that coral mortality is largely decoupled from changing levels of herbivory or water quality, and that reef dynamics on a regional level are at best weakly linked to present and past levels of nutrients or fishing pressure.

Improving water quality and conserving stocks of reef fish should be and clearly are high priorities of management, but the positive, localized impact on corals will be minimal in the face of regional- to global-scale stressors such as disease epizootics and increasing sea-surface temperature. Management steps are already in progress in the Florida Keys to clean up nearshore waters as well as system-wide water quality and habitat restoration efforts under the Comprehensive Everglades Restoration Plan. When completed, engineering solutions to improve the quality of nearshore waters will only benefit the offshore reefs. Unfortunately, no form of locally-based stewardship, scientific management or scientific policy including total protection could have prevented or changed the overall trajectory of coral loss or ameliorated the major disturbances responsible for reef decline in Florida.

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Transport Along and Across Hawk Channel: The Last Link in the Gulf-to-Atlantic Transport Pathway to the Reef Tract

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Two field studies were conducted in 2004 and 2005 in Hawk Channel, the narrow continental shelf on the Atlantic side of the Florida Keys. The study site was 5.5 km south of Long Key Viaduct in the Middle Keys. At the study site, the orientation of the Keys, the reef tract and the axis of Hawk Channel are all approximately 065-245°. The objectives of the study were to measure the flow of water along and especially across the shelf, and to assess the likelihood that Florida Bay water could be transported from the mouth of Long Key Channel to the reef tract, about 10 km seaward. Long Key Channel is one of the primary conduits for water leaving Florida Bay. Previous studies have suggested that the long-term mean outflow of Florida Bay water is often between 250 and 450 $m^3 s^{-1}$. The first field study was conducted over a 153-day period from April 21 to September 21, 2004 to characterize flow from late spring to late summer. The second study was conducted over a 189-day period from November 9, 2004 to May 1, 2005 to characterize flow from mid fall through late spring.

A Sontek ADP current profiler recorded current speed and direction hourly in seven one-meter thick layers from the top of a near-bottom blanking zone (Layer 1) to a near-surface layer (Layer 7) just below the effects of surface wind waves and surface reflection. Wind stress was calculated from observations made hourly at a C-MAN meteorological tower at Sombrero Reef, 29 km southwest of the Hawk Channel study site. Current data from Layers 1 and 7 are used to compare and contrast near-bottom and near-surface flow patterns, and to investigate across-shelf transport in response to wind forcing.

Wind conditions during both field studies were typical of normal seasonal patterns. During the spring-summer study, wind stress was persistently westward (out of the east, using the oceanographic convention) from late April through mid July. Wind stress during the final two months is more difficult to characterize, but the pattern includes a 360° counterclockwise loop during the final month of the study. The resultant heading was 288°. During the fall-spring study, wind stress was much more variable over time scales of weeks to months. The resultant heading was toward 247°, but ±45° variations in direction persist for several days at a time as cold fronts move through the study area.

In spite of distinct differences in seasonal wind forcing, flow patterns from the two studies include several similar features. In both studies, the mean along-shelf flow is west southwestward, toward Key West. Brief interruptions, especially in surface layers, can be traced back to wind forcing. This is consistent with results of several previous studies involving single current meters moored at near-bottom or mid-depth levels. With increasing depth, current directions lie to the left of the near-surface current. The mean surface-to-bottom deflection was 5.2° in the first study and 5.6° in the second study. In both studies, near-surface flow is deflected landward of an along-channel heading, and near-bottom flow has a distinct and persistent seaward component. Near-surface flow during the first field study had a resultant direction of 266°, which is approximately 20° landward of an along-isobath heading. Near-surface flow during the second study had a resultant direction of 256°. The near-bottom resultant directions were 214° and 238°, respectively, indicating that seaward flow is more pronounced when wind forcing has a more landward heading. Near-surface and near-bottom flow are highly correlated.

Correlation coefficients calculated with Layer 1 and Layer 7 data from the spring-summer and fall-spring time series were 0.768 and 0.770, respectively.

Results document a seaward transport pathway in the lowest layers of the water column throughout the year. Thus, Florida Bay water can be carried across Hawk Channel toward the reef tract, but only when it emerges from Long Key Channel and descends as a relatively high-density, near-bottom plume. This would be the case during winter months (the dry season), when density increases by some combination of lower temperature and higher salinity. Data from Layer 7 suggest that Florida Bay water would be held against the Keys and not move across Hawk Channel when it emerges as a relatively low-density surface plume. This would be the case during summer months (the wet season), when density is lowered by some combination of higher temperature and lower salinity. Wind directions characteristic of winter months are oriented in a more along-shelf direction and thus do not encourage seaward flow in near-bottom layers. Also, more energetic wind forcing during winter months encourages vertical mixing, diluting bay water by distributing it throughout the water column. While the study reveals a seaward transport pathway, it is likely that the interaction of hydrologic forcing and meteorological forcing reduces the transport of Florida Bay water to the reef tract.

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Poster Abstracts

Adjacent Systems

Listed alphabetically by presenting author and abstract title.
Presenting authors appear in **bold**.

Florida Keys Tidal Restoration Pre-Construction Monitoring

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Clear baseline information from a variety of parameters is necessary in order to effectively evaluate biological change following ecosystem restoration. With the explicit goal of improving near shore environmental conditions and enhancing benthic invertebrate diversity, larval transport, and recruitment of marine fish to near shore communities, the plan of Florida Keys Tidal Restoration Project (FKTR) is to restore tidal connections that were eliminated during the construction of Flagler's railroad in the early 1900's. The objective of the FKTR Pre-Construction Monitoring Program was to collect information that can be used as a baseline to evaluate biological change resulting from the restoration of tidal flow.

Pre-construction period efforts included water quality monitoring; juvenile spiny lobster population assessments; surveys of the seagrass, hardbottom, benthic infaunal and sediment communities; and the creation of a geo-referenced habitat map via digital orthophotography. Pre-construction monitoring began during February of 2004 and will continue through January of 2006.

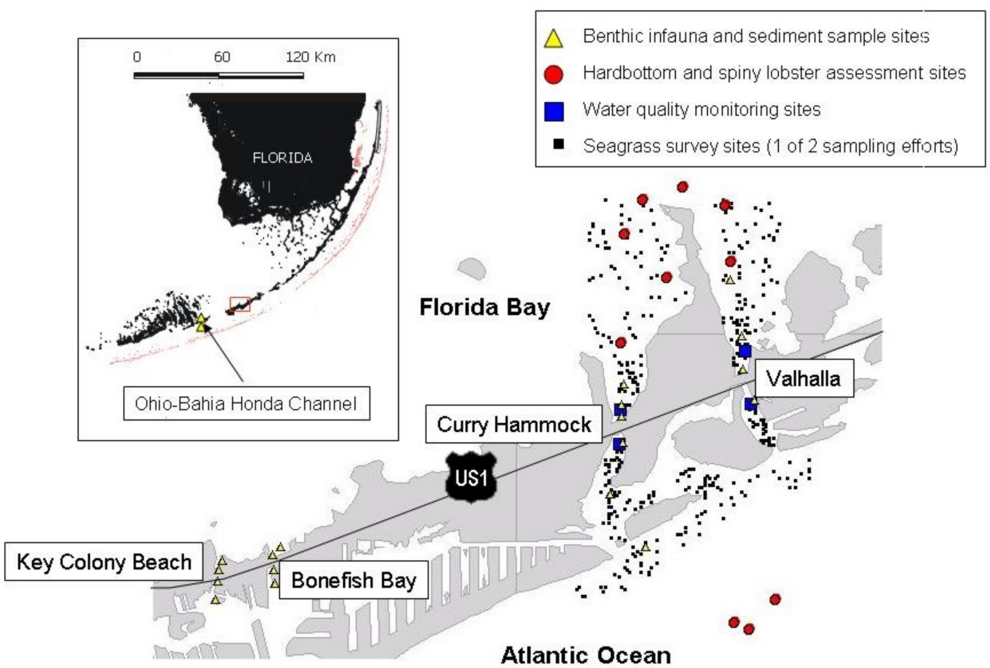

Figure 1. Florida Keys Tidal Restoration pre-construction monitoring project.

Water quality has been monitored at the location slated for restoration (Curry Hammock), and at an adjacent control location (Valhalla) (Figure 1). At each location, two water quality monitoring stations were established, one on the Florida Bay side of the US 1 causeway and one on the Atlantic Ocean side. At each station, water quality data was collected via an *in-situ* deployed data sonde which collected hourly data for 14 days of each month. Parameters measured included dissolved oxygen (DO), pH, depth, temperature, salinity/conductivity, and turbidity. Most values were consistently similar at all four of the water quality stations. Salinity values averaged 38.3 ppt with only 0.2 ppt difference in mean values at the bayside vs. oceanside stations. Of note were the often very low DO values during the overnight hours as a result of O2 demand for decomposition of the detritus that collects in these often stagnant areas.

Surveys of the benthic sessile, motile, and macrofaunal communities were designed to estimate the abundance and size structure of the prominent, sessile taxa that create structural complexity of the near shore hardbottom community (e.g., sponges, octocorals, hard corals), the large, motile taxa that dwell in those structures (e.g., spiny lobster, stone crab), and the abundance of the dominant red macroalgae (*Laurencia* spp.), which is the primary habitat into which early-benthic-stage spiny lobster recruit. Within the hardbottom habitats surrounding Curry Hammock and Valhalla, a total of ten randomly chosen sites were surveyed on two separate occasions. Biannual surveys were conducted for early-benthic-stage juvenile lobsters (*e.g.,* lobsters that have recruited within the past year) at the same sites selected for hardbottom assessment. For each survey, two divers searched for and captured all lobsters encountered during a 10-minute search. The two resulting 10-minute searches were pooled and considered as one 20-minute survey. In general, we observed more lobster in the bayside surveys, presumably due to the higher structural complexity of the hardbottom habitat and the more abundant *Laurencia* spp. Surveyed lobster sizes ranged from 13 to 68 mm carapace length.

Seagrass sampling was designed to provide estimation of the aerial extent, density, and species composition of those communities in the area. The seagrass habitat on both the bay and ocean sides of the Curry Hammock and Valhalla Beach locations was sampled during the spring of 2004 and fall of 2005. The sampling strategy involved 360 sampling locations chosen in a double-stratified, random design for each of the two sampling efforts. At both the bayside and oceanside sites very close to US 1, there was a zone of barren, silty, anoxic mud. Farther away from US 1, the study area was dominated by dense beds of *Thalassia testudinum* and *Syringodium filiforme* which gave way to patchy seagrass beds and hardbottom habitat of sponges and octocorals. Approximately 20 percent of the study sites had seagrass coverage of 50% or more.

We collected benthic infaunal and sediment samples semiannually from the Florida Bay and Atlantic sides of US 1 at five locations. Additionally, each site had an associated core sample taken for sediment grain size and percent organic analysis. Final analysis is pending.

Aerial photography of the Curry Hammock and Valhalla sites was completed in December of 2004 for use in creating a high-resolution, geo-referenced habitat map of the FKTR project area. Production of the map is in its final stages.

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Observations of Unsteady Internal Motions on a Fringing Coral Reef

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Unsteady internal motions propagating over shallow coral reefs dissipate energy, induce mixing, and alter the turbulent bottom boundary layer. These motions may also have a profound effect on the transport of nutrients to reef organisms. For most coral reef systems, surface gravity waves provide the vertical mixing necessary to deliver nutrients to benthic organisms. However, the role of internal waves in coral reef systems is less understood but may be the dominant mechanism is some locales. For example, the unique oceanographic conditions in the Florida Straits (a geostrophic balance where isopycnals tilt up on the western boundary) result in a dynamical internal wave field incident on one of the most threatened coral reef systems in the world. From a physical oceanographic prospective, several questions arise for these systems: 1) How does the presence of internal motions on a rough coral reef slope change the flow in the turbulent bottom boundary layer and vertical mixing on the reef? 2) How much energy from the internal wave field is used in mixing the water column? 3) Can we quantify the cross-shelf nutrient flux from internal waves and how does this compare to an estimate of nutrient fluxes from terrestrial sources? Understanding the role that internal waves play in coral reef ecology is essential to modeling key biological processes and the connectivity of coral populations or designing and managing marine reserves and fisheries.

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Optimization of Water Quality Monitoring in Biscayne Bay, Florida

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The South Florida Water Management District (SFWMD) is continuously challenged with providing the resources needed to accommodate substantial and diverse water quality data needs. With over 1500 monitoring sites, SFWMD has an extensive water quality monitoring network that spans a wide variety of ecosystems over a large geographic area. The network consists of individual monitoring projects driven by a diverse set of mandates and objectives, and the monitoring must be accomplished under the constraint of priority initiatives being supported by limited resources. It is anticipated that costs and monitoring commitments will only continue to increase in the future. With a goal of reducing operating costs and improving service, while ensuring that future monitoring complies with regulatory requirements and generation of high quality, scientifically defensible data, the optimization of seventeen individual water quality monitoring projects is being conducted. Data from two monitoring programs conducted in Biscayne Bay were evaluated to determine data comparability and identify key parameters for completing the optimization analysis. The results of this comparison and findings from the statistical analysis conducted for the optimization will be presented.

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Uses and Economic Contribution of Biscayne Bay, Florida

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Biscayne Bay is a large, shallow tropical saline lagoon surrounded by the large and diverse metropolitan area of Greater Miami and Miami Beach. Biscayne Bay is the most prominent feature in Miami-Dade County's landscape. However, there is very little definitive understanding of the magnitude or extent of the Bay's economic contribution to the community. This study is the first to assess the current and historic uses and economic contribution of the Bay that provides baseline information to evaluate the impact of Bay management on the local economy.

Biscayne Bay supports a wide variety of recreational and economic uses. The uses evaluated in this study are:

- Recreational fishing, swimming, boating, sailing and other activities
- Commercial Fishing
- Shipping operations at the Port of Miami and the Miami River
- Cruise Ship Operations at the Port of Miami

The objectives of this project were to:

(1) Estimate the intensity of Biscayne Bay uses from 1980 to 2004; and,

(2) Estimate the economic contribution of Biscayne Bay uses to the economies of Miami-Dade County, southeast Florida and Florida from 1980 to 2004 in terms of the direct, indirect and induced sales, income, employment and tax revenues generated by the uses of the Bay.

This study provides a wealth of information regarding the uses and economic contribution of Biscayne Bay. This presentation will summarize the methods and results of this study. Some of the conclusions are as follows.

Recreation. Miami-Dade County residents and visitors spent 65.5 million person-days participating in a wide-variety of recreation activities on or at Biscayne Bay in 2004. A person-day is one person participating in a primary recreation activity for all or part of one day. Of the many activities that are enjoyed by recreators during a day, only one "primary" activity is counted per day. The four most popular recreation activities on Biscayne Bay were: (1) viewing the Bay from shore while dining, shopping, jogging or strolling (25 percent); (2) swimming from shore (17 percent); (3) fishing from a boat (13 percent); and (4) sailing (9 percent).

In 2004, the expenditures made to recreate on or at Biscayne Bay generated $3.8 billion in additional county production; provided $2.1 billion in income to county residents, created 57,100 jobs and produced $257 million in tax revenues. Biscayne Bay-related recreation contributes to 3.4 percent of Miami-Dade County's economy, 1.3 percent of the southeast Florida economy and 0.5 percent of Florida's economy as measured by its relative contribution to income.

Biscayne Bay-related recreation use intensity and its economic contribution grew steadily since 1980 with the exception of 1992 and 1993. Recreation activity fell during these two years after Hurricane Andrew struck the county on August 24, 1992. By 1995, Bay-related recreation use intensity had completely recovered.

Commercial Fishing. In 2002, the $13.2 million in sales associated with commercial marine landings related to Biscayne Bay generated $28 million in additional county production, provided $17 million in income to Miami-Dade County residents, created 470 jobs and produced $1.8 million in tax revenues. The Biscayne Bay-related commercial fishery represents 0.03 percent of the Miami-Dade County economy. The value of commercial marine species caught in Biscayne Bay has increased significantly since 1980. Meanwhile, the harvested value of species dependent on Biscayne Bay for survival and caught outside of the Bay has declined significantly since 1993.

Shipping. The value of cargo shipped into and out of the Miami River is about $4 billion while the value through the Port of Miami is about $17 billion. This $21 billion worth of goods represents about 42 percent of the value of all cargo passing through Florida's seaports. Of this 42 percent, 34 percent represents the Port of Miami and 8 percent represents the Miami River. About 4 million people boarded cruise ships at the Port of Miami in 2003 which is 29 percent of all cruise ship passengers using Florida's seaports.

The $3.9 billion in sales of businesses that directly depend on the Port of Miami generated $8.2 billion in additional county production; provided $3.9 billion in income to county residents, created 74,000 jobs and produced $331 million in tax revenues. The Port of Miami contributes to 6.2 percent of Miami-Dade County's economy, 2.5 percent of the southeast Florida economy and 0.9 percent of Florida's economy as measured by its relative contribution to income. Cargo shipping and cruise ship services through the Port of Miami and their associated economic contributions have grown steadily and significantly since 1980.

The $353 million in sales of businesses that directly depend on the Miami River generated $683 million in additional county production; provided $339 million in income to county residents, created 6,100 jobs and produced $37 million in tax revenues. The Miami River contributes to 0.6 percent of Miami-Dade County's economy, 0.2 percent of the southeast Florida economy and 0.09 percent of Florida's economy as measured by its relative contribution to income. Cargo shipping services through the Miami River and their associated economic contributions grew steadily from 1980 to 1995 and has since fallen and become cyclical through 2002.

All Activities Evaluated. Overall, the activities on Biscayne Bay in 2004 contributed $12.7 billion in output, $6.3 billion in income, 137,600 jobs and $627 million in tax revenue to Miami-Dade County. These values represent 10 percent of all income earned in the county, 11 percent of employment in the county and 11 percent of all excise taxes, property taxes, fees, licenses, and sales tax revenues collected in the county.

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Post Hurricane Katrina Surface-Water Monitoring in Biscayne Bay, Card Sound, Barnes Sound, and Miami-Dade Watersheds

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Miami-Dade Department of Environmental Resources Management (DERM) is responsible for post-flooding event monitoring of surface waters in Miami-Dade County. On the evening of August 25, 2005, Hurricane Katrina, a Category 1 storm, made landfall in northeast Miami-Dade and followed a west-southwest path across the county. Intense rain occurred over southern Broward County and Miami-Dade County, with 36-hour accumulations of as much as 15-20 inches reported in portions of southern Miami-Dade County.

Water managers responsible for operation of the Central and Southern Florida Flood Control project released water from coastal canals and used “forward pumps” on the C-5 (Tamiami Canal) and C-6 (Miami Canal) to assist in lowering groundwater elevations in advance of the storm. Despite these efforts, extensive flooding was reported in south Miami-Dade residential and agriculture areas. Coastal water control structures remained open for at least six consecutive days to relieve flooding, and return water levels to normal elevations.

Beginning on August 27, 2005, surface water sampling was initiated Biscayne Bay, Dumfoundling Bay, Card Sound, Barnes Sound, Manatee Bay and canals and rivers discharging to the coastal area. The principal goal of the sampling program is to document flood-event-related impacts on salinity patterns and related physical parameters, nutrients, and bacterial indicators of sewage pollution. Field data was collected at 50 sites, with physical parameters (e.g., dissolved oxygen, temperature, pH, specific conductivity, and salinity) assessed at the surface, 1 meter, and the bottom. Water samples were collected at 1 meter, and were analyzed in the laboratory for total phosphorus, ammonia-nitrogen, and nitrate/nitrite-nitrogen. Surface samples were collected and analyzed for bacterial indicators of sewage pollution. Sampling was conducted on Aug. 27th, 28th, and every other day thereafter until typical concentrations or patterns were documented.

As of the date of preparation of this abstract, only preliminary results are available. However, significant impacts on salinity patterns and oxygen concentrations were documented at canal mouths and in nearshore bay waters, particularly those with limited tidal flushing. Waters of Manatee Bay, for example, were fresh from the surface to bottom. Field crews also observed possible evidence of groundwater or spring discharges in south Biscayne Bay. Early results documented bacterial indicators of sewage contamination at levels in excess of local and state standards at virtually all canals and in nearshore waters affected by canal discharges. Because of the unusually large volume of freshwater released, even areas of tidal waters that are not typically affected by urban or agricultural discharges showed widespread evidence of sewage impacts.

Results of the Hurricane Katrina event monitoring will be compared to long-term data for August and September, and also to other less significant flood events in the recent past. Analyses of geographical patterns and temporal trends will be included. Available information documenting accumulated rainfall, flood relief measures, and discharge volumes will be provided.

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Hurricane Impacts on Salinity, Water-Level, and Temperature in Biscayne Bay, Florida

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Biscayne National Park

Biscayne Bay is the largest estuary on the coast of southeast Florida and is continuous with the southern Everglades and Florida Bay system. Intense urban development and altered drainage from the Everglades have contributed to its transition to a marine lagoon from a freshwater estuary. A system of canals controls freshwater surface flows to Biscayne Bay causing severe fluctuations in salinity, resulting in large-scale ecological degradation in the Bay. Dramatic changes in nearshore vegetation and seagrass beds which provide important habitat, as well as protection from storm damage and erosion, have been compromised. As a common threat to South Florida, hurricanes cause significant hydrological alterations from flooding, with long-term disruption to resources.

Hurricane Katrina made landfall at the Broward/Miami Dade county line at 6:30 PM, Thursday, August 25, 2005. The storm moved to the southwest over Miami Dade County with the strongest winds and rain to the south and east of the eye, located over Biscayne Bay. Maximum winds reached 80 mph and rainfall in the area around Biscayne Bay ranged from 11.13 to 16.33 inches. Although, only a category one hurricane, Katrina did cause large changes in the physical parameters recorded in Biscayne Bay.

As part of a long term research project, Biscayne National Park maintains 50 YSI multiparamater instruments placed strategically throughout the bay. Many of these sites have two meters, one located near the surface and one at the bottom of the water column. These instruments are deployed continuously and collect depth, temperature, and salinity measurements every 15 minutes. This data set allows us to not only quantify long term trends in Biscayne Bay, but also to document episodic events such as Hurricane Katrina.

Biscayne Bay did not experience a storm surge, and average water levels actually decreased in many locations. This decrease was likely due to the strong winds from the west pushing water away from the shoreline. The large amount of rainfall did not cause salinity to decrease significantly, however canal discharge both before and after the storm was considerable. Salinity near canals and areas of freshwater input declined dramatically, with some meters recording salinity near 0 ppt. Benthic meters experienced approximately a 10 ppt decline producing a strong halocline in many locations throughout the Bay. Water temperatures at all sites decreased during the hurricane by more than 5 degrees Celsius.

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Coral Reef Rapid Assessment and Monitoring in the Florida Keys: 1998 - 2005

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[2]Rosensteil School of Atmospheric and Marine Sciences, University of Miami
[3]Boston University Marine Program

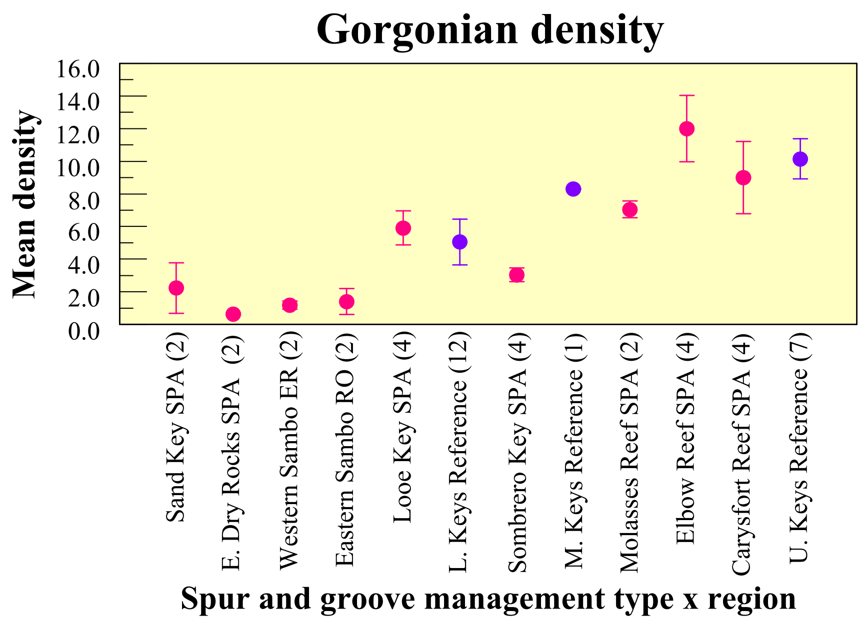
This project works at multiple spatial scales and across multiple habitat types with managed areas (Sanctuary Preservation Areas, Research Only Areas, and Ecological Reserves) nested in the design, measuring a large suite of parameters to evaluate condition and factors causing coral reef change in the Florida Keys National Marine Sanctuary. A pilot project started in 1998-99 was expanded in 2001-2002 to include nearly 300 sites from south of Miami to the Dry Tortugas. Work completed in 2005 included nearly 200 additional sites to detect change over time and to expand the number of sites in certain habitat types, especially patch reefs.

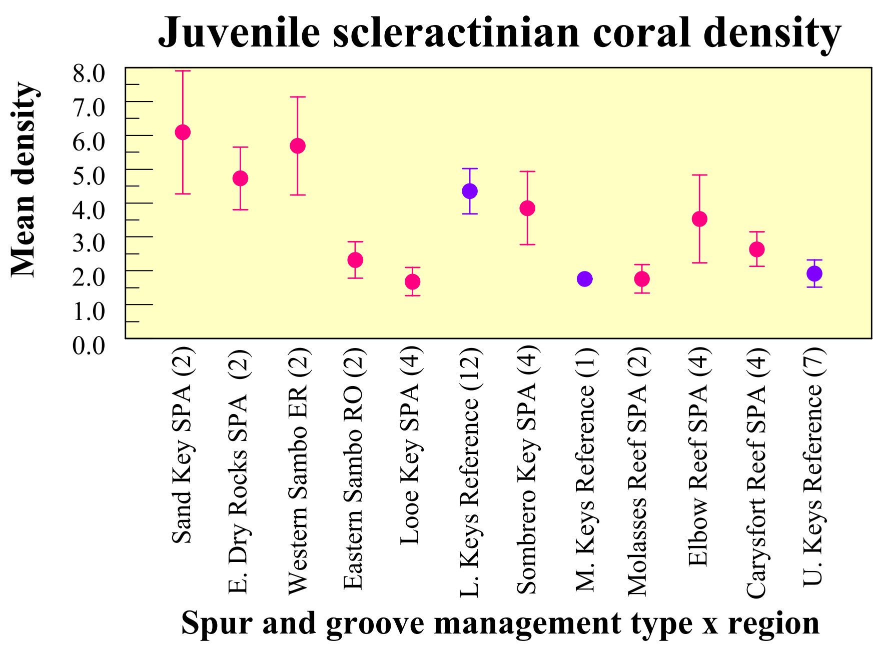
The program was developed in partnership with the sanctuary to address high priority management questions and issues documented in the FKNMS Science Plan, and include but are not limited to: 1) determine the distribution, abundance, and condition of various habitat types throughout the region, including the Dry Tortugas; 2) detect change (rapidly) in coral reef community structure caused by natural and anthropogenic disturbances; and 3) assess the effectiveness of SPAs, ROAs, and ERs. Work proposed here acknowledges that natural and human-caused stressors interact with geography, history, and chance to dramatically affect the way coral reefs look and function in the Keys.

Field work is conducted by experts with taxonomic skills to produce high resolution and reliable results using scuba, underwater slates, and a sophisticated statistical design that is optimized based on site numbers, desired detection limits, and funding. Accomplishments include data management protocols that facilitate rapid publications (12 peer reviewed publications so far, 5 more in review, and 6 manuscripts in preparation) and frequent presentations for managers.

A two-stage stratified random sampling design is used to document benthic cover, mean density of juvenile corals, adult corals and octocorals, and size-frequency and condition estimates of coral colonies. Colony density and size measurements (max diameter, max height, second diameter) of each species are obtained for juveniles (<4cm diameter) and adults. Percentage of dead tissue is estimated. Causes of mortality are noted where possible. Condition factors such as disease, bleaching, and overgrowth by algae or sponge are noted. Octocoral species density; species richness of coral, octocoral and sponge; and benthic cover are also measured. For select species of sponges size measurements are also recorded. Benthic cover is determined by linear point-intercept techniques. Demographic data are used to identify the density and distribution of individuals within size classes, and to estimate growth and mortality within the size classes found in the populations. Results will help determine whether or not coral populations are able to maintain cover and population size based on growth, mortality and recruitment estimates.

Results from 2001-02 that set a system-wide baseline (note, however, that sampling started after dramatic coral decline and change previously occurred throughout the system), for example documenting variability in gorgonian density and juvenile coral density among sites, habitat types, and inside and outside management areas will be compared with results obtained in 2005.





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Mapping Vegetation in the Biscayne Bay Coastal Wetlands

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In order to plan for hydrologic restoration and to assess the success of the Comprehensive Everglades Restoration Plan's (CERP) Biscayne Bay Coastal Wetlands (BBCW) Project, an accurate inventory of the area's vegetation is necessary prior to project initiation. This vegetation inventory will aid project planners in accomplishing various tasks, including (1) describing and defining existing conditions, (2) evaluating and differentiating project alternatives by attempting to predict vegetation changes in response to proposed hydrologic changes, and (3) quantifying ecological benefits provided by restoration as required by the U.S. Army Corps of Engineers' planning process. This poster briefly describes the methods used in creating a current vegetation map and portrays the location and spatial extent of each of the 28 vegetation and non-vegetation classes used to produce the map. The extent of the mapping effort covers 17,875 acres of the BBCW project area between Shoal Point and Turkey Point.

The general zonation of coastal vegetation in southeastern Miami-Dade County is well understood. Several existing spatial data layers portraying land cover and/or vegetation coverage of all or part of the project area were considered for this effort (SFWMD 1999, FWCC 2004, Gaiser and Ross 2003, EPA 1994). However, due to a number of factors such as spatial coverage, spatial resolution and accuracy, levels of classification, and suitability of the classification system, none of these maps were deemed suitable for the overall project purpose. In addition, vegetation in the area has changed significantly in recent years due to storms and encroaching urban and agricultural development rendering some of the existing data obsolete.

The new map was created using a monoscopic "on-screen" digitizing technique and ArcGis 8.3® geographic information system (GIS) software. Distinct vegetation types and/or communities were delineated from a high resolution (2 ft. x 2 ft. elements) digital 2004 natural color air photo mosaic. The imagery was geo-referenced to the State Plane coordinate system, Zone 3601, NAD 83, Units feet. A total of 114 individual sites were ground-truthed via aerial survey or ground transportation. Extensive local knowledge of the area's vegetation provided by the Miami-Dade County Department of Environmental Resource Management and supporting collateral data sources (EPA 1994; Gaiser and Ross 2003) contributed greatly to the accuracy of the map.

The new map uses a custom classification system comprised of 26 vegetation classes and two additional non-vegetation categories that portray areas of open water and any regions that have been filled, developed, or mechanically disturbed (mostly by agriculture). Thirteen of the 26 vegetation classes are composites of native and/or non-natives classes, which were required due to the high complexity of the vegetation in the project area. An example of this complexity is provided by the fact that a total of 1,050 vegetation polygons were delineated within the 17,875 acres included in this mapping effort, resulting in an average polygon size of 17 acres. Many of the classes include non-native species, which is a reflection of the anthropogenic disturbance in the project area. The table below shows only the six most dominant classes found in the project area. Agriculture and other development cover 24% of the project area—mostly along the western half. Mangroves are the dominant vegetation type along the shoreline, with coastal band mangroves and dwarf mangroves accounting for 15% and 9% of the total project area, respectively. Three vegetation classes dominated by freshwater wetland species have roughly equal representation and include native forested-shrub wetland / Brazilian pepper mix (11%), sawgrass (8%), and native forested-shrub wetland / Australian pine mix (7%). Nine of the 26 vegetation classes include non-native species, with the non-native species usually dominating the native species in community structure and spatial extent. Combined, these non-native classes cover 5,177 acres or 29% of the project area.

Vegetation Class	Acres	Percent of Total Acres
Filled-Developed-Disturbed	4250.7	23.8
Coastal band mangrove	2737.0	15.3
Native forested-shrub wetland / Brazilian pepper	1901.3	10.6
Dwarf mangrove (dense and sparse)	1593.7	8.9
Sawgrass	1470.6	8.2
Native forested-shrub wetland / Australian pine	1314.9	7.3
All other classes combined	4606.8	25.8

In conclusion, the newly created map highlights the broad and diverse representation of wetland habitat types that exist in the BBCW project area. It is apparent that the project area contains a very complex mix of vegetation types much of which has resulted from anthropogenic actions—primarily drainage to facilitate agricultural and urban development, and the suppression of fire. The BBCW project represents an opportunity to restore the various habitats that comprise the local ecosystem. The project's objective of re-establishing more natural overland flow patterns by diverting water from conveyance canals into the coastal wetlands should serve to restore and enhance freshwater and estuarine wetlands in the project area, thus increasing the function of these habitats for fish and wildlife. In the broader picture, the BBCW project is an important component of CERP because it encompasses such a large area and includes diverse habitat types in a region that is otherwise heavily urbanized.

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Using Natural Geochemical Tracers to Discern the Dominant Sources of Freshwater into Biscayne Bay, Southeast Florida

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Biscayne Bay is a sub-tropical estuary located on the carbonate platform of south Florida. The water occupying Biscayne Bay is a balance of saltwater influx from the open ocean and freshwater inputs from precipitation, surface water runoff, and submarine groundwater discharge. The bays watershed includes a total of 3 million inhabitants, the major urban centers of Miami and Ft. Lauderdale as well as the Everglades system. With the development of south Florida, the natural diffuse groundwater and stream flow into the bay has been replaced by a large system of canals and levees in an effort to control flooding and drain swampland. The Comprehensive Everglades Restoration Plan includes changes in the freshwater deliveries to Biscayne Bay from point-source discharges via canals to non-point source discharges via wetlands and groundwater flow. The balance of salinity in Biscayne Bay effects sensitive seagrass and tidal ecosystems including numerous species of corals and other biota. A comprehensive understanding of the flow of freshwater into the bay is crucial to future planned developments and restorations. The goal of this study is to use naturally occurring geochemical constituents as tracers to identify and quantify the sources of freshwater, i.e. rainfall, canal flow, and groundwater, discharge to Biscayne Bay.

In this study, discrete samples of precipitation, canal water, terrestrial groundwater, marine groundwater, and bay surface water are collected monthly and analyzed for the stable isotopes of hydrogen and oxygen as well as for major cations and anions. Initial results indicate that fresh groundwater has an isotopic signature (**del ^{18}O = -2.66 per mil, del D, -7.60 per mil**) similar to rainfall (**del ^{18}O = -2.86 per mil, del D =-4.78 per mil**). Canal water has a heavy isotopic signature (**del ^{18}O = -0.46 per mil, del D = -2.48 per mil**) due to evaporation. Thus it is possible to use stable isotopes of oxygen and hydrogen to separate canal water from precipitation and groundwater as a source of freshwater into the bay. Other geochemical constituents, such as calcium and magnesium are being investigated to further discern between the sources of canal water, rainfall and fresh groundwater. Both the stable isotopes and ion values will be placed in a mixing model to discern the dominant sources of freshwater into the Bay in both time and space.

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Diatom Records of Environmental Changes in Biscayne Bay Sediments.

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The ecology of Biscayne Bay has been greatly affected by natural and human activities in the adjacent landscape. The quality and quantity of freshwater flowing into Biscayne Bay have been altered by construction of canal systems that control movement of water throughout south Florida. Preliminary analyses of paleosediments in Biscayne Bay also suggest that major changes have occurred both prior to and since 20th century development of the surrounding region (Stone et al. 2000; Wingard et al. 2003, Swart 2004, Wingard et al. 2004).
Diatoms are often advocated as good indicators of environmental changes in aquatic environments and have been successfully used to study salinity changes in Florida Bay paleo sediments (Huvane & Cooper, 2001; Wachnicka & Gaiser (*In progress*)). In this study we used the fossil record of diatoms extracted from sediment cores collected at several sites in Biscayne Bay to determine the history of environmental changes, such as salinity and nutrients, which took place over the last several hundred of years. Additionally we conducted extensive autecological studies of diatom species living in the modern environments at 58 sites in Biscayne Bay which resulted in generation of rich information on ecological preferences for each species that can be used to explain the changes in diatom communities recorded in sediment cores. All three sediment cores have been divided into distinct three major bio-zones and several sub-zones using stratigraphically constrained cluster analysis. Each of these zones is composed of distinct diatom assemblages. Uppermost sediments, from early 1960's, are dominated by marine epiphytic and benthic species that are less common or absent in the lower parts of the cores (eg. *Hyalosynedra laevigata, Mastogloia corsicana, Mastogloia bahamensis, Dimeregramma dubium*). Beneath this upper zone is a diatom community with little compositional overlap, being dominated by *Cyclotella litoralis, Amphora ostrearia* var. *vitrea, Tryblionella granulata.* Basal sections of the three cores differ from each other. A sediment core collected from Featherbed Bank contains freshwater taxa which were not found in the remaining cores (eg. *Brachysira neoexilis, Brachysira serians, Eunotia implicate, Eunotia veneris*). Basal diatom assemblages from Card Bank and No Name Bank contain characteristic benthic and epiphytic marine species (eg. *Grammatophora oceanica, Grammatophora macilenta, Diploneis didyma, Tryblionella granulata*). In general, changes in diatom communities preserved in sediment cores indicate fluctuation in abundance of macrophyte communities and predominant marine conditions at all three sites. Appearance of freshwater taxa among typical marine diatom species in the bottom part of the Featherbed Bank core may indicate freshwater inflow at this site.

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Regression Analysis of Salinity in Caloosahatchee Estuary

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The C43 (Caloosahatchee River) Basin Reservoir project is a component of the Comprehensive Everglades Restoration Plan (CERP). Comparison of various alternatives of sizing the reservoir in this project requires estimating of the salinity distribution in a period of 36 years in the downstream Caloosahatchee Estuary. A regression analysis model based on Curvilinear Hydrodynamic 3-Dimensional model (CH3D) was developed for the simulation. The output of this analysis provides input to an ecological model. The regression model was designed to use the freshwater discharges from an upstream control structure to estimate the salinity distribution at the downstream sites. It was constructed in two phases. During the first phase, the relationship between constant upstream freshwater discharges and their corresponding equilibrium salinities at the downstream sites was established. During the second phase, a Fortran program was developed to adjust the predicted salinity curves to match the monitoring salinities and CH3D simulation results. The matching criterion was judged by the Root Mean Square (RMS) value between regression results and monitoring data. After the regression model is calibrated, it can be used to quickly estimate the salinity variation in any time span for the specific sites. The salinity data was simulated quite well by the regression model (see Figure1) with most of the RMS errors in the range of 1 ppt to 4 ppt.

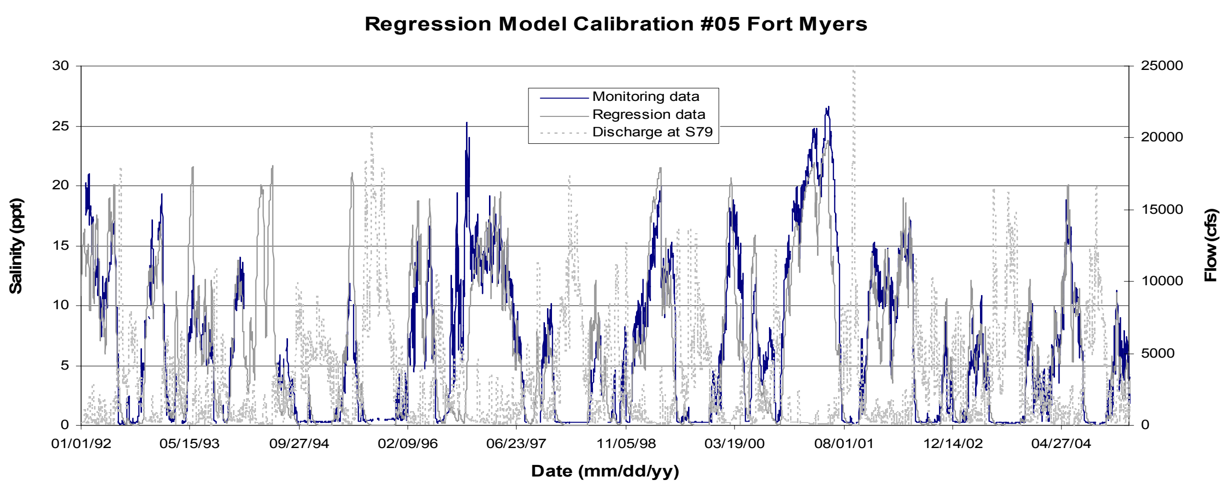

Figure 1. Regression Model's Salinity vs. Monitoring Salinity.

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