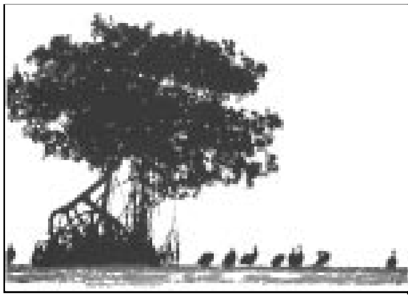
Program & Abstracts

1999 Florida Bay

and Adjacent Marine Systems Science Conference

November 1-5, 1999
Westin Beach Resort
Key Largo, FL



1999 Florida Bay
and Adjacent Marine Systems Science Conference

November 1– 5, 1999 • Westin Beach Resort
Key Largo, FL

Conference Organizing Committee

Robert J. Brock, Supervisory Marine Biologist, National Park Service, Everglades/ Dry Tortugas National Parks, Homestead, Florida

Dianne K. Berger, Sea Grant Extension Agent, University of Florida Sea Grant, Tavernier, Florida

Nancy Gladson Diersing, Sea Grant Extension Agent, University of Florida Sea Grant, Tavernier, Florida

William K. Nuttle, Executive Officer, Florida Bay Science Program, Key Largo, Florida

Beth Miller-Tipton, Director and ***Shelby Tatlock***, Conference Assistant, Office of Conferences and Institutes (OCI), University of Florida, Institute of Food and Agricultural Sciences, Gainesville, Florida

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Abstract Directory

Question 1. ***How and at what rates do storms, changing freshwater flows, sea level rise, and local evaporation/precipitation patterns influence circulation and salinity patterns within Florida Bay and outflows from the Bay to adjacent waters?***

Oral Abstracts 139
Poster Abstracts 161

Question 2. ***What is the relative importance of the advection of exogenous nutrients, internal nutrient cycling including exchange between water column and sedimentary nutrient sources, and nitrogen fixation in determining the nutrient budget for Florida Bay?***

Oral Abstracts 71
Poster Abstracts 95

Question 3. ***What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?***

Oral Abstracts 111
Poster Abstracts 127

Question 4. ***What are the causes and mechanisms for the observed changes in seagrass and the hardbottom community of Florida Bay? What is the effect of changing salinity, light and nutrient regimes on these communities?***

Oral Abstracts 1
Poster Abstracts 19

Question 5. ***What is the relationship between environmental change, habitat change and the recruitment, growth, and survivorship of higher trophic level species?***

Oral Abstracts 39
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Paleoecology of Florida Bay

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Adjacent Marine Systems and Linkages to Florida Bay

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Conference History and Organization

The Florida Bay Science Conference provides an opportunity annually for researchers to exchange technical information, share that information with resource managers and other interested conference attendees, and establish collaborative partnerships. This year's conference allows investigators from more than 90 research and monitoring projects the opportunity to highlight their findings in platform and poster presentations.

As in past conferences, the sessions are organized around the five major questions that are recognized as central to understanding the problems affecting Florida Bay. This year's conference reflects a broadening in the scope by including a full day session devoted to research on adjacent coastal systems. Posters are organized similarly, except for an additional category devoted to paleoecology. In addition, a special synthesis session of invited presentations is scheduled for Thursday afternoon when scientists and regional resource managers will review research results in light of information needed for ecosystem restoration.

The Florida Sea Grant College Program organized the first Florida Bay Science Conference in 1995, and continues to assist the PMC in conference organization and dissemination of scientific results. Florida Sea Grant is a statewide, university-based program that not only conducts coastal research and education, but also communicates scientific information through its extension activity.

Conference Objectives

The objectives of the Florida Bay and Adjacent Marine Systems Science Conference are to:

- *Synthesize results of research and model simulations*
- *Introduce ecological performance measures applied to restoration*
- *Highlight linkages between adjacent marine systems*

Regional Context

Florida Bay is one component of the marine and coastal ecosystems of South Florida. Waters from the Gulf of Mexico and southwestern coastal Everglades influence the Western Bay, the Northern Bay receives the drainage from much of the adjacent mainland marsh, and the Eastern Bay abuts the populated Florida Keys. Bay water, in turn, flows through the Florida Keys channels out to the reef tract and northward via Hawk Channel into Biscayne Bay. The connectivity of these waters is obvious. Collaboration among federal and state agencies that share management responsibilities for these waters is required to effectively collect data and build the tools essential for guiding restoration of the regional ecosystem.

Poster Session Information

A formal Poster Session and Reception is scheduled in the main ballroom from 6:00pm – 9:30pm on Wednesday, November 3. The Poster Session Room will be open to set up poster displays from 2:00pm-3:00pm that afternoon. Posters will be available for general viewing from 3:00pm-6:00pm, and presenters must be stationed at their posters during the formal session from 6:00pm-9:30pm. **Poster displays MUST be set up by 3:00pm on Wednesday and be removed immediately following the Poster Session which concludes at 9:30pm.** The conference is not responsible for the loss of or damage to poster displays not taken down by 9:30pm at which time an independent vendor will dismantle and remove the boards.

Discussion Periods

As one of the primary purposes of the Florida Bay Science Conference is to promote the free exchange of technical information by researchers, discussion periods are scheduled at the end of each topical session to allow for questions and comments and to promote synthesis across results among projects. Oral presenters, along with their co-authors, will be asked to assemble at the front of the room following each session to field questions and participate in the discussion period.

Abstract Book Organization

Abstracts are organized according to the program agenda, which is divided by Question Number. Oral abstracts are listed in presentation order according to the agenda, followed by poster abstracts which are in alphabetical order by the presenting author's last name, which appears in bold.

This publication will also be available online after the conference at the following web site: <http://www.aoml.noaa.gov/flbay/abstracts.html>. Abstracts from all previous Florida Bay Science Conferences are also available through this site. For information about the Florida Bay Web Site, please contact DawnMarie Welcher at NOAA/AOML/OCD, 4301 Rickenbacker Causeway, Miami, FL 33149. PH: (305) 361-4388, FAX: (305) 361-4392, E-Mail: <welcher@aoml.noaa.gov>.

For more information about the science program in Florida Bay and Adjacent Marine Systems, contact Bill Nuttle at Everglades National Park, Florida Bay Interagency Science Center, 98630 Overseas Highway, Key Largo, FL 33037. PH 305-852-0320; FAX: 305-852-0325; E-mail: <nuttlew@fiu.edu>.

Additional information on marine science and restoration can be obtained by contacting Florida Sea Grant, Florida Bay Education Office, 93911 Overseas Highway, Tavernier, FL 33070. PH 305-853-3592; FAX 305-853-3595; E-mail: <ndiersing@gnv.ifas.ufl.edu>.

Program Management Committee (PMC)

The Program Management Committee was formed in 1994 to assure that the many individually funded scientific projects in Florida Bay were integrated into a comprehensive program addressing key issues. The scope and membership of the PMC expanded in 1998 to include consideration of research in adjacent marine systems. The PMC consists of scientific program managers from:

- **Dade County Department of Environmental Resources Management**
- **Florida Department of Environmental Protection**
  - *Rookery Bay National Estuarine Research Reserve*
- **Florida Fish and Wildlife Conservation Commission**
  - *Florida Marine Research Institute*[*]
- **National Oceanic and Atmospheric Administration**
  - *Florida Keys National Marine Sanctuary*
  - *National Marine Fisheries Service*
  - *Office of Oceanic and Atmospheric Research*
- **National Park Service**
  - *Biscayne National Park*
  - *Everglades National Park*[*]
- **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**
  - *Biological Resources Division*
  - *Geologic Division*
  - *Water Resources Division*

([*]Current PMC Co-Chairs)

Primary Functions of the PMC

(a) Develop and implement a research strategy designed to merge scientific understanding of the Bay with management's decision making processes;

(b) Facilitate a consensus-based process for determining science needs and priorities;

(c) Promote funding of critical science needs;

(d) Develop and maintain an open and scientifically sound review process for evaluating research results and for advancing the program; and

(e) Communicate research results and program progress to management as well as the scientific and public community.

Scientific Oversight Panel

Dr. William C. Boicourt, University of Maryland, Horn Point Laboratory, Center for Environmental Science, Cambridge, Maryland
- Dr. Boicourt is Professor of Physical Oceanography and specializes in physical oceanographic processes including circulation of the continental shelf and estuaries.

Dr. Linda A. Deegan, The Ecosystem Center, Marine Biological Laboratory, Woods Hole, Massachusetts
- Dr. Deegan is an Associate Scientist at the Marine Biological Laboratory (MBL). Her research has focused on fish community ecology, fisheries and coastal ecosystem-watershed relationships.

Dr. Kenneth L. Heck, Dauphin Island Sea Laboratory, University of South Alabama Dauphin Island, Alabama
- Dr. Heck is Professor of Marine Sciences and is a Marine Ecologist specializing in the study of seagrass ecosystems along the Atlantic and Gulf coasts of the United States.

***Dr. John E. Hobbie* (Chair)**, The Ecosystem Center, Marine Biological Laboratory, Woods Hole, Massachusetts
- Dr. Hobbie is a Co-Director of The Ecosystems Center and is a Coastal Microbial Ecologist specializing in biogeochemical cycles of large coastal and wetlands systems.

Dr. Steven C. McCutcheon, Hydrologic and Environmental Engineering, Athens, Georgia
- A member of the 1996 Bay Circulation and Water Quality Modeling Workshops and Co-Chair of the Model Evaluation Group. Dr. McCutcheon is a specialist in water quality issues, hydrodynamic modeling, sediment transport and hazardous waste management.

Dr. John D. Milliman, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia
- Dr. Milliman is a Marine Geologist and formerly a Senior Scientist at the Woods Hole Oceanographic Institution. Dr. Milliman's research interests include marine carbonates and river fluxes to the oceans at local, regional and global scales.

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

Program Agenda

Monday, November 1, 1999

am

11:00 **Registration Opens**

pm

1:00-1:20 **Opening Remarks by the PMC.**

Question 4. ***What are the causes and mechanisms for the observed changes in seagrass and the hardbottom community of Florida Bay? What is the effect of changing salinity, light and nutrient regimes on these communities?***

1:20-1:25 **Introduction to Seagrass Research. *Michael B. Robblee***, PMC Member, U.S. Geological Survey, Biological Resources Division, Miami, FL

1:25-1:45 **Recent Changes in Florida Bay Seagrass Community Structure: Scale Matters. *Michael Durako***, *Jill Paxson* and *John Hackney*, The University of North Carolina at Wilmington, Center for Marine Science Research, Wilmington, NC; *Margaret Hall* and *Manuel Merello*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

1:45-2:05 **Seagrass Dieoff in Florida Bay 1989-1999: Decadal Trends in Abundance and Growth of *Thalassia testudinum*. *Joseph C. Zieman,*** Dept. of Environmental Sciences, University of Virginia, Charlottesville VA; *James Fourqurean*, Southeast Research Program, Florida International University, Miami FL; *Thomas Frankovich*, Dept. of Environmental Sciences, University of Virginia, Charlottesville VA.

2:05-2:25 **The Statistical Relationship between Benthic Habitats and Water Quality in Florida Bay: An Ecologically Relevant Performance Measure for Responding to the USACOE Restudy. *James W. Fourqurean*** and *Joseph N. Boyer*, Florida International University, Miami, FL; *Michael J. Durako*, University of North Carolina at Wilmington, Wilmington, NC.

2:25-2:50 **A Conceptual Model of Florida Bay Seagrass Mortality (1987-1991): Links Between Climate, Circulation, and Sediment Toxicity. *Paul Carlson***, *Laura Yarbro* and *Tim Barber*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL; *Dewitt Smith*, Everglades National Park, FL.

2:50-3:10 **Seagrass Disease and Mortality in Florida Bay: Understanding the Role of *Labyrinthula*. *B. A. Blakesley***, *J. H. Landsberg, M. O. Hall, S. E. Lukas, B. B. Ackerman, M. W. White, J. Hyniova* and *P. J. Reichert*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

3:10-3:35 **Refreshment Break**

<u>Monday, November 1, 1999</u> *(continued)*

3:35-3:55 **Effect of Fluctuating Salinity on SAV in Experimental Tanks. 2. Mesocosm Experiments and Preliminary Results.** ***Tom C. Chesnes***, *Clay L. Montague*, *Christos C. Anastasiou*, and *Bridget L. Coolican*, University of Florida, Department of Environmental Engineering Sciences, Gainesville, FL.

3:55-4:15 **Sulfide Effects on *Thalassia testudinum* Carbon Balance and Adenylate Energy Charge.** ***James M. Erskine*** and *Marguerite S. Koch*, Aquatic Plant Ecology Laboratory, Biological Sciences Department, Florida Atlantic University, Boca Raton, FL.

4:15-4:35 **Sulfide as a Phytotoxin to the Tropical Seagrass, *Thalassia testudinum:* Interactions with High Salinity and Temperature.** ***Marguerite S. Koch***, *James M. Erskine* and *Santiago F. Perez*, Aquatic Plant Ecology Lab, Florida Atlantic University, Boca Raton, FL.

4:35-5:15 **Panel Question and Answer Session**

6:00-9:00 **Welcome Reception** *(Poolside)*

<u>Tuesday, November 2, 1999</u>

am

7:00-8:00 **Morning refreshments**

<u>Question 5</u>. What is the relationship between environmental change, habitat change and the recruitment, growth, and survivorship of higher trophic level species?

8:00-8:15 **Introduction to Higher Trophic Research.** ***Nancy B. Thompson***, PMC Member, NOAA, National Marine Fisheries Service, Miami, FL.

8:15-8:35 **Pink Shrimp Recruitment Dynamics as an Ecological Performance Measure for Evaluating Water Management Effects on Florida Bay.** ***Joan A. Browder***, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; *Nelson M. Ehrhardt*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.

8:35-8:55 **Salinity Changes and Model Predictions: Will Spiny Lobster Tolerate Our Environmental Monkey-Business?** ***Mark J. Butler,*** Old Dominion University, Norfolk, VA.

8:55-9:15 **Responses of Benthic Fauna to Salinity Shifts in Florida Bay: Evidence from a More Robust Sample of the Molluscan Community.** ***William G. Lyons,*** Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

Tuesday, November 2, 1999 *(continued)*

9:15-9:35	**Past and Present Trophic Structure of Florida Bay: Stable Isotope Analyses.** *Jeffrey P. Chanton*, ***L. S. Chasar*** and *T. Petrosky*, Department of Oceanography, Florida State University, Tallahassee, FL; *Christopher Koenig*, *Felicia Coleman*, *A. Prasad* and *T. Bevis*, Department of Biology, Florida State University, Tallahassee, FL.
9:35-9:55	**Fish Recruitment, Composition, Growth, and Habitat Use in Florida Bay.** *Gordon W. Thayer*, *Allyn B. Powell*, ***Lawrence R. Settle*** and *Donald E. Hoss*, NOAA, Beaufort Laboratory, Beaufort, NC; *Mark Wuenschel*, State Universty of New York, Syracuse, NY.
9:55-10:15	**Refreshment Break**
10:15-10:35	**Link between Offshore Larval Supply and Recruitment into Florida Bay.** ***W. J. Richards,*** NOAA Fisheries, Miami, FL; *M. M. Criales*, *C. Yeung*, *D. Jones*, *T. Jackson* and *M. Lara*, RSMAS, University of Miami, Miami, FL.
10:35-10:55	**Nesting Patterns of Roseate Spoonbills in Florida Bay 1950-1999: Implications of Landscape Scale Anthropogenic Impacts.** ***Jerome J. Lorenz***, National Audubon Society, Tavernier, FL; *John C. Ogden*, South Florida Water Management District, West Palm Beach, FL; *Robin D. Bjork*, Oregon State University, Corvallis, OR; *George V. N. Powell*, Monteverde, Puntarenas, Costa Rica.
10:55-11:15	**Evaluation of Ecological Response to Salinity Variation in Florida Bay.** ***Darlene Johnson***, Florida International University and National Marine Fisheries Service; *James Colvocoresses* and *William B. Lyons*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Peterburg, FL.
11:15-11:35	**A Meta-Analysis Approach to Performance Measure Development.** *J. A. Browder*, ***A. M. Eklund***, *D. Johnson*, *D. Harper* and *D. McClellan*, NOAA Fisheries, Southeast Fisheries Science Center, Miami, FL; *T. Schmidt*, National Park Service, Everglades National Park, Homestead, FL; *J. Colvocoresses* and *R. E. Matheson*, Florida Marine Research Institute, St. Petersburg, FL; *S. Sogard*, NOAA Fisheries, Hatfield Marine Science Center, Newport, OR; *G. Thayer* and *A. Powell*, NOAA Fisheries, Southeast Fisheries Science Center, Beaufort, NC.
11:35-12:00	**Panel Question and Answer Session**
12:00-1:30	**Lunch on Own**

Tuesday, November 2, 1999 *(continued)*

Question 2. ***What is the relative importance of the advection of exogenous nutrients, internal nutrient cycling including exchange between water column and sedimentary nutrient sources, and nitrogen fixation in determining the nutrient budget for Florida Bay?***

pm

1:30-1:35 **Introduction to Nutrient Exchange Research.** ***David T. Rudnick***, PMC Member, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL.

1:35-1:50 **Spatial Structure of Water Properties in Florida Bay.** ***George A. Jackson*** and *Adrian B. Burd*, Department of Oceanography, Texas A&M University, College Station, TX.

1:50-2:05 **The Carbonate and Nutrient Systems in Florida Bay.** ***Frank J. Millero***, *Xiaorong Zhu* and *William Hiscock*, University of Miami, RSMAS, MAC, Miami, FL.

2:05-2:20 **Phosphate Distribution Coefficients for Suspended Sediments in Florida Bay.** ***Jia-Zhong Zhang***, *Charles Fischer* and *Chris Kelble*, NOAA/AOML/OCD, Miami, FL; *Frank Millero*, RSMAS, University of Miami, Miami, FL.

2:20-2:35 **Nutrient Bioassays and the Redfield Ratio in Florida Bay.** ***Larry Brand*** and *Maiko Suzuki*, University of Miami, RSMAS, Miami, FL.

2:35-2:50 **Nutrient Cycling and Transport in the Florida Bay - Everglades Ecotone.** ***David Rudnick***, *Christopher Madden*, *Fred Sklar*, *Stephen Kelly*, *Chelsea Donovan*, *Karl Picard*, *Jason McCauliffe* and *Michael Korvela*, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL; *Enrique Reyes*, *Jaye Cable*, *John Day*, *Martha Sutula*, *Carlos Coronado-Molina*, *Brian Perez* and *Robert Lane*, Coastal Ecology Institute, Louisiana State University, Baton Rouge, LA; *Daniel Childers*, *Stephen E. Davis* and *Damon Rondeau*, Southeastern Environmental Research Center, Florida International University, Miami, FL; *Marguerite Koch* and *Robert Benz*, Department of Biology, Florida Atlantic University, Boca Raton, FL; *Jeffrey Cornwell* and *Michael Owens*, Horn Point Environmental Laboratory, University of Maryland, Cambridge, MD.

2:50-3:05 **The Influence of Southern Everglades Wetlands on Nutrient Inputs to Florida Bay.** ***Daniel Childers***, *Stephen E. Davis*, *Frank Parker* and *Damon Rondeau*, Southeastern Environmental Research Center, Florida International University, Miami, FL.; *David Rudnick*, *Christopher Madden* and *Fred Sklar*, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL; *Carlos Coronado-Molina*, Coastal Ecology Institute, Louisiana State University, Baton Rouge, LA.

Tuesday, November 2, 1999 *(continued)*

3:05-3:35 **Refreshment Break**

3:35-3:50 **Molecular Markers of Organic Matter Inputs and Transformations in Estuarine Environments of South Florida: Shark River and Taylor Slough.** ***Rudolf Jaffé***, *Maria Hernandez, Maria do Carmo Peralba* and *Ralph Mead*, Florida International University, Miami, FL.

3:50-4:05 **Atmospheric Deposition of Nitrogen and Phosphorous to the South Florida Bay Ecosystems.** ***P. Y. Whung***, ARL/NOAA, Silver Spring, MD; *C. Fischer*, AOML/MOAA, Miami, Florida; *T. Meyers*, ATDD/NOAA, Oak Ridge, TN.

4:05-4:20 **Trace Element Distribution in Florida Bay: Atmospheric or Hydrologic Deposition?** ***E. A. Shinn*** and *C. D. Reich*, USGS, St. Petersburg, FL.

4:20-4:35 **Eutrophication Model of Florida Bay.** ***Carl F. Cerco***, *Mark Dortch*, *Barry Bunch* and *Alan Teeter*, US Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS.

4:35-4:50 **Elevated Mercury Concentrations in Fish from Eastern Florida Bay.** ***David W. Evans*** and *Peter H. Crumley*, NOAA/Center for Coastal Fisheries Habitat Research, Beaufort Laboratory, NC.

4:50-5:30 **Panel Question and Answer Session**

6:00-7:00 **Networking Social** *(on the Beach)*

Wednesday, November 3, 1999

am

7:00-8:00 **Morning Refreshments**

Question 3. ***What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?***

8:00-8:20 **Introduction to Plankton Research.** ***John Hunt***, PMC Member, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Marathon, FL.

8:20-8:40 **Remote Sensing of Phytoplankton Dynamics in Florida Bay Using Hyperspectral Imaging Sensor (AVIRIS) Data.** ***Laurie L. Richardson***, Florida International University, Miami, Florida; *Fred A. Kruse*, Analytical Imaging and Geophysics, LLC, Boulder, CO; *Paul V. Zimba*, USDA-ARC, Stonesville, MS.

8:40-9:00 **Seasonal Variations in Diatom Growth and Distribution in Western Florida Bay and the West Florida Shelf.** ***Jennifer L. Jurado*** and *Gary L. Hitchcock*, RSMAS, University of Miami, Miami, FL.

Wednesday, November 3, 1999 *(continued)*

9:00-9:20 **Estimates of Phytoplankton Growth, Production and Nutrient Requirements Based on a Drifter Tracked Water Parcel in Western Florida Bay, USA.** ***G. A. Vargo***, *M. B. Neely* and *L. Melahn*, University of South Florida, St. Petersburg, FL; *G. L. Hitchcock*, *J. Jurado* and *D. Mir*, RSMAS, University of Miami, Miami, FL.

9:20-9:40 **The Relationship between Inputs of Fresh Water to Florida Bay and Environmental Patterns of Physico-Chemistry, Light Climate and Primary Production.** ***Christopher J. Madden*** and *Stephen Kelly*, South Florida Water Management District, Everglades Systems Research Division; *Jason McAuliffe* and *Chelsea Donovan*, Florida Center for Environmental Studies, Key Largo, FL.

9:40-10:00 **Refreshment Break**

10:00-10:20 **Relationship of Sedimentary Sulfur, Iron and Phosphorus Cycling to Water Quality in Florida Bay: How Seagrass Die-Offs Contribute to Algal Blooms.** ***Randolph Chambers*** and *Lisa Millman*, Fairfield University, Fairfield, CT; *James Fourqurean*, SERP, Florida International University, Miami, FL.

10:20-10:40 **Differences in Microzooplankton-Phytoplankton Interactions in Florida Bay by Ecological Region.** ***Robert J. Brenner*** and *Michael J. Dagg*, Louisiana Universities Marine Consortium, Chauvin, LA.

10:40-11:00 **Modeling The Water Column Ecosystem in Florida Bay.** ***Adrian B. Burd*** and *George A. Jackson*, Department of Oceanography, Texas A&M University, College Station, TX.

11:00-11:20 **A Synoptic Study of the Short-term Variability in a Florida Bay Diatom Bloom, January, 1999: Biomass, Production, Growth, and Losses.** *Synoptic Study Team.*

11:20-11:40 **Panel Question and Answer**

11:40-2:00 **Lunch on Own**

pm

2:00-3:00 **Poster Presenters to Set-up Displays** *(Coral Reef Ballroom)*

3:00-6:00 **Posters Available for Viewing** ***(Poster Directory on Page xxi)***

6:00-9:30 **Formal Poster Session and Reception** *(Coral Reef Ballroom)*

Thursday, November 4, 1999

am

7:00-8:00 **Morning Refreshments**

Question 1. ***How and at what rates do storms, changing freshwater flows, sea level rise, and local evaporation/precipitation patterns influence circulation and salinity patterns within Florida Bay and outflows from the Bay to adjacent waters?***

8:00-8:10 **Introduction to Florida Bay Circulation Projects.** ***Peter B. Ortner***, PMC Member, NOAA, Atlantic Oceanographic and Meteorological Laboratory, Miami, FL.

8:10-8:30 **First Year Results from Enhanced Observations of Circulation and Exchange Processes in Western Florida Bay and Connecting Coastal Waters, including Effects of El Nino and Hurricane Georges.** ***Thomas N. Lee*** and *Elizabeth Williams*, RSMAS/University of Miami, Miami, FL; Elizabeth Johns and Doug Wilson, NOAA/AOML, Miami, FL.

8:30-8:50 **Tidal and Non-tidal Exchanges through Seven Mile Channel.** ***Ned P. Smith***, Harbor Branch, Oceanographic Institution, Fort Pierce, FL.

8:50-9:10 **A Two-Dimensional Physics Based Numerical Hydrodynamic and Salinity Model of Florida Bay.** ***Keu W. Kim,*** *Robert McAdory* and *Gary Brown*, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

9:10-9:30 **Responses of Salinity in Florida Bay to Changes in Freshwater Inputs and Bathymetry: Speculative Simulation Scenarios Using the FATHOM model.** ***Bernard J. Cosby***, University of Virginia, Charlottesville, VA; *William K. Nuttle* and *James W. Fourqurean*, Florida International University, Miami FL.

9:30-9:50 **An Estimate of Groundwater Flux in Florida Bay with Geochemical Tracers.** ***Zafer Top*** and *Larry Brand*, University of Miami, Miami, FL; *William Burnett*, *Jeffrey Chanton*, *Reide Corbett* and *Kevin Dillon*, Florida State University, Tallahassee, FL.

9:50-10:20 **Refreshment Break**

10:20-10:40 **An Evaluation of NEXRAD (WSR88D) Data as a Measure of Fresh Water Flux into the Florida Bay/Everglades System.** ***Paul T. Willis***, NOAA/AOML/CIMAS, Miami, FL.

10:40-11:00 **Simulations of Anthropogenically Generated Microclimates over the Florida Peninsula and their Impact on the Florida Bay Water Cycle.** ***Craig A. Mattocks***, University of Miami/CIMAS, NOAA-AOML/Hurricane Research Division, Miami, FL; *Paul Trimble*, *Matthew Hinton*, *Beheen Trimble* and *Marie Pietrucha*, South Florida Water Management District, West Palm Beach, FL.

Thursday, November 4, 1999 *(continued)*

11:00-11:20 **Reconstructing the Salinity History of Florida Bay Using Ostracode Shell Chemistry.** ***Gary S. Dwyer***, Division of Earth and Ocean Sciences, Duke University, Durham, NC; *Thomas M. Cronin*, US Geological Survey, Reston, VA.

11:20-12:00 **Panel Question and Answer Session**

12:00-1:30 **Lunch on Own**

Special Session*. *What Do We Know Now and What Do We Need to Know for Restoration?
(No abstracts were solicited for these presentations.)

Objective: This special session at the Florida Bay Science Conference invites resource managers to identify what we need to know about Florida Bay for ecosystem restoration to proceed and be successful. At the same time, scientists will describe what we now know about conditions in Florida Bay that help define ecosystem restoration goals.

Moderator: ***Tom Armentano***, National Park Service, Everglades National Park

pm

1:30-1:35 **Introduction to Synthesis in Florida Bay**
Tom Armentano, co-chair of the Florida Bay PMC

1:35-1:50 **What Do We Need to Know? — State/Regional Perspective**
Mike Collins, Chair of the South Florida Water Management District Governing Board

1:50-2:05 **What Do We Need to Know? — Federal Perspective**
To be determined

2:05-2:20 **Existing Framework for Incorporating Science into Restoration Planning**
John Ogden and ***David Rudnick***, South Florida Water Management District

2:20-2:35 **Results from Paleoecological Studies**
Ellen Prager, Consultant and Freelance Writer

2:35-2:50 **Sources of Salinity Variation and Forecasting Changes in the Bay**
Tom Lee, University of Miami

2:50-3:20 **Ecological Response to Salinity Variation**
Joan Browder, National Marine Fisheries Service and ***Bill Krucyinski***, US Environmental Protection Agency (invited)

3:20-3:50 **Refreshment Break**

3:50-4:00 **Ecological Objectives and Performance Measures for Restoration**
John Hunt, co-chair Florida Bay PMC

Thursday, November 4, 1999 *(continued)*

4:00-5:30 **Panel Discussion: Setting a Direction, What Can We Expect from Science?**

Resource managers and scientists will be asked to define questions that will be the focus of the research program in the next few years. Speakers preceding this discussion will be asked to submit a 3 to 5 bullet summary of their talks to begin the panel's discussions.

Panel Moderator: ***John Hobbie***, Chair, Science Oversight Panel

5:30 **Evening on Own**

Friday, November 5, 1999

am

7:00-8:00 **Morning Refreshments**

8:00-8:10 **Introduction to Research in Adjacent Marine Systems I. *Benjamin D. Haskell***, NOAA, Florida Keys National Marine Sanctuary, Marathon, FL.

8:10-8:30 **A Spatially-Intensive Assessment of the Multispecies Reef Fishery Resources in the Dry Tortugas Region. *Jerald S. Ault***, *Steven G. Smith*, *Jiangang Luo*, *Geoffrey A. Meester* and *Guillermo Diaz*, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *James A. Bohnsack* and *Peter Fischel*, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL; *Steven Miller* and *Dione Swanson*, National Undersea Research Center, Key Largo, FL.

8:30-8:50 **Initial Responses of Exploited Organisms to No-Take Protection Zones in the Florida Keys National Marine Sanctuary. *James A. Bohnsack***, *David B. McClellan*, *Douglas E. Harper*, *Peter Fischel*, *Anne Marie Eklund*, *Stephania K Bolden* and *Joaquin Javech*, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; Jerald S. Ault, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.

8:50-9:00 **Questions**

9:00-9:20 **Modeling the Southeast Florida Coastal Ecosystem - Hydrodynamic Transport, Salinity, and Trophodynamics. *John D. Wang***, *Jerald S. Ault*, *Brian K. Haus*, *Jiangang Luo* and *Javier Rivera*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.

9:20-9:30 **Questions**

9:30-9:55 **Refreshment Break**

Friday, November 5, 1999 *(continued)*

9:55-10:15	**Detection of Seagrass Cover and Water Clarity in Florida Bay and the Keys.** ***Richard P. Stumpf***, NOAA, National Ocean Service, Silver Spring MD; *Michael J. Durako*, University of North Carolina at Wilmington, Wilmington NC; *James W. Fourqurean*, Florida International University, Miami FL; *Varis Ransibrahmanakul*, TPMC, Silver Spring MD; *Megan L. Frayer*, Florida Marine Research Institute, St. Petersburg, FL.
10:15-10:35	**The Relative Influence of Florida Bay on the Water Quality of the Florida Keys National Marine Sanctuary.** ***Joseph N. Boyer*** and *Ronald D. Jones*, Southeast Environmental Research Center, Florida International University, Miami, FL.
10:35-10:55	**Historical Changes in Mangrove, Seagrass and Calcareous Algal Communities in South Florida.** ***Harold R. Wanless***, Department of Geological Sciences, University of Miami, Coral Gables, FL; *Lenore P. Tedesco* and *Bob E. Hall*, Department of Geology, Indiana University, Purdue University at Indianapolis, Indianapolis, IN.
10:55-11:15	**The Origin of Variations in the Stable Oxygen, Hydrogen, and Carbon Isotopes of Waters in the Coastal Waters of South Florida.** ***Peter K. Swart*** and *Réne Price*, MGG/RSMAS, University of Miami, Miami, FL.
11:15-11:30	**Questions**
11:30-11:50	**An Environmental Information Synthesizer for Expert Systems.** ***James C. Hendee***, AOML/National Oceanic and Atmospheric Administration; Miami, FL.
11:50-12:00	**Questions**
12:00-1:30	**Lunch on Own**

pm

1:30-1:35	**Introduction to Research in Adjacent Systems II.** ***Susan Markely***, PMC Member, Miami-Dade Department of Environmental Resources Management, Miami, FL.
1:35-1:50	**Environmental History of Biscayne Bay.** ***A. Y. Cantillo***, NOAA/NOS/ National Centers for Coastal and Ocean Science, Center for Coastal Monitoring and Assessment, Silver Spring, MD; *K. Hale*, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *E. Collins*, NOAA/NESDIS/NOAA Central Library, Silver Spring, MD; *L. Pikula*, NOAA/NESDIS/Miami Regional Library, Miami, FL; *R. Caballero*, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL.
1:50-1:55	**Questions**

Friday, November 5, 1999 *(continued)*

1:55-2:10 **A Closer Look at the Tides of Biscayne Bay, Card Sound and Barnes Sound. *Ned P. Smith,*** Harbor Branch Oceanographic Institution, Fort Pierce, FL.

2:10-2:15 **Questions**

2:15-2:30 **Design-Based Sampling to Assess Fish and Macroinvertebrate Populations in Biscayne Bay and the Adjacent Coral Reef System. *Jerald S. Ault*,** *Steven G. Smith*, *Geoffrey Meester*, *Guillermo Diaz* and *Jiangang Luo*, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *James A. Bohnsack*, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL.

2:30-2:35 **Questions**

2:35-2:50 **Groundwater Discharge and Nutrient Loading to Biscayne Bay. *Michael Byrne*** and *John Meeder*, Southeast Environmental Research Center, Florida International University, Miami, FL.

2:50-2:55 **Questions**

2:55-3:10 **Tidal Creek Flux Studies, Biscayne National Park. *John Meeder*,** *Amy Renshaw* and *Michael Ross*, Southeast Environmental Research Center, Florida International University, Miami, FL.

3:10-3:30 **Refreshment Break**

3:30-3:45 **Influence of Freshwater Discharge and Ammonia Loading on Inshore Benthic Community Structure in Biscayne Bay. *John Meeder*,** *Braxton Davis*, *Jeff Absten* and *Joseph N. Boyer*, Southeast Environmental Research Center, Florida International University, Miami, FL.

3:45-3:50 **Questions**

3:50-4:05 **The L-31E Surface Water Rediversion Project: Coastal Wetland Ecosystems and Some Initial Treatment Results. *M. S. Ross*,** *J. F. Meeder*, *P. L. Ruiz*, *D. Reed* and *M. Lewin*, Florida International University, Southeast Environmental Research Center, Miami, FL; *R. Alleman*, South Florida Water Management District, West Palm Beach, FL.

4:05-4:10 **Questions**

4:10-4:25 **Juvenile Jewfish Distribution and Abundance in Altered and Unaltered Habitats of the Ten Thousand Islands of Southwest Florida. *Anne-Marie Eklund*,** National Marine Fisheries Service, Miami, FL; *Christopher C. Koenig*, *Felicia C. Coleman* and *Todd Bevis*, Florida State University, Tallahassee, FL; *Matt Finn*, University of Maryland, College Park, MD.

4:25-4:30 **Questions**

Friday, November 5, 1999 *(continued)*

4:30-4:45	**Multi-Taxon Analysis of the "White Zone," a Common Ecotonal Feature of South Florida Coastal Wetlands.** ***Evelyn Gaiser***, *Michael Ross*, *John Meeder* and *Matthew Lewin*, Southeast Environmental Research Center, Florida International University, Miami, FL.
4:45-4:50	**Questions**
4:50-5:05	**Seagrass Ecosystem Responses to Variable Hydrologic and Geographic Conditions: A Comparative Simulation Analysis of *Thalassia testudinum* in Florida Bay and the Caloosahatchee Estuary.** ***David F. Gruber***, Florida Center for Environmental Studies/South Florida Water Management District Key Largo, FL; *Christopher J. Madden*, South Florida Water Management District, West Palm Beach, FL; *W. Michael Kemp*, University of Maryland, Cambridge, MD.
5:05-5:10	**Questions**
5:10-5:25	**To be determined**
5:25-5:30	**Questions**
5:30	**Conference Concludes**

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Poster Directory

(Posters are listed in alphabetical order by presenting author's last name.)

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54 **Historical Salinity Effects on Microfauna in the Lower Everglades and Florida Bay.** ***Pat Blackwelder***, RSMAS, University of Miami, Miami, FL and Oceanographic Center, Nova Southeastern University, Dania, FL; *Terri Hood*, *Carlos Alvarez-Zarikian* and *Peter Swart*, RSMAS, University of Miami, Miami, FL; *Chuck Featherstone* and *Terry Nelsen*, AOML, NOAA, Miami, FL. ***(Pg. 181)***

20 **The Distribution of Benthic Chlorophyll in Florida Bay Sediments.** ***Larry E. Brand*** and *Maiko Suzuki*, University of Miami, RSMAS, Miami, FL. ***(Pg. 129)***

21 **Long Term Changes in Turbidity in Florida Bay.** ***Larry E. Brand***, University of Miami, RSMAS, Miami, Florida; *Thomas W. Schmidt*, South Florida Natural Resources Center, Everglades National Park, Homestead, FL. ***(Pg. 130)***

61 **Long-Term Florida Bay Salinity History: A Synthesis of Multi-Proxy Evidence from Sediment Cores.** ***Lynn Brewster-Wingard***, *Thomas Cronin*, *Bruce Wardlaw*, *Jeffery Stone* and *Sara Schwede*, US Geological Survey, Reston, VA; *Scott Ishman*, Southern Illinois University, Carbondale, IL; *Charles Holmes*, *Robert Halley* and *Marci Marot*, U. S. Geological Survey, Reston, VA; *Gary Dwyer* and *Jacqueline Huvane*, Duke University, Durham, NC. ***(Pg. 182)***

34 **Simulation Model of Pink Shrimp Recruitment Dynamics in Florida Bay: Studies to Support the Model.** ***Joan Browder***, National Marine Fisheries Service/NOAA, Miami, FL; *Maria Criales*, Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *Zoula Zein-Eldin*, National Marine Fisheries Service/NOAA, Galveston, TX; *Carlos Rivero*, GEOCORE, Rosenstiel School of Marine and Atmospheric Science, Miami, FL. ***(Pg. 61)***

35 **Trophic Structure in a Tropical Hard-Bottom Community: A Stable Isotope Analysis.** *Donald C. Behringer, Jr.* and ***Mark J. Butler IV***, Department of Biological Sciences, Old Dominion University, Norfolk, VA; *Sam C. Wainright*, Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ. ***(Pg. 62)***

28 **Determination of Arsenic in Seagrass in Florida Bay Using Inductively Coupled Plasma Mass Spectrometry and Its Relationship with Phosphorus.** ***Yong Cai,*** Florida International University, Department of Chemistry and Southeast Environmental Research Center, Miami, FL; *Myron Georgiadis*, Florida International University, Department of Chemistry, Miami, FL; *James Fourqurean*, Florida International University, Southeast Environmental Research Center and Department of Biological Sciences, Miami, FL. ***(Pg. 21)***

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39 **Update of Results of the Mussel Watch Project in South Florida and the Caribbean.** ***A. Y. Cantillo***, *G. G. Lauenstein*, *T. P. O'Connor* and *W. E. Johnson*, NOAA/NOS/National Centers for Coastal and Ocean Science, Center for Coastal Monitoring and Assessment, Silver Spring, MD. ***(Pg. 235)***

25 **Spatial and Temporal Patterns of Submerged Macrophyte Community Structure Found within Land-Margin Aquatic Habitats of Northern Florida Bay**. ***Evan Chipouras***, *Clay L. Montague*, *Linda M. Jones*, *Tom Chesnes* and *Casie J. Regan*, University of Florida, Gainesville, FL. ***(Pg. 24)***

29 **Turtlegrass (*Thalassia testudinum*) Mortality on Florida Bay Mudbanks.** ***Rebecca M. Conroy,*** Jitka Hyniova, *Paul R. Carlson, Jr.*, *Herman Arnold*, *Barbara A. Blakesley*, *Susan E. Lucas* and *Laura A. Yarbro*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL. ***(Pg. 26)***

9 **Nitrogen and Phosphorus Retranslocation in Mangrove Forests Located at the Everglades Salinty Transition Zone,** ***Coronado-Molina C.***, *J. W. Day Jr.*, *E. Reyes* and *B. Perez*, Department of Oceanography and Coastal Sciences, Coastal Ecology Institute, Louisiana State University; *S. Kelly*, The South Florida Water Management District, West Palm Beach, FL. ***(Pg. 97)***

62 **Historical Trends in Epiphytal Ostracodes from Florida Bay: Implications for Seagrass and Macro-benthic Algal Variability**. ***T. Cronin***, *L. Wingard*, *S. Ishman* and *H. Dowsett*, US Geological Survey, Reston, Virginia; *C. Holmes*, US Geological Survey, St. Petersburg, FL. ***(Pg. 184)***

45 **The Fate of Wastewater-Borne Nutrients in the Groundwaters of the Florida Keys**. ***Kevin Dillon***, *Reide Corbett*, *Jeff Chanton* and *Bill Burnett*, Department of Oceanography, Florida State University, Tallahassee, FL; *Lee Kump* and *Katherine Elliott*, Department of Geosciences, Pennsylvania State University, University Park, PA. ***(Pg. 236)***

48 **Seagrass Status and Trends Monitoring Program in the Florida Keys National Marine Sanctuary**. ***James W. Fourqurean***, *Bradley J. Peterson*, *Alan Willsie* and *Craig D. Rose*, Florida International University, Miami, FL; *Michael Durako*, University of North Carolina at Wilmington, Wilmington, NC; *Joseph Zieman*, University of Virginia, Charlottesville, VA. ***(Pg. 237)***

30 **Demographic Growth Characteristics of *Thalassia testudinum*: Leaf Morphology and Productivity**. ***Thomas A. Frankovich*** and *Joseph C. Zieman*, University of Virginia, Charlottesville, VA; *Micaiah Weatherly*, Florida International University, Miami, FL. ***(Pg. 29)***

16 **Distribution of Florida Bay Sediment Nutrients.** ***A. Gasc***, RSMAS/MBF, University of Miami, Miami, FL; *A. M. Szmant*, Dept. of Biological Sciences, University of North Carolina at Wilmington, Wilmington, NC. ***(Pg. 98)***

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27	**Allometric Relationships in *Thalassia testudinum*. *John Hackney*** and *Michael Durako*, University of North Carolina at Wilmington, Wilmington, NC. ***(Pg. 30)***
L-1	**Seagrass Change in Florida Bay from 1995 to 1999: Good News or Bad News? *Margaret O. Hall***, *Marit I. Alanen*, *Manuel F. Merello*, *Mary W. White* and *Barbara A. Blakesley*, Florida Marine Research Institute, St. Petersburg, FL; *Michael J. Durako*, University of North Carolina at Wilmington, Wilmington, NC. ***(Pg. 31)***
1	**Modern and Historical Bathymetry of Florida Bay. *Mark Hansen*** and *Nancy T. DeWitt*, USGS, St. Petersburg, FL. ***(Pg. 163)***
5	**Freshwater Flows into Northeastern Florida Bay.** *Eduardo Patino*, ***Clinton Hittle*** and *Mark Zucker*, US Geological Survey, Miami, FL. ***(Pg. 164)***
2	**Buttonwood Embankment: The Historical Perspective on Its Role in Northeastern Florida Bay Hydrology. *Charles W. Holmes*** and *M. E. Marot*, USGS. St. Petersburg, FL; *Debra Willard*, *Lynn Brewster-Wingard* and *Lisa Wiemer*, USGS. Reston, VA. ***(Pg. 166)***
46	**SEAKEYS 1999: Florida Keys Monitoring Initiative. *J. C. Humphrey,*** *S. Vargo* and *J. C. Ogden*, Florida Institute of Oceanography, St. Petersburg, FL; *F. J. Hendee*, AOML/National Oceanic and Atmospheric Administration, Miami, FL. ***(Pg. 240)***
60	**Diatoms as Indicators of Environmental Change in Florida Bay. *Jacqueline K. Huvane*** and *S. R. Cooper*, Duke University Wetland Center, Durham, NC. ***(Pg. 186)***
3	**Surface Salinity Variability of Florida Bay and Southwest Florida Coastal Waters. *Elizabeth Johns*** and *W. Douglas Wilson*, National Oceanic and Atmospheric Administration, Atlantic Oceanographic and Meteorological Laboratory, Miami, FL; *Thomas N. Lee*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL. ***(Pg. 169)***
47	**Florida Bay Watch: Results of Four Years of Nearshore Water-Quality Monitoring in the Florida Keys**, ***Brian D. Keller***, The Nature Conservancy, Marathon, FL. ***(Pg. 242)***
23	**Zooplankton Production in Florida Bay: Nutritional Constraints on Egg Production. *G. S. Kleppel*** and *S. E. Hazzard*, University of South Carolina, Columbia, SC. ***(Pg. 131)***
11	**Periphyton and Sediment Bioassessment in North Florida Bay. *Michael Lewis,*** *David Weber* and *Roman Stanley*, USEPA/GED, Gulf Breeze, FL. ***(Pg. 99)***

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19 **Photosynthetic Pigment-Based Chemotaxonomy as Applied to Florida Bay Phytoplankton, Water, Macrophytes, Microphytobenthos and Sediments.** ***J. William Louda***, *Joseph W. Loitz*, and *Earl W. Baker*, Florida Atlantic University, Boca Raton, FL; *David T. Rudnick*, South Florida Water Management District, West Palm Beach, FL. ***(Pg. 133)***

12 **Contaminants in Fish Tissues Collected from the Lower C-111 Canal and Selected Tributaries in Northeastern Florida Bay.** ***John Macauley*** and *Larry Goodman*, USEPA/ GED, Gulf Breeze, FL. ***(Pg. 100)***

31 **The Long-Term Effects of Overgrazing of a Seagrass Bed by a Front of Sea Urchins, *Lytechinus variegatus*, in Western Florida Bay.** ***Silvia Maciá*** and *Diego Lirman*, Center for Marine and Environmental Analyses, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL. ***(Pg. 33)***

6 **Refinement of Salinity Transfer Functions for Florida Bay to Assess C-111 Structural and Operational Modifications.** ***Frank E. Marshall III***, Cetacean Logic Foundation, Inc., New Smyrna Beach, FL. ***(Pg. 172)***

32 **Comparison of Grid Interpolation Methods for Mapping Seagrass (*Thalassia testudinum*) in Florida Bay.** ***Manuel Merello***, *Paul Carlson* and *Kevin Madley*, Florida Marine Research Institute, St. Petersburg, FL. ***(Pg. 34)***

24 **Effect of Fluctuating Salinity on Submersed Vegetation in Experimental Tanks. 1. Background and Description of Facility for Producing Salinity Fluctuation.** ***Clay L. Montague***, *Christos C. Anastasiou*, *Tom Chesnes* and *Bridget Coolican*, University of Florida, Department of Environmental Engineering Sciences, Gainesville, FL. ***(Pg. 35)***

36 **The Effects of Primary Productivity and Environmental Stress on Food Chain Length in Florida Bay.** ***Patricia Mumford*** and *James Fourqurean*, Department of Biological Sciences/SERP, Florida International University, Miami, FL; *Michael Robblee*, USGS/Biological Resources Division, South Florida/Caribbean Field Lab, Miami, FL; *Brian Fry*, Coastal Ecology Institute, Louisiana State University, Baton Rouge, LA. ***(Pg. 67)***

43 **Comparative Studies of Seagrass and Epiphyte Communities in Florida Bay and Two Other South Florida Estuaries in Relation to Freshwater Inputs.** ***Laura Murray***, Florida Center for Environmental Studies, Key Largo, FL; *W. Michael Kemp*, University of Maryland, Cambridge, MD; *David F. Gruber*, Florida Center for Environmental Studies, Key Largo, FL. ***(Pg. 244)***

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55 **Understanding Long-Term Rainfall, Freshwater Flow and Salinity Patterns with Concomitant Responses of Benthic Microfauna, Stable Isotopes, and Pollen in Oyster and Florida Bays.** ***Terry A. Nelsen***, *Ginger Garte* and *Charles Featherstone*, NOAA/AOML/OCD, Miami, FL; *Patricia Blackwelder*, University of Miami, RSMAS, Miami, FL and NOVA Southeastern University, Dania, FL; *Terri Hood*, *Carlos Alvarez-Zarikian* and *Peter Swart*, University of Miami, RSMAS, Miami, FL; *Harold R. Wanless*, University of Miami, Coral Gables, FL; *Lenore Tedesco*, *C. Souch*, *J. Pachut* and *J. Arthur*, Indiana University/Purdue University Indianapolis, Indianapolis, IN. ***(Pg. 189)***

59 **Lignin Phenols in Sediments from Florida Bay as Indicators of Seagrass History.** ***William H. Orem***, *Harry E. Lerch* and *Anne L. Bates*, US Geological Survey, Reston, VA; *Charles W. Holmes* and *Marci Marot*, US Geological Survey, St. Petersburg, FL. ***(Pg. 191)***

8 **A Pump Test for Taylor Slough and Florida Bay Restoration.** ***Jose Otero***, *Dewey Worth*, and *Lisa Smith*, South Florida Water Management District, West Palm Beach, FL ***(Pg. 173)***

26 **Branching Frequency of *Thalassia testudinum* Banks Ex Konig as an Indicator of Growth Potential within Ten Basins of Florida Bay.** ***Jill C. Paxson*** and *Michael J. Durako*, The University of North Carolina at Wilmington, Center for Marine Science Research, Wilmington, NC. ***(Pg. 36)***

42 **Preliminary Data and Document Rescue of Material Relevant to the South Florida Ecosystem.** *A. Y. Cantillo*, NOAA/NOS/National Centers for Coastal and Ocean Science, Center for Coastal Monitoring and Assessment, Silver Spring, MD; ***L. Pikula***, NOAA/NESDIS/Miami Regional Library, Miami, FL.; *K. Hale*, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL. ***(Pg. 246)***

52 **Linking Ecotoxicity and Risk Management to Sustainable Restoration of South Florida Ecosystems – Summary of Workshop.** ***Gary M. Rand***, FIU/SERC, Miami, FL; *G. Scott*, NOAA, Charleston, SC; *M. A. Lewis*, USEPA, Gulf Breeze, FL; *G. Ronnie Best*, USGS-BRD, Miami, FL; *D. M. Axelrad*, DEP, Gainesville, FL; *T. Gross*, USGS-BRD, Gainesville, FL. ***(Pg. 247)***

10 **Nutrient Exchange between NE Florida Bay and a Mangrove Creek in the Southern Everglades.** *M. Sutula*, ***E. Reyes***, *J. W. Day* and *B. Perez*, Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA; *D. Childers*, Southeast Environmental Research Program, Florida International University, Miami, FL. ***(Pg. 101)***

22 **Salinity, Nutrient and Light Requirements and Nutrient Competition within Several Dominant Microalgal Taxa of Florida Bay.** ***Bill Richardson***, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL. ***(Pg. 136)***

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17 **Benthic Nutrient Fluxes near Florida Bay's Mangrove Ecotone.** ***David Rudnick*** and *Stephen Kelly*, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL; *Chelsea Donovan* and *Karl Picard*, Center for Environmental Studies, Florida Atlantic University, Boca Raton, FL; *Jeffrey Cornwell* and *Michael Owens*, Horn Point Environmental Laboratory, University of Maryland, Cambridge, MD. ***(Pg. 102)***

37 **Evaluation of Recent Trends (1985-1998) in the Recreational Fisheries of Florida Bay and Adjacent Waters: An Update.** ***Thomas W. Schmidt*** and *Gabriel A. Delgado*, South Florida Natural Resources Center, Everglades National Park, Homestead, FL. ***(Pg. 65)***

33 **The Use of Short-Shoot Demographic and Allometric Scaling Data to Estimate the Productivity of a *Syringodium filiforme* Meadow.** ***Arthur C. Schwarzschild***, University of Virginia, Charlottesville, VA; *W. Judson Kenworthy*, NOAA/NOS Beaufort Lab, Beaufort, NC. ***(Pg. 37)***

51 **The Effect of Salinity Stress on the Wound Healing Rate of *Plexaurella* Sp?, a Soft Coral from the Near Shore Waters of the Florida Keys.** ***Charles Shaffer*** and *Charles Bigger*, Florida International University, Miami, FL; *Christina Beck* and *Adam Shop*, Wittenberg University, Springfield, OH. ***(Pg. 250)***

7 **Sedimentation and Erosion in the Florida Bay Mangrove Transition Zone.** ***Fred Sklar*** and *Michael Korvela*, South Florida Water Management District, West Palm Beach, FL. ***(Pg. 174)***

49 **Physical Forcings and Vegetation Patterns Across Mangrove/Marsh Ecotones in Southwest Florida**. ***Thomas J. Smith III***, US Geological Survey, Biological Resources Division, Miami, FL. ***(Pg. 251)***

15 **Seasonal Changes in Nutrient Profiles at the Sediment-Water Interface at the Mangrove-Seagrass Ecotone in Northeastern Florida Bay.** ***Brett S. Solomon*** and *Marguerite S. Koch*, Aquatic Plant Ecology Lab, Florida Atlantic University, Boca Raton, FL. ***(Pg. 104)***

38 **The Recovery of Sponge Populations in Florida Bay and the Upper Keys Following a Widespread Sponge Mortality**. ***John M. Stevely*** and *Donald E. Sweat*, Florida Sea Grant College Program, Palmetto, FL. ***(Pg. 68)***

56 **The Signature of Hurricane Sedimentation in the Lower Everglades/Florida Bay Ecosystem: Recognition of Sedimentologic, Geochemical and Microfaunal Indicators.** ***L. P. Tedesco***, *C. Souch*, *J. Pachut* and *J. A. Arthur*, Department of Geology, IUPUI, Indianapolis, IN; *H. R. Wanless*, University of Miami, Coral Gables, FL; *P. Blackwelder*, University of Miami, RSMAS, Miami, FL and Nova Southeastern University, Dania, FL; *T. Hood* and *C. Alvarez-Zarikian*, University of Miami, RSMAS, Miami, FL; *J. Trefry*, *W. J.Kang* and *S. Metz*, Florida Institute of Technology, Melbourne, FL; *T .A. Nelsen*, NOAA/AOML/OCD, Miami, FL. ***(Pg. 194)***

Poster No.

44 **Modeling the Southeast Florida Coastal Ecosystem - Hydrodynamic Transport, Salinity, and Trophodynamics.** ***John D. Wang***, *Jerald S. Ault*, *Brian K. Haus*, *Jiangang Luo* and *Javier Rivera*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL. ***(Pg. 253)***

50 **Recruitment of Mangroves Following Catastrophic Disturbance by Hurricane Andrew.** ***Kevin R. T. Whelan***, AScI Corporation, Miami, Florida; *Thomas J. Smith III*, United States Geologic Survey- Biological Resources Division, Miami, FL. ***(Pg. 256)***

58 **Impact of Hydrologic Changes on the Everglades/Florida Bay Ecosystem: A Regional, Paleoecological Perspective.** ***Debra A. Willard,*** *G. Lynn Brewster-Wingard*, *Thomas M. Cronin* and *Scott E. Ishman*, US Geological Survey, Reston, VA; *Charles W. Holmes*, USGS Center for Coastal and Marine Geology, St. Petersburg, FL. ***(Pg. 196)***

4 **Interaction of Freshwater Riverine Discharges from the Everglades with the Gulf of Mexico and Florida Bay: Preliminary Results from a Moored Array and Shipboard Surveys.** ***W. Douglas Wilson,*** *Elizabeth Johns* and *Ryan Smith*, Atlantic Oceanographic and Meteorological Laboratory, National Oceanic and Atmospheric Administration, Miami, FL; *Thomas N. Lee* and *Elizabeth Williams*, Rosenstiel School for Marine and Atmospheric Science, University of Miami, Miami, FL. ***(Pg. 175)***

13 **Nutrient Flux at the Sediment-Water Interface in Florida Bay.** ***Laura A. Yarbro*** and *Paul R. Carlson*, FWCC Florida Marine Research Institute, St. Petersburg, FL. ***(Pg. 106)***

14 **Geochemical Measurements of Carbonate Sedimentation and Organic Productivity in Florida Bay: A Potential Measure of Restoration Progress.** ***Kimberly Yates*** and *Robert* H*alley*, US Geological Survey, Center for Coastal Geology, St. Petersburg, FL. ***(Pg. 109)***

57 **A Century of Hydrological Variability in the Lower Everglades National Park as Interpreted from Stable Isotopes on Ostracods and Foraminifers.** ***Carlos A. Alvarez Zarikian***, *Pat L. Blackwelder* and *Terri Hood*, University of Miami-RSMAS, Miami, FL; *Terri Nelsen* and *Charles Featherstone*, NOAA-AOML, Miami, FL. ***(Pg. 198)***

Oral Abstracts

Monday, November 1, 1999

1:00pm-5:15pm

QUESTION 4

Monday, November 1, 1999

pm

1:00-1:20 **Opening Remarks by the PMC.**

Question 4. ***What are the causes and mechanisms for the observed changes in seagrass and the hardbottom community of Florida Bay? What is the effect of changing salinity, light and nutrient regimes on these communities?***

1:20-1:25 **Introduction to Seagrass Research.** ***Michael B. Robblee***, PMC Member, U.S. Geological Survey, Biological Resources Division, Miami, FL

1:25-1:45 **Recent Changes in Florida Bay Seagrass Community Structure: Scale Matters.** ***Michael Durako***, *Jill Paxson* and *John Hackney*, The University of North Carolina at Wilmington, Center for Marine Science Research, Wilmington, NC; *Margaret Hall* and *Manuel Merello*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

1:45-2:05 **Seagrass Dieoff in Florida Bay 1989-1999: Decadal Trends in Abundance and Growth of *Thalassia testudinum*. *Joseph C. Zieman*,** Dept. of Environmental Sciences, University of Virginia, Charlottesville VA; *James Fourqurean*, Southeast Research Program, Florida International University, Miami FL; *Thomas Frankovich*, Dept. of Environmental Sciences, University of Virginia, Charlottesville VA.

2:05-2:25 **The Statistical Relationship between Benthic Habitats and Water Quality in Florida Bay: An Ecologically Relevant Performance Measure for Responding to the USACOE Restudy.** ***James W. Fourqurean*** and *Joseph N. Boyer*, Florida International University, Miami, FL; *Michael J. Durako*, University of North Carolina at Wilmington, Wilmington, NC.

2:25-2:50 **A Conceptual Model of Florida Bay Seagrass Mortality (1987-1991): Links Between Climate, Circulation, and Sediment Toxicity.** ***Paul Carlson***, *Laura Yarbro* and *Tim Barber*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL; *Dewitt Smith*, Everglades National Park, FL.

2:50-3:10 **Seagrass Disease and Mortality in Florida Bay: Understanding the Role of *Labyrinthula*. *B. A. Blakesley***, *J. H. Landsberg*, *M. O. Hall*, *S. E. Lukas*, *B. B. Ackerman*, *M. W. White*, *J. Hyniova* and *P. J. Reichert*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

3:10-3:35 **Refreshment Break**

3:35-3:55 **Effect of Fluctuating Salinity on SAV in Experimental Tanks. 2. Mesocosm Experiments and Preliminary Results.** ***Tom C. Chesnes***, *Clay L. Montague*, *Christos C. Anastasiou*, and *Bridget L. Coolican*, University of Florida, Department of Environmental Engineering Sciences, Gainesville, FL.

<u>Monday, November 1, 1999</u> *(continued)*

3:55-4:15 **Sulfide Effects on *Thalassia testudinum* Carbon Balance and Adenylate Energy Charge.** ***James M. Erskine*** and *Marguerite S. Koch*, Aquatic Plant Ecology Laboratory, Biological Sciences Department, Florida Atlantic University, Boca Raton, FL.

4:15-4:35 **Sulfide as a Phytotoxin to the Tropical Seagrass, *Thalassia testudinum:* Interactions with High Salinity and Temperature.** ***Marguerite S. Koch***, *James M. Erskine* and *Santiago F. Perez,* Aquatic Plant Ecology Lab, Florida Atlantic University, Boca Raton, FL.

4:35-5:15 **Panel Question and Answer Session**

6:00-9:00 **Welcome Reception**

Recent Changes in Florida Bay Seagrass Community Structure: Scale Matters.

Michael Durako, *Jill Paxson*, and *John Hackney*, The University of North Carolina at Wilmington, Center for Marine Science Research, Wilmington, NC; *Margaret Hall* and *Manuel Merello*, Florida Marine Research Institute, St. Petersburg, FL.

Analyses of seagrass cover/abundance changes in ten basins within Florida Bay sampled by the Fish-Habitat Assessment Program (FHAP) since 1995 indicate that *Thalassia testudinum* (turtle grass) remains the dominant seagrass and that the abundance of this species has varied by only ± 6% of the mean at the bay scale. However, at the basin scale, abundance of *Thalassia* has varied by an average of ± 20% (range 6-39%). Thus, the relative stability of bay-scale *Thalassia* abundance, masks dramatic basin-scale declines along the western margin of the Bay which are partially offset by increases in abundance in central and eastern basins.

The abundance of *Halodule wrightii* (shoal grass) at the bay scale has doubled since 1995. In Johnson Key Basin (JKB), one of the chronically turbid regions in western Florida Bay, *Halodule* abundance has increased over 400% from 1995-1998. *Halodule* replaced *Thalassia* as the most abundant seagrass in JKB, in spring 1997. Seagrass species richness in JKB has also steadily increased. In 1995, only 3 species were observed in this basin [*Thalassia testudinum*, *Syringodium filiforme* (manatee grass), and *Halodule wrightii*], *Thalassia testudinum* was the dominant species, and most of the sites within the basin had only 1 or 2 species present. The small-bodied, low-light adapted species, *Halophila engelmanni* (star grass), was first observed during fall 1996 at one station in JKB. By spring 1998, *Halophila* was present at 15 of the 32 stations, most of the stations in the basin had 2-3 species, and stations with 3-4 species were common, reflecting the recruitment of *Halophila* and the spread of *Halodule* and *Syringodium*. Abundance of *Halophila* in JKB was observed to be much lower during fall 1998 FHAP sampling. The fall sampling was initiated nine days following the passage of Hurricane Georges over the Florida Keys. Many uprooted fragments of *Halophila* were observed in JKB during this sampling. The other seagrasses in Florida Bay seemed relatively unaffected by this storm, although loss of senescent leaves, reduction in epiphytes, and less leaf litter on the bottom were observed. During the spring 1999 sampling, small patches of *Halophila* were observed in Rankin Lake, Whipray Bay and Twin Key Basin, in addition to JKB. This rapid increase in spatial distribution suggests that the hurricane may have played a role in distributing propagules.

During spring 1995, an estimated 39% (107.1 km^2) of the area of the ten sampled basins was without *Halodule*. The zero-abundance area for *Halodule* has dropped by more than half over the last 3 years (95.3, 68.9, and 48.6 km^2 for 1995, 1996, 1997, and 1998, respectively) as the Bay-wide abundance has doubled, and this species is now present in all ten basins sampled by FHAP. In addition, fruits of *Halodule* were observed in Spring 1999 core samples from several basins for the first time, indicating that conditions in the Bay have become favorable for sexual reproduction in this species. In contrast, the estimated area of the Bay without *Thalassia* has exhibited a small, but steady increase over this time period (2.7, 2.9, 3,4, and 3,5 km^2 for 1995, 1996, 1997, and 1998, respectively). The recent losses of *Thalassia* have corresponded with areas where turbidity has been most severe (e.g., secchi depths <0.5 m) and persistent. Increases in the distribution and abundance of *Halodule* and the recent appearance and spread of *Halophila* in the turbid western Florida Bay basins, indicate a change to a shade-adapted seagrass community. The most recent losses of *Thalassia* may be primarily the result of light-stress induced mortality, although the *Thalassia* losses were often spatially co-incident with areas where the marine slime mold, *Labyrinthula*, a possible pathogen of *Thalassia*, was prevalent. Over the time period sampled by FHAP, we have seen the predominant seagrass community in the western basins of Florida Bay shift from monotypic *Thalassia*, to a more heterogeneous community with an increase in species diversity.

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Seagrass Dieoff in Florida Bay 1989-1999: Decadal Trends in Abundance and Growth of *Thalassia Testudinum*.

Joseph C. Zieman, Dept. of Environmental Sciences, University of Virginia, Charlottesville VA; *James Fourqurean*, Southeast Research Program, Florida International University, Miami FL; *Thomas Frankovich*, Dept. of Environmental Sciences, University of Virginia, Charlottesville VA.

Over a decade ago, 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. Initially the dieoff occurred only in stands of dense *T. testudinum*. The largest dieoff zones were in western Florida Bay, but with some dieoff in the denser beds of the eastern Bay. The abundance and productivity of *Thalassia testudinum* was measured at 5 stations associated with the seagrass dieoff and 3 control stations, including one on the seaside of Key Largo, outside of Florida Bay, from 1989 to 1995. During the initial decline salinity was very high, exceeding 46 psu, and regional oceanic temperatures were higher than normal in the late summer through late fall months. By 1991 salinities decreased to 29-38 psu. Temperature extremes were dampened but the patterning remained altered from long-term means. Seagrass standing crop and short shoot density declined at nearly all stations until 1994. Turnover rate was lower than the long-term Florida average during the years of high salinity, and progressively increased from 1989 to 1994. At this point the data show three distinct phases. The first is the initial dieoff phase (1987-1991) where standing crop and areal productivity were high but then declined as dieoff progressed. In this phase water clarity was good but became progressively worse. A second phase 1992-1997 where seagrasses continued to decline in response to deteriorated water quality. In 1998 a new phase seems to have begun with a begun with a significant upturn in both productivity and standing crop. This appears to be associated with progressively improving water quality.

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The Statistical Relationship between Benthic Habitats and Water Quality in Florida Bay: An Ecologically Relevant Performance Measure for Responding to the USACOE Restudy.

James W. Fourqurean and *Joseph N. Boyer*, Florida International University, Miami, FL; *Michael J. Durako*, University of North Carolina at Wilmington, Wilmington, NC

Extensive modifications to the natural flow of freshwater through the Everglades ecosystem have been made over the past 70 years. These modifications have drained water from historic freshwater marshes and sloughs and diverted water that once flowed through the Shark and Taylor Sloughs to Florida Bay. The ecological consequences of this diversion have never been fully explored, but it is clear that the diversion has changed the flux of organic matter to Florida Bay as well as the amount and variability of freshwater runoff and salinity of the bay. Paleoecological evidence is mounting that the flora and fauna of the bay may have changed as a result of engineering of the Everglades watershed. It has also been suggested that reduction in the variability and amount of freshwater runoff has caused an amarinization of Florida Bay, leading to changes in the species composition and biomass of the seagrass beds of Florida Bay. Human alteration of freshwater flow has also been implicated as a potential cause of the recent dieoff of seagrasses in western Florida Bay; but this contention remains an untested hypothesis.

Because of the sensitivity of Florida Bay to freshwater inflows, it is widely held that changes in water management may cause further changes in the biota of Florida Bay. Unfortunately, there are few tools available to predict changes in Florida Bay that may occur under various management scenarios. This project provides a method for predicting the changes in benthic habitats in Florida Bay that would likely result from Restudy scenarios. Present-day Florida Bay supports one of the most extensive seagrass beds in the world, with over 2000 km^2 of seagrass. Species composition and density of seagrasses in the bay are controlled by salinity, sediment accumulation and phosphorus availability. Seagrasses are sensitive to changes in water quality; in fact major losses of seagrasses have been attributed worldwide to declining water quality. Because of this sensitivity and their ecological importance, seagrasses can be used as sentinel organisms to assess water quality. Recovery of seagrass habitat in degraded areas is also a goal of many restoration efforts, since seagrasses are know to contribute significantly to the high productivity of many estuaries (e.g. Chesapeake Bay). In Chesapeake Bay, statistic relationships between water quality variables and seagrass survival have been used to establish a habitat criterion for the survival of seagrasses (Dennison et al. 1993); these criteria have in turn been used to set goal for restoration efforts. We expand on the habitat criteria approach to develop a tool for predicting the response of Florida Bay to changes in water management practices: we develop a series of relationships that will predict the probability of a given type of benthic habitat will occur under a water quality regime.

There is a spatial pattern to water quality in Florida Bay. In general, the mangrove-lined upper estuaries experience greater variability and lower mean salinity; while the western margin of Florida Bay within Everglades National Park has a much more constant salinity. Average depth also increases from east to west; water depth along with water clarity control the amount of light reaching the benthos. The amount of light reaching the bottom is a primary determinant of seagrass biomass. Phosphorus availability increases from east to west in Florida Bay, and phosphorus controls biomass of both seagrasses and phytoplankton in the bay. Currently funded monitoring programs collect data on the temporal and spatial variability of water quality, and allow for a spatially explicit description of the water quality regime. We use data from the SFWMD-ENP funded water quality monitoring program at FIU, as well as more frequent data from Everglades National Parks marine monitoring program, to describe means and variances of water quality variables. We apply modern multivariate data-reduction techniques to determine which water quality parameters describe independent modes of variation in the water quality data set. Statistically-independent water quality parameters are used in conjunction with spatially-explicit maps of benthic habitat type to develop a discriminate function that will allow for the prediction of the probability of occurrence of distinct habitat types under a given water quality regime.

Distinct benthic habitat types will be determined using the species distribution data that is being collected in four separate, but coordinated, monitoring programs. Data from three of these programs has recently been compiled to generate the first detailed maps of the spatial distribution of seagrasses in south Florida (Fourqurean et. al. in press). Cover and abundance data from these monitoring programs are used to define naturally occurring assemblages on benthic plants that define distinct benthic habitat types. We used a clustering algorithm to define subsets of stations with similar plant communities. Our knowledge of the data suggests that these habitat types will be distributed in spatially distinct areas of the bay; indeed habitat types have been used to describe the zonation of Florida Bay. The habitat types will be the groups used to create the discriminate function describing the most probable habitat type to occur.

The statistical models developed in this project will be used in conjunction with output from other models to predict the effects of Restudy scenarios on the benthic habitats of Florida Bay. It must be noted that this project will not address the mechanisms or degree of change in water quality that results from Restudy scenarios; other models (like the NSM, FATHOM, and the Florida Bay salinity transfer function models currently employed by the Restudy) must simulate water quality change across Florida Bay that will provide the input to the new models developed in this project. As a consequence, we anticipate that the benthic habitat change predictions of our models will the most reliable in the regions most closely coupled with water management practices, i.e. in the enclosed, mangrove-lined estuaries on the fringe of Florida Bay. As the fidelity of the physical water quality models to the behavior of the system declines, the benthic changes predicted by our model will also decline. But, since the statistical relationships will be based on data from more marine areas as well as upper estuaries, the basic relationships between actual water quality (not modeled) and benthic habitats will be robust.

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A Conceptual Model of Florida Bay Seagrass Mortality (1987-1991): Links between Climate, Circulation, and Sediment Toxicity.

Paul Carlson, *Laura Yarbro*, and *Tim Barber*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL; and *Dewitt Smith*, Everglades National Park.

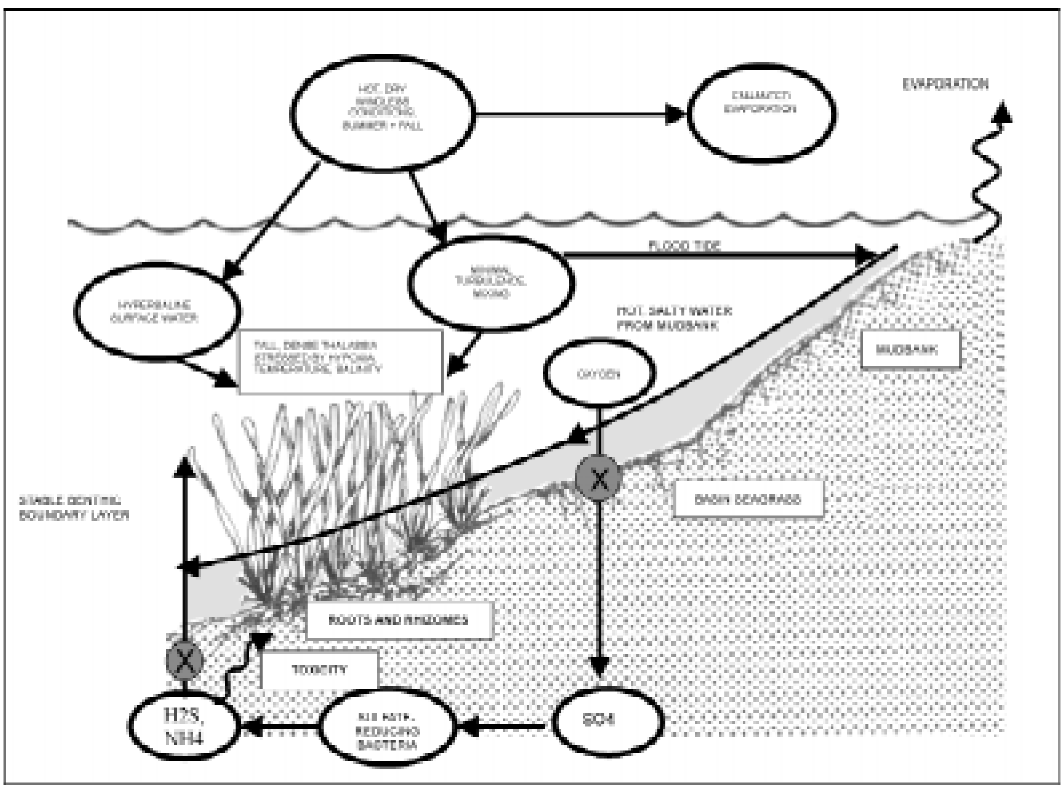
Twelve years have passed since the first reports of massive mortality of *Thalassia testudinum* in Florida Bay, but the causes of the phenomenon are still unknown. Several factors have been implicated in the 1987-1991 die-off, and each might have played a role in causing die-off, but the exact chain of events and processes, which caused die-off, has not been demonstrated.

The initial report of the die-off (Robblee et al. 1991) suggested that "abnormally high water temperature, recent reduced frequency of hurricanes, high salinity, a pathogenic slime mold (*Labyrinthula* sp.), …and chronic hypoxic of *Thalassia*…" were under investigation. Carlson et al. (1994) suggested that high sediment porewater sulfide concentrations were probably "not the primary cause, but a synergistic stressor…in concert with other factors (such as hyperthermia, hypersalinity, and microbial pathogens)" which caused die-off. Durako and Kuss (1994) demonstrated that *Thalassia* leaf segments infected with *Labyrinthula* had lower photosynthetic rates and higher respiratory rates than uninfected tissue, but, in greenhouse bioassay experiments (Carlson, Durako, and Porter, unpublished), Florida Bay *Labyrinthula* isolates infected, but did not kill, *Thalassia* seedlings. Zieman et al. (1994) documented "large increases in seagrass biomass prior to the dieoff and a decline in turnover rate or specific plant productivity during the die-off" which they related to climatic factors: hypersalinity, hyperthermia, and " a reduction of historical tropical storm frequency and intensity." Tomasko and Lapointe (1994) agreed that hyperthermia might have contributed to die-off, but discounted the role of hypersalinity, suggesting instead that large increases in *Thalassia* biomass related to increased nutrient loading contributed to die-off. We present below a conceptual model which explains the linkage between climatic and other factors active at the time of die-off and the proximal cause of die-off: sediment sulfide toxicity.

In this model, we propose that many of these factors played contributing roles in early seagrass die-off, but that die-off was caused primarily by the formation of a stable benthic boundary layer of hypersaline water which killed *Thalassia* by exposing root, rhizomes, and lateral meristems to toxic sulfide and ammonia concentrations (Figure 1). Hot, dry conditions in the late 1980's led to extremely hypersaline conditions in Florida Bay (Zieman et al. 1994). Under these conditions, evaporation of water driven onto the large, shallow banks of the western Bay by wind and tide created a layer of brine which slid into the adjacent, basin *Thalassia* beds. The brine formed a benthic boundary layer up to 20 cm thick, preventing the diffusion of oxygen into the sediments and the outward diffusion of sulfide and ammonia from the sediments to the overlying water. The stability of the benthic boundary layer was enhanced by the dense *Thalassia* canopy, which reduced turbulent mixing within the seagrass beds. The roots, rhizomes, and lateral meristems of *Thalassia* were then exposed to toxic concentrations of sulfide and ammonia accumulating in sediment porewater and bottom water isolated by the benthic boundary layer.

This model incorporates many of the stressors which have been previously suggested as factors contributing to the die-off but offers a framework which links distal factors related to climate with proximal factors like sediment toxicity. Hypersalinity and high temperatures weakened *Thalassia*, making it vulnerable to sulfide and ammonia toxicity. The slime mold *Labyrinthula* might have played a similar role. The model is also consistent with the spatial and temporal pattern of die-off during the period 1987-1991. Die-off in western basins was caused by the proximity of large mudbanks. Dense beds were more susceptible than sparse beds because the dense seagrass canopy stabilized the boundary layer. This hypothesis is also supported by field experiments, which exposed *Halodule*, *Syringodium*, and *Thalassia* to elevated porewater sulfide concentrations. Porewater sulfide concentrations comparable to peak values during dieoff in 1989-1991 (10mM) killed 68% of *Thalassia* 5% of *Halodule* and 12% of *Syringodium*.

Additional data on sediment toxicity and boundary layer formation will be presented to support the model. It should be noted, however, that this model applies primarily to the initial massive die-off episodes between 1987 and 1991. Since 1991, salinity in Florida Bay has moderated in response to more normal rainfall patterns and surviving seagrasses have suffered severe light stress due to secondary processes (phytoplankton blooms, sediment resuspension).



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Seagrass Disease and Mortality in Florida Bay: Understanding the Role of *Labyrinthula.*

B. A. Blakesley, *J. H. Landsberg*, *M. O. Hall*, *S. E. Lukas, B. B. Ackerman, M. W. White, J. Hyniova,* and *P. J. Reichert*, Florida Marine Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL

Biannual data from four years of seagrass disease monitoring in Florida Bay were examined to determine the relationship between the distribution and abundance of the seagrass *Thalassia testudinum* and the parasitic slime mold *Labyrinthula*. Ten basins with varied physical characteristics were studied intensively, including microscopic examination of nearly 10,000 *Thalassia* blades from more than 2,500 sites within these basins. We used ArcView's Spatial Analyst program and the Inverse Distance Weighted (IDW) method to develop a spatial contour surface, to better visualize the pattern of infection and changes in distribution and abundance in *Thalassia*. Maps of these data showed similar spatial patterns of *Labyrinthula* incidence and *Thalassia* loss. Both the highest incidence of the slime mold and greatest severity of *Thalassia* lesions occurred in the same basins where *Thalassia* losses were the highest.

Results thus far have allowed us to develop a hypothetical model to describe and categorize the effects of *Labyrinthula* on *Thalassia* in Florida Bay (see figures A and B). We hypothesize that there are five main interacting factors involved in determining the extent to which *Labyrinthula* affects *Thalassia* in Florida Bay.

1. **Salinity** controls infection. Results from both lab and field studies show that low salinities prevent *Labyrinthula* from infecting *Thalassia.* ArcView analyses of field data suggest that existing infection will be reduced by a drop in salinity to below 15 ppt such as might happen with a low salinity pulse due to heavy rains from hurricanes or a change in water management practices. Rapid reductions in infection after salinities decreased as well as rapid increases in the incidence of infection after salinities increased have been noted in both Madeira and Eagle basins. In these two basins, because *Thalassia* densities were low and there were no other apparent environmental stressors, disease in *Thalassia* was not a problem (Fig. A).

2. **Seagrass density** determines the extent to which *Labyrinthula* infection spreads because the slime mold transmission is thought to depend on blade-to-blade contact (Muehlstein 1992). Conditions in high-density seagrass beds are more conducive to initial pathogen transfer and such beds may therefore have high infection levels and substantial seagrass mortality (e.g. western basins). Low-density beds in either optimal or suboptimal seagrass conditions have low infection and little mortality (e.g. eastern basins). ArcView analyses of our field data show that basins with dense seagrass beds have more infection (in both incidence and severity of *Labyrinthula*-induced lesions and associated seagrass mortality) than less dense beds (Fig. B).

3. **Pathogenicity** of *Labyrinthula* will determine severity of infection. Pathogenic strains (or species) cause damage to seagrass blades by inducing necrotic lesions. Such lesions reduce

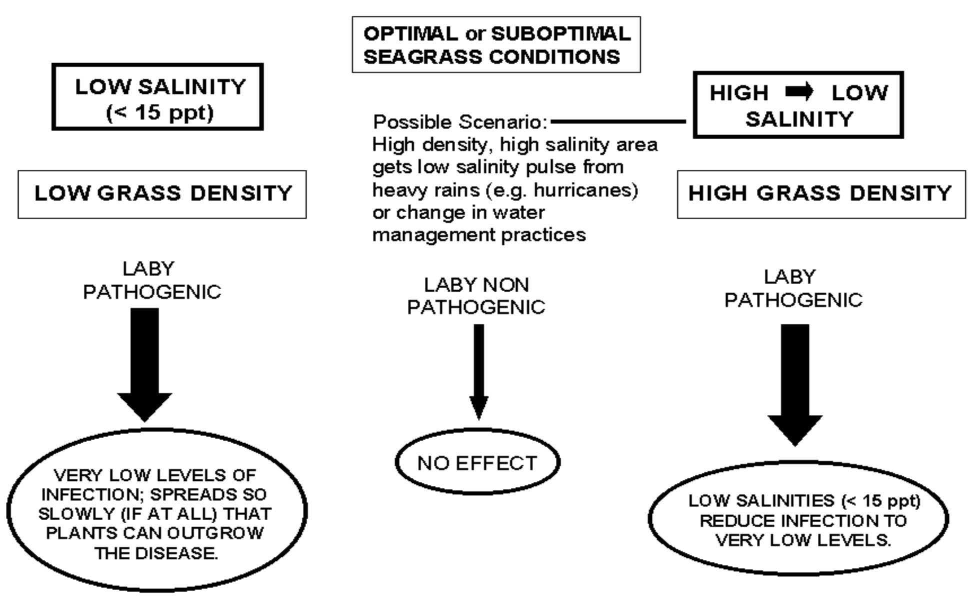
the photosynthetic capabilities of the seagrass (Durako and Kuss 1994), thereby reducing the amount of oxygen translocated to belowground tissues and increasing seagrass vulnerability to sulfide-induced hypoxia (Carlson et al. 1994). In lab experiments non-pathogenic *Labyrinthula* do not appear to have detrimental effects on the seagrass, whereas pathogenic *Labyrinthula* have induced lesions in apparently “healthy” seagrass. Pathogenic *Labyrinthula* may cause thinning and patchy die-off in seagrass beds even with no apparent environmental stressors (e.g. Sunset Cove; Fig. B).

4. **Environmental stressors** (abiotic factors) such as low light or high temperatures may weaken *Thalassia* and in combination with infection by pathogenic *Labyrinthula* may cause seagrass die-off. ArcView analyses of our field data show that basins with apparently lowered light levels due to resuspended sediments and persistent algal blooms also have increased incidence of *Labyrinthula*, increased lesion coverage on blades, and the highest seagrass losses (e.g. western basins; Fig. B).

5. **Seagrass resistance** to disease, due to genetic factors or production of phenolic compounds may play an important role in determining *Thalassia* abundance in Florida Bay. Phenol production, a defense mechanism against *Labyrinthula*, is influenced by availability of nutrients, substrate, and other environmental components.

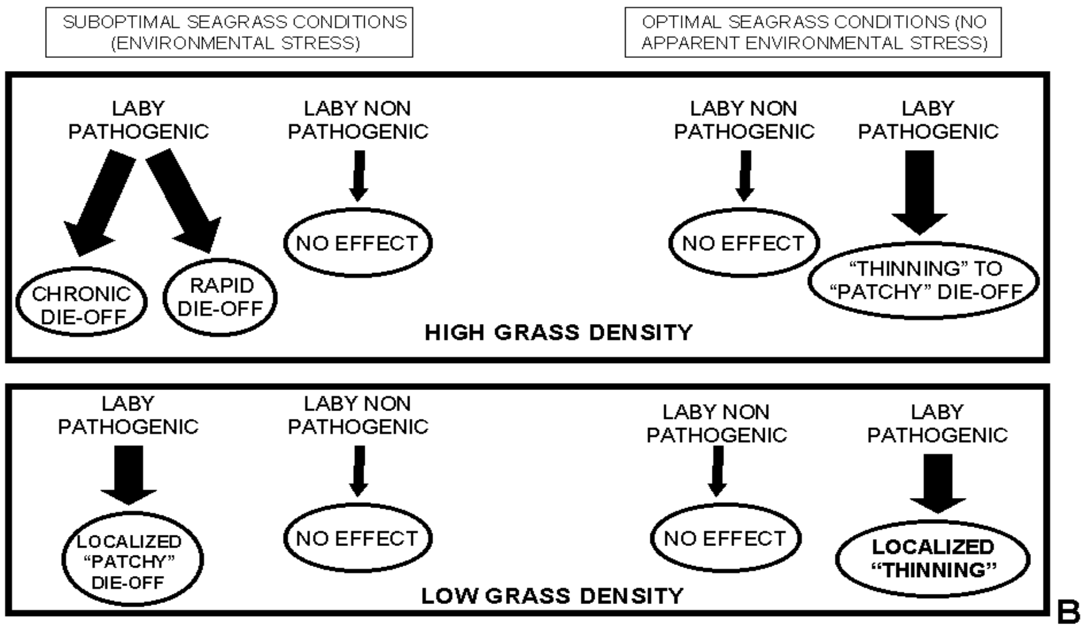
Further experimental work is planned in the field and in mesocosms to test our hypotheses. A better understanding of the interactions between the growth characteristics of *Thalassia*, its response to changes in environmental conditions, and *Labyrinthula*’s role as parasite or pathogen is important in determining management strategies in Florida Bay.

HYPOTHETICAL MODEL OF EFFECT OF THE SEAGRASS PARASITE *LABYRINTHULA* ON *THALASSIA TESTUDINUM* IN FLORIDA BAY AT LOW SALINITIES (< 15 ppt). DISEASE SPREADS BY BLADE-TO-BLADE CONTACT.



A

HYPOTHETICAL MODEL OF EFFECT OF THE SEAGRASS PARASITE *LABYRINTHULA* ON *THALASSIA TESTUDINUM* IN FLORIDA BAY AT HIGHER SALINITIES (> 15 ppt.)
DISEASE SPREADS BY BLADE-TO-BLADE CONTACT.



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Effect of Fluctuating Salinity on SAV in Experimental Tanks. 2. Mesocosm Experiments and Preliminary Results.

Tom C. Chesnes, *Clay L. Montague*, *Christos C. Anastasiou*, and *Bridget L. Coolican*, University of Florida, Department of Environmental Engineering Sciences, Gainesville, FL.

Salinity fluctuation may be a major factor in preventing establishment of macrophyte communities in northeastern Florida Bay. Salinity does not long remain within an acceptable range for seagrass community development. To test this salinity fluctuation hypothesis, mesocosm experiments are being conducted in Key Largo, Florida. Three seagrass species, *Ruppia maritima*, *Halodule wrightii* and *Thalassia testudinum* were subjected to various salinity regimes in controlled experiments. Regimes have included changes in salinity amplitude, frequency of fluctuation, and suddenness of change. Tests of the effects of oscillations around different mean salinities and at different seasons were performed. Survival and growth of the seagrasses are determined nondestructively using a color index and counts of leaves during the course of the experiment. Pre- and post-experimentation morphometrics are also compared. Physical parameters other than salinity, such as light, temperature, and nutrients are monitored in the experimental tanks.

Thalassia was the least tolerant of the species studied to fluctuations in salinity. Decreases in green leaf count, leaf height, number of turions, and color index were seen in those individuals subjected to treatments involving wide salinity fluctuation. Period of oscillation and suddenness of salinity change had no influence on the rate of impairment on this species. Mild fluctuations were significantly detrimental to *Thalassia* as well, but to a lesser extent. Salinity fluctuation within the higher salinity range was less harmful to *Thalassia* than those treatments oscillating within a less saline range.

Halodule did not fare well in any of the mesocosm experiments to date. Impairment was greatest in treatments involving wide salinity fluctuation, especially those with longer periods of oscillation. No statistically significant difference was seen between those individuals subjected to a stable salinity of 18‰ and those undergoing a treatment of mild salinity fluctuation (ranging from 11 to 25 ‰, every four days). As seen with *Thalassia*, *Halodule* exhibited greater survival in fluctuations with higher salinities.

Greatest tolerance to the salinity fluctuation treatments has been seen in *Ruppia maritima*. Mild fluctuations in salinity have even led to increased growth in this species in some experiments. *Ruppia* fared equally well in treatments testing fluctuations around different means, showing growth in both cases. Decreased survival of this species was shown in treatments of wide salinity fluctuation with shorter, quicker periods of oscillation. Statistically significant decreases in leaf height, number, color index , rhizome length, and turion number were all measured for individuals in this treatment. Experiments are currently ongoing. Further results will be presented.

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Sulfide Effects on *Thalassia testudinum* Carbon Balance and Adenylate Energy Charge.

James M. Erskine and *Marguerite S. Koch*, Aquatic Plant Ecology Laboratory, Biological Sciences Department, Florida Atlantic University, Boca Raton, FL

Low iron content in carbonate sediments limits the formation of iron-sulfide compounds such as pyrite, making seagrasses in the tropics more susceptible to sulfide toxicity. Sulfide accumulation in sediments may have been responsible for widespread “die-back” of the tropical seagrass, *Thalassia testudinum*, in a subtropical lagoon, Florida Bay. Hydroponic chambers were used to determine the effects of sulfide (0.0, 2.0, 4.0, 6.0 and 10.0 mM) on adenylate ratios, energy charge (EC), leaf O_2 flux, and growth of *T. testudinum* under light-saturated conditions. *Thalassia testudinum* did not suffer mortality under short-term exposure to sulfide concentrations of 10 mM, however several metabolic stress responses were observed. Root ATP, energy charge and the ATP:AMP ratio were all significantly reduced ($P < 0.05$) after short-term exposure to 2.0 to 10.0 mM sulfides. Root EC declined from 0.78 in the control to a range of 0.63-0.59 in the 2.0-6.0 mM treatments, and fell to a low of 0.43 in the 10.0 mM treatment. Leaf elongation rates declined ($P < 0.05$) by an average of 43% in 2.0 to 6.0 mM sulfide and 67% in 10 mM sulfide. Although root EC, ATP production and growth rates significantly declined under root sulfide exposure, sulfide concentrations of 2.0 to 10.0 mM failed to produce visual signs of acute sulfide toxicity, such as leaf chlorosis, leaf or root necrotic tissue development, or loss of leaf or root turger. Photosynthesis and leaf EC remained high after sulfide treatments, suggesting a resilience of *T. testudinum* to short-term sulfide exposure. Our data do not support the hypothesis that sulfide alone initiated “die-off” episodes in Florida Bay, although this phytotoxin may play a critical role when *T. testudinum* is subjected to additional stress such as hyper-salinity and high temperature.

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Sulfide as a Phytotoxin to the Tropical Seagrass, *Thalassia Testudinum*: Interactions with High Salinity and Temperature

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Sulfide toxicity is one of the dominant hypotheses put forward to explain *Thalassia testudinum* wide spread "die-back" in Florida Bay. Several experiments have been conducted to simulate high sulfide exposure to below ground tissues of *Thalassia testudinum* under controlled hydroponic conditions. Under light saturation, *Thalassia* exhibited physiological stress to sulfide levels of 2 mM and above; however, no lethal responses were observed that might implicate sulfide alone causing *Thalassia* mortality. Three additional experiments were conducted to further evaluate sulfide effects under low light conditions (150 µmol PAR m^{-2} s^{-1}), long-term (28 days) exposure to up to 6 mM sulfide concentrations, and exposure to 6 mM sulfide under high salinity (55 ppt) and temperature (34^{o}C).

Under low light levels, no significant differences were found in growth rates of plants growing for 28 days in 0, 2, 4, or 6 mM sulfides. This experiment was repeated with the addition of the 10 mM treatment, and again no significant effects on *Thalassia* growth rate was observed over nine days. After the growth experiment, plants were incubated in whole plant chambers under light-saturation to determine photosynthetic rates, and in the dark to determine respiration rates. Net photosynthesis and respiration rates tended to increase as a function of sulfide exposure, however not statistically significant, but similar to earlier findings with leaf segments (Erskine and Koch, in review). Maintenance of plant oxygen levels may explain the lack of growth response of *Thalassia* to sulfide exposure. Under sulfide exposure of 0, 2, 4, 6, and 10 mM, internal rhizome oxygen concentrations were similarly high, between 32 to 38 O_2 (%) under light-saturated conditions. Using additional plants that were not in the above experiment, *Thalassia* was found to respond to dark and light cycles by changing its internal oxygen levels from approximately 10 to 35 O_2 (%), respectively.

Since the maintenance of leaf photosynthesis appeared to be an important mechanism for *Thalassia* resilience to sulfide exposure, we conducted a third experiment to test the importance of membrane permeability. It was hypothesized that a breakdown of the membrane integrity by high temperature and salinity may increase the susceptibility of *Thalassia* to sulfide exposure. Closed chamber tanks with circulating aeration systems were used to control elevated temperature with a thermostat-controlled water heater. Salinity was added to ambient water using Instant Ocean. In each tank, *Thalassia* was exposed to 0 and 6 mM sulfide. The tank treatments included a high temperature, high salinity, high temperate X high salinity interaction, and control at ambient temperature and salinity. After 15 days, mortality was observed in all three plants exposed to high salinity and temperature under 6 mM sulfide exposure, while those in the 0 mM treatment had zero mortality. The greatest effects on photosynthetic biomass at the end of the experiment, was the salinity and salinity X temperature treatment in both the 0 and 6 mM sulfide exposure. Based on our series of experiments, we conclude that sulfide alone may cause physiological stress in *Thalassia*, but "die-back" mortality events occur when sulfide exposure is accompanied by hyper-saline and high temperature conditions.

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Poster Abstracts

QUESTION 4

Determination of Arsenic in Seagrass in Florida Bay Using Inductively Coupled Plasma Mass Spectrometry and Its Relationship with Phosphorus.

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There is an increasing interest in arsenic study in the environment because of its toxicity to plants, animals and human beings, and because of its large numbers of natural and anthropogenic sources (1). Arsenic cycling and its impact in estuarine and coastal marine ecosystem are especially important due to the land drainage, industrial discharge, and harbor or leisure activities in these areas. Because of the chemical similarity between arsenate, which is the predominant inorganic arsenic form in aquatic systems, and phosphate, arsenate interferes with the important biochemical functions of phosphate, particularly phosphorylation and ATP production (2). Nutrients cycling (P, N) in the Florida Bay has been extensively studied in recent years (3). However, there is no any information available concerning the occurrence, transport, uptake, and transformation of arsenic in these coastal marine systems. One of the most important biomes studied in marine coastal areas is seagrass. Seagrasses support complex food webs based on their physical structure and primary production capacity and rank with mangroves and coral reefs as some of the most productive coastal habitats in the world (4). In Florida Bay, the entire bottom is dominated by seagrass (3). In order to evaluate the behavior of arsenic in this ecosystem and its relationships with phosphate, accurate and reliable arsenic concentrations in seagrass are needed. In this paper, we report a rapid and simple digestion procedure followed by inductively coupled plasma mass spectrometry (ICP-MS) for arsenic analysis in seagrass that should be applicable to arsenic analysis in a broad range of marine plants. We used a very simple digestion method (HNO_3+ H_2O_2) to digest seagrass samples. The influence of chlorine concentrations and matrix effects on arsenic determination were studied. The proposed procedure was validated by analyzing standard reference material. Finally, this method was successfully applied to a number of seagrass samples collected from Florida Bay.

Sample preparation is in many cases a key step in achieving accurate and reliable results for environmental analysis. For many detection systems, such as hydride generation atomic absorption spectrometry (HG-AAS), the determination of total arsenic in biological samples requires the complete oxidation of the sample and organoarsenicals must be converted to inorganic arsenic compounds during the digestion procedure. For ICP-MS, however, such requirement may not be necessary because of the high energy and ionization power provided by the plasma, which may easily ionize organoarsenic compounds directly. This is demonstrated by analyzing one inorganic arsenic standard and three most important organoarsenic compounds present in marine organisms, namely methylarsonic acid (MAA), dimethylarsinic acid (DMAA), and arsenobetaine. The results indicate that complete sample dissolution other than complete decomposition of organoarsenic compounds to inorganic arsenic can be sufficient for the determination of total arsenic concentration in environmental and biological samples using ICP-MS.

Both spectroscopic interferences and matrix effects were studied. For arsenic analysis the major interference is from $^{40}Ar^{35}Cl$ at mass 74.931 amu. To be able to achieve a full baseline separation between this polyatomic interference and the analyte ^{75}As at 74.921 amu, a high resolution MS with an $M/\Delta M$ of >8000 is required. When the conventional quadrupole ICP-MS is used, the interference caused by $^{40}Ar^{35}Cl$ can be corrected for by the use of an elemental interference equation. During the course of this study, difficulties were encountered in using these equations. In order to understand these interferences, experiments were designed to evaluate the formation of polyatomic ion ArCl under our experimental conditions and the limitations of the interference equation. At concentrations below 0.5 ppm of chloride, the count numbers recorded were similar to the reagent blank, indicating no interference caused by Cl. However, the mass 75 count number was increased linearly with the concentration of Cl from 5 to 5000 ppm. By comparison with the data of As solutions, an As equivalent concentration of 2 ppb for a 500 ppm Cl was observed. In our present studies on the As in seagrass, the concentration of As in the final sample solution is in the range of 1-3 ppb, while the concentration of Cl may be as high as several thousand ppm if perchloric acid is used. In other words the count number at mass 75 resulted from ArCl may be 10 fold higher than that obtained from As.

The occurrence of matrix effects is a critical problem in ICP-MS. Significant effects of HNO_3 concentrations in the final solution on As signal was observed during the course of this study. A series of 2 μg/L As solutions were prepared in 1, 2, 5, 7, and 10% of HNO_3. Internal standards scandium, yttrium, and indium were spiked in each of the solutions at 50 μg/L. Arsenic concentrations calculated against an external calibration curve prepared in 5% HNO_3, were 2.86 ± 0.09, 2.53 ± 0.11, 1.91 ± 0.04, 1.75 ± 0.05, and 1.44 ± 0.10 μg/L for 1, 2, 5, 7, and 10% of HNO_3 solutions, respectively. It clearly indicated that the arsenic signal was significantly suppressed by increasing HNO_3 concentration and the extents of the effects of HNO_3 on the signal suppression apparently depend on the mass number. Based on these results, the concentrations of HNO_3 in final sample and standards solutions must be matched if the internal standard method is used.

Finally, using the ICP-MS method proposed in this paper we analyzed 35 samples of *Thalassia testudinum* leaves from Florida Bay for As content. These samples had a range of As content from 0.96 - 3.36 ppm, with a mean of 1.75 ± 0.63 ($\pm$ 1 s.e.). We also measured the phosphorus content of these leaf samples, P content ranged from 544 - 1916 ppm with a mean of 1110 ± 401. There was a strong linear relationship between P and As content of the leaves; as P content increased, so did As content (linear regression, $As = 0.48 + 0.00115\,P$, $r^2 = 0.53$, $P < 0.001$). P content of seagrass leaves in south Florida is a function of the availability of P in the environment; hence there is a strong gradient in P content of *T. testudinum* such that P content is minimum in northeast Florida Bay and increases to the west and south (Fourqurean et al 1992). As content of *T. testudinum* leaves mirrors this pattern. Apparently, there is a relatively constant AS:P ratio in seagrass tissues over a wide range of P availability in Florida Bay.

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Spatial and Temporal Patterns of Submerged Macrophyte Community Structure Found within Land-Margin Aquatic Habitats of Northern Florida Bay.

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The submerged macrophyte communities found within the numerous interconnected lakes and bays located along the northern land margin of Florida Bay are among those likely to experience the most direct and immediate effects of anthropogenic alterations in freshwater flow that are planned as part of the greater South Florida Restoration initiative. A two-year study was conducted between August 1996 and August 1998 during which approximately biweekly measurements were made of salinity, temperature, light-availability, and water-column and sediment depths at ten monitoring sites that span the full salinity gradient found within these land-margin aquatic habitats. Corresponding measurements of total-plant and species-specific percent-cover were made during each site visit. Descriptions of the sampling methodology employed for this field study were included in presentations made by Chipouras & Montague and by Chipouras, Montague, Jones, Chesnes, & Regan at the 1998 Florida Bay Science Conference. These details can be found in the abstracts for these presentations included in the Conference Proceedings or in Part 1 of this project's Final Field Studies Research Report that been submitted to the South Florida Water Management District.

Two approaches were taken in analyzing the data obtained from this field study. First, a UPGMA clustering algorithm was applied separately to the data obtained for each of the physical variables that were measured across the ten sites at approximately two-week intervals for the two-year period. The same clustering algorithm was applied to the concurrent species-specific percent-cover measurements made across the ten sites. For each of the resulting dendrograms, two matrices were constructed. The first matrix contained the number internodes in the dendrogram found between each of the possible pair-wise combinations of the ten monitoring sites. The second matrix contained the distance measurements computed for each of these same pair-wise combinations of the ten monitoring sites. Finally, the amount of consistency between the physical-variable and percent-cover dendrograms was quantified by calculating the Pearson correlation coefficient using the corresponding internode or distance scores in each of the matrix pairs. Of the physical variables measured in this study, only salinity produced a site clustering pattern that was significantly positively correlated with the clustering pattern produced by the concurrent species-specific percent-cover scores.

The sensitivity of this approach to detecting the potential effects of landscape-level changes in freshwater inflow was demonstrated when the two-year data set was split into separate annual data sets for years shown to have markedly different rainfall and associated salinity patterns. The previously found positive correlation between the salinity and percent-cover clustering patterns was found for each of the annual data sets and probably reflects concomitant shifts in site-specific salinity and submerged-macrophyte community structure. These findings suggest that this combined sampling and analytical approach may lend itself well to evaluating the effects of anthropogenic alterations in freshwater flow to these land-margin aquatic habitats. At present, it remains unknown whether the observed changes in these submerged macrophyte communities are correlated with changes in other physical parameters or other biological community components in these habitats.

Whereas the first analytical approach was aimed at describing landscape-level changes in submerged-macrophyte community structure, the second approach was aimed at describing the temporal characteristics of what are thought to be species-specific responses to changing salinity. In particular, these results are needed in order to compare them with the effects on selected submerged macrophytes of ongoing controlled salinity manipulations being made in mesocosms at the Key Largo Research facility by Chesnes, Montague et al.

The results of an earlier field study conducted in similar habitats by Montague and Ley (1993) suggest that the magnitude of salinity fluctuation may be an important determinant of submerged macrophyte community structure. This hypothesis is based on the negative correlation that was found between site-specific salinity standard deviation and log total plant biomass. However, no attempt was made to examine the temporal patterns of the total or species-specific components of the submerged macrophyte community to changing salinity.

In this study, an analysis was employed in which total and species-specific percent-cover scores were correlated with the measurements of physical variables made concurrently and with physical measurements made on each of the three preceding sampling dates. For the ten submerged macrophytes routinely found at one or more of these ten sites, salinity was the factor most often found to be significantly correlated with percent-cover. At some sites and for some species, available light is also correlated with percent cover. The results suggest that the lag between salinity change and plant responses is different for different species and that some show greater resistance to acute salinity changes of short duration. Further evidence supporting this difference in susceptibility depending on how salinity change is distributed over time is provided when percent cover is correlated with the magnitude of the rate of salinity change between sampling visits rather than using the instantaneous salinity value on any given sampling date.

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Turtlegrass *(Thalassia Testudinum)* Mortality on Florida Bay Mudbanks.

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We have completed two years of a three-year study to determine the spatial extent, seasonal variation, possible causes and remedies of seagrass die-off on mudbanks in Florida Bay. Mudbank seagrasses were apparently unaffected by extensive basin die-off between 1987 and 1990 (Robblee et al., 1991). However, comparison of 1987 and 1995 aerial photos showed considerable seagrass mortality on mudbanks, particularly in the central and southern portion of Florida Bay. Several factors are believed to have contributed to basin seagrass die-off including sediment sulfide toxicity and hypoxic stress (Carlson et al., 1994), density dependence (Hall et al., in press), seagrass disease associated with the slime mold *Labyrinthula* (Landsberg et al., 1996), and climatic changes. We are examining the potential contribution of these factors to mudbank seagrass mortality in Florida Bay.

Three sites (Spy, Crab, and Gopher Key Banks) were chosen for intensive quarterly sampling. Die-off patches were located on the eastern, middle, and western portion of each bank, and seagrass and sediment samples were collected from the die-off patch itself (Dead zone), the patch edge (Margin zone), and apparently healthy seagrass surrounding the patch (Dense zone). Seagrass and macroalgal cover and species composition in each zone were estimated by the Braun-Blanquet method. We also collected *Thalassia* shoots for morphological information and to be examined for *Labyrinthula* infection. The physiological state of mudbank *Thalassia* was assessed by analyzing rhizome carbohydrate reserves, and sediment sulfide concentrations were measured to determine sulfide stress potential.

Rhizome carbohydrate (sugar, starch, and total carbohydrate) concentrations were higher in the Dead zone than in the Margin or Dense zones for most sampling sites and dates (Figure 1). These data suggest that plants in the “Dead” zone have more sunlight, due to less crowding than all other zones, and can therefore make and store more energy in the form of carbohydrates. This ability to stockpile reserves also suggests that the dead zones are recovering rather than continuing to die.

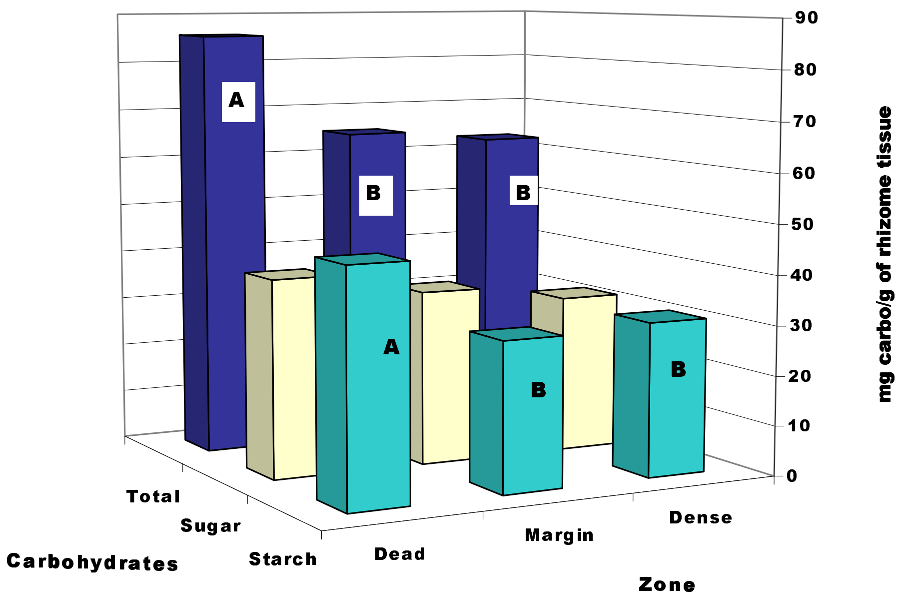

Figure 1: January 1999 Rhizome carbohydrate content. Data are mg carbohydrate/ gram of fresh rhizome tissue. Values with the same letter are not significantly different (Duncan's multiple range test).

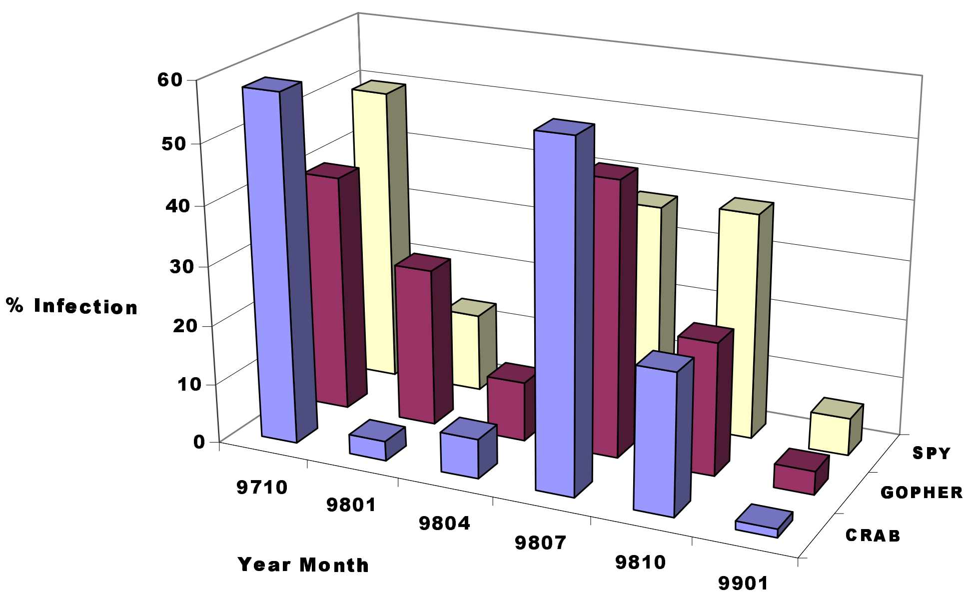

Figure 2: *Labyrinthula* infection rates on three Florida Bay mudbanks. Almost 5000 *Thalassia* blades were evaluated for lesion coverage and *Labyrinthula* was confirmed microscopically from *Thalassia* blades at all three mudbanks during all sampling seasons (Figure 2). Infection rates were higher in summer and fall than in winter and spring. Spatial trends in *Labyrinthula* infection are not evident from analyses conducted to date.

From our preliminary results, we conclude that seagrass is recovering at several of our study sites. It is not clear, however, whether all mudbank seagrass communities throughout Florida Bay are also recovering. In the final year of this project, we will focus on 1) the role of climatic factors (wind, temperature, and tidal inundation) on bank die-off, correlating the effect of temperature, salinity, tidal fluctuation and other physical parameters with the health of the mudbank seagrass, 2) analysis of mudbank seagrass population dynamics from aerial photographs, 3) nutrient limitations of *Thalassia* on mudbanks, and 4) experiments to determine the effects of sediment chemistry and *Labyrinthula* infection on the survival and growth of Thalassia.

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Demographic Growth Characteristics of *Thalassia Testudinum*: Leaf Morphology and Productivity.

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We investigated the relationships between leaf morphology (number of leaves, leaf length, leaf width, and leaf area), productivity (leaf production and turnover rate) and short shoot age. Two *Thalassia testudinum* populations representative of bayside and seaside communities in the Florida Keys were sampled, and estimates of short-shoot recruitment and mortality were calculated from age distributions. Sunset Cove, Florida Bay was sampled during January and August 1998 and Tavernier Key was sampled during August 1998. A total of 625 short shoots were analyzed individually. The mean age of short shoots within each seagrass meadow was calculated from the mean number of leaf scars and an estimate of the plastochron interval for each of the sites. Age analysis revealed similar mean ages between meadows (range = 1.2 - 1.4 years), but greater maximum age at Tavernier Key (4.9 years) than at Sunset Cove (3.6 years). Quadratic regression analyses revealed statistically significant relationships between the seagrass performance parameters and short shoot age, but these relationships can be interpreted as biologically insignificant due to the poor fit of the regression curves ($r^2 < 0.10$). The results of this study reveal that the seagrass performance parameters (number of leaves, leaf length and width, leaf area, leaf production and leaf turnover rate) are age-independent for *Thalassia testudinum* in the seagrass meadows studied.

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Allometric Relationships in *Thalassia testudinum.*

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Thalassia testudinum Banks ex König is the dominant seagrass in Florida Bay, where it occurs in beds of varying density. Since 1995, seagrasses have been monitored in Florida Bay as part of the Fish-Habitat Assessment Program (FHAP), which was initiated in response to a widespread seagrass die-off in the region. The vegetative growth of *Thalassia* and other seagrasses is supported by the products of photosynthesis from their leaves. Therefore, seagrasses must utilize these light-harvesting antennae for recovery from die-off events and for expansion into vacated areas. Leaf size is variable in *Thalassia* and has been shown to be affected by environmental and physiological conditions. In other plants, leaf size has also been shown to be affected by plant density. Leaf morphometrics and biomass of *Thalassia* short-shoots were examined in quantitative core samples taken from yearly spring sampling at more than 300 stations in ten basins of Florida Bay, which represent a continuous gradient of conditions across the bay. Shoot-specific characteristics, such as length and width, and area-specific characteristics, such as standing crop (above-ground biomass) and leaf area index (a measure of leaf area and plant density), were examined to determine how these characteristics vary among basins within this system, possibly in relation to some stress gradient, and to determine how these characteristics are affected by density. If a model of allometric properties of *Thalassia* can be developed and calibrated against visual Braun-Blanquet data, the use of destructive harvest techniques can be minimized during FHAP sampling. This will allow more intensive spatial sampling, a larger sample size, and more accurate estimates of distribution and abundance.

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Seagrass Change in Florida Bay from 1995 to 1999: Good News or Bad News?

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Due to concern regarding the effects of die-off and persistent water turbidity on the health of Florida Bay seagrasses, the Florida Marine Research Institute (FMRI) initiated the Fisheries Habitat Assessment Program (FHAP) during spring 1995. A major goal of FHAP is to correlate patterns of seagrass change (e.g. regions of seagrass loss or gain, species change) with potential causative factors (e.g. turbidity, salinity, disease). This type of information is critical for resource managers to identify "hot-spots" of seagrass decline, and to predict possible ecosystem changes resulting from proposed restoration activities in Florida Bay

FHAP sampling is conducted during spring and fall at over 300 randomly selected stations in ten Florida Bay basins (Rabbit, Johnson, Rankin, Twin, Whipray, Madeira, Calusa, Crane, Eagle, and Blackwater). At each sampling station, physical parameters such as water temperature, salinity, light attenuation and water depth are measured. Next, seagrass cover is visually quantified within four 0.25 m^2 quadrats using a modified Braun-Blanquet cover/abundance scale. The Braun-Blanquet method is non-destructive, requires relatively little time per sample (approximately ten minutes for four quadrats), and closely approximates quantitative characteristics of seagrasses (e.g. shoot density and standing crop).

Upon completion of the Braun/Blanquet assessment at each station, ten turtlegrass shoots are collected and later screened for the presence of the pathogenic slime mold *Labyrinthula*. *Labyrinthula* has been isolated from turtlegrass in die-off patches, and may be involved in die-off. The slime mold is evident when long, brown streaks (lesions) appear on turtlegrass leaves; these lesions inhibit *Thalassia's* ability to photosynthesize. Coincident sampling of seagrass and slime mold makes it possible to determine whether there is any spatial correspondence between areas of severe *Labyrinthula* infection and those of turtlegrass decline.

FHAP sampling has been conducted every spring and fall since 1995. Contour maps of seagrass and *Labyrinthula* distribution and abundance in the ten study basins have been produced for each sampling event with GIS software (ArcView Spatial Analyst) using an inverse weighted distance method. Maps of changes in seagrass distribution and abundance between sampling events have also been produced.

Despite persistent water column turbidity, ongoing seagrass die-off, and *Labyrinthula* infection, turtlegrass remained the most widespread and abundant seagrass species in Florida Bay from 1995 to 1999. *Thalassia* cover in most of the central and northeastern basins exhibited little net change, or small increases in abundance. However, there were substantial declines in *Thalassia* abundance in western Florida Bay between 1995 and 1999 **(BAD NEWS!)**. In contrast, abundance of *Halodule wrightii* (shoal grass) increased considerably in most of the western and central basins from 1995 to 1999 **(GOOD NEWS!)**.

The most dramatic changes in *Thalassia testudinum* and *Halodule wrightii* abundance from 1995 to 1999 occurred in Rabbit Key, Twin Key, Johnson Key, and Whipray Basins. Turtlegrass declined substantially in Twin Key Basin through spring 1997, and in western Rabbit Key Basin through the spring of 1998 **(BAD NEWS!)**. In Johnson Key Basin, *Thalassia* abundance doubled from spring 1995 to 1996, but then declined through the spring of 1998 **(MORE BAD NEWS!!)**. However, results from the springs of 1998 and 1999 suggest that turtlegrass in western Florida Bay is no longer declining, and in fact appears to be increasing in abundance in many locations **(GOOD NEWS!!)**. In addition, *Halodule* coverage has steadily increased in most of western and central Florida Bay since 1997 **(MORE GOOD NEWS!!!)**. *Halodule* has recolonized areas in western Rabbit Key Basin where *Thalassia* had been almost entirely lost **(REALLY GOOD NEWS!!!!)**.

A variety of factors such as reduced water clarity, die-off, *Labyrinthula* infection and high sediment sulfide levels may have been involved in the decline of *Thalassia testudinum* in western Florida Bay between 1995 and 1999. Establishing the causative mechanism(s) is problematic due to substantial spatial coincidence of the environmental stressors that are most likely responsible for turtlegrass loss. Although quantitative data on light availability in Florida Bay are scarce, persistent water column turbidity probably contributed to *Thalassia* decline – greatest losses of turtlegrass occurred in chronically turbid areas, and *Thalassia* abundance increased as water clarity improved over the past two years. Whether or not *Labyrinthula* infection also influenced *Thalassia* decline is difficult to determine at this point. However, spatial coincidence among the distributional patterns of *Labyrinthula* abundance in the fall and *Thalassia* loss in the following spring suggests that the slime mold affects turtlegrass decline. It should be noted that *Labyrinthula* is rarely found in Florida Bay at salinities below 15 ppt, and there was little decline in turtlegrass abundance in basins that are periodically subjected to low salinities. Large increases in the distribution and abundance of *Halodule wrightii* may reflect the lower light requirement of shoal grass relative to that of turtlegrass, the ability of *Halodule* to rapidly colonize areas where the *Thalassia* canopy has been removed, or the resistance of shoal grass to die-off and/or *Labyrinthula* infection.

The Long-Term Effects of Overgrazing of a Seagrass Bed by a Front of Sea Urchins, *Lytechinus variegatus*, in Western Florida Bay.

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In the summer of 1997 an extremely dense population of sea urchins, *Lytechinus variegatus*, was discovered in a *Syringodium filiforme* bed in western Florida Bay. The urchins formed a grazing front 2-3 m wide and approximately 4 km long with an average density of 100 individuals/m^2, and a maximum of 222/m^2. Before dispersing in January 1998, the urchin front passed through an area of 10km^2. Within that area, large portions of the seagrass canopy were completely grazed away, leaving only bare sediment.

For the past two years, we have been monitoring a permanent site through which the urchin front passed in November 1997. Prior to grazing, the site was dominated by a dense *S. filiforme* population, with very little *Thalassia testudinum* present. Sixteen weeks after the grazing event, both above- and belowground seagrass biomass were reduced to negligible levels. By 37 weeks post-grazing (July 1998), there was no seagrass biomass remaining at the site. In January 1999, however, *T. testudinum* began to recolonize the site. Until then, no *T. testudinum* biomass had been recorded at the site since the grazing event. The *T. testudinum* population appears to be doing very well, with a biomass of 40 g dry/m^2 as of April 1999. No regrowth of *S. filiforme* has been recorded. If this recovery pattern holds over time, the site will most likely be converted from a *S. filiforme* dominated to a *T. testudinum* dominated system.

The urchin front appears to have also had long-term effects on certain sediment characteristics. Percentage of organic matter in the sediments increased sharply immediately after passage of the front. Although it has been decreasing with time, as of April 1999 (72 weeks post-grazing), organic content of the sediment was still double the pre-grazing value. Sediment depth greatly decreased immediately after the grazing event, and remains low relative to pre-grazing levels. There has been, however, much variability in sediment depth over time, and long-term changes may not be a direct consequence of the activities of the urchin front. Grain size composition is the only sediment parameter studied which has returned to pre-grazing levels, despite a significant decrease in the silt/clay fraction immediately following the grazing event.

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Comparison of Grid Interpolation Methods for Mapping Seagrass (*Thalassia testudinum)* in Florida Bay.

Manuel Merello, *Paul Carlson* and *Kevin Madley*, Florida Marine Research Institute, St. Petersburg, FL.

Grid files are used to create continuous coverage maps from data collected at irregular intervals. A grid is comprised of evenly spaced rows and columns the intersection of which is a grid node that has an X, Y, and Z value. Gridding creates Z values at each node by interpolating from the collected data. In essence, gridding provides a method to fill in gaps within the study area where no data exists. Subsequently, the grids can be used to produce contour maps that present three-dimensional data as two-dimensional representations.

Inherent assumptions and biases exist in the interpolation methods used to create contour plots. The interpolated grid node values and not the original data determine the locations of contour lines. Some methods are better than others in preserving the original data. We are testing two commonly used interpolation methods (kriging and inverse distance) for mapping seagrass cover data.

Submerged aquatic vegetation was surveyed using a modified Braun-Blaunquet abundance scale at two sites in Rabbit Key Basin on the western side of Florida Bay. Surfer software interpolation procedures were used to create grid files of *Thalassia testudinum* Banks ex König coverage for the surveyed areas. We repetitively resample our data set by randomly removing 5 of 30 data points and use the remaining 25 points to generate a regularly spaced array (interpolated grid file). Estimated values from the grid file are compared with actual values for the 5 randomly selected points, and the process is repeated 20 times for each interpolation method. The interpolation method with the closest agreement between actual and estimated data values will be subjected to additional testing for parameters such as smoothing options and grid density.

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Effect of Fluctuating Salinity on Submersed Vegetation in Experimental Tanks. 1. Background and Description of Facility for Producing Salinity Fluctuation.

Clay L. Montague, *Christos C. Anastasiou*, *Tom Chesnes* and *Bridget Coolican*, University of Florida, Department of Environmental Engineering Sciences, Gainesville, FL.

At the northern margin of Florida Bay, submersed vegetation (SAV) is usually sparse, but dense beds occur occasionally. Salinity can change by 20‰ within a day. Earlier, the salinity fluctuation within a site predicted SAV biomass best among all measured variables. Severe salinity fluctuation was thought to curtail development of estuarine SAV communities owing to physiological stress. To test whether estuarine plants are damaged by severe salinity fluctuation, direct experimentation on plant sprigs was done. Plants were exposed to repeated salinity cycles in a specially built salinity-fluctuation facility.

The facility consists of a saltwater well (36‰); a reservoir refilled with city water; head tanks for each water type (refilled automatically); a gravity-driven water mixing system that allows four simultaneous salinity patterns; and twelve 1000-l vaults for experimental subjects. Salinity changes within treatments were set by hand. Vaults are randomly assigned to treatments before each experiment.

Six sprigs of three SAV species (*Ruppia maritima*, *Halodule*, *wrightii*, and *Thalassia testudinum*) were planted in tubs in each experimental tank. Experiments included treatments to compare the effects of frequency, amplitude, and suddenness of change in salinity. Survival and growth of sprigs were non-destructively monitored during experimentation. Pre- and post-experiment morphometric comparisons were also made.

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Branching Frequency of *Thalassia testudinum* Banks Ex Konig as an Indicator of Growth Potential within Ten Basins of Florida Bay.

Jill C. Paxson and *Michael J. Durako*, The University of North Carolina at Wilmington, Center for Marine Science Research, Wilmington, NC.

Thalassia testudinum (turtle grass) comprises a decreasing percentage of the marine angiosperms in Florida Bay within the Everglades National Park boundaries. Many factors have been attributed to the loss of this species since 1987. The Fish-Habitat Assessment Program (F-HAP) was established to provide insight into the temporal and spatial distribution of seagrasses and macroalgae, and morphometrics and demography of *T. testudinum*. Variable characteristics of each basin affect the growth strategy of *T. testudinum*. Light penetration to the leaf blades varies as a function of depth and turbidity, and the occurrence of the slime mold *Labyrinthula* has been shown to affect photosynthetic characteristics of *T. testudinum.* Each of these factors will play an important role in the potential for growth into new or previously inhabited areas of these basins. This monopodial species is meristem dependent. Excess carbon is needed to proliferate the apical meristem for lateral growth and spread. A combination of physical parameters from F-HAP, AVHRR, and the Aquatic Health Team of the Florida Marine Research Institute will be used to assess the growth strategy of this climax species. Core samples taken from ten basins (over 300 stations) of Florida Bay have been used to examine the relationship between rhizome branching and shoot density changes. Basin-specific characteristics may provide information regarding the growth responses of this species as a function of available light or presence of *Labyrinthula*. Apical meristem density may also have a potential use as an Aecoindicator giving insight to the potential for loss or gain of seagrass density within these basins.

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The Use of Short-Shoot Demographic and Allometric Scaling Data to Estimate the Productivity of a *Syringodium filiforme* Meadow.

Arthur C. Schwarzschild, University of Virginia, Charlottesville, VA; *W. Judson Kenworthy*, NOAA/NOS Beaufort Lab, Beaufort, NC.

Short-shoot demographic and allometric scaling data were collected from three sites in a *Syringodium filiforme* meadow growing in outer Florida Bay, FL and used to estimate meadow productivity (g dry weight m^{-2} $year^{-1}$). Demographic data consisted of rhizome and short-shoot components. Rhizome data included apical density, branching rates, and node formation rates. Short-shoot data included leaf formation rates, short-shoot density, age distribution, recruitment and mortality. The allometric data consisted of measurements of age specific leaf sheath and stem lengths. Length to dry weight regressions were generated for each plant module. The allometric data was used to calculate age specific short-shoot productivity. Total productivity, including leaf, sheath, stem and rhizome was estimated by combining the age specific productivity values with the demographic data. Site specific productivity values ranged from 706 g dry weight m^{-2} $year^{-1}$ to 1915 g dry weight m^{-2} $year^{-1}$ and varied with water depth and short shoot density. These values fell within the published ranges calculated for other populations of *Syringodium filiforme* using traditional methods.

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Oral Abstracts

Tuesday, November 2, 1999

8:00am-12:00pm

QUESTION 5

Tuesday, November 2, 1999

am

7:00-8:00 **Morning refreshments**

Question 5*. *What is the relationship between environmental change, habitat change and the recruitment, growth, and survivorship of higher trophic level species?

8:00-8:15 **Introduction to Higher Trophic Research.** ***Nancy B. Thompson***, PMC Member, NOAA, National Marine Fisheries Service, Miami, FL.

8:15-8:35 **Pink Shrimp Recruitment Dynamics as an Ecological Performance Measure for Evaluating Water Management Effects on Florida Bay.** ***Joan A. Browder***, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; *Nelson M. Ehrhardt*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.

8:35-8:55 **Salinity Changes and Model Predictions: Will Spiny Lobster Tolerate Our Environmental Monkey-Business?** ***Mark J. Butler,*** Old Dominion University, Norfolk, VA.

8:55-9:15 **Responses of Benthic Fauna to Salinity Shifts in Florida Bay: Evidence from a More Robust Sample of the Molluscan Community.** ***William G. Lyons,*** Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

9:15-9:35 **Past and Present Trophic Structure of Florida Bay: Stable Isotope Analyses.** *Jeffrey P. Chanton***, *L. S. Chasar*** and *T. Petrosky*, Department of Oceanography, Florida State University, Tallahassee, FL; *Christopher Koenig*, *Felicia Coleman*, *A. Prasad* and *T. Bevis*, Department of Biology, Florida State University, Tallahassee, FL.

9:35-9:55 **Fish Recruitment, Composition, Growth, and Habitat Use in Florida Bay.** *Gordon W. Thayer, Allyn B. Powell,* ***Lawrence R. Settle*** and *Donald E. Hoss*, NOAA, Beaufort Laboratory, Beaufort, NC; *Mark Wuenschel*, State Universty of New York, Syracuse, NY.

9:55-10:15 **Refreshment Break**

10:15-10:35 **Link between Offshore Larval Supply and Recruitment into Florida Bay.** ***W. J. Richards,*** NOAA Fisheries, Miami, FL; *M. M. Criales*, *C. Yeung*, *D. Jones*, *T. Jackson* and *M. Lara*, RSMAS, University of Miami, Miami, FL.

10:35-10:55 **Nesting Patterns of Roseate Spoonbills in Florida Bay 1950-1999: Implications of Landscape Scale Anthropogenic Impacts.** ***Jerome J. Lorenz***, National Audubon Society, Tavernier, FL; *John C. Ogden*, South Florida Water Management District, West Palm Beach, FL; *Robin D. Bjork*, Oregon State University, Corvallis, OR; *George V. N. Powell*, Monteverde, Puntarenas, Costa Rica.

Tuesday, November 2, 1999 *(continued)*

10:55-11:15 **Evaluation of Ecological Response to Salinity Variation in Florida Bay.** ***Darlene Johnson***, Florida International University and National Marine Fisheries Service; *James Colvocoresses* and *William B. Lyons*, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Peterburg, FL.

11:15-11:35 **A Meta-Analysis Approach to Performance Measure Development.** *J. A. Browder*, ***A. M. Eklund***, *D. Johnson*, *D. Harper* and *D. McClellan*, NOAA Fisheries, Southeast Fisheries Science Center, Miami, FL; *T. Schmidt*, National Park Service, Everglades National Park, Homestead, FL; *J. Colvocoresses* and *R. E. Matheson*, Florida Marine Research Institute, St. Petersburg, FL; *S. Sogard*, NOAA Fisheries, Hatfield Marine Science Center, Newport, OR; *G. Thayer* and *A. Powell*, NOAA Fisheries, Southeast Fisheries Science Center, Beaufort, NC.

11:35-12:00 **Panel Question and Answer Session**

Pink Shrimp Recruitment Dynamics as an Ecological Performance Measure for Evaluating Water Management Effects on Florida Bay.

Joan A. Browder, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; *Nelson M. Ehrhardt*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL

Pink shrimp recruitment is proposed as a measure of ecological performance in Florida Bay for use in developing, testing, and implementing new designs for South Florida's water management system. Pink shrimp is an ecologically sensitive species that is uniquely qualified to represent the ecological response of Florida Bay to changes in water management. Past statistical and population analyses suggest that this predominantly annual species is influenced by seasonal and inter-annual variation in freshwater inflow to Florida Bay, as well as other environmental factors. Florida Bay and other lower southwest coast estuaries are nursery grounds for pink shrimp, which are harvested on the Tortugas fishing grounds. Spawning takes place off shore, and eggs and larvae are carried shoreward by coastal and tidal currents. Postlarval immigration and settlement and juvenile growth and survival are influenced by environmental variables. The outcome of these processes is recruitment to the fishery. The short life span of the species makes it more likely that environmental effects can be detected by statistical methods. The database concerning the Tortugas fishery is one of the longest and largest data series available for the development of performance measures. Regular acquisition and recording of pink shrimp catch and effort data and some key associated environmental factors produced a data base of monthly values starting in January, 1960 In addition to fisheries data, substantial data exist on pink shrimp juveniles on pink shrimp nursery grounds. Long data series are essential to determining the ecological responses of Florida Bay to environmental change.

We are using three general approaches in performance-measure development based on pink shrimp: short term, mid term, and long term. The short-term projects are statistical analyses based on the use of fishery catch rates (catch per unit of effort [CPUE]) as indices of pink shrimp abundance. Mid-term projects will be based on statistical analyses of refined estimates of pink shrimp abundance, developed in cohort analysis and virtual population analysis. Refined abundance estimates are being prepared as a precaution against the potential for having fishery artifacts (such as might be caused by technological and market changes) in the time series. New approaches to standard stock assessment techniques have been developed specifically for this project. Our long-term projects are centered around the development of a simulation model. This model, at its present development state, already is capable of providing predictions of recruitment using the output of salinity models. Nevertheless, we consider its development a long-term response to the need for performance measures because we are continuing to obtain biological information to refine and expand this model.

Our short-term projects were conducted to meet immediate needs. The first pink shrimp-based performance measure developed in this project was a designed as a prototype of an approach to help interpret data acquired from monitoring. The problem it addressed was how to evaluate data collected for a single year in relation to that year's water management activities in an ecosystem where the annual rainfall pattern varies substantially. Our analysis used the database from 1963-1964 through 1994-1995 to find a statistical relationship between average pink shrimp catch rates for biological years (July-June) and certain months of rainfall. The resulting model was used to predict pink shrimp for the next year (in this case, 1995-1996). Simplistically, the difference between the rainfall-based predicted average catch rate and the catch rate observed for that year was assumed to be the management effect, positive or negative. The accuracy of this assumption depends, of course, on the importance of other, unknown, sources of variation not included in the model. Separate analyses were conducted for small shrimp (68 count catch category), which are considered as newly recruited to the fishery, and larger shrimp (all other catch categories). An equation explaining 89% of the variation in small shrimp catch rate was found with seven rainfall months (at Royal Palm Hammock in Everglades National Park). The fit of the model to the CPUE data was improved and a pattern was eliminated from the residuals by including a dummy variable that distinguished catch rates through 1980 and after 1980. The dummy variable may have approximated the influence of some unknown environmental variable or might have represented a change in the behavior of the fishery. On inquiry of fishery experts and port agents, we learned that a market change that occurred in the early 1980s could have led operators to try to catch more small shrimp.

One performance indicator based on pink shrimp has already been used in preparation of the Comprehensive Plan for redesigning the water management system (often referred to as "the Restudy") that was sent to Congress on July 1, 1999. The pink shrimp-based performance indicator used in the Restudy was a statistical model in which catch rates were related to water releases (or flow) across the Tamiami Trail into Everglades National Park. A good fit to annual average CPUE for biological years was found with a model using large shrimp CPUE of the previous year, air temperature for certain months, and several months of water flow across the Tamiami Trail. The total model explained 92% of variation in CPUE. The flow variables accounted for about 52% of CPUE variation. Separate variables were used for flow occurring east and west of the L67 levee, and the western flow explained a greater percent of the variation than the eastern flow (39%, compare to 10%). Regression coefficients were positive for some flow months and negative for others, suggesting that timing, as well as volume of flow, is an important factor to shrimp production.
Rainfall and water flow are thought to influence pink shrimp through their influence on salinity patterns, but an analysis of pink shrimp abundance in relation to salinity has not been conducted, and performance measure models to use with output of the hydrodynamic models are needed. A third short-term project in progress is to examine pink shrimp CPUE in relation to salinity and temperature in Florida Bay, represented by data for the period 1989 through 1997 from Everglades National Park. Results from this new analysis will be included in our presentation at the Conference.

Our mid-term work to be presented at this Conference is being conducted as two parallel and iterative activities: (1) modeling the dynamics of pink shrimp cohorts and (2) statistical analysis and modeling of recruitment processes in relation to environmental variables. Recruitment abundance trends by two independent stock assessment methods, calibrated length cohort analysis and sequential population analysis, are being compared to determine the statistical robustness of the abundance estimation. Recruitment trends will then be analyzed relative to estimate monthly and seasonal catchability coefficients to determine the degree of temporal aggregation of pink shrimp. These coefficients will be used together with recruitment trends to demonstrate the dynamic linkages that exist between pink shrimp population processes and dynamic Florida Bay environmental characteristics. Key influencing variables suggested by our previous analyses include temperature, rainfall, wind, and freshwater outflow from Everglades National Park. We will present new data relating pink shrimp to salinity in Florida Bay and to sea level dynamics. Performance measures will be presented that have been developed from pink shrimp population dynamics and are based on abundance indices that are free of any possible fishery-related artifacts.

Our long-term effort is centered around a simulation model. The basic model simulates the growth and survival of a pink shrimp cohort from post-larval settlement to capture in the fishery. This model can predict recruitment using observed daily salinity and temperature data or data simulated by a hydrodynamic model.

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Salinity Changes and Model Predictions: Will Spiny Lobster Tolerate Our Environmental Monkey-Business?

Mark J. Butler, Old Dominion University, Norfolk, VA

The Caribbean spiny lobster, *Panulirus argus*, supports the most economically valuable fishery in Florida and is an abundant, wide-ranging, benthic predator in the Florida Keys. Adult lobsters live and reproduce on coral reefs, and produce long-lived (6-9 mo.) larvae that are planktonic and disperse in oceanic currents. Postlarvae return inshore and settle in macroalgae within shallow hard bottom areas, as do the subsequent juveniles and subadults, which also forage in seagrass. Despite their utilization of an array of habitats to complete their complex life cycle, spiny lobsters are truly marine not estuarine animals. The postlarval and juvenile stages are especially sensitive to changes in salinity, but in Florida dwell primarily in nurseries bayside of the Keys. However, it is in precisely these areas that salinities are expected to change under proposed water management strategies.

A few years ago, we developed a spatially explicit, individual-based simulation model describing spiny lobster recruitment in the Florida Keys. Previously, we used this model to predict possible changes in juvenile lobster population size, hence recruitment to the fishery, in response to sponge-killing phytoplankton blooms and variation in larval supply. In this presentation, I will discuss model predictions of lobster recruitment with respect to changes in salinity and temperature in Florida Bay.

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Responses of Benthic Fauna to Salinity Shifts in Florida Bay: Evidence from a More Robust Sample of the Molluscan Community.

William G. Lyons, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL

Background: The work described here was conducted to map the composition and distribution of benthic molluscan assemblages in Florida Bay and to assess changes in those assemblages related to changing salinity regimes. Knowledge acquired from this study will improve understanding of the historical conditions evidenced in core samples and will allow better prediction of the consequences to benthic communities of activities that would alter the salinity regime of the bay.

Living mollusks were sampled quantitatively between 1994 and 1996 at 101 sites distributed evenly throughout the bay: methods, dates of sampling, and values of observed ambient salinities were reported by Lyons (1998). It is sufficient here to report that bottom salinities measured at all sites during summer ranged from 14.8 °/oo to 51.8° /oo in 1994 (hypersaline), 0 °/oo to 35.5 °/oo in 1995 (hyposaline), and 0.8 °/oo to 40.9 °/oo in 1996 (moderate). Raw samples were sieved and divided into two particle-size fractions in the field, and all previously reported results have been based only on mollusks from large-fraction ($\geq$3 mm) samples. To summarize those results: An analysis of intersite similarity based on species composition and relative abundance of larger mollusks at all sites in 1994 produced groups of site clusters that resembled “subenvironments” defined earlier by Turney and Perkins (1972), but with important differences: the 1994 analysis did not discern Turney and Perkins’ “Atlantic” and “Northern” subenvironments, and an area of about 200-km^2 in the south-central bay, classified as “Transitional” by Turney and Perkins, clustered with the “Interior” group in this study. The molluscan fauna was relatively depauperate at most high-salinity sites in the central bay, but a robust, euhaline fauna occurred in the eastern bay, where the salinity range was about 30-35 °/oo.

A reduced set of 30 sites, selected by stratification within site-groups from 1994, was sampled in 1995, a period when marked salinity changes and faunal shifts occurred in northern, eastern, and central parts of the bay. Species formerly found at sites near the northern shore disappeared there but reappeared at sites a few kilometers southward in the bay. The euhaline fauna of sites in the eastern-most bay became reduced or disappeared when salinities there dropped into the teens and low twenties, but elements of that fauna began to appear at previously depauperate sites in the central bay, evidently in response to the return of a more favorable salinity regime there. An analysis of intersite similarity, using data from 101 sites during summer 1996, showed that several sites in the 200-km^2 area of the south-central bay now clustered with the “transitional” subenvironment as species from the west recruited to those sites, presumably in response to the return of a more favorable salinity regime.

New results that follow were obtained from mollusks obtained in small size-fraction ($\geq$1 mm<3mm) samples collected during 1994 and 1996, *i.e.*, during a period of high salinity and during a period that followed shifts from high to low and back to moderate salinity. These results were compared with those obtained from the large-fraction samples to ascertain whether the bay's assemblages of smaller mollusks cluster differently than do those of the larger fauna. New analyses of intersite similarity, using data combined from both sample size-fractions, were prepared to more accurately depict assemblages based on the bay's entire complement of mollusks, and to refine our understanding of how those assemblages respond to fluctuating salinity.

Methods: Budgetary constraints initially permitted sorting of only 2 of the 5 small-fraction subsamples collected at each site during summers of 1994 and 1996. However, this 40% effort constituted 404 subsamples from the 101 sites, and their results were sufficient to indicate that a substantial part of the Florida Bay mollusk community had been missed by the larger gear. We remedied this deficiency by working up the 3 remaining small-fraction subsamples from each of the 30 sites previously selected by stratification, and, in an effort to reduce bias that might be introduced by a stratification scheme based on large-fraction samples, we did the same for the remaining subsamples from 15 additional sites. Thus, complete small-fraction data were obtained for 45 sites during summers of 1994 and 1996, and data were obtained for 40% of the small-fraction samples from the remaining 56 sites sampled during each of the two years. Together, these account for 2/3 of all of the small-fraction samples for each of the two years: [5 of 5 subsamples $\times$ 45 sites] + [2 of 5 subsamples $\times$ 56 sites] = 337 [of total 505] subsamples; $337 \div 505 \times 100 = 66.7\%$.

Results: With addition of the smaller material, total specimen abundance increased from about 13,750 to 21,530 in 1994 and from 7,850 to 14,030 in 1996. The 1994 "large" collections were dominated by a mussel, *Brachidontes exustus* (78% of all specimens), and a similar dominance was reflected in "small" samples for 1994. Thus, although total specimen abundance was lower in 1996 than in 1994, both species richness and the overall abundance of "non-mussel" mollusks actually increased in 1996.

General species richness increased greatly with addition of the small-fraction material. The number of species increased from 93 (large fraction) to 175 (total) in 1994 and from 130 to 202 in 1996. The sum of species collected during the program increased about 50%, from 155 in "large" fractions to 235 in the total samples. As with "large" material, many species in small-fraction samples were rare and occurred only at the western or southern peripheries of the bay, but many small species common and characteristic of the bay fauna were also represented. The "common and characteristic" smaller mollusks fit into and strengthened the species groupings (assemblages) identified previously for the "larger" material. Like the larger species, they generally exhibited discreet distribution patterns restricted to particular areas of the bay, and, like the larger material, populations of individual species showed interannual movement within subenvironments, evidently in response to changing salinity in various parts of the area represented by that subenvironment. Small specimens of species from the "larger" samples were also common in the material, and some such specimens filled distribution gaps present among the "larger" samples, further strengthening results obtained in the analysis of intersite similarity.

Summary: Most Florida Bay mollusks seem to have fairly precise salinity tolerances: many species tolerate little fluctuation in salinity, many others tolerate greater fluctuation, and a few seem to thrive where salinities vary most. In this study, many populations of individual species were seen to shift location, via recruitment and mortality, in response to locally fluctuating salinity. Most such population shifts occurred within individual subenvironments, *i.e.*, among single faunal assemblages, but conditions of extreme hyper- or hyposalinity produced more severe impacts, resulting in die-off of a resident fauna and replacement of that fauna by more tolerant species.

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William G. Lyons - Florida Fish and Wildlife Conservation Commission

Past and Present Trophic Structure of Florida Bay: Stable Isotope Analyses.

Jeffrey P. Chanton, ***L. S. Chasar*** and *T. Petrosky*, Department of Oceanography, Florida State University, Tallahassee, FL; *Christopher Koenig*, *Felicia Coleman*, *A. Prasad* and *T. Bevis*, Department of Biology, Florida State University, Tallahassee, FL.

The objective of this project is to investigate changes in the dependence of the Florida Bay trophic web on various sources of primary production and to estimate the consequences of environmental change, if it exists, on associated fisheries. Our working hypothesis is that the Florida Bay trophic structure has shifted from a benthic system dependent on primary production by seagrass epiphytic algae (or seagrass itself) to a pelagic system dependent upon planktonic alga production. Our sampling design incorporates a series of six sites within Florida Bay along an "impact gradient". We can detect shifts in trophic structure with multiple stable isotope analyses of producers and consumers. Historical (museum) samples will be analyzed for comparison to modern collections. We are currently developing a method for obtaining ^{13}C from bone apatite in preserved fish, and are investigating the viability of using ^{15}N and ^{34}S isotopes for preserved tissue specimens. These techniques would allow access to trophic histories of museum specimens for the past several decades.

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Fish Recruitment, Composition, Growth, and Habitat Use in Florida Bay.

Gordon W. Thayer, Allyn B. Powell, ***Lawrence R. Settle*** and *Donald E. Hoss,*
NOAA, Beaufort Laboratory, Beaufort, NC; *Mark Wuenschel*, State University of New York, Syracuse, NY

Continuous sampling on a bi-monthly basis with an otter trawl for juvenile and small resident fishes, and submerged aquatic vegetation (SAV) has been conducted from July 1994 to the present. Mean short-shoot densities for three sampling periods (1984-85, 1994-96, and 1997-98) showed little to no improvement in the average short-shoot density of *Thalassia* in any of the three strata (Atlantic, Central and Gulf), and a trend for continued decreasing densities in our Gulf stratum. Similar observations were made for *Halodule* in the Atlantic and Central strata; however, there has been a 2-3 fold increase in *Halodule* densities in the Gulf stratum since 1994-96 and densities during the current study phase are similar to those observed more than a decade earlier. *Syringodium filiforme*, which only appears in our Gulf stratum samples, displayed about a 30% increase during the present sampling period relative to 1994-1996.

Trends in fish densities and composition are beginning to mirror those of the 1980's. Our collections during 1994-1996 indicated a major increase in the densities of the bay anchovy, *Anchoa mitchilli*, and a concomitant decrease in the densities of small resident fishes. There has been a sizable decrease in anchovies during 1997-98, and an increase in the proportion of the dominant species represented by the benthic feeding mojarra, *Eucinostomus*.

Several fishes show increases in absolute density relative to the 1994-96 period, but remain at considerably low densities relative to the observed die-off of seagrasses. Excluding 1999 data, anchovies remain at densities higher than the late 1980's, but are much reduced relative to the 1994-96 period. *Lucania parva* and *Lagodon rhomboides* have began to rebound from the lows observed in 1994-96, but remain at densities approximately 50% lower than observed in the late 1980's. Densities of mojarras, *Eucinostomus* spp., appear to nearly equal those observed almost 12 years previously.

Our ichthyoplankton sampling effort represents a significant decrease in areal coverage compared to past ichthyoplankton sampling, but is appropriate in providing ancillary information to address the needs of the Strategic Science Plan. Since July 1997 to the present we have been monitoring ichthyoplankton (targeting spotted seatrout) at four stations. The objectives of this aspect of our work is to monitor the composition of ichthyoplankton, especially spotted seatrout spawning at two stations where spawning has only recently been observed (i.e., Little Madeira Bay and Whipray Basin) and two stations that are historical spawning areas (i.e., Palm Key Basin and Bradley Key). Stations are sampled with a bow-mounted push net for ichthyoplankton and a bottom sled for later life history stages. Results of our sampling from 1997-1999 will be presented.

Spotted seatrout otolith microstructure analysis is a major component of our Florida Bay study. For our analysis we have concentrated on juveniles collected in 1995. To date all the samples have been polished and increments counted for age determination (n=349).

Measuring increment widths for growth determinations is the remaining process for growth analysis to begin. Our objective, here, is to determine weekly growth rates and using time series analysis, examine spotted seatrout growth relative to temperature and salinity. Due to the polishing plane of the otoliths, inherent technique problems had to be addressed. It is not possible to measure daily increments along a single straight-line path. The measuring path consists of two sections, a ventral path from the core to the 21st increment and a ventral-medial path along the sulcus, from the 21st increment to the edge. The 21st increment was selected as the path transition increment by test reading 30 otolith sections (almost 10% of the sample), representing the entire range of sample fish lengths.

Growth rates were estimated from otoliths of juvenile great barracuda (*Sphyraena barracuda*) collected in Florida Bay during three sampling phases conducted from 1990 to 1998. We used growth rate as an index to evaluate differences in habitat value for juvenile barracuda. Barracuda utilizing Florida Bay as a nursery habitat have a protracted spawning period. Back-calculated spawning dates ranged from late January through September with a peak during July. No significant differences in average growth rate were detected across sampling periods or regions of the Bay. However, it appears that fish inhabiting the Gulf region have a slower growth rate during the offshore pelagic larval stage.

An individual based bioenergetics model for spotted seatrout is being developed to relate the task of capturing sufficient energy to generate adequate growth to the ambient environmental conditions existing in Florida Bay. This approach will enable us to test hypotheses regarding responses of larvae to differing environmental scenarios (e.g., hypersaline and high temperature conditions). The data needed to develop the model include respiration, consumption, and egestion rates over a range of salinities and temperatures.

Estimates of oxygen consumption were determined for larval spotted seatrout at two temperatures (30 and 32EC), and four salinities (10, 20, 35, and 45 ppt). Routine metabolic rate was determined for 177 individuals (4.6-15.5 mm). The variation in oxygen consumption was high, especially for small larvae. There does not appear to be a strong effect of salinity on respiration rates for spotted seatrout in the size range tested. However, until we increase the number of measurements over a wider range we will not be certain of the influence of salinity on respiration. The temperature effect on metabolism was not significant for the two temperatures tested. This is probably due to the moderate increase in temperatures tested (2E C), and we expect that over a wider range in temperatures, the relationship between oxygen consumption and temperature will be more evident.

Laboratory consumption and gut evacuation rates have not yet been determined for the range of salinities and temperatures. Experiments are planned to evaluate these parameters for juveniles and larvae. Estimates of consumption and gut evacuation rates from field collected material is underway. Estimates are being determined from 100 juvenile spotted seatrout collected over a 24-hr period in July, 1999.

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Link between Offshore Larval Supply and Recruitment into Florida Bay.

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The pelagic larvae of many valuable marine species in South Florida such as snappers (Lutjanidae), penaeid shrimps *(Farfantepenaeus* spp.) and spiny lobsters (*Panulirus argus*) are spawned offshore. With the help of physical transport processes, the larvae migrate into Florida Bay, where they spend their juvenile lives before returning to offshore habitats to complete their adult life cycles. Larval supply, a major determining factor of the strength of the adult year-class, is therefore strongly linked to physical processes. These linkages need to be elucidated and incorporated into the modeling of marine population dynamics and the management of fisheries.

Larval supply to Florida Bay is not only affected by the complex local circulation directly offshore in the Straits of Florida, but also by physical processes upstream in the Gulf of Mexico. Locally, mesoscale gyres propagating along the shelf between the Dry Tortugas and the lower Florida Keys are instrumental in the retention and concentration of larvae near the coast. Local winds and Florida Current flow interacting with the bathymetry can effect the onshore entry and recirculation of larvae. In the Gulf of Mexico, the variable Loop Current connects upstream larval sources to the Florida Keys, and also modulates the formation of gyres within the Straits of Florida.

Such advances in the understanding of coastal transport mechanisms and larval recruitment offshore of the Florida Keys stemmed from the multidisciplinary SEFCAR project (Southeast Florida & Caribbean Recruitment Project) conducted between 1989-1995. Our present research seeks to bridge the gap of knowledge in nearshore processes at the point of entry into Florida Bay to paint a more complete picture of larval transport and supply. A necessary step is to arrive at a conceptual model of larval transport based on multivariate correlations between the abundance pattern of pelagic larval stages entering Florida Bay and a suite of abiotic indicator variables of physical transport.

We have been monitoring the influx of settlement stages of fish, shrimp and lobster into Florida Bay at Long Key Channel and Whale Harbor Channel from July 1997 to June 1999. Channel nets were moored on the Bay side near the mouth of the channels and sampled monthly at each site on three consecutive nights around the new moon. Two nets, respectively of 1 mm and 2 mm mesh, were fished simultaneously at each site from about 1-2 m below the surface. Nets were usually deployed before dusk and were emptied shortly after the following dawn each day to target the optimal dark-flood time window for larval migration into the Bay. Intensive sorting and identification of larvae and juveniles of fish, shrimp and lobsters is presently being conducted on the 249 samples collected through June 1999.

The physical correlates collected concurrently with the biotic sampling were temperature and volume flow. Many data sources are also queried for other important physical parameters, including consultation with physical oceanographers with projects in the region, investigating various aspects of circulation and transport. SEAKEYS/C-MAN (Coastal-Marine Automated Network) meteorological stations at the Florida Keys reef tract and in Florida Bay provide the salient regional wind data, in addition to measurements of other oceanographic variables. AVHRR (Advanced Very High Resolution Radiometer) satellite SST imagery (Johns Hopkins University), TOPEX/ERS-2 satellite altimetry plots (Colorado Center for Astrodynamics Research), and MODAS (Modular Ocean Data Assimilation System) three-dimensional temperature and salinity plots (Naval Research Lab) are used to characterize the oceanography of the upstream and local pelagic environments. These complementary data allow us to determine the position, extent, and variability of oceanographic fronts and recirculation features that could dramatically affect the origin, transport, and retention of pelagic larval stages that subsequently recruit into Florida Bay.

Multivariate statistical methods and high-dimensional data visualization techniques are employed to 1) explore the relationships of meteorological and oceanographic features (abiotic variables) with larval supply (biotic variables), and 2) determine which abiotic variables best explain the structure in the biotic data. The ten that are deemed most significant of a suite of abiotic variables (e.g. mean water temperature, water temperature range, salinity, volume transport during dark-flood tide, wind stress, wind direction, presence of upstream mesoscale eddies, latitudinal intrusion of the Loop Current, mean surface current velocity of the Florida Current, Julian day, sample collection site, and phase of new moon, etc.) are examined for possible relationships to larval supply. For the biotic data, catches are standardized to numbers per unit volume and fourth-root-transformed. The biotic data matrix is converted into a symmetrical Bray-Curtis coefficient-based dissimilarity matrix. The abiotic data are normalized to equally weigh each variable for constructing a symmetrical Euclidean distance-based distance matrix.

The biotic and abiotic matrices are then compared using Mantel tests based on a weighted Spearman rank correlation coefficient. This allows determination of the intensity of the correlation between the biotic and abiotic matrices and the amount of variance in the biotic data explained by the abiotic variables. Permutation-based significance testing (one-tailed, alpha=0.05) of biotic/abiotic correlations are conducted to allow exclusion of assumptions of normality in the data. Mantel tests are run according to a combinatorial algorithm to determine which subset of abiotic variables best explains the biotic structure (i.e., maximize the correlation coefficient). Complementary UPMGA-based Cluster Analysis and Non-metric Multidimensional Scaling (NMDS) are used to visualize multivariate patterns in the data and explore the multidimensional correlations obtained from the Mantel tests.

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Nesting Patterns of Roseate Spoonbills in Florida Bay 1950-1999: Implications of Landscape Scale Anthropogenic Impacts.

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Roseate Spoonbills (*Ajaia, ajaja*) are listed as a species of special concern in the State of Florida and ninety percent of the states' breeding population nests on mangrove islands in Florida Bay. During the last half of the 1800's, and continuing through the early 1900's, the Roseate Spoonbill population was greatly reduced by direct human disturbance in the form of hunting and colony disruption. By 1935, continued human depredation on adults and eggs had probably eliminated all colonies except the Bottle Key colony, which had been reduced to 15 breeding pairs. In 1950, bay-wide surveys of nesting spoonbills indicated that the population had begun to recover with both the number of nests and the number of colonies having increased from the 1930's. Similar baywide surveys have continued intermittently through to present day. We analyze 50 years of nesting data in conjunction with foraging information in order to determine the suitability of spoonbills as an indicator species for Florida Bay.

Since 1950, spoonbills have nested on 30 keys in five sub-regions of Florida Bay. Nesting effort through time at any given colony was initially low for the first year(s) followed by a period of increase, a peak of variable duration in nest numbers, followed by a period of decrease to a lower level. This temporal sequence in nesting effort at a given colony can loosely be described as a bell-shaped pattern. Colonies in close spatial proximity tended to follow the same approximate temporal sequence in nesting effort resulting in a similar bell-shaped pattern when colonies were combined on a sub-regional scale. This may indicate that the observed pattern was a result of environmental fluctuations at the sub-regional level. Understanding the driving mechanism(s) behind the observed patterns is critical if Spoonbills are to be used as a gage by which the general condition of Florida Bay is measured and by which management and restoration decisions are made.

In his landmark work on Roseate Spoonbills, Robert Porter Allen identified four factors that could potential explain the observed pattern: 1) parasites and disease may impact nesting success and result in colony abandonment; 2) disruption of nesting by raccoon invasion and subsequent nest predation may disband a colony; 3) direct human disturbance (hunting and general colony disruption) may result in colony abandonment; and 4) availability and quality of food resources for a colony may change through time resulting in variable usage of the colony. We evaluated each of these factors and the preponderance of scientific evidence indicated that the availability and quality of food resources have been altered by land and water management practices in and around the Florida Bay landscape.

From 1950 through 1960, the number of spoonbills increased bay-wide with the majority of spoonbills nesting in the southeastern and southwestern sub-regions of Florida Bay. These birds' primary foraging grounds were wetlands on the mainline Florida Keys. Starting in the late 1950's and continuing through 1972, a large percentage of these wetlands were destroyed through dredge and fill type urban development. Coincident with this development, the nesting effort and nesting success of Roseate Spoonbills decreased within these sub-regions. These observations indicate that anthropogenic alterations to the landscape explain the bell-shaped temporal pattern in spoonbill nesting at the colony and regional levels. Furthermore, spoonbills appear to adjust nesting patterns when human activities alter primary foraging grounds indicating that their responses are related to food abundance, availability and quality.

Roseate Spoonbills began nesting in the northeastern sub-region of the bay in the early 1950's. During the period of dredge and fill urban development on the mainline keys, spoonbill nesting effort increased sharply in the northeastern sub-region. The period of increase in the northeast coincides with the abandonment of colonies initially in the southeastern sub-region and then abandonment of the southwestern colonies. Records indicate that between 1974 and 1993, the majority of spoonbill nests in Florida Bay were located in the northeastern sub-region, however the number of nests steadily declined between 1985 and 1998. The 1999 nesting survey indicated the lowest number of nests in the northeastern sub-region since 1967, and for the first time, the majority of spoonbill nests were located in the northwestern sub-region. The shift from the northeast to the northwest indicates the northeastern sub-region is no longer as desirable for nesting spoonbills as it had been in the recent past.

The primary foraging grounds for birds nesting in the northeastern sub-region were the wetlands north of Florida Bay and east of southern Biscayne Bay from Terrapin Point to Turkey Point. During the period of record, these wetlands were subjected to three distinct periods of water management practices. During Period I (1950-1963) the impact of water management on the wetlands was relatively small. Period II (1963-82) was characterized by the construction and operation of the C-111 and associated canals. Period III (1983-1999) was characterized by the completion and operation of the South Dade Conveyance System. During Periods I and II, spoonbills utilizing the northeastern colonies had high nesting success and the overall number of nests increased during the periods. During Period III, spoonbill nest success was low and the number of nests declined sharply. A striking implication of these findings is that current water management practices in the southern Everglades have resulted in the ecological degradation of the coastal wetlands in northeastern Florida Bay. The severity of this degradation is such that the resulting impact on Roseate Spoonbills was similar in scale to the complete destruction of more than half of the suitable foraging wetlands on the Florida Keys.

These data suggest that nesting Roseate Spoonbills exhibit a measurable response to water management practices in the southeastern Everglades and respond in a predictable manner, thereby making them good indicator species for the restoration of the Everglades/Florida Bay watershed

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Evaluation of Ecological Response to Salinity Variation in Florida Bay.

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This project on community responses to salinity was conducted in conjunction with National Park Service funded efforts to describe seagrass performance measures (Fourqurean, Boyer, and Durako) and single-species responses to salinity (NMFS, Browder, Eklund, Johnson, et al). Salinity responses, along with synergetic effects of other environmental factors, upon Florida Bay benthic and juvenile fish communities were examined using GIS, multi-dimensional scaling and cluster analysis techniques.

Data collected by Florida Marine Research Institute's Benthic Faunal Mapping Study and Fisheries Independent Monitoring Programs were used in this study. Data consisted of molluscan core data collected from 1994-1996 and juvenile fish data collected using trawl and seine gear from 1994-1997. Water quality data collected with biological sampling and environmental data derived from (Southwest Florida Water Management District-Everglades National Park; Florida Marine Research Institute monitoring program) and habitat/seagrass data (South Florida Water Management District and Miami-Dade Environmental Resource Management) synthesized by James Fourqurean were integrated into the study. A comparison of actual and interpolated salinity data will be presented.

Species communities and water quality/habitat variables were clustered spatially using multiple-dimensional scaling to identify variables that structure dominant species communities. Mantel tests were used to determine which subset of habitat/abiotic variables best explain community clusters. Various aspects of salinity (average, low, high, range) were used in the analysis to examine how thresholds and time scales (ambient, 3-month, 6-month and yearly) affect the structuring of animal communities. Resulting variables identified in the analyses can be used in regression models to determine the predictive responses of organisms to salinity changes in Florida Bay due to various salinity regimes and management scenarios.

This was a preliminary study designed to identify performance measures which can be used to evaluate U.S. Corps of Engineers restudy scenarios and to make predictions of community response to changes in freshwater flows into Florida Bay. Performance measures are the resulting dominant species clusters by habitat.

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A Meta-Analysis Approach to Performance Measure Development.

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We are preparing a relational database, using data provided from at least seven field studies. For up to 24 taxa from the combined data sets, we are examining abundance indicators in relation to habitat, salinity, and other environmental variables. A GIS system will help us in planning the analyses and interpreting the results. We'll use advanced regression techniques to build performance measure models that can be utilized to test the effects of water management actions on Bay fish communities. The first phase of the project, acquisition of data and organization of the database, is underway. Funded primarily by Everglades National Park (ENP), this study is a cooperative project of the National Marine Fisheries Service, ENP, and the Florida Marine Research Institute (FMRI). Our project is being coordinated with a complementary project by Florida International University that is funded by FMRI.

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Poster Abstracts

QUESTION 5

Simulation Model of Pink Shrimp Recruitment Dynamics in Florida Bay: Studies to Support the Model.

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A simulation model has been developed to predict pink shrimp recruitment from Florida Bay as a function of temperature and salinity through their effect on growth and survival. The model will be expanded to include dynamics of immigration and settlement of post-larvae to Florida Bay nursery grounds. Results of two ongoing projects that are providing information for this modeling effort are presented.

A series of experiments were conducted to determine the response of growth and survival of young shrimp to temperature and salinity. The series of temperatures and salinities tested extended across the full range of temperatures and salinities found in Florida Bay and nearby Whitewater Bay. Temperatures ranged from 15 degrees C to 33 degrees C, and salinities ranged from 2 ppt to 50 ppt. Experimental results will be presented.

Preliminary results on pink shrimp postlarvae in Florida Bay (P. Ortner's zooplankton samples, AOML-NOAA) show a patchy distribution. A large number of postlarvae were found at Sandy Key in the western portion of the Bay and at Shell Key in the Middle Florida Keys. A moderate number of postlarvae were found at Whipray and Cross Keys in the central part of the Bay, and no postlarvae were found at Eagle and Duck Keys in the northeastern stations. The high abundance of postlarvae at Sandy Key was formed by a large peak of postlarvae found in September1998, and at Shell Key by a large peak in November 1998. Postlarvae at Shell Key (Middle Keys) were significantly older (in number of rostral spines) than the ones at Sandy Key (western site). However the size of the postlarvae at both places (total length and carapace length) was very similar. The different larval transport and environmental conditions to which postlarvae are exposed during their onshore migration are probably factors affecting the age of the postlarvae at these two stations. An analysis of the presence of postlarvae at Sandy and Shell Keys in relation to the phase of tide shows that all postlarvae were caught during the flood-tide period.

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Trophic Structure in a Tropical Hard-Bottom Community: A Stable Isotope Analysis.

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Tropical hard-bottom areas are a prominent but largely overlooked habitat in the shallow coastal zones of the Caribbean. Bushy, red macroalgaes are the dominant primary producers in hard-bottom communities, although hard-bottom is often interspersed with seagrass meadows. It is widely assumed that seagrasses produce most of the energy in these clear, shallow coastal waters and thus export energy, via detritus, to nearby hard-bottom areas. However, this notion has not been tested explicitly. Therefore, we used carbon and nitrogen stable isotope analysis to investigate the trophic structure of hard-bottom communities in the Florida Keys, USA. We chose sites within three general regions: impacted bay, non-impacted bay, and near-shore ocean-side. Impacted areas are sites in central Florida Bay that had been exposed to massive cyanobacteria blooms during 1991-1995, which devastated the hard-bottom sponge communities and may have altered the trophic or energetic structure of those regions as well. Thus, we included these sites to evaluate the effect of broad-scale perturbation on hard-bottom trophic structure. Our results indicate that most of the primary production in hard-bottom communities is autochthonous and derived from red macroalgae. Trophic structure and energy flow in impacted bayside sites was not appreciably different from non-impacted bayside sites or ocean-side sites, despite the impact on the sponge communities.

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The Effects of Primary Productivity and Environmental Stress on Food Chain Length in Florida Bay.

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Food webs are used to describe the feeding relationships among organisms, generally assigning each organism to a particular trophic level for that community. The environmental processes that influence food chain length have been accounted for by two major hypotheses. The first, the energetic constraints hypothesis, proposes that the length of the food chain is limited by the amount of energy available between trophic levels. Taken simply, it is predicted that an increase in primary productivity would result in an increase in food chain length. The dynamic stability hypothesis argues that the length of a food chain is limited by its stability to environmental disturbances or stresses. We investigated the possibility of a relationship between food chain length, primary productivity, and local environmental stress. Not much is known concerning the trophic interactions among species that utilize the seagrass beds in Florida Bay, nor what consequences primary productivity and abiotic stress have had in influencing these trophic relationships.

Six basins within Florida Bay were chosen for this investigation based upon their historical salinity regimes. Three of the basins (Deer Key, Little Madeira Bay and Whipray Basin) were labeled as stressed while the other three (Buchanan Bank, Cross Bank, and Rabbit Key Basin) were labeled as non-stressed. Within each basin we arbitrarily selected three high productivity level sites and three low productivity sites based upon *Thalassia testudinum* areal leaf productivity. Original site selection was made from visual references, so a 2-way ANOVA was used to examine significant differences between productivity levels within each basin and confirm that the sites differed. Tukey's post hoc multiple comparison of productivity level sites within each basin revealed significant differences for all six basins studied. Total epiphytic load was also measured at each site, as it has been suggested that epiphytes can be a direct source of carbon available to higher trophic levels through grazing whereas seagrass must enter through the detrital pool. Total epiphyte load across all the sites ranged from 13.69 to 1770.63mg epiphyte g^{-1} seagrass, with a median load of 302.37mg g^{-1}. Total epiphytic load varied significantly across stress levels, but not across productivity levels.

A total of 18 species of fish and 15 species of invertebrates were collected, totaling over 2,240 individuals caught. Dominant fishes, in order of total abundance, were the code goby (*Gobiosoma robustum*), the gold spotted killifish (*Floridichthys carpio*), the rainwater killifish (*Lucania parva*), the gulf toadfish (*Opsanus beta*), and the clown goby (*Microgobius gulosus*). Dominant decapods included caridean shrimp species, the pink shrimp (*Farfantepenaeus duorarum*), the snapping shrimp (*Alpheus heterochaelis*), and the mud crab (*Eurypanopeus depressus*). Fish and decapod densities varied widely among all the sites sampled. Densities of 5 fish species and 3 decapod species were high enough at sites where they were present (>0.2 individuals m^{-2}) to allow meaningful comparisons. All other species were not included in any statistical analyses. Looking across stress and productivity levels, absolute abundance of fish was not found to differ between the two levels. Using only the 3 most common species of invertebrates, absolute abundance was found to vary between stress levels, with higher abundance in lower stress level sites, but there were no differences between productivity levels.

We also collected POM, seagrass, epiphytes, and individual *Opsanus beta* for isotopic analyses. We used naturally occurring ^{15}N stable isotopes to determine the trophic position of each, then compared the trophic positions across the bay to determine whether *Thalassia testudinum* leaf productivity or salinity played a role in structuring the food chain. POM $\delta^{15}N$ was not found to differ among stress levels, productivity levels, or basins. Epiphytic values, along with seagrass and individual fish, did vary in their $\delta^{15}N$ across Florida Bay.

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Evaluation of Recent Trends (1985-1998) in the Recreational Fisheries of Florida Bay and Adjacent Waters: An Update.

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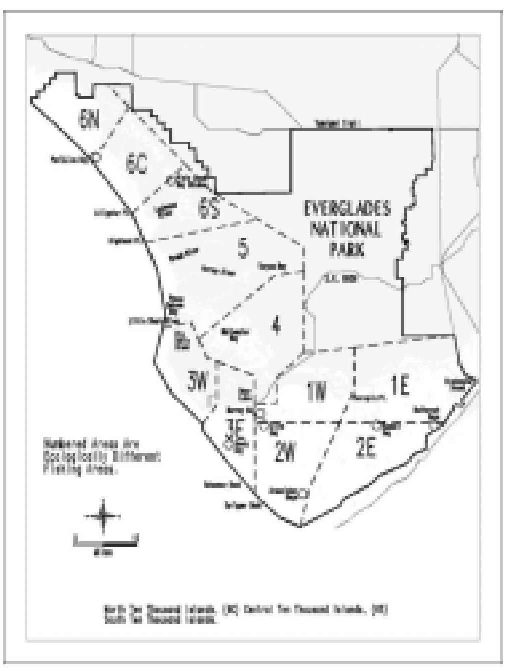
Fishing activity and harvest of sportfish from Everglades National Park (ENP) have been monitored nearly continuously since 1958. This project represents one of the longest ongoing marine recreational fishery monitoring programs in the world. A stock assessment based on catch and catch-per-unit effort (CPUE) from 1985 to 1998 of guided and non-guided anglers was conducted on four of the most popular gamefish in Florida Bay: snook (*Centropomus undecimalis*), gray snapper (*Lutjanus griseus*), spotted seatrout (*Cynoscion nebulosus*), and red drum (*Scianops ocellatus*). This research is focused on the higher trophic level fishery resources of Florida Bay and adjacent waters. The responses of catch and CPUE to fishing effort and environmental factors such as rainfall, water level, and salinity were determined. For the purposes of this study, catch rates were used as an index of the relative abundance of the major gamefish as CPUE is directly related to environmental parameters and is not directly affected by fishing regulations. Spotted seatrout and snook CPUE responses to environmental factors were used to develop performance measures for the interagency Florida Bay restoration process.

Methods (data collection/recording format) employed to obtain sportfishing monitoring and boating activity in ENP have been previously documented. Data recorded included area fished (see attached figure), reported catch (fish kept and released), harvest (kept only), effort (angler hours and trip hours), species preference, angler residence, and fish lengths.



Snook The popularity of snook has increased dramatically from 1985 to 1997. Guide catch rates have been declining since 1992-1993. However, sport catch rates have shown a cyclical trend every four years. The peaks may reflect recruitment of small juvenile snook, which were released in prior years because of size restrictions. Recruitment may also be enhanced by increased rainfall/runoff. The declines in snook stock size from 1985 to 1988 may have been due to low rainfall and water levels in the upper marsh regions as Schmidt and Alvarado (1998) reported a significant linear relationship between those parameters and CPUE from 1985-1996; however, the longer period of record did not substantiate this. There was a weak correlation between water levels recorded three years before and catch rates from 1985-1998 ($r=0.591$, $N=11$, $p>0.05$). Although, no statistical correlation was found, the trend seen suggests that a period of generally high salinity leads to a decline in snook abundance. The annual estimated total catch of snook for the sport fishery highly correlated with the estimated total effort placed on the stock between 1985 and 1998. This suggests that current catches do not greatly impact the Florida Bay stock and that additional increases in catch are possible. However, it should be noted that snook catches decreased dramatically in 1998 after five years of good catches and all time high in effort in 1997.

Gray Snapper The percentage of anglers reporting catches of gray snapper has remained quite stable from 1985 to 1998. During the 1990's, the annual guide and non-guided estimated total harvest for gray snapper has dropped as low or lower than anytime during the previous record. Catch rates have also shown the same general decreasing trend over the same time period. The lower harvest may be due to the state regulations imposed on the fishery in 1988 and 1990. Overall, a positive ($r=0.601$, $N=14$, $P<0.03$) relationship was found between catch rates of gray snapper and mean annual salinities found in northern Florida Bay, suggesting that periods of high salinity may lead to increased abundance of gray snapper. Average annual water levels recorded at P-37 were significantly inversely related to gray snapper catch rates during the same year ($r=0.712$, $N=14$, $P=0.004$), indicating that during periods of reduced water levels in the upper Taylor Slough, abundance of gray snapper increased. Rainfall was also inversely correlated with gray snapper catch rates ($r=0.506$, $N=14$, $p>0.06$) suggesting that periods of high salinity and/or low rainfall may lead to increased abundance of gray snapper. A statistically significant linear relationship was found between yearly effort from 1985-98 and the resultant catch for gray snapper suggesting that fishing effort did not severely impact the fishery.

Spotted Seatrout Sport fishermen harvest rates for seatrout have been holding steady since 1990 in Florida Bay. However, guide harvest rates have been almost halved since 1989; yet, guide catch rates have increased over the same time period. The catch rate of sport fishermen has also been increasing steadily since 1994 in Florida Bay. The lack of increase in harvest associated with the increase in catch may be due to new size regulations and to the increase in catch-and-release practices by fishers. Spotted seatrout catch rates and salinity seem to follow the same trend; as salinity increased to a high in 1990, seatrout catch rates increased and as salinities dropped in the proceeding years, catch rates also decreased; however, there was no statistically significant relationship between the two variables from 1985-1998 as there was during the period of 1985-1996 (Schmidt and Alvarado, 1998). When catch rates were correlated with annual water levels recorded at P-37 from the previous year, a significant negative relationship was found ($r=0.552$, $N=13$, $p=0.05$). This suggests that increased rainfall/water levels improve recruitment through increased growth and survival of larvae and juveniles. A statistically significant linear relationship was found between yearly effort from 1985-98 and the resultant catch for spotted seatrout suggesting that fishing effort did not severely impact the stock.

Red Drum The percentage of boats catching red drum decreased dramatically from 1985 to 1988 when the fishery was closed due to overexploitation. When harvest was reopened, the percentage of anglers catching the species increased steadily to a 14 year high in 1997. Red drum harvest rates in Florida Bay have remained quite stable since 1989 when bag limits of 1 fish per person were imposed. Sport fishermen catch rates have been increasing steadily since 1994. Annual estimated total harvest data from guided and non-guided fishermen suggests that red drum catches had been steadily increasing. The reduced abundance of red drum during the late 1980's may have been due to a combination of prior intense fishing pressure and increased rainfall. Previous studies have shown that low rainfall may lead to an increase in the abundance of red drum. However, no statistically significant relationships were found between red drum catch rates and any of the environmental variables from 1985-1998 (rainfall, water level, and salinity). A statistically significant linear relationship was found between yearly effort from 1985-1998 and the resultant catch for red drum. There was no decrease in total catch with increasing effort indicating yearly fishing effort did not severely impact the fishery.

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The Recovery of Sponge Populations in Florida Bay and The Upper Keys Following A Widespread Sponge Mortality.

John M. Stevely and *Donald E. Sweat*, Florida Sea Grant College Program.

During 1992 and 1993, widespread sponge mortalities significantly impacted sponges in an area that encompasses Florida Bay and the upper and middle Keys. The extent of the impacted area has been estimated to be approximately 1000 km^2. The cause of the mortalities has been attributed to cyanobacteria blooms. It has been hypothesized that the sponge mortalities resulted from clogging of the sponges' filter feeding mechanism, bloom toxicity, or perhaps lowered dissolved oxygen levels. However, at this point the exact cause has not been documented.

Because sponges are a significant component of the filter-feeding community, information on their abundance is critically important in modeling plankton-dependent energy pathways and evaluating filter-feeding impacts on water clarity. Sponges are also known to provide shelter for a myriad of higher trophic level organisms, including juvenile spiny lobsters. Without information on abundance and species composition of sponge communities, it will be difficult, if not impossible, to evaluate changes in hard bottom communities and document the restoration of the Florida Bay ecosystem.

The work described here was initiated in response to concerns regarding the ecological and fishery impacts resulting from increase commercial sponge harvesting effort in the late 1980's and early 1990's. The objective of the initial phase of the work (conducted in 1991 and 1992) was to document and quantify the contribution of commercial sponges (sponges of the genera *Hippospongia* and *Spongia*) to total sponge community biomass. The data collected during this initial phase provided an invaluable baseline data set of sponge abundance and biomass in the affected area prior to the sponge mortalities and documented the severity of the impact on sponge biomass. A total of 15 areas were sampled (five areas north of Long Key, four areas within Everglades National Park, two areas west of Everglades National Park, and four areas north of Marathon). The total area surveyed was 34600 m^2.

Sampling methodology consisted of counting all sponges found within twelve 100-m x 2-m transects at each area. Specific numerical abundance was recorded only for commercial species (*Hippospongia lachne*, *Spongia barbara*, *Spongia graminea*) and the largest most common species (*Spheciospongia vesparia*, *Ircinia campana*, *Ircinia strobilina*, and *Ircinia sp.*). All other sponges were lumped into a miscellaneous unidentified category. In addition to numerical counts, data on volumetric biomass of the different sponge species and sampling categories were collected.

Beginning in 1994, the work entered a second phase: the documentation of the magnitude of the impact of the sponge mortalities on sponge biomass, and the long-term analysis of the recovery of the total sponge community. Two of the original 15 survey areas (one north to Long Key, and one north of Marathon) have been sampled in 1993, 1994, 1995, 1997, 1998, and 1999. Sampling of a third area in Everglades National Park was begun in 1995.

Additionally, as resources have allowed, sporadic field observations have been conducted at two other sites.

Results of the 1994 field work documented highly significant declines in sponge numerical abundance, with even more significant reductions (up to 90%) in a sponge community volumetric biomass. However, the severity of the mortality varied significantly over the area affected by the cyanobacterial blooms. Sponges of the genera *Ircinia*, *Spongia,* and *Hippospongia* appeared to be the most susceptible to the mortalities. The loggerhead sponge *(Spheciospongia vesparia*) appeared to be more resistant than many other species, but was completely eliminated throughout extensive areas. One species, *Cinachyra* sp., appeared to be particularly resistant, but subsequent sampling suggests that the possibility that this species is particularly opportunistic and was able to rapidly colonize cannot be ruled out.

As work has progressed a more comprehensive description of the sponge faunas at each area has been undertaken. A total of 30 sponge taxa were recorded during the 1997 survey and we now have a reasonable complete description of the sponge fauna and relative abundance of sponge species found at the three survey areas. Furthermore, a more complete, long-term picture is beginning to emerge regarding the extent and description of the sponge community recovery.

Recently collected data (1998 and 1999) has documented a highly significant recovery in certain species of the genera *Hippospongia, Spongia* - the commercial sponges - and *Ircinia*. However, the extent of the recovery of these sponges is not uniform throughout the sampled areas. For example, the commercial sponge *Spongia barbara* has fully recovered at the Long Key site while the commercial sponge *Hippospongia lachne* has not yet been found at this site. In contrast, observations in other areas have shown a rapid recovery of *H. Lachne*.

Two species of the genus *Ircinia (Ircinia strobilina,* and *Ircinia sp.)* have recovered rapidly in recent years. In contrast, *Ircinia campana* (a large, formerly abundant sponge commonly referred to as the vase sponge) has shown no indications of any recovery.

The most conspicuous sponge, *Spheciospongia vesparia* (loggerhead sponge), in terms of volumetric biomass contribution to the total sponge community biomass, has shown almost no signs of recovery. However, 1999 data indicate that signs of recovery are becoming apparent at the Marathon sampling site. Prior to the sponge mortalities *Spheciospongia vesparia* accounted for approximately 59% of the total sponge community volumetric biomass and *Ircinia campana* (vase sponge) contributed approximately 10%. Therefore, these two species taken together accounted for almost 70% of the total sponge community biomass prior to the mortalities. Based on the data collected to date, these two dominant species (in terms of sponge biomass) may take many years to recover to abundances observed prior to the sponge mortalities.

As the project evolves into a truly long-term evaluation of the recovery sponge populations, data is being collected that indicate that there are several sponge species that have exhibited rather dramatic fluctuations in abundance since the sponge mortalities. These data may indicate that certain sponge species (*Halichondria melandadocia, Adocia sp., Hytrios sp.*, *Cinachyra sp.)* can undergo significant “natural” fluctuations in abundance. It is also possible that these population fluctuations either represent a long-term response to the initial sponge mortalities or changing environmental conditions.

Project plans call for continued sampling in future years. Future data will document and assess the long-term recovery of hard bottom sponge communities. These data will also assist in monitoring ecological conditions and modeling Florida Bay food webs. Furthermore, such long-term analysis may provide insights into differences in the life histories and ecology of certain sponge species.

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Oral Abstracts

Tuesday, November 2, 1999

1:30pm-5:30pm

QUESTION 2

Tuesday, November 2, 1999

Question 2*.** ***What is the relative importance of the advection of exogenous nutrients, internal nutrient cycling including exchange between water column and sedimentary nutrient sources, and nitrogen fixation in determining the nutrient budget for Florida Bay?

pm

1:30-1:35 **Introduction to Nutrient Exchange Research.** ***David T. Rudnick***, PMC Member, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL.

1:35-1:50 **Spatial Structure of Water Properties in Florida Bay.** ***George A. Jackson*** and *Adrian B. Burd*, Department of Oceanography, Texas A&M University, College Station, TX.

1:50-2:05 **The Carbonate and Nutrient Systems in Florida Bay.** ***Frank J. Millero***, *Xiaorong Zhu* and *William Hiscock*, University of Miami, RSMAS, MAC, Miami, FL.

2:05-2:20 **Phosphate Distribution Coefficients for Suspended Sediments in Florida Bay.** ***Jia-Zhong Zhang***, *Charles Fischer* and *Chris Kelble*, NOAA/AOML/OCD, Miami, FL; *Frank Millero*, RSMAS, University of Miami, Miami, FL.

2:20-2:35 **Nutrient Bioassays and the Redfield Ratio in Florida Bay.** ***Larry Brand*** and *Maiko Suzuki*, University of Miami, RSMAS, Miami, FL.

2:35-2:50 **Nutrient Cycling and Transport in the Florida Bay - Everglades Ecotone.** ***David Rudnick***, *Christopher Madden*, *Fred Sklar*, *Stephen Kelly*, *Chelsea Donovan*, *Karl Picard*, *Jason McCauliffe* and *Michael Korvela*, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL; *Enrique Reyes*, *Jaye Cable*, *John Day*, *Martha Sutula*, *Carlos Coronado-Molina*, *Brian Perez* and *Robert Lane*, Coastal Ecology Institute, Louisiana State University, Baton Rouge, LA; *Daniel Childers*, *Stephen E. Davis* and *Damon Rondeau*, Southeastern Environmental Research Center, Florida International University, Miami, FL; *Marguerite Koch* and *Robert Benz*, Department of Biology, Florida Atlantic University, Boca Raton, FL; *Jeffrey Cornwell* and *Michael Owens*, Horn Point Environmental Laboratory, University of Maryland, Cambridge, MD.

2:50-3:05 **The Influence of Southern Everglades Wetlands on Nutrient Inputs to Florida Bay.** ***Daniel Childers***, *Stephen E. Davis*, *Frank Parker* and *Damon Rondeau*, Southeastern Environmental Research Center, Florida International University, Miami, FL.; *David Rudnick*, *Christopher Madden* and *Fred Sklar*, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL; *Carlos Coronado-Molina*, Coastal Ecology Institute, Louisiana State University, Baton Rouge, LA.

Tuesday, November 2, 1999 *(continued)*

3:05-3:35 **Refreshment Break**

3:35-3:50 **Molecular Markers of Organic Matter Inputs and Transformations in Estuarine Environments of South Florida: Shark River and Taylor Slough.** ***Rudolf Jaffé***, *Maria Hernandez, Maria do Carmo Peralba* and *Ralph Mead*, Florida International University, Miami, FL.

3:50-4:05 **Atmospheric Deposition of Nitrogen and Phosphorous to the South Florida Bay Ecosystems.** ***P. Y. Whung***, ARL/NOAA, Silver Spring, MD; *C. Fischer,* AOML/MOAA, Miami, Florida; *T. Meyers,* ATDD/NOAA, Oak Ridge, TN.

4:05-4:20 **Trace Element Distribution in Florida Bay: Atmospheric or Hydrologic Deposition?** ***E. A. Shinn*** and *C. D. Reich*, USGS, St. Petersburg, FL.

4:20-4:35 **Eutrophication Model of Florida Bay.** ***Carl F. Cerco***, *Mark Dortch*, *Barry Bunch* and *Alan Teeter*, US Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS.

4:35-4:50 **Elevated Mercury Concentrations in Fish from Eastern Florida Bay.** ***David W. Evans*** and *Peter H. Crumley*, NOAA/Center for Coastal Fisheries Habitat Research, Beaufort Laboratory, NC.

4:50-5:30 **Panel Question and Answer Session**

6:00-7:00 **Networking Social**

Spatial Structure of Water Properties in Florida Bay.

George A. Jackson and *Adrian B. Burd*, Department of Oceanography, Texas A&M University, College Station, TX

The spatial distribution of water constituents provides important information about the processes governing the plankton in Florida Bay. We have been working with members of several research groups to determine these patterns and understand their implications, particularly for the development of a plankton model.

Peter Ortner of AOML, Gary Hitchcock of RSMAS, and their collaborators have been collecting continuous data along a ship's track within Florida Bay. We are analyzing the temperature, salinity, and chlorophyll data. Our results to date indicate correlation length scales for these parameters of about 2.5 – 3 km. This distance is comparable to the basin scale for the region.

We have also been looking at larger scale patterns in the data collected by Joe Boyer and collaborators at Florida International University. They have been collecting data on biologically important water parameters at a grid of stations within Florida Bay since 1991. We have been analyzing their data for spatial patterns and combining the results with information about the currents associated with tides in Florida Bay. The current information has been provided by Mark Dortch and his collaborators at the USACOE. Our analysis suggests that basins in eastern Florida Bay have residence times of 30 days, while those to the west have residence times less than a week. Coupling of the spatial distribution of water parameters with the results of the residence time analysis suggests that some regions in Florida Bay act as sources and some as sinks for nitrogen and phosphorus.

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The Carbonate and Nutrient Systems in Florida Bay.

Frank J. Millero, *Xiaorong Zhu* and *William Hiscock*, University of Miami, RSMAS, MAC, Miami, FL.

To better understand the relationship between nutrients and the carbonate system in Florida Bay, we have completed several survey cruises in recent years along the southern Florida coast. During these cruises, our group measured carbonate system parameters that include total alkalinity (TA), total carbon dioxide (TCO_2), pH and partial pressure of carbon dioxide (pCO_2). In addition to the above parameters, surface water temperature, salinity and nutrients such as nitrate, nitrite, phosphate and silicate were also measured. Moreover, we also measured water samples collected from Florida Bay by other groups. The combination of such data sets allows us to characterize the relationship between the carbonate and nutrient systems in Florida Bay. Our work will help to contribute to the determination of the saturation states of calcite and aragonite particles that can absorb phosphate as well as to examine the uptake of inorganic carbon by phytoplankton. Total alkalinity and pH were measured by titration technique, total carbon dioxide was measured by Single-Operator Multiparameter Metabolic Analyzer and pCO_2 was measured by a Li-Cor CO_2 Analyzer. Surface nutrient data was collected continuously on cruises via a flowing multi-parameter nutrient system, developed in our laboratory. This system measures the concentration of nitrate, nitrite, silicate, and phosphate from a flowing seawater line onboard the research vessel. The continuously flowing nutrient system has the advantage of providing real-time data and a greater density of measurements than discrete sampling. The greater density of measurements can, for instance, help to identify changes in the nutrient concentration due to circulation patterns of water masses or frontal movements. The nutrient data was constructed into contour plots and has also been compared to the carbonate system data to help identify changes in nutrient concentrations related to the degradation of plant material.

The results of our two recent cruises (November 1998 and June 1999) were presented in this study. All the measurements were constructed into contour plots. These plots showed that the phosphate concentration in Florida Bay and Ponce de Leon Bay were considerably higher during the winter season than during the summer season. Silicate, on the another hand, indicated higher concentrations during the warmer month than the colder month. Several maxima points located along the coast south of Cape Ramano indicated that the extra sources in this region are likely due to nutrients regenerated from sediments or continental outflow. In both cruises, the silicate and phosphate showed close correlation that suggests they might share a common source. Contour plots of carbonate parameters showed local maxima of TA, pCO_2 and TCO_2 in Ponce de Leon Bay and at the mouth of the Shark River. Nitrate and nitrite are inversely correlated with salinity, indicating that the Shark River is a major source of these components. The concentration maxima of TA, $pCO_{2,}$ and TCO_2 in the same region as nitrate and nitrite suggest these nutrients may contribute to the determination of the saturation state of carbonate.

Phosphate Distribution Coefficients for Suspended Sediments in Florida Bay

Jia-Zhong Zhang, *Charles Fischer* and *Chris Kelble*, NOAA/AOML/OCD, Miami, FL; and *Frank Millero*, RSMAS, University of Miami, FL

The distribution coefficient Kd (Kd = Cs/Cw, where Cs is concentration of phosphorus on particle surface and Cw in seawater) is a key parameter that governs phosphorus partitioning between seawater and particle surface. To estimate the distribution coefficient for phosphorus partitioning between suspended sediments and seawater, surface sediments were collected from Florida Bay at various locations with different environmental conditions. The sediment was equilibrated with low nutrient seawater for 24 hours at constant temperature. The particles were then separated from seawater by filtration. The phosphate concentrations in equilibrated seawater were determined by spectrophotometric method using an autoanalyzer. The sediments were then equilibrated with a 1 M $MgCl_2$ solution at pH of 8 for 4 hours. The sorbed and desorbable phosphorus was then extracted into the solution by a complexing reaction with $MgCl_2$. The extracted phosphate was determined after separation from the suspended sediments. The results showed a linear correlation between phosphate concentrations in seawater and exchangeable phosphate on the sediment surface. Preliminary estimated Kd is of 100 L/kg. Further experiments are underway to study the effect of salinity and temperature on the Kd. A fitted equation of Kd as a function of salinity and temperature can be used in a water quality model to predict the fate of input phosphorus in Florida Bay.

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Nutrient Bioassays and the Redfield Ratio in Florida Bay.

Larry Brand and *Maiko Suzuki*, University of Miami, RSMAS, Miami, Florida

Ratios of total N : total P and inorganic N : inorganic P are well above the Redfield ratio of 16 throughout Florida Bay. This has led many researchers to assume that P is the primary limiting nutrient and that inputs of N to Florida Bay are not a cause of the algal blooms. It is well known however that many organic N molecules are not readily available to phytoplankton while many organic P molecules are, due to the activity of phosphatase enzymes. This reflects the fact that organic N is bound by direct carbon bonds while organic P is bound by ester bonds. Examination of the ratio of inorganic N : total P indicates ratios greater than the Redfield ratio in eastern Florida Bay and ratios less than the Redfield ratio in western Florida Bay. This suggests the potential for P limitation in the east and N limitation in the west. The results of around 700 nutrient bioassays conducted over one year show mostly N limitation in the west and P limitation in the east, with a spatial distribution similar to the inorganic N : total P ratios. The observation of N limitation in western Florida Bay suggests that indeed much of the organic N from the west is not available to the phytoplankton. The largest algal blooms (determined from around 7800 chlorophyll measurements over three years) are in central Florida Bay where high P from the west meets high N from the east, and the inorganic N : total P ratio is close to the Redfield ratio.

The three most likely sources of P in the west are as follows:

1. The Gulf of Mexico could be a source of the P, especially in light of the low inorganic N : total P ratios observed there.
2. P from erosion of phosphorite deposits in central Florida, enhanced by phosphate mining, and transported down the Peace River and along the southwest coast of Florida could be a source.
3. Phosphorite deposits mixed with quartz sand may have groundwater moving up through them, transporting P up into Florida Bay. The distribution of water column P correlates well with the phosphorite deposits; and ^{4}He and ^{222}Rn tracer data (Top et al., 1999) indicate significant amounts of groundwater entering Florida Bay.

All three possibilities are long term sources that have probably not changed significantly over the past few decades, and thus alone cannot explain the ecological changes in Florida Bay that have occurred since 1981. It appears more likely that N inputs have increased in the past few decades. The dramatic increase in sugar cane production after 1959 (Snyder and Davidson, 1994) probably greatly increased the amount of N injected into the Everglades. The N and P concentration gradients along the canals from stations S2 and S7 in the north in the Everglades Agricultural Area to station S18C in the south right before the water flows into Florida Bay show the decline in nutrient concentrations as the water moves south. While most of the P is scavenged out quickly by the limestone and vegetation in the Everglades, approximately 60 µM N remains in the water at the southern end of the Everglades. This explains the high concentrations of N and low concentrations of P in the northeast corner of Florida Bay. The flow of this N-rich water into Florida Bay increased around 1980 for two reasons. As a result of the eutrophication of Lake Okeechobee, backpumping of water from the Everglades Agricultural Area into the lake was greatly reduced and the flow of water to the south was greatly increased. At the same time, more agricultural land in South Dade county needed to be drained because of a shift from winter-time farming to year-round farming (Ley, 1995), and more land needed to be drained because of development of more suburban areas west of the Miami-Ft. Lauderdale metropolis. As a result, more N-rich water was pumped through an expanded South Dade Conveyance System into Florida Bay. This increased flow coincides with the observations by frequent boaters in Florida Bay of increased algal blooms in Florida Bay starting around 1981 (DeMaria 1996).

It is hypothesized that the increase in freshwater flow into Florida Bay proposed by the Central and Southern Florida Project Comprehensive Review Study will increase the flux of N into eastern Florida Bay, which will then mix with P from the west and increase the algal blooms observed in central Florida Bay.

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Nutrient Cycling and Transport in the Florida Bay - Everglades Ecotone.

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The purpose of our research has been, first, to document temporal and spatial patterns of nutrient cycling and exchange between the mangrove zone of the southern Everglades and Florida Bay and, second, to understand the effects of changing freshwater flow on these patterns. Since January 1996, we have intensively studied an area with the main outlet of freshwater from Taylor Slough, Taylor River, as well as two other areas with significant freshwater inputs to the Bay, McCormick Creek and Trout Creek. For these creeks and nearby sites, we have measured net exchange of water and nutrients, nutrient distributions in porewater and bulk sediment, nutrient fluxes between sediments and water, nutrient fluxes between the prop roots of small mangrove islands and water in Taylor River, submersed macrophyte productivity, mangrove tree productivity, and net soil accretion.

Temporal variations in nutrient exchange between Florida Bay and the three creeks were largely driven by variations in water discharge, rather than variations in nutrient concentrations. Discharge was largely a function of water levels in the freshwater Everglades, but wind-driven forcing was important when freshwater head was low. A net export of P, N, and C from the wetland to the bay was measured at each of the three creek sites. Approximately 97% of these exported materials was in the form of dissolved organic matter. Total export from the southern Everglades to northern Florida Bay in 1997 is estimated to have been 4220 MT of C, 254 MT of N, and 3.3 MT of P. This yields a flow-weighted mean TN concentration of 56 µM and TP concentration of 0.33 µM, and an N:P molar ratio of 170. The Everglades thus appears to be an important C and N source, but not an important P source, for Florida Bay. Because of the high magnitude of its discharge, Trout Creek was the largest source of exported materials, accounting for 61% of C and N exports and 55% of P exports.

Nutrient exports are influenced by nutrient processing within the mangrove ecotone. In situ enclosures around mangrove islands within this wetland demonstrated that these islands are net sources of nitrate and nitrite throughout the year, indicating the importance of nitrification in the prop root system. This oxidized nitrogen may be readily denitrified within adjacent sediments. Nutrient fluxes within benthic chambers demonstrated that mangrove pond sediments are a net sink for N, with nitrate and nitrite uptake and very low ammonium regeneration. Preliminary N2 flux measurements found that these sediments have rapid rates of coupled nitrification and denitrification. Ammonium and P regeneration from sediments at nearby sites in Florida Bay were also very low, relative to dissolved oxygen uptake. Benthic nutrient regeneration does not appear to be strongly influenced by salinity levels. It appears that changing freshwater flow will not strongly change patterns of nutrient cycling and that the impact of increased nutrient inputs to the Everglades systems will be moderated because of the strong affinity of wetland and bay sediments for P and possibly because of N removal in the mangrove wetland.

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The Influence of Southern Everglades Wetlands on Nutrient Inputs to Florida Bay.

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The research we report here is a large portion of a major multi-year, multi-PI effort to document temporal and spatial patterns of nutrient cycling and exchange between the southern Everglades and Florida Bay and to understand the effects of changing freshwater flow on these patterns. Since January 1996, we have intensively studied the mangrove wetlands of the southern Everglades. One focus has been quantifying nutrient fluxes through Taylor River, McCormick Creek, and Trout Creek. Temporal variations in nutrient exchange were largely driven by water discharge, which in turn was largely controlled by water levels in the [upstream] freshwater Everglades. We found a net export of P, N, and C to the bay at all three creek sites; nearly all (97%) as dissolved organic matter. We estimated total export in 1997 from the southern Everglades to northern Florida Bay at 4220 MT of C, 254 MT of N, and 3.3 MT of P. The southern Everglades thus appears to be an important source of C and N, but not of P, to Florida Bay.

We have also been conducting process-based research in the southern Everglades mangrove zone since 1996. Over two years we quantified wetland-water column exchanges in the dwarf and fringe mangroves of this area using ecosystem enclosures in the former and modified, mid-channel flumes for the latter. Both season and water source controlled nutrient concentrations in these wetlands. Generally, organics came from upland sources (wet season) and inorganics came from the (dry season). The dwarf mangroves took up NH_4^+ and released oxidized inorganic N (NO_x) in proportion to one another, suggesting a wetland nitrification phenomenon. Furthermore, NO_x flux was negatively related to water column concentration (r2=0.644, p<0.0001). These dwarf wetlands consistently took up total nutrients (N, P, and OC). The fringe system often imported both forms of DIN in proportion to concentrations.

Mangrove productivity and the fate of leaf biomass are two other critical processes we have been quantifying. Litterfall in the dwarf mangrove wetlands varied from 0.556 (dry season) to 0.755 gdw m^{-2} d^{-1} (rainy season), or 200 to 285 gdw m^{-2} y^{-1}. These values are about 20 to 35% higher than the value reported for this forest type. The rate of litterfall in the fringe forest ranged from 1.72 (dry season) to 2.58 gdw m^{-2} d^{-1} (rainy season), or 440 to 940 gdw m^{-2} y^{-1}. In litter decomposition experiments we found that red mangrove leaves from both wetland types lost ≈ 40% of their original dry weight y^{-1} while black mangrove leaves lost 80%. During this time, the N content of red mangrove leaves increased from 5 to 14 mg g^{-1} and P content increased from 0.1 to 0.35 mg g^{-1}. Black mangrove leave N and P both increased about 50% during this first year of decomposition. In a 3 week leaching study we found that leaching accounted for more mass loss from leaves than did biotic decomposition. Most P leaching occurred in the first 24 hours, and most labile P had leached from leaves in 5 days--at which point each leaf had contributed ≈ 1 μM P gdw^{-1} leaf mass to the water column. Leaching of P was significantly greater in 16 and 32 ppt water compared to freshwater. Carbon leaching was more gradual than P, continually increasing over 3 weeks.

The main source of freshwater to this mangrove zone is [upstream] Everglades marshes. Primary hydrologic inputs there are rainfall and canal inflows. We have been quantifying short and long-term effects of increased canal inflows in the marshes of the ENP Panhandle area since 1997. We use 60m throughflow flumes located at the canal edge and fixed-point transects to quantify nutrient inputs and dynamics. Immediately after removal of the C-111 canal levees, in 1997, we saw a major influx of P and particularly N to these marshes, with rapid uptake of both by the marsh (within 2 km of the canal). However, by the 1998 wet season canal inputs of N and P were only slightly above ambient marsh concentrations. While the marsh was still a sink for P, it was now a source of N and C, primarily in dissolved organic forms. Our flume data showed very rapid N transformations within 60m of the canal, with NH_4^+ uptake and NO_x release (as in the mangrove wetlands). We have also been monitoring *Cladium* aboveground biomass and productivity along these marsh transects as an indicator of long-term ecosystem change. Nearly 2 years of these data showed a significant increase in biomass at the site closest to the canal only (likely a nutrient response) but a significant increase in biomass at all sites recently (likely a flow response). We have expanded this research effort to Taylor Slough in Summer 1999, completing our southern Everglades Integrated Research Program. As more freshwater endmember data become available, we will continue to develop and perfect our nutrient budgets and process-based models of this entire region--from the canal to the estuary.

Molecular Markers of Organic Matter Inputs and Transformations in Estuarine Environments of South Florida: Shark River and Taylor Slough.

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Organic matter, ubiquitous in aquatic environments, remains a central theme of investigation in estuaries. The sources and fate of such natural organic matter in South Florida estuarine environments was characterized using a molecular marker or 'biomarker' approach. Two sediment transects from the estuarine zone of the Harney River and the Taylor Creek, into the Florida Shelf and Florida Bay respectively, were characterized for their solvent extractable organic compounds. The molecular distributions and compound specific stable isotope data for several compound classes were correlated with possible biological sources, such as mangroves, seagrass, sawgrass and periphyton. Specific molecular markers as well as hierarchical clustering classification in conjunction with correspondence factorial analysis were used to trace the contribution of different sources of organic matter in this system. In addition, preliminary data on seasonal variations in the composition of suspended particulate matter in the Harney River were obtained.

The sediment samples described above were analyzed for all major lipid fractions. Although the general molecular distribution of the lipids was, as expected, mainly characterized by higher plant material, i.e. long chain fatty acids and alcohols and long chain alkanes with a strong odd over even carbon number predominance, some clear differences were also observed within this set of samples. N-heptadecane (nC_{17}) was relatively abundant in all shelf samples and Taylor River sediments, indicating a significant planktonic source of organic matter. However, in the Harney River samples, nC_{17} was present only in trace amounts. Higher diagenetic activity in the river sediments compared to the Shelf is likely to cause the degradation of this relatively labile compound. Interestingly, however, a highly branched $C_{20:1}$ alkene and the corresponding $C_{20:0}$ alkane were observed in abundance in both rivers. These compounds were found to be particularly abundant in the lipid extract of the Periphyton samples, and may therefore, serve as a biomarker for this type of biomass in the Everglades ecosystem. Other highly branched C_{25} and C_{30} isoprenoids were also identified, and assigned a microbial marine and freshwater origin respectively. The distribution of these compounds throughout the Harney River transect clearly shows that marine derived organic matter inputs during incoming tides are significant in this tidally influenced system. On the contrary, such tidal influences were not observed for the Taylor Creek transect.

Samples from the mangrove dominated parts of the estuaries contained significant amounts of higher plant triterpenoids (3-oxytriterpenoids), which were very low in abundance or absent in the peat samples. Compounds such as those derived from the amyrine, taraxerone and lupane family seem to be mainly derived from the mangroves in these systems. Surprisingly, another group of molecular markers for mangroves in this system were the n-alkenes, which presented a strong odd/even carbon number predominance. N-alkenes were very abundant in fresh mangrove leaves.

The presence of ring-A degraded triterpenoids in these samples suggest anaerobic conditions of these organic rich sediments. Aromatic and aliphatic tetracyclic triterpenoids were observed mainly in the anoxic Harney River and Taylor Creek sediments, while their pentacyclic counterparts were found in the peat samples. Abundance of these compounds in Florida Shelf samples and Florida Bay were minor. In fact, the limited number of Florida Bay samples analyzed were highly depleted in molecular markers of higher plant origin. However, ring-A degraded triterpenoids were detected in suspended particulate matter from the Harney River, clearly indicating the presence of re-suspended sediments in the estuarine zone. Although the above mentioned degradation products are present in both systems (Shark and Taylor Slough) and are indicative of microbial activity in the sediments, additional evidence for active microbial recycling was evident by the abundance of hopanoids. However, the molecular distribution of this group of compounds, shown to be exclusively derived from bacteria, was more complex in sediments from the Taylor Creek compared to the Harney. Compounds such as des-E-hopanes and abundant seco-hopanes were identified. Such compounds are rarely reported in recent environments, and are often found in ancient sediments and oil, being derived from thermocatalytic processes. However, they have also been found to be derived from their hopanoid precursors through microbial degradation. The reasons for the different fingerprints of microbial lipids between the two transects is presently unknown, and requires further investigation. Florida Bay sediments also showed elevated hopanoid levels, most likely derived from cyanobacterial mats, as well as the presence of sterenes and steradienes.

Finally, the molecular distribution of the alkan-2-ones in this system was quite different from the expected higher plant fingerprint. These ketones show a typically higher plant distribution for the peat and the River sediment samples. However, these distributions show a gradual change from Everglades to the marine samples, by shifting from a C_{27}, C_{29} and C_{31}, C_{33} dominated signal for the peat and mangrove sediments respectively, to a C_{25} dominated distribution at the mouth of the Harney River and Florida Shelf samples. For the Taylor Creek, such changes were not noted, most likely due to the fact that this system is not strongly influenced by tidal action. This result suggests that the marine samples are strongly influenced by organic matter derived from Seagrass, which was found to be dominated by the C_{25} alkan-2-one. Sediments from Florida Bay presented a mainly seagrass-derived signal in their ketone distribution.

Stable isotope measurements of the individual ketones, performed by GC/isotope ratio/MS confirmed this hypothesis by showing $^{13}C/^{12}C$ ratios of about -15 ^{o}/oo for the seagrass derived ketone and -31 ^{o}/oo for the mangrove derived compounds. A clear shift from mangrove to seagrass was also observed in the sedimentary C_{25} ketone isotopic composition throughout the studied transect for the Harney River. This trend was confirmed through correspondence factorial analysis. Heavier stable isotopic compositions were also observed for the n-alkanes at the marine influenced stations compared to the freshwater influenced endmembers. However, due to the relatively high abundance of n-alkanes in the cuticular leaf waxes of mangrove-derived organic matter, this trend was significantly less obvious compared to the alkane-2-ones. Isotopic composition of the C_{20} highly branched compounds (determined jointly) suggests an origin from diatom. This is presently being further investigated in our laboratory.

Sterols, fatty acids and alcohols were also analyzed, but will not be discussed in detail here. Basically, these classes of lipids supplied information regarding higher plant vs. microbial inputs of organic matter. Presence of dinosterol in a few of the Florida Shelf samples suggest presence of organic matter derived from dinofalgellates, while an unusually high relative abundance of the C_{22} n-alcohol, particularly in the marine influenced samples suggests the presence of marine decomposer organisms.

These preliminary results are a clear indication that the application of molecular markers identified for South Florida estuarine systems has a high potential to aid in the better understanding of the biogeochemical cycling of organic matter in coastal environments.

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Atmospheric Deposition of Nitrogen and Phosphorous to the South Florida Bay Ecosystems.

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The monitoring nutrient deposition to South Florida Bay is now underway. A 10- meter meteorological tower was installed at the Keys Marine Laboratory at Long Key in April 1998. Air samples, both dry and wet deposition, such as gaseous ammonia (NH_3), particulate ammonium (NH_4^+), particulate nitrate (NO_3^-), organic phosphorous (org-PO_4) and total phosphorous (PO_4) are measured. Meteorological parameters such as wind speed, wind direction, air temperature, relative humidity and solar radiation are also collected at the sampling site.

Atmospheric nitrogen include NH_3, NH_4^+ and NO_3^- were sampled using treated filter-packs. The preliminary results for the gaseous nitrogen species during the period of April, 1998 and March, 1999 showed that the NH_3 concentrations varied greatly (between 0.034 and 0.76 ug/m^3) with relatively higher concentrations in the Summer season. The averaged particulate NH_4^+ and NO_3^- concentrations were 1.20 ug/m^3 and 2.17 ug/m^3, respectively. The observed atmospheric NH_3 concentrations in South Florida Bay were similar to the averaged NH_3 concentrations in other coastal regions (such as Tampa Bay and Chesapeake Bay).

Since late October of 1998, aerosol monitoring of phosphorous and wet deposition of nitrogen has been underway. The sampling protocol, sample analysis and shipping logistics have been worked out in collaboration with the laboratory at the Illinois State Water Survey who conduct the analysis for the National Atmospheric Deposition Program (NADP). Samples collected through mid-February have been analyzed. For this period, the average dry deposition rate of ammonium aerosol was estimated to be about 0.18 mg/m^2/wk, compared to an average wet deposition rate of (0.1 mg/m^2/wk). The averaged weekly wet deposition rate of nitrate was on the order of 0.7 mg/m^2/wk. For Phosphorous, there has only been one week in which the wet deposition data were above the detectable limit. However, measurable air concentrations have been obtained each week in order to obtain a dry deposition rate. At this time, the averaged weekly PO_4^- deposition rate was estimated to be about 0.1 mg/m^2/wk. The analysis for organic contributions (that do no show up as PO4) have revealed some suggestive trends. For the last four sampling periods, total PO4 (which includes the organic fraction) have been generally 30% higher than the inorganic fractions. Further analyses of elemental ratios will be used to determine the possible origin of this organic fraction.

AVERAGE DEPOSITION RATE TO DATA (October 98 - mid February 99)

Average weekly wet NH_4 deposition	0.11 mg $NH_4/m^2/wk$
Average weekly wet NO_3 deposition	0.71 mg $NO_3/m^2/wk$
Average weekly dry NH_4 deposition	0.18 mg $NH_4/m^2/wk$
Average weekly dry PO_4 deposition	0.1 mg $PO_4/m^2/wk$

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Trace Element Distribution in Florida Bay: Atmospheric or Hydrologic Deposition?

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The fine fraction (<63 µ) from 190 Florida Bay surficial sediment samples was analyzed for 30 elements using ICP (induction coupled plasma spectrography). Contour maps of the elemental data show concentrations of phosphorous, iron, aluminum, and chromium, at least one order of magnitude greater in those areas where seagrass mortality began in the late 1980s. The zones of elevated trace element content also coincide with areas of reduced circulation, i.e., shallow basins in the west-central bay, remote from both Gulf and Atlantic tidal influence. These areas are known to experience periodic hypersalinity during periods of reduced rainfall. To determine if the increase is of recent origin, additional samples were taken every 2 cm down-core from two different mudbanks and analyzed for trace elements. One core was taken in the area of elevated trace elements (Whipray basin) and the other was taken outside (Russell bank). The core from Whipray basin, the zone where seagrass mortality has been most pronounced, showed an upward increase of P, Fe, Al, and Cr through time. Pb-210 dating showed the upward increase in trace elements began about 30 years ago. Three explanations for the localized increase in trace elements have been considered. First, the trace elements were transported and deposited by longshore currents moving southward along the west side of Florida. Second, the trace elements precipitated directly from hypersaline waters that periodically form in these restricted basins. Third, the trace elements were deposited from the atmosphere but accumulated preferentially in the poorly circulated basins. Although arguments can be made for all three origins we favor the atmospheric dust hypothesis because the period of concentration coincides with a well-documented increase in transatlantic dust transport that began in the early 1970s.

African dust transportation and deposition reached maximum levels in Miami and throughout the Caribbean between 1983 and 1987 and is still rising in concert with desertification of northern Africa. In addition to trace elements, especially iron, African dust contains numerous fungal spores, one of which is the cause of a Caribbean-wide seafan disease. We speculate that death of seagrass in the west-central bay basins was caused by a combination of hypersalinity, elevated trace elements/nutrients, fungal spores, and anoxia related to reduced circulation. Regardless of the origin of elevated trace elements, the large elemental dataset should be useful to others conducting biological and geological research in Florida Bay.

Sediment ICP data also revealed a north-south central-bay zone of elevated copper adjacent to but not coincident with the zone of elevated P, Fe, Al, and Cr. The north end of the north-south zone of elevated copper extends northward into the Taylor River Slough, suggesting run-off, possibly from agricultural areas further north.

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Eutrophication Model of Florida Bay.

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The initial application of the CE-QUAL-ICM eutrophication model to Florida Bay has been completed. The model simulates salinity, temperature, suspended solids, phytoplankton, organic carbon, as well multiple forms of nitrogen, phosphorus and silica. The model was applied to the period 1996-1997 using time steps of 12 minutes on a grid of over 1000 elements. Forcing functions for the model included recently calculated loads from the mainland, atmosphere and Keys as well as observed conditions at the system boundaries.

Transport information to drive CE-QUAL-ICM was provided by an existing RMA10-WES hydrodynamic model of Florida Bay. The water quality grid was overlaid on the finite-element hydrodynamic grid, which contained roughly 13,000 elements. RMA10 was applied to the years 1996-1997. Characteristic transport for 28-day periods in the wet and dry seasons of each year were looped to provide two years of transport for the eutrophication model.

The eutrophication model was coupled to a predictive sediment diagenesis model which computed sediment oxygen demand and sediment-water fluxes of ammonium, nitrate, dissolved phosphate and silica. Forcing functions for the diagenesis model included computed temperature, dissolved oxygen, and deposition of organic matter.

The eutrophication model incorporated a predictive submerged aquatic vegetation (SAV) module which simulated two species: *Thalassia testudinum* and *Halodule wrightii*. The SAV module interacted with a sediment resuspension algorithm, which predicted suspended solids as a function of wind-generated wave energy and SAV density.

The presentation focuses on comparison of computed and observed properties in the water column, in the SAV beds, and in the benthic sediments. Based on model computations, initial nitrogen and phosphorus budgets for Florida Bay are presented.

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Elevated Mercury Concentrations in Fish from Eastern Florida Bay.

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Health advisories are posted in northern Florida Bay warning of elevated levels of mercury in some upper trophic level fish. Spotted seatrout, crevalle jack, ladyfish, bluefish and gafftopsail catfish have been found with mean mercury concentrations greater than the Florida advisory level of 0.5 ppm wet weight. We have sought to unravel the origin of these elevated mercury levels through spatial patterns of mercury concentrations in biota, temporal patterns associated with seasonal inputs of freshwater from the Everglades, and food web structure as revealed by stable carbon, nitrogen, and sulfur isotope analyses.

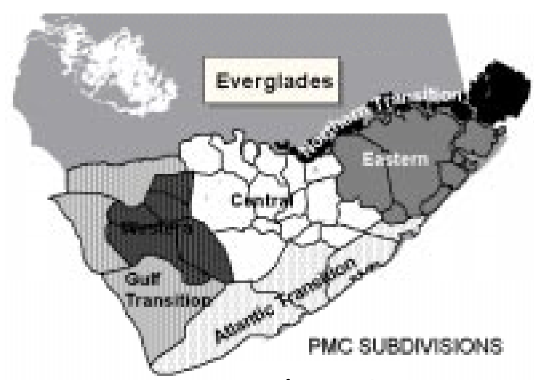

Figure 1

We have hypothesized that waters draining from the Everglades into northeastern Florida Bay could introduce methyl mercury into the food web supporting game fish caught for human consumption. We have sampled biota since December 1995 from throughout Florida Bay for mercury. Initial efforts have focused on three species of forage fish: bay anchovies, rainwater killifish, and mojarra, which are pelagic, seagrass canopy, and benthic feeders, respectively. They are important prey species of fish and avian predators. Additional samples of top predator fish, spotted seatrout, red drum, and gray snapper have been acquired through cooperators at FMRI, ENP , and FSU's Oceanography Dept. In analyzing the spatial distribution of mercury in fish, we have adopted a modification of the PMC's subdivisions of Florida Bay (**Figure 1**), adjusting boundaries to match the basin boundaries employed in the FATHOM salinity mass balance model. We have further grouped the Northern Transition, Eastern, and Central subdivisions into an "Interior " region closest to freshwater inflows from the Everglades and grouped the Gulf Transition, Atlantic Transition, and Western subdivisions into an "Outer" region remote from freshwater inflows. Highest mercury concentrations are observed in fish from the interior region in the central and eastern subdivisions of Florida Bay (**Table 1**). Spotted seatrout almost always exceed the 0.5 ppm advisory level in this region. Mercury concentrations in red drum frequently exceed this level, while mercury concentrations in gray snapper rarely exceed this level. Because of biomagnification processes, prey species are expected to have about one fifth of the mercury concentration of their predators. Mercury concentrations in bay anchovies are consistent with this expectation, exceeding 0.1 ppm throughout most of the interior region. Rarely are such concentrations exceeded in the outer region Mercury concentrations in mojarra and rainwater killifish are also highest in the interior.

Table 1. Mercury Concentrations (μg/g wet weight) in Forage and Game Fish in Subdivisions of Florida Bay and the Lavaca Bay Superfund Site in Texas

PMC Subdivision	Forage Fish			Game Fish		
	Bay Anchovy	Rainwater Killifish	Mojarra	Spotted Seatrout	Red Drum	Gray Snapper
Gulf Transition	0.062	------	------	0.308	0.323	0.102
Western	0.031	0.043	0.020	------	0.394	0.157
Atlantic Transition	------	0.121	0.062	0.784	0.178	0.132
Outer Bay	**0.052**	**0.069**	**0.048**	**0.627**	**0.298**	**0.131**
Central	0.122	0.162	0.049	1.300	0.585	0.294
Eastern	0.211	0.121	0.082	------	1.170	0.475
Northern Transition	0.105	0.123	0.111	1.955	0.567	0.314
Interior Bay	**0.148**	**0.128**	**0.079**	**1.518**	**0.668**	**0.341**
Lavaca Bay,Texas	**0.28**	**------**	**------**	**0.37**	**1.13**	**------**

The pattern of mercury concentrations among pelagic and benthic feeding species are expected to reflect the relative importance of the water column and sediments as proximate sources in mercury contamination. In this regard, Florida Bay contrasts with a Superfund site at Lavaca Bay, Texas where historic mercury contamination resides in bottom sediments. At the latter site, benthic feeding red drum exhibit higher mercury concentrations in comparison to more pelagic feeding spotted seatrout (**Table 1)**. Conversely, in eastern Florida Bay, mercury concentrations in spotted seatrout exceed those in red drum. Moreover, pelagic feeding anchovies in Florida Bay have higher mercury concentrations than benthic feeding mojarra or killifish feeding in the seagrass canopy. We conclude that in eastern Florida Bay, the pelagic food web is preferentially contaminated with mercury, thereby implicating a water column source.

If freshwater flow from the Everglades carries methyl mercury into the interior region of Florida Bay, we would expect fish from the Northern Transition subdivision to be most highly contaminated, because they are closest to the presumed Everglades source. This is not the case, however, as fish from the Eastern subdivision have highest mercury concentrations (**Table 1)**.

For short-lived species, mercury concentrations might follow the time trends in a presumed exposure to a freshwater source of methyl mercury. We hypothesize that highest mercury concentrations in anchovies will be observed late in the rainy season in response to seasonal freshwater inputs from the Everglades. We hope to use predictions from FATHOM to estimate methyl mercury concentrations within the bay and thereby link restoration activities to mercury levels in fish.

We are using stable isotope ratios of C, N, and S as tracers of trophic transfers. Analyses to date have been performed on a subset of the game fish samples provided by FMRI. Most fish show $*C^{13}$ values expected from a seagrass or epiphyte base to the food web. This is consistent with most predictions of the ATLSS model of the Florida Bay food web. A few fish collected near the mainland shore have $*C^{13}$ values suggesting a mangrove based food web. We have yet to find a $*C^{13}$ values consistent with a phytoplankton source. $*N^{15}$ values suggest that the trophic level of spotted seatrout is higher than that of red drum, which is higher than that of gray snapper. This is consistent with the pattern of mercury concentrations and the effects of trophic biomagnification. We have collected a broad range of other organisms from the bay. We expect mercury and stable isotope analyses to reveal the regional trophic pathways leading to elevated mercury concentrations in upper trophic level predators and to identify the species most vulnerable to accumulation of high mercury levels.

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Poster Abstracts

QUESTION 2

Nitrogen and Phosphorus Retranslocation in Mangrove Forests Located at the Everglades Salinty Transition Zone

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Green and Senescent leaves were collected in mangrove forests located along a salinity gradient in Taylor Slough at the Everglades National Park, Florida. Data were compared between two dwarf red mangrove forests and a mangrove forest located in the Ridge zone. The objective was to assess the relative importance of nutrient conservation of Rhizophora mangle trees along a salinity gradient among the three mangrove forests.

Nitrogen and phosphorus tissue concentrations were higher in green leaves of mangrove trees located in the Ridge zone compared to that of the trees located in the dwarf zone. There were differences in the amount of nitrogen retranslocated among the three mangrove zones. Mean retranslocation of nitrogen was 29 and 37 % in the dwarf forests and 49% in the Ridge forest. Mean phosphorus retranslocation was 85%; However, it was similar among the three mangrove forests.

The high phosphorus retranslocation reflects the low availability of this nutrient in carbonate environments and suggests that phosphorus is used very efficiently. The low nitrogen retranslocation also suggests that this nutrient is not limiting the plant growth.

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Distribution of Florida Bay Sediment Nutrients.

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In shallow estuaries such as Florida Bay, the sediment compartment is generally the largest nutrient pool within the system and the dynamics of nutrient exchanges at the sediment-water column interface can play a large role in determining the availability of nutrients for primary producers. Concentrations of DIN, SRP and silica were measured in the sediment porewaters of Florida Bay, as well as in the water column, during summer and winter surveys in 1997 and 1998. Sediment bulk nitrogen and phosphorus were also measured. A total of 24 stations distributed within the 5 major zones of the Bay were sampled in quadruplicate.

Sediment bulk nitrogen concentrations were lowest in the Eastern zone of Florida Bay and highest in the Western zone, and this pattern was consistent over the four 1997-1998 surveys. Concentrations in the Western zone of the Bay were usually higher during winter than during summer while the contrary was observed for most stations in the Central zone. Porewater DIN concentrations (mostly NH_4^+) ranged from 20 to 130 µM, and were not well correlated with sediment total N content. Water column N distributions (NH_4^+ and NO_3^-+NO_2^-) during summer and winter 1998 were similar among the different zones of the bay, and remained lower than 14 uM whereas they were as high as 28 µM in 1997. The more temporally and spatially patchy water column and sediment porewaters concentrations likely reflect the patchiness of new inputs of inorganic and labile organic N to the sediments, and local rates of diagenesis, while the total N concentrations likely reflect the longer-term patterns of N supply and accumulation of less labile fractions.

Sediment bulk P concentrations measured during summer 1998 had the same pattern as in 1997, with lowest concentrations in the Eastern Zone, and increasing concentrations towards the Western zone. Porewater P concentrations were generally low (most < 2 µM), and were not correlated with total P concentrations. In contrast to patterns observed in 1997, water column SRP distributions measured in 1998 ranged from 0.1 to 0.4 uM and did not show any pattern over the different zones of the bay.

Bulk sediment TN to TP (elemental) ratios were generally in the range of 30-50 similar to those found in tissues of nutrient-replete seagrasses and macroalgae. However, N:P ratios in the sediment porewaters were higher than 150 for 92 % of the stations sampled in 1997 and 79 % of the stations sampled in 1998. Since porewater nutrients would be the fraction of sediment nutrients most readily available to plants, these high ratios suggest that P is the more limiting nutrient to Florida Bay benthic primary producers.

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Periphyton and Sediment Bioassessment in North Florida Bay.

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Periphyton colonization and sediment bioassessment were used in a survey to determine the relative environmental condition of multiple sampling sites located in Florida Bay and four peripheral slough areas during the summer of 1995. The primary focus of the study was to provide much needed information on sediment toxicity, since its magnitude and extent in the Florida Bay/Everglades transitional area is almost unknown. Periphyton biomass, pigment content, tissue quality and community composition were determined. In addition, benthic community composition and toxicities of whole sediments and associated pore waters were determined using two species of rooted macrophytes (*Spartina alterniflora, Scirpus robustus*), an epibenthic invertebrate (*Mysidopsis bahia*) and bioluminescent bacteria. Several location differences were observed in the survey for the response parameters. Periphyton biomass was significantly greater in the Taylor River and the least in Shell Creek ($P = 0.05$). Most whole sediments were not acutely toxic to mysid shrimp. The maximum level of mortality observed for the benthic invertebrate was 20% above that observed for the reference sediment. The sediments were not phytoinhibitory but those collected from the Taylor River were 2 to 3 times more phytostimulatory than others ($P = 0.05$) based on ash free dry weight. Contaminant residues in the periphyton were similar at most sites; however, mercury, chromium and nickel concentrations were greater for periphyton colonized in the Taylor River and Trout Creek areas. Structural characteristics of the periphytic algal community usually were statistically similar ($P = 0.05$) but a consistent trend of lower density and diversity was evident for Shell Creek. The benthic community was the least diverse and dense in the Canal C-111. The results of this study provide an initial indication of differences in the role of several slough areas as possible sources of bioavailable contaminants to Florida Bay, which warrants additional investigation.

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Contaminants in Fish Tissues Collected from the Lower C-111 Canal and Selected Tributaries in Northeastern Florida Bay.

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A survey was conducted in the spring and fall of 1997 to determine the concentrations of selected contaminants in the edible portions of fish tissues. Twenty-seven sites from the lower C-111 Canal system and northeastern Florida Bay were visited and the resident populations of fish sampled by hook and line. Largemouth Bass, spotted sunfish, and mayan cichlid samples collected during the spring period of low rainfall and agricultural pesticide application were contrasted to those collected during the fall period of high rainfall. Samples were analyzed for organochlorine pesticides using GC and GC/MS protocols, for total mercury using ICP, and for methyl mercury using ethylation GC separation and detection with atomic fluorescence. Concentrations of total and methyl mercury found in fillets of fish from 10 - 11 locations ranged from (0.16 - 0.98 ug/g) and (0.12 - 1.0 ug/g) respectively. The higher concentrations were measured in fish from two NE Florida Bay sites. Concentrations of 4-4 DDE, heptachlor, and trans-nonachlor above the method detection limit (mdl) were measured in fish collected from 11 lower canal sites. Concentrations of 3.2 to 350. ng total endosulfan/g (endosulfan I, II, sulfate) were measured in fish from four canal sites during the spring. The same locations sampled in the fall had concentrations ranging from less than the mdl to 1.6 ng total endosulfan/g. There appears to be a seasonal correlation with the concentrations of contaminants in fish tissues from this area.

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Nutrient Exchange between NE Florida Bay and a Mangrove Creek in the Southern Everglades.

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Hydrological restoration of the Everglades will result in increased freshwater flow to Florida Bay. The exchange of nutrients between Taylor River and NE Florida Bay was measured to establish baseline estimates of nutrient flux before restoration work begins. Specifically, the objectives were to determine the trends in nutrient concentration and flux from Taylor River and determine the importance of relative effect of freshwater flow, rainfall, wind-driven and tidal forcing on water exchange and nutrient concentration at the mouth of the creek. Four 10-day intensive studies were conducted per year for a total of ten studies through out the period of January 1996 - May 1998 to determine the flux of dissolved inorganic and total N and P. A daily record of TN and TP flux was generated from daily water samples taken from May 1, 1996 through May 1, 1998, and flow was recorded at the creek mouth in 15-minute intervals through out this period. TN concentration was variable (50 -90 M) and highly correlated with freshwater flow. TP concentration stayed relatively constant throughout rainy and dry season flow conditions. There was an annual export of TP and TN of magnitude of 6270 moles yr-1 and 1,380,163 moles yr-1 respectively. Water exchange was influenced to a greater extent by freshwater flow and wind than by tide or local rainfall. Organic N and P dominated total nutrient flux during the five sampling periods (89 - 94%). Peak TP and TN export occurred during the beginning of the rainy season coincident with heavy rainfall in the watershed, while peak import was associated with wind-driven forcing. The lack of variation in TP relative to TN concentration in the salinity transition zone of the Everglades and the high total and inorganic N:P ratios (120-200) give evidence for highly phosphorus-limited environment.

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Benthic Nutrient Fluxes near Florida Bay's Mangrove Ecotone.

David Rudnick and *Stephen Kelly*, Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL; *Chelsea Donovan* and *Karl Picard*, Center for Environmental Studies, Florida Atlantic University, Boca Raton, FL; *Jeffrey Cornwell* and *Michael Owens*, Horn Point Environmental Laboratory, University of Maryland, Cambridge, MD.

To understand the ecosystem-level effects of the hydrological restoration of Florida Bay and the Everglades, we measured benthic fluxes of dissolved oxygen and nutrients in and near the mangrove ecotone of Florida Bay. Five sites along north-south transects through Little Madeira Bay and Terrapin Bay were seasonally measured using in situ chambers from May 1996 through May 1998 and less frequently measured since then. Only dark chamber results are reported here. The salinity regimes differed greatly among sites, ranging from the rapid changes within a pond in the mangrove ecotone to the more gradual changes found the bay south of Little Madeira Bay (sLMAD). Sediment characteristics and submersed aquatic vegetation (SAV) coverage and biomass also differed among sites. The sediments of the mangrove pond, which had ephemeral *Ruppia maritima* and *Chara* sp. coverage, had about two to three times higher concentrations of organic C, N, and P than the sediments of other sites.

Mean dissolved oxygen uptake in dark chambers ranged from 54 mg m^{-2} h^{-1} (SE = 3) at the sLMAD site to 107 mg m^{-2} h^{-1} (SE = 21) south of Crocodile Point. Oxygen uptake rates were positively correlated with temperature and SAV biomass, explaining 55% of the variance of these fluxes. Phosphorus fluxes were low at all sites, with TP uptake by sediments at all sites except in the mangrove pond, where there was a net P release (mean ± SE of 0.7 µmoles m^{-2} h^{-1} ± 0.6). Net uptake of nitrate and nitrite by the sediments occurred at all sites. Net release of ammonium from the sediments occurred at all sites but ranged very widely among sites (from 6 µmoles m^{-2} h^{-1} ± 13 to 114 µmoles m^{-2} h^{-1} ± 37 near Crocodile Point). Eastern bay sites had lower rates than the central bay sites and sites closest to mangrove wetlands had lower rates than the more offshore sites. Relative to oxygen uptake, ammonium release was very low, with mean O:N molar ratios ranging from 50 to 320.

For all sites other than the pond sites, ammonium flux rates were strongly correlated with temperature. Between temperatures of 20^{o}C and 25^{o}C, fluxes were very low (relative to oxygen) and even net ammonium uptake frequently occurred. At temperatures above 30^{o}C, these fluxes were five fold to ten fold higher. This extreme temperature sensitivity, and the high O:N ratios observed, may indicate the importance of denitrification. Preliminary measurements of N_2 fluxes within the chambers have yielded results consistent with this hypothesis. When this N_2 flux is added to the dissolved inorganic N flux from the pond sediment, the O:N ratio dropped to near 20; coupled nitrification and denitrification appears to account for most of the "missing" nitrogen.

These results demonstrate the strong retention of both P and N by the benthic community of northern Florida Bay and the mangrove ecotone. Despite changes in sedimentary ion exchange that occur with changing salinity, we found no clear relationship between salinity levels and net benthic fluxes; salinity does not appear to strongly influence nutrient regeneration rates. Thus, an increase in freshwater flow associated with Everglades restoration is not likely to alter nutrient regeneration patterns. Our finding of low inorganic N regeneration also indicates that the coastal benthic community may retain or denitrify increased N inputs to this region that could occur in association with increased freshwater flow.

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Seasonal Changes in Nutrient Profiles at the Sediment-Water Interface at the Mangrove-Seagrass Ecotone in Northeastern Florida Bay.

Brett S. Solomon and *Marguerite S. Koch*, Aquatic Plant Ecology Lab, Florida Atlantic University, Boca Raton, FL.

Nitrogen and Phosphorous cycling in seagrass ecosystems adjacent to upland mangrove communities is little understood, particularly in carbonate lagoons. We characterize seasonal fluctuations in salinity, pH, and nutrient profiles at the sediment-water interface at two mangrove-seagrass transition zones in northeastern Florida Bay. Surface and pore water samplers (0.2 M mesh) were deployed at four sites, two interior and two Bayward, for five sampling periods from January 1997 to January 1998.

Salinity fluctuations were dependent on both season and geographical location of the study sites. The May dry season surface water salinities were highest (³ 30 ppt), and surface water salinities were greater than those in the pore water. During the August rainy season, surface water salinities declined in all sites. Crocodile Point, a Bayward site, had the most stable seasonal salinity (25 to 35 ppt) among sites. Terrapin Bay, an interior site, had the widest salinity fluctuation, from 10 to 32 ppt. Seasonal pH profiles from all four sites were similar, excluding salinity as a main driver of pH change across the sediment-water interface. More likely, benthic micro-algae and submerged aquatic vegetation, dominated by seagrasses, may be causing surface water pH to rise above 8.0. Increases in pH at this interface may be important in shifting the carbonate equilibria toward calcium carbonate precipitation. This precipitation may facilitate co-precipitation of phosphorus in the surface waters also controlling SRP flux from the sediment to the overlying water.

SRP concentrations across sites and season were primarily below 0.2 µM in both the surface and pore waters, and 50 and 35% of the observations were below 0.1 µM in the surface and pore water, respectively. SRP in the pore waters was similar to concentrations in the surface water, suggesting that SRP flux rates from the sediments should be low or nonexistent. Seasonal changes in the pore water SRP were minimal, with only slightly higher concentrations found during the rainy season. The highest concentrations, with several observations over 1.0 µM SRP, were found during August and November.

In contrast to SRP, ammonium concentrations were high in the porewaters, and showed steep concentration gradients at the sediment-water interface. The steep concentration gradient suggests that sediments may be a source of inorganic N to the water column during some times of the year, and was most noted at the western sites during August 1997. Ammonium concentrations were maximum during the summer (August 1997), when temperature and fresh water flows are greatest. In addition to seasonal fluctuations, geographical differences were observed with the most interior sites having higher pore water NH4+ concentrations compared to the Bayward sites. The lower NH4+ levels in the Bayward sites may be related to higher NH4+ uptake rates by *Thalassia*, which dominates in the Bayward sites, compared to the smaller stature *Halodule*, which is dominant at Terrapin Bay, and *Ruppia* and *Chara* in Pond One, both interior sites. An east-west gradient was also noted. Ammonium concentrations exceeded 400 uM for western sites compared with eastern sites that never exceeded 200 uM.

Profiles of oxidized N forms, nitrate and nitrite, were low compared to the ammonium concentrations. Both nitrate and nitrite concentrations or NOx did not show any distinctive depth distribution among sites, with the exception of January 1997 at Crocodile Point. Nitrate and nitrite concentrations were generally similar for surface and pore water at the four sites across seasons. At the Crocodile Point site in both January 1997 and 1998, nitrite concentrations were 8 to 2 times higher, respectively, in the surface waters compared to the pore water. The increase in surface water NO2- and NO3- concentrations in January suggest high nitrification rates at Crocodile Point during the winter months.

Nitrogen mineralized in the sediment may be an important link to N availability in the water column. This transfer of nutrients may be partially responsible for continuous algal blooms at the Terrapin site. Phosphorous from the central Bay may be contributing to blooms at this site, because sediment does not appear to be a P source to the water column, based on the SRP gradient at the sediment-water interface measured in this study.

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Nutrient Flux at the Sediment-Water Interface in Florida Bay.

Laura A. Yarbro and *Paul R. Carlson*, FWCC Florida Marine Research Institute, St. Petersburg, FL.

Benthic remineralization and fluxes of nutrients are potentially important sources of nitrogen, phosphorus, and silica for phytoplankton in Florida Bay because sediment nutrient pools far exceed amounts found in Bay waters. To determine the potential contribution of benthic nutrients to the annual fall-winter phytoplankton blooms, we measured *in situ* rates of net nutrient flux at six sites in Florida Bay on five sampling dates between September 1997 and March 1999 using clear, cylindrical acrylic chambers. Sites were chosen to represent a range of sediment nutrient and bottom cover types in Florida Bay.

On most sampling dates, we measured benthic nutrient flux at night to avoid artifacts associated with light and dark incubations during daylight hours. At each site, four chambers (60 cm in diameter) were deployed in the afternoon and sampled every 1-3 hours through the next morning. Oxygen was injected into chambers as necessary to prevent anoxia. Dark chambers were used in August, 1998 because weather conditions were unsuitable for night operations. Water samples were filtered through GFC filters into acid-washed polypropylene bottles and immediately frozen on dry ice. We measured filterable reactive phosphorus (FRP), total dissolved phosphorus (TDP), nitrate (NO3), ammonium (NH4), silicate (SiO4) and total dissolved nitrogen (TDN) using manual and TRAACS analytical protocols. Levels of FRP and TDP were often near the level of detection (0.01 uM) whereas SiO4 concentrations were generally 15-50 uM, ammonium 0.1-8 uM, and TDN 15-45 uM. Dissolved organic phosphorus (DOP) was determined by the difference between TDP and FRP, and dissolved organic nitrogen was determined by the difference between TDN and the sum of NO3 and NH4.

Silicate fluxes ranged from–337 umol/m^2-h at Rankin Lake in September 1997 to 766 umol/m^2-h at Rankin Lake in August 1998. Ammonium fluxes ranged from –8.3 umol/m^2-h in Rankin Lake in November 1998 to 156 umol/m^2-h at Sunset Cove in November 1998. Ammonium fluxes were generally high in fall and low in March 1999. TDN fluxes were highly variable among sites and sampling dates, ranging from -340 umol/m^2-h at Rabbit Key Basin in August 1998 to 193 umol/m^2-h at Sunset Cove in November 1998. DON fluxes also varied among sites and sampling dates, ranging from 5.7 umol/m^2-h at Swash in May 1998 to 250 umol/m^2-h at Rabbit Key Basin in August 1998. However, net DON flux of was always from sediments to water.

Because FRP concentrations were so low, flux estimates were highly variable (Table 1). Fluxes of FRP and TDP ranged from net uptake of –0 to 3 umol/m^2-h to sediment release of 0-20 umol/m^2-h, but most fluxes were less than 1 umol/m^2-h. While the Johnson Key Basin showed higher net uptake of phosphorus by the benthic community for all sampling dates, the other sites showed more consistent release.

Table 1: Average fluxes of FRP and TDP at six sites in Florida Bay for 5 sampling dates.

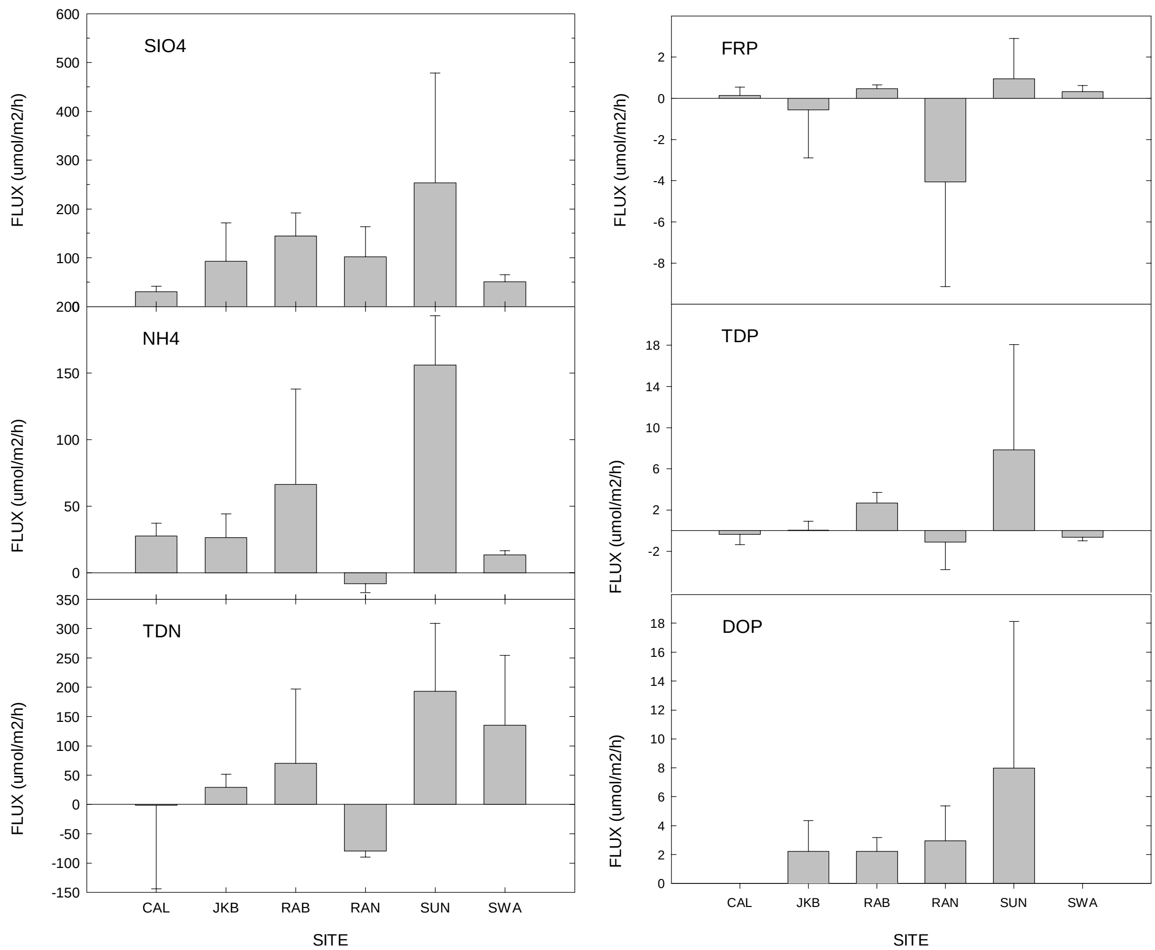
FRP FLUX (umol/m^2/h)

	Calusa	Johnson Key Basin	Rabbit Key	Rankin Lake	Sunset Cove	Swash
Sept. 97	-0.20	-0.02				0.02
May 98	0.17	-1.54	-0.36	0.39		-0.15
Aug. 98	1.54	-3.56	0.30	1.54		0.26
Nov. 98	0.14	-0.55	0.47	-4.06	0.94	0.32
Mar. 99	1.99	0.04	0.53	-0.39	1.06	0.30

TDP FLUX (umol/m^2/h)

	Calusa	Johnson Key Basin	Rabbit Key Basin	Rankin Lake	Sunset Cove	Swash
Sept. 97	-0.20	0.19				1.47
May 98	-1.12	3.27	0.70	-0.52		-0.27
Aug. 98	0.00	-0.62	11.57	-6.23		0.19
Nov. 98	-0.38	0.03	2.68	-1.12	7.85	-0.67
Mar. 99	0.40	1.45	-0.94	0.11	1.58	-0.25

Fluxes in November 1998 show typical variation among sites (Figure 1). Sunset Cove showed substantial net flux from the sediments for all nutrients on the two dates of measurement, probably reflecting the proximity of this site to the developed area of Key Largo. Given the large pools of phosphorus in Florida Bay sediments, we were surprised by the consistent, nearly non-detectable concentrations of FRP and TDP and the low but highly variable fluxes, both in magnitude and direction. Benthic chambers give consistent and reliable estimates of non-limiting nutrients (such as silica and ammonium for most sites and sampling dates), but phosphorus fluxes are very difficult to resolve in a phosphorus-limited system like Florida Bay.



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Geochemical Measurements of Carbonate Sedimentation and Organic Productivity in Florida Bay: A Potential Measure of Restoration Progress.

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Water management practices in South Florida are already being altered in an effort to restore the Everglades and Florida Bay. Resulting changes in water chemistry will first affect biogeochemical processes, and may result in changes in species distributions (such as seagrass, algae, etc.) in the Bay. Monitoring changes in biogeochemical processes is critical to early identification of ecological response to restoration and predicting changes in species distribution within the Bay.

We have developed and tested techniques for measuring critical biogeochemical processes in the Bay including carbonate sediment production by calcifying organisms and dissolution, photosynthesis, and respiration (referred to collectively as productivity). Carbonate sedimentation and organic productivity are most effectively determined from precise, *in situ* measurements of alkalinity, pH, temperature, conductivity, and air:sea CO_2 and O_2 gas fluxes. Productivity on Russell Bank was determined in July 1998 and March 1999 using an “upstream/downstream” technique for measuring spatial geochemical changes. Sontek current meters were deployed on the banks to characterize current velocity and direction. Geochemical parameters were measured at upstream and downstream stations along north/south transects across the bank every 4 hours. Maximum rates of productivity during incubation periods were used to calculate rates of calcification, photosynthesis, and respiration. Productivity in basins adjacent to Buchanon and Russell Banks was determined in March 1999 by measuring temporal geochemical changes over 24 hour periods in a large, *in situ* incubation chamber that isolates the mass of water overlying benthic substrate. Basin water was turbid due to sediment resuspension from winter storms.

Preliminary results of Russell bank productivity measurements indicate maximum rates of net calcification of 0.54 g $CaCO_3$ $m^{-2}day^{-1}$ during July and 0.18 g $CaCO_3$ $m^{-2}day^{-1}$ during March. Estimates of annual production rates from these measurements suggest net sediment accumulation rates of approximately 0.1 mm yr^{-1}. Maximum rates of photosynthesis in Russell Bank ranged from 0.03 g carbon $m^{-2}day^{-1}$ in March to 0.67 g carbon $m^{-2}day^{-1}$ in July. Results of basin productivity measurements indicate net dissolution of carbonate sediments during turbidity events resulting from sediment resuspension. Net rates of photosynthesis for basins were –0.3 g carbon m^{-2} day^{-1} near Buchanon Bank (indicating that respiration dominates over photosynthesis) and 0.08 g carbon $m^{-2}day^{-1}$ near Russell Bank. Rates of carbonate sediment production and photosynthesis measured geochemically are similar to rates determined by measuring accumulated calcium carbonate sediments and standing crops of seagrasses in the Bay. These field investigations indicate that geochemical productivity measurements are an effective measure of these biogeochemical processes.

Biogenic calcification, photosynthesis, and respiration are sensitive to changes in water quality including salinity and nutrients. Monitoring these biogeochemical processes as water quality changes during restoration efforts can be used as an effective ecological performance measure for restoration progress, and will provide insight into the link between biological function and environmental quality.

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Oral Abstracts

Wednesday, November 3, 1999

8:00am-11:30am

QUESTION 3

Wednesday, November 3, 1999

am

7:00-8:00 **Morning Refreshments**

Question 3. ***What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?***

8:00-8:20 **Introduction to Plankton Research.** ***John Hunt***, PMC Member, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Marathon, FL.

8:20-8:40 **Remote Sensing of Phytoplankton Dynamics in Florida Bay Using Hyperspectral Imaging Sensor (AVIRIS) Data.** ***Laurie L. Richardson***, Florida International University, Miami, Florida; *Fred A. Kruse*, Analytical Imaging and Geophysics, LLC, Boulder, CO; *Paul V. Zimba*, USDA-ARC, Stonesville, MS.

8:40-9:00 **Seasonal Variations in Diatom Growth and Distribution in Western Florida Bay and the West Florida Shelf.** ***Jennifer L. Jurado*** and *Gary L. Hitchcock*, RSMAS, University of Miami, Miami, FL.

9:00-9:20 **Estimates of Phytoplankton Growth, Production and Nutrient Requirements Based on a Drifter Tracked Water Parcel in Western Florida Bay, USA.** ***G. A. Vargo***, *M. B. Neely* and *L. Melahn*, University of South Florida, St. Petersburg, FL; *G. L. Hitchcock*, *J. Jurado* and *D. Mir*, RSMAS, University of Miami, Miami, FL.

9:20-9:40 **The Relationship between Inputs of Fresh Water to Florida Bay and Environmental Patterns of Physico-Chemistry, Light Climate and Primary Production.** ***Christopher J. Madden*** and *Stephen Kelly*, South Florida Water Management District, Everglades Systems Research Division; *Jason McAuliffe* and *Chelsea Donovan*, Florida Center for Environmental Studies, Key Largo, FL.

9:40-10:00 **Refreshment Break**

10:00-10:20 **Relationship of Sedimentary Sulfur, Iron and Phosphorus Cycling to Water Quality in Florida Bay: How Seagrass Die-Offs Contribute to Algal Blooms.** ***Randolph Chambers*** and *Lisa Millman*, Fairfield University, Fairfield, CT; *James Fourqurean*, SERP, Florida International University, Miami, FL.

10:20-10:40 **Differences in Microzooplankton-Phytoplankton Interactions in Florida Bay by Ecological Region.** ***Robert J. Brenner*** and *Michael J. Dagg*, Louisiana Universities Marine Consortium, Chauvin, LA.

10:40-11:00 **Modeling The Water Column Ecosystem in Florida Bay.** ***Adrian B. Burd*** and *George A. Jackson*, Department of Oceanography, Texas A&M University, College Station, TX.

Wednesday, November 3, 1999 *(continued)*

11:00-11:20 **A Synoptic Study of the Short-term Variability in a Florida Bay Diatom Bloom, January, 1999: Biomass, Production, Growth, and Losses.**
Synoptic Study Team.

11:20-11:40 **Panel Question and Answer**

11:40-2:00 **Lunch on Own**

pm

2:00-3:00 **Poster Presenters to Set-up Displays**

3:00-6:00 **Posters Available for Viewing**

Remote Sensing of Phytoplankton Dynamics in Florida Bay Using Hyperspectral Imaging Sensor (AVIRIS) Data.

Laurie L. Richardson, Florida International University, Miami, FL; *Fred A. Kruse*, Analytical Imaging and Geophysics, LLC, Boulder, CO; *Paul V. Zimba*, USDA-ARC, Stonesville, MS.

We have been investigating the application and use of hyperspectral imaging sensor data for the detection and discrimination of algal (phytoplankton) populations in Florida Bay. The sensor we are working with is AVIRIS (the Airborne Visible Infrared Imaging Spectrometer). AVIRIS is the first hyperspectral imaging sensor to be deployed at high altitude that is available for environmental research, and is a prototype for future generations of hyperspectral satellite-borne sensors. AVIRIS is flown on NASA's high-altitude ER-2 aircraft at an altitude of 65,000' to provide a spatial resolution of 20 m. The sensor provides spectral data from 365 to 2500 nm via 224 contiguous bands, each of which is ca. 10 nm wide. As a hyperspectral-imaging sensor, each pixel of an image contains an associated spectrum.

AVIRIS data were collected and analyzed to discriminate and map different phytoplankton assemblages throughout Florida Bay based on detection of spectrally based optical (reflectance) signatures dominated by taxonomically significant algal pigments. The AVIRIS data were supported by accessory pigment data collected by HPLC analysis of water collected from the bay, and phytoplankton cell counts.

Eleven AVIRIS scenes were collected on one day (March 23, 1996). During the flight, pigment samples were collected from 7 basins within Florida Bay. It is well known that individual basins within Florida Bay are highly variable in terms of phytoplankton population composition, both spatially and temporally. Our sampling and analysis revealed different phytoplankton assemblages throughout the bay, as is typical.

Image processing of AVIRIS data, supported by the groundtruth data, was carried out using ENVI (the Environment for Visualizing Imagery) software to produce classified imagery in which classifications depict phytoplankton bloom composition. In this way, we were able to discriminate and map blooms that consisted of: 1) diatoms and cyanobacteria; 2) diatoms only; and 3) mixed blooms of diatoms, cyanobacteria and microgreen algae. Classification results revealed that while basins were dominated by one type of bloom, patches of differing phytoplankton composition were also detectable.

The value of remote sensing is the provision of regional scale, quantitative, and synoptic data sets. The new capability of discriminating different phytoplankton populations should prove invaluable in ongoing efforts to understand the large-scale complexities of the Florida Bay ecosystem.

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Seasonal Variations in Diatom Growth and Distribution in Western Florida Bay and the West Florida Shelf.

Jennifer L. Jurado and *Gary L. Hitchcock*, RSMAS, University of Miami, Miami, FL.

Analyses of biogenic silica ($BSiO_2$) and chlorophyll *a* (chl *a*), in the total and >5μ size fraction, were made to quantify diatom growth rates and distributions in western Florida Bay and the west Florida shelf. A summer bloom produced maximum $BSiO_2$ concentrations of 18.67 μM in the western Bay in June. $BSiO_2$ concentrations decreased to 3.25 μM in September but by November bloom concentrations of 17.47 μM were measured. During this period the percent of total chl *a* found in the >5μ size fraction increased from 66 to > 90 percent. In autumn $BSiO_2$ concentrations were greatest in western basins where the $BSiO_2$:chl *a* ratio in the >5μ size fraction was minimal while nominal $BSiO_2$ concentrations were found in northeastern basins and $BSiO_2$:chl *a* ratios in the >5μ size fraction were elevated. This apparent disparity might be attributed to the resuspension of heavily silicified benthic diatoms characteristic of northeasterly basins. A positive correlation was found between $BSiO_2$ and chl *a* (>5μ) from October to December 1998 when total chl *a* concentrations were greater than 2.0 μg/L. $BSiO_2$ and $BSiO_2$/chl *a* (>5μ) concentrations were inversely proportional to dissolved inorganic silicate SiO_2 concentrations during this period. In December SiO_2 levels were maximal near Cape Sable with concentrations reaching 30.85 μM while $BSiO_2$ concentrations measured 1.42 μM. A silicate gradient was observed extending into the western Bay where concentrations fell to undetectable levels while $BSiO_2$ concentrations increased to 20.99 μM. $BSiO_2$/chl *a* (>5μ) increased from 0.79 to 6.19 μmol/μg as silicate concentrations decreased in surface waters. In February $BSiO_2$ was no longer inversely proportional to silicate concentrations.

Dilution grazing experiments were conducted in December 1998, and January, February, April and June 1999. Duplicate samples for six dilutions were enriched with the PO_4, NO_3 and SiO_2 to final concentrations of 1 μM, 10 μM, and 10μM, respectively. Growth rates were measured based on the response of the >5μ chl *a* size fraction. Growth rates in December were 1.9 day^{-1} when the $BSiO_2$: chl *a* ratio in the >5μ size fraction was 0.61 μmol Si (μg chl *a*)$^{-1}$. In January a series of dilution experiments were performed over several days at the termination of the winter diatom bloom. Extreme variability was observed as growth rates increased from 0.3 to 1.20 day^{-1} and the $BSiO_2$: chl *a* ratio in the >5μ size fraction decreased from 8.81 to 1.35 μmol Si (μg chl *a*)$^{-1}$. During this period the relative abundance of diatoms increased from 34 to 94 %, followed by a decline to 76 percent. The elevated $BSiO_2$:chl *a* ratios in the >5μ size fraction observed during January may reflect an increase in the abundance of empty diatom frustules due to resuspended bottom sediments, or the remnants of the bloom. Dilution grazing experiments in February yield maximum growth rates of 2.4 day^{-1}. Unenriched controls without nutrient additions demonstrated negative growth rates in about half the experiments (December, January, and February) and only minimal growth in the remainder of the experiments (January, January, and June). These observations suggest that dissolved nutrient concentrations were often insufficient to sustain growth above losses due to grazing, sinking, or natural mortality.

$BSiO_2$ dissolution rates were measured in dark incubations in June 1998, and January, April and June 1999. Dissolution rates in June 1998 averaged 9.76 to 10.77 μmol Si (kg day)$^{-1}$ when temperatures were ca. 30^{o}C. Positive and negative changes were both observed in $BSiO_2$ concentrations during the January experiments when temperatures averaged 17^{o}C. Dissolution rates were 2.95 and 5.10 μmol Si (kg day)$^{-1}$ when diatom growth rates were 0.3 and 0.69 day^{-1}, respectively, while $BSiO_2$ production of 1.02 μmol Si (kg day)$^{-1}$ was observed when growth rates were 1.20 day^{-1}. The time averaged difference between net $BSiO_2$ production or dissolution may be dependent upon average growth rates during the incubation period.

Previous research has documented diatom division during dark incubation, a process that might mask $BSiO_2$ dissolution and would explain increases in $BSiO_2$ levels in rapidly growing samples. In contrast to June 1998, for which no growth data is available, diatoms in June 1999 demonstrated $BSiO_2$ production rates of 2.75 μmol Si (kg day)$^{-1}$ with growth rates greater than 2.0 day^{-1}. For those experiments where $BSiO_2$ dissolution was observed, the reduced dissolution rates in winter months is consistent with previous studies that have observed a temperature-dependent reduction in biogenic silica dissolution rates. Water column regeneration of SiO_2 from $BSiO_2$ dissolution may provide a significant means by which silica is recycled in the surface waters of Florida Bay. Future studies will quantify silica dissolution in the water column and benthic regeneration as sources of silicate to sustain diatom blooms in the western basins of Florida Bay, and the role of benthic microalgae as potential mediators of benthic SiO_2 flux.

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Estimates of Phytoplankton Growth, Production and Nutrient Requirements Based on a Drifter Tracked Water Parcel in Western Florida Bay, USA.

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Our study is one part of a larger program designed to determine the role of advective nutrient flux in meeting the nutrient demands of phytoplankton in western Florida Bay and the Southwest Florida Shelf south of Cape Romano. One phase of this program utilizes tracer/drifter studies to track a parcel of water in which phytoplankton growth and loss estimates along with dissolved and particulate nutrient availability are followed.

A series of CODE type drifters were deployed in northwestern Florida Bay in the channel between East Cape Sable and Sandy Key. During the first two days their trajectories displayed a series of East-West tidal ellipses within the channel but after two days, all drifters migrated into a North-South trajectory along the western boundary of Florida Bay. Samples were taken twice daily for dissolved inorganic and organic nutrients, particulate carbon, nitrogen and phosphorus, and chlorophyll-a. Production, and therefore nutrient requirements, are based on phytoplankton growth rates estimated from cage cultures and dilution gradient experiments and diurnal changes in biomass within the patch of water tracked by the drifters.

Daily increments in POC represent growth rates of 0.54 and 0.51 per 12 hrs. for June 17 and 18. Observable growth occurred in dialysis cultures started on June 18. The average daily growth rate for this experiment was 0.52/day; a value reasonably similar to the rates calculated from the increment in POC. No growth occurred in the dilution gradient experiments without nutrient additions. When N, P, and Si were added to the dilution gradient bottles at a ratio of 1:10:10, growth rates ranged from 0.4 to 1.1/day and 0.8 to 1.0/day on June 17 and 18, respectively. This suggests that the growth rate and biomass in this region was nutrient limited. It is of interest to note that the average growth rate with nutrient additions in the 100% bottles (no dilution) averaged 0.74/day, which corresponds to our rate of 0.75/day obtained in dialysis culture. In addition, regression analysis of the dilution series indicates that microzooplankton grazing was negligible.

Potential nutrient input from the Shark River, located north of the study area, is derived from property-salinity relationships. TDP concentration in the River ranged from 8 to 27 ug/l. Although the TDP distribution along the salinity gradient was not conservative, at approximately 30 psu (the salinity at drifter locations) we would expect approximately 13 ug/l. This is essentially the same concentration we measured at the drifters. Thus, as indicated by T. Lee and G. Hitchcock (pers. comm.), the Shark River can serve as a source of nutrients for this area.

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The Relationship between Inputs of Fresh Water to Florida Bay and Environmental Patterns of Physico-Chemistry, Light Climate and Primary Production.

Christopher J. Madden and *Stephen Kelly*, South Florida Water Management District; Everglades Systems Research Division; *Jason McAuliffe* and *Chelsea Donovan*, Florida Center for Environmental Studies, Key Largo, FL.

The amount and timing of Everglades fresh water input to Florida Bay is an important determinant of water column nutrient, light, salinity regimes throughout much of the estuary, which, in turn, influences partitioning and rates of primary productivity. Since 1997, a large, multi-disciplinary program of monitoring and experimentation has been aimed at discerning 1) the time and space scales of Everglades influence on northern Florida Bay, 2) the nature of harmful and beneficial material and energy inputs to the Bay, and 3) the response of primary production to these factors. An associated ecological modeling program has also been initiated, with the objective of testing hypotheses about the interaction of fresh and marine waters in the estuary, and developing an understanding of managing freshwater inputs to optimize estuarine function.

Factors associated with fresh water inputs change on sub-daily, diel, seasonal and interannual timescales. Spatial gradients in water quality properties are apparently related, in an east-west direction, to differences in Everglades hydrological inputs, and in a north-south direction, to meteorological and hydrological forcing along an estuarine salinity gradient. Freshwater effects on water quality and primary production are being examined through high-resolution mapping of physico-chemical parameters and seasonal measurements of seagrass, microphytobenthos (MPB), phytoplankton and epiphyte productivity.

Chlorophyll, salinity, temperature, water clarity, dissolved oxygen, and pH are routinely measured bi-weekly to bi-monthly in high-resolution 2-D mapping transects with a continuous flow-through system. Water transparency is measured by flow-through transmissometer and chlorophyll by in vivo fluorescence. Range and variability of water quality parameters in each basin along the southern Everglades boundary respond differently to wet season inputs, each with distinct nutrient, salinity and turbidity characteristics, largely dependent on the strength of hydrologic connectivity of the basin with the Everglades. Transitional basins maintain near-oceanic salinities until rains begin in June, when central basins apparently receive the earliest and largest pulse of freshwater from Taylor Slough. The spring estuary is generally characterized by strong turbidity fronts, diffuse freshwater sources, and large phytoplankton patches. Low turbidity is generally found in regions strongly influenced by inputs of fresh water. Chlorophyll levels in central basins are 40-200% greater than in eastern basins. The summer estuary is characterized by ubiquitous stenohaline salinities in the transitional basins. In the near-field Bay (measured from Duck Key to Rankin Key), salinities are generally euryhaline. However, during summer periods of low rainfall, the Bay becomes hypersaline, with concentrations of near 50 PSU measured on several occasions in 1997 and 1998. Strong differences in phytoplankton chlorophyll concentration and distribution routinely occurred in the eight northern transitional basins.

High chlorophyll and increased phytoplankton productivity occurred at salinity discontinuities near inputs of fresh water, against a background of low chlorophyll levels.

Light control of primary productivity is influenced by mineral and organic turbidity, due to: 1) phytoplankton blooms, 2) resuspension due to wind shear, and 3) carbonate precipitation processes. Light regime is determined by a combination of factors related to hydrology and rates of autochthonous production. Temporal patterns in light attenuation are related to seasonal wet-dry hydrological patterns of Everglades' discharge, and water column turbidity increases in the dry season. Analysis of suspended particulate material, chlorophyll a concentration, and light attenuation (Kd) in east-west transects across eight distinct basins reveals strong spatial heterogeneity in light climate and in the concentrations of components which attenuate PAR. Dominant factors influencing attenuation shift from physical (e.g., wind shear) to biological (e.g. phytoplankton shading) among different basins, related to hydrology, autotrophic production, and basin morphometry. On north-south transects, downwelling attenuation tends to decrease with distance from freshwater sources, indicating that freshwater input may increase water transparency. Calculations of light availability for autotrophic components of the estuarine system indicate frequent potential light limitation of photosynthesis. From east to west, primary productivity and biomass of all autotrophic components (seagrass, epiphytes, MPB, and phytoplankton) increases, and an increasing fraction of primary production diverts to phytoplankton and epiphyte components. This shift follows a water column nutrient gradient that appears to be not directly (but perhaps indirectly) related to freshwater inputs, and whose source is as yet unidentified.

Managed changes in Everglades' hydrology will enhance freshwater inputs to the estuary. Relationships between freshwater input and spatial and temporal gradients in factors contributing to PAR attenuation in the water column are critical management issues for the transitional bays of northern Florida Bay. Current re-plumbing of Everglades' hydrology for restoration will increase and redistribute freshwater flows to the region. Our ongoing program will allow us to predict likely effects of water management on water quality, primary production, and overall estuarine function.

Christopher J. Madden - South Florida Water Management District

Relationship of Sedimentary Sulfur, Iron and Phosphorus Cycling to Water Quality in Florida Bay: How Seagrass Die-Offs Contribute To Algal Blooms.

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We collected surface sediments from some 70 locations throughout Florida Bay and the adjacent northwestern shelf to determine the spatial distribution of sulfur, iron and phosphorus compounds and their relationship to primary production in Florida Bay. A measured decreasing gradient in total P in surface sediments from west-east across Florida Bay supported the observed P-limitation of seagrass production along the same gradient. Further sediment P correlated positively with total P in the water column, demonstrating strong benthic-pelagic coupling in the bay.

Total sediment P also correlated positively with 1N extractable iron, with a Fe:P ratio of 2:1. Although iron concentrations are low in these carbonate surface sediments relative to terrigenous sediments, iron oxides can influence P mobility. In the absence of iron oxides in surface sediments, released P may stimulate phytoplankton production in the water column. A sediment index of iron availability correlated negatively with water column chlorophyll concentrations that were highest near regions of seagrass die-off.

The observed distributions of Fe and P in surface sediments to the north and west of Florida Bay suggest multiple sources including local dissolution and transport, discharge from Shark River Slough, and transport from the Gulf of Mexico. Water currents appear to redistribute the iron and phosphorus, leading to zones of relative abundance and depletion. We saw no evidence for the occurrence of a Miocene sand channel.

Confirming the work of other researchers in Florida Bay, the deposition of iron-sulfide minerals in Florida Bay is Fe-limited. In areas north and west of Florida Bay where Fe concentrations were high but seagrass was absent, Fe-S mineral deposition is limited by organic matter as an energy source for sulfate reduction. Pyrite is the most abundant Fe-S mineral in Florida Bay sediments, found in concentrations up to 50 µmol gdw^{-1}.

Because of the dual influence of iron oxide as a contributor to P limitation and a buffer to sulfide toxicity, we compared the depth distribution of sulfur, iron and phosphorus compounds in sediment cores collected from control sites and experimental sites amended with a surface application of reactive iron aggregates. After two months, deposition of iron monosulfides (FeS) and pyrite (FeS_2) in the upper 2.5 cm of sediments was significantly greater in iron-enriched plots (63.3 ± 13.1 µmol S gdw^{-1}) relative to controls (25.6 ± 6.0 µmol S gdw^{-1}). Sediment phosphorus concentrations were higher in surface sediments and elevated in iron-enriched plots (51.9 ± 26.5 µmol P gdw^{-1}) relative to controls (7.7 ± 0.8 µmol P gdw^{-1}), concomitant with elevated concentrations of dithionite-extractable iron oxides. Nuisance algal blooms in Florida Bay are stimulated by water column phosphorus, so phosphorus sorption to iron-enriched sediments could enhance bay water quality. Our hypothesis that decreases in sediment sulfide toxicity would be apparent in measurements of plant vigor is being tested during summer 1999.

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Differences in Microzooplankton-Phytoplankton Interactions in Florida Bay by Ecological Region.

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Utilizing a variety of physical and biological parameters including hydrology, geology, water column characteristics, the distribution of fauna, and benthic plant communities, researchers have divided Florida Bay into four ecological regions. Recently, the character, distribution and dynamics of cyanobacterial blooms were added to the list of properties supporting the partitioning of the bay into the aforementioned regions. Based upon the results reported by others, we hypothesized that there would be differences in the rates of both microphytoplankton growth and microzooplankton grazing between the four described regions. We also hypothesized that there would be differences in the concentrations of microzooplankters between the regions, as well as in the pigment-specific microphytoplankton growth and microzooplankton grazing rates.

In an attempt to test the hypotheses, dilution experiments were conducted bimonthly utilizing fluorometric analysis of Chl *a* to determine microphytoplankton growth rates and microzooplankton grazing rates. Four sites were used, each representing one of the described ecological regions. Sampling was initiated in September 1997 and concluded in September 1998. In addition to the fluorometric determination of growth and grazing rates, water temperature and salinity at each site were recorded and samples were collected to allow determination of pigment-specific growth and grazing rates, as well as concentrations of microzooplankton.

Analysis of microphytoplankton growth rates at each site showed no significant difference between sites. There was also no significant difference seen in microzooplankton grazing rates between sites. The means of the phytoplankton growth rates at the four sites ranged from a low of 0.63 d^{-1} to a high of 0.92 d^{-1}. The means of the microzooplankton grazing rates ranged from 0.37 d^{-1} to 0.64 d^{-1}. In contrast to some of the data in print, we found no significant difference in chlorophyll concentrations between sites. Measured Chl *a* concentrations were also lower than those reported in the literature, though the dates of sampling were only coincident with those of others during the first month of our sampling period. During that month we obtained results similar to those in the literature. Perhaps the lower values measured during the rest of our sampling period are evidence that the phytoplankton community in the bay has been undergoing some type of change since the publication of the most recent chlorophyll data. It is also possible that the lower values are an artifact of the bimonthly sampling regime or are the result of differences in the locations of the sites used to represent each region relative to those used by other researchers.

Samples of the nauplius community were collected bimonthly at eight sites beginning in September 1994 and concluding in November 1998 as part of a larger project. They were obtained by pouring 10 L of surface water through a sieve with 20 μm mesh. Organisms retained on the mesh were preserved with 10% formalin (final conc.) for subsequent counting. Statistical analysis of the samples showed that nauplius concentrations in the north-central region were significantly higher than in the other three regions. They also showed a great deal of variability, ranging from 23.8 L^{-1} to over 940 L^{-1}. Annual lows in concentration in the north-central region tended to occur in January and highs in September of a given year, though there were some exceptions to the trend. Since no difference was found between the remaining sites, the concentrations of those 3 sites were averaged together for each sample period. The means oscillated about a concentration of 100 nauplii L^{-1} over the course of the study, with lows typically occurring in March and highs in September of each year. As with the site in the north-central region, there were exceptions to that trend. Through March 1998 the mean nauplius concentrations of the 3 combined sites never exceeded 200 L^{-1}.

Results from analyses of the microplankton community do not currently support partitioning the bay into ecological regions, though there is evidence that the north-central region does differ from the rest of the bay. This may change as more results are obtained and analyzed. The analysis of the nauplius data will be more current by November. Results for the pigment-specific growth and grazing experiments and the numerical counts of microzooplankton will also be completed by, and reported, in November. It is hoped that those results will shed additional light on the interactions between microzooplankton and microphytoplankton and provide more information on the reported ecological regions of the bay.

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Modeling the Water Column Ecosystem in Florida Bay.

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Florida Bay is a complex coastal system. The region is influenced by freshwater inputs, anthropogenic nutrient additions and the Gulf of Mexico. The hydrodynamics of the bay is strongly influenced by a series of mud banks, which divide the bay into numerous partially isolated basins. Among the major regions is a eutrophic area around Rankin Bight in which the small alga *Synechococcus sp.* dominates, a westerly region heavily influenced by the Gulf of Mexico in which diatoms dominate and an easterly region characterized by relatively low phytoplankton concentrations. The shallow depth of the bay means that interactions between the water column and benthos are more important than in other coastal systems.

Applying inverse analysis techniques to data collected in the Rankin and Duck Key regions by M. Dagg, R. Brenner, P. Ortner, G. Hitchcock and G. Kleppel has allowed us to analyze the food-web structure in these regions. The calculations reveal that the systems are similar with about one third of the primary production being exported from the mesozoa and detritus. Incorporating bacterial growth data collected by Cottner et al. results in lowered carbon exports with the largest change being for the Rankin area. Including bacteria also introduces extensive recycling of carbon between the DOC and bacterial pools. Imposing a penalty on the recycling results in an import, rather than export, of carbon into the two areas, with again the greatest change being for the Rankin area.

Using results from the inverse model we have been able to construct simple forward models of the water-column food web in the two regions. These models show the seasonal cycle in phytoplankton in the Rankin region. However, there is considerable uncertainty in these results. As more information about relevant physiological parameters becomes available, the results of the forward model will improve.

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Poster Abstracts

QUESTION 3

Distribution of Benthic Chlorophyll in Florida Bay Sediments.

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In shallow tropical ecosystems, light often reaches the benthos. Ecologically it can be advantageous for microalgae in such ecosystems to live at the sediment surface or in the top few millimeters of sediment where light (including UV) is less intense and nutrient concentrations are greater. We have hypothesized and confirmed that indeed there is more microalgal biomass per area at the sediment surface than there is in the water column above in Florida Bay. Average concentrations of benthic chlorophyll measured over a two-year period range from around 24 to 120 mg/m^2 while only around 0.5 to 10 mg/m^2 of chlorophyll in the water column above are measured.

Given the high benthic microalgal biomass, we have also hypothesized that resuspension of benthic microalgae could generate much of the water column microalgal biomass observed. That hypothesis appears to be incorrect. Water column chlorophyll has a very distinct spatial distribution in Florida Bay, with the highest concentrations in the north-central area, intermediate concentrations in the northwest and south-central areas, and lowest concentrations in the eastern part of the bay. There is no obvious spatial pattern to the concentrations of benthic chlorophyll, and no strong correlation with water column chlorophyll. Much of the variability in the benthic chlorophyll appears to be local variability on the scale of centimeters to meters. Within individual basins of Florida Bay however, weak correlations between turbidity and water column chlorophyll do exist over time, as resuspension of sediments does lead to higher water column chlorophyll concentrations. The correlation is weak however and resuspension does not appear to be the major source of water column chlorophyll overall.

Because sediments and their porewaters can be a significant source of nutrients by either diffusion or resuspension, nutrient bioassay experiments have been conducted to determine whether N or P is the limiting nutrient when the sediments are resuspended in the water column. The distribution of N and P limitation in nutrient bioassays when sediment is added to the overlying water to yield a turbidity of around 50-100 NTU shows N limitation in the north-central and northwestern parts of the bay and P limitation in the rest of the bay. This spatial pattern is similar to that observed for nutrient bioassays of the water column.

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Long Term Changes in Turbidity in Florida Bay.

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A comparison of turbidity data collected between 1973 and 1976 (by T. S.) and between 1996 and 1999 (by L. B.) indicate a dramatic increase in turbidity in Florida Bay. The data collected in the 1970's were with a Hach 2100A Turbidimeter and the data collected in the 1990's were with either a LaMotte 2008 or LaMotte 2020 Turbidimeter. While the use of different instruments could account for small differences between the two data sets, it is highly unlikely to account for the dramatically different turbidities observed between the two time periods.

An examination of the average data in the 1970's indicates that the water was probably always somewhat turbid along the extreme northern coastline of the bay. The entire bay however was much less turbid at that time than today. During the rainy season, when wind speeds are usually low, turbidity levels are only around twice as high in the 1990's as in the 1970's. During the dry season, however, when wind speeds are usually higher, turbidity levels are much higher than in the rainy season in most parts of the bay in both the 1970's and 1990's. Dry season turbidities are also dramatically higher in the 1990's than in the 1970's. This is particularly true in eastern Florida Bay.

In the central and western parts of the bay, the increase in turbidity is most likely the result of the massive seagrass dieoff in the 1980's. Lack of thick meadows of seagrass blades to reduce currents, and roots to hold down sediments could easily lead to the high turbidity observed today. More problematic is the large increase in turbidity in the eastern part of the bay where there were few seagrasses to begin with and little seagrass dieoff. This is also an area that is relatively sediment starved. Two, not mutually exclusive hypotheses come to mind. One is that resuspended sediments from the central bay after the seagrass dieoff eventually were transported to the east where they are easily resuspended because of sparse seagrass cover. A second hypothesis is that algal mats may have held sediments down initially. Today we find high benthic microalgal biomass at the sediment surface throughout the bay. We hypothesize here (with no supporting data) that nitrogen fixing cyanobacteria may have been a significant component of the benthic microalgal community. When nitrogen-rich water began being pumped from the Everglades through Taylor Slough and the C111 canal into Florida Bay in the 1980's, the resulting high nitrogen concentrations could have destabilized the benthic microalgal community, resulting in the inability to continue to hold down sediments. While data do not exist to test this hypothesis during the 1970's-1990's time period in Florida Bay, mesocosm experiments could test the principle.

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Zooplankton Production in Florida Bay: Nutritional Constraints on Egg Production.

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Calanoid copepods are significant in pelagic food webs and abundant in Florida Bay. Although adult calanoids do not appear directly responsible for controlling ultraplankton bloom persistence in the bay, their nauplii (ca. 70 □m in diameter) are capable of ingesting small cells and may periodically be significant grazers of some bloom species (Dagg and Ortner 1996; Kleppel et al. 1998). Copepod predation pressure on heterotrophic protist grazers may periodically exert an indirect influence on bloom dynamics. Further, copepods are important components in the diets of many fishes and as such, they represent an important link between primary producers and higher trophic levels in the bay.

Studies of the diet and egg production of the calanoid copepod *Acartia tonsa*, a biomass dominant mesozooplankton species in Florida Bay, have been underway in since 1995. Our earlier studies revealed that the feeding and egg production of this copepod were largely independent of temperature but might be associated with attributes in the food environment (Burkart 1998). Ingestion and egg production rates tended to be higher at locations on the north (mainland) side of the bay, than at locations on the more oligotrophic, south side. Further, there was a direct correlation between the egg production rate and the biomass of heterotrophic protists in the diet, suggesting a nutritional link to copepod production.

We have pursued this problem further by studying the nutritional characteristics of the seston in relation to the diet and egg production of *Acartia tonsa*. Measurements were made at two stations in July and September 1997 and January, March and May 1998. One station was in the vicinity of Rankin Key in the north-central bay. The other was off Duck Key, in the southeast. The area around Rankin Key has experienced extensive seagrass mortality events and persistent ultraplankton blooms. The site off Duck Key has not experienced such activity. Grazing and egg production measurements were performed by 24-h, in situ bottle incubations and analyzed by microscopy (Kleppel et al. 1998). Selective feeding was detected by comparing the frequency distribution of taxa in the diet with that in the food environment with a χ^2 goodness of fit test (Cowles 1979). The gross efficiency of egg production was determined by dividing the egg production rate (as carbon) by the ingestion rate (as carbon). Particulate organic macronutrients -- proteins, lipids and carbohydrates -- were measured on samples collected on GF/C filters, by colorimetric methods summarized by Carter (1995).

The planktonic protist assemblages off Rankin and Duck Keys were distinct from one another and biomass was usually higher at Rankin Key. Biomass peaks off Duck Key were dominated by cells <5 μm which are not efficiently captured by Acartiidae (Paffenhöfer 1988). Copepod diets were diverse, and rarely selective. The seston off Rankin Key was rich in protein and carbohydrates but contained relatively low amounts of lipids (Jónasdóttir et al. 1995). Off Duck Key, all macronutrient levels were low. Ingestion rates were variable ranging from 0 to about twice the estimated body –C content copepod^{-1}d^{-1}. Rates were higher in the wet than the dry season. Mean egg production rates ranged from 1-16 eggs female^{-1}d^{-1}, with the highest rates at Rankin Key in September. The gross efficiency of egg production was uniformly low, never exceeding 6% at Rankin Key and 15% at Duck Key (typical is 30-50%). Regression analysis led us to suspect that egg production was most likely limited by gross C availability off Duck Key and by protein availability in the seston off Rankin Key. The inconsistency in this observation is that lipid, rather than protein concentrations, appeared to be in short supply in the seston. We tested the hypothesis that egg production was affected by the efficiency of protein transfer from the diet to the eggs rather than the concentrations present in the seston. We computed the efficiency of egg production on the basis of lipid and protein and discovered that while lipid is "handled" very efficiently (ca. 80%) at low ambient concentrations, protein is handled inefficiently (<1%) at all ambient concentrations. Possible causes of inefficient protein metabolism include imbalances caused by amino acid deficiencies (Anderson and Hessen 1995) and the presence of toxic contaminants.

Current research is focused on periodic spikes in egg production efficiency that appear throughout our data, and on the logic that if *Acartia* is abundant in Florida Bay it must enjoy some measure of reproductive success that is not adequately described by mean rates. We are studying egg production during bloom periods when we suspect that rates may be considerably higher than average.

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Photosynthetic Pigment-Based Chemotaxonomy as Applied to Florida Bay Phytoplankton, Water, Macrophytes, Microphytobenthos and Sediments.

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This report covers the technique of chemotaxonomy, using the chlorophyll and carotenoid pigments, as applied to the study of a variety of photoautotrophs and their 'organic fossils' within the Florida Bay ecosystem.

Essentially, each phototrophic organism produces an array of photosynthetic and photoprotectorant pigments which has evolved in manners allowing an organism a competitive advantage within its specific niche. This array of pigments is usually shared by that organism's relatives (congeners, con-familials, *etc.*) up to a phylogenetic level of at least division and sometimes to class. A few rare instances (oscillaxanthin *inter alia*) allow identification of genus or even species. Thus, identifying certain 'biomarker' pigments specific to a certain class or division is the same as identifying the taxon. Along with the <u>qualitative</u> aspect of 'biomarker equating to taxon' is the unraveling of <u>quantitative</u> pigment relationships in order to estimate the relative contribution of each taxon to the community under study. In this work, we based all estimates upon the quantitative relationships of the so-called 'accessory' pigments, mainly carotenoids, to chlorophyll-*a* for oxygenic phototrophs and relate bacteriochlorophyll-*a* plus its derivatives to chlorophyll-*a* for the anoxygenic phototroph contributions. Therefore, after analyzing source biota and/or performing regression analyses on sample sets, one can derive simple regression formulae for the estimation of the taxa detected. More complex mathematical treatments are also known. In the present report, we expand upon our studies of South Florida ecosystems. As an example, we find that a common Florida Bay diatom, *Cyclotella choctawatcheeana*, certain congeners, and a variety of other diatom species contain chlorophyll-*a* in a 1.1 – 1.2:1 molar ratio with the carotenoid fucoxanthin. Therefore, for each mole of fucoxanthin identified from a sample, one may reasonably expect 1.2 moles of 'diatom-contributed' chlorophyll-*a*. Performing this operation on a variety of taxa, using their specific pigments, then allows the <u>*chemo*taxonomic</u> structure of the community to be estimated.

Application of the chemotaxonomic principles covered above to the waters and microphytobenthos of Florida Bay proved to be a fruitful endeavor. First, evaluation of water samples in a SE-NW transect of the bay revealed pigment patterns which gave (chemo-) taxonomic distributions exactly matching the known (=microscopic / published) distributions of phytoplankton. That is, a strong cyanobacterial dominance in the central bay which blends into a cyanobacterial / diatom / dinoflagellate assemblage towards the Atlantic (Hawk Channel) waters and gives way to a diatom / cyanobacterial + dinoflagellate community as the open Gulf is approached. Next, examination of the surficial sediments revealed a microphytobenthos plus sediment, which was easily characterized as a diatomaceous cyanobacterial biofilm underlain by purple sulfur bacteria. Here, zeaxanthin, fucoxanthin plus chlorophylls-*c*, and bacteriochlorophyll-*a* plus spirilloxanthin revealed these taxa, respectively. This method of taxonomic assessment, *albeit* at Division / Class levels rather than by species, could easily be automated and allow detailed spatial and temporal ecosystem monitoring.

Examination of turtle grass (*Thalassia testudinum*) in fresh and dead states revealed much about the fate of the photosynthetic pigments in this important biomass source. Collection of fresh healthy blades, removal of all epiphytes, and freezing as a pretreatment to deactivate the enzyme chlorophyllase allowed the extraction, separation and identification of the predicted green plant pigment assemblage. That is, chlorophylls-*a* / -*b*, lutein, neoxanthin, violaxanthin, antheraxanthin, and β-carotene were found. If the blades were not frozen prior to extraction, considerable conversion of the chlorophylls to the corresponding chlorophyllides (hydrolysis of phytol ester) was observed. This same response might well be expected in nature coincident with mechanical disruption of cellular compartmentalization. Finally, dead / brown *Thalassia* leaves, freed of obvious epiphytes, were analyzed in order to assess any pigment survival. Instead of finding green plant pigment remnants, other than a bit of lutein, we found pigments indicating a healthy viable diatom assemblage. That is, chlorophylls-*a* / -*c*, fucoxanthin, diadinoxanthin and diatoxanthin dominated. Apparently, dead / detrital *Thalassia* blades afford an excellent substrate for various benthic diatoms in the Florida Bay ecosystem. Some of the color of the dead blades may also derive from the olive-brown hues of these chrysophytes. Upon burial, dead *Thalassia* blades may also be expected to 'protect' their internal / surficial diatoms from the vigorous heterotrophic cycling ('grazing') which individual cells experience. This could direct the early diagenesis of a certain portion of the diatom pigments in various sedimentary strata.

Several sediment cores were examined from Whipray Basin and from Pass-Eagle Keys Bank. In all cases, the microphytobenthos described above, a diatomaceous cyanobacterial biofilm / mat underlain with purple-sulfur bacteria, was concluded as being the major contributor of identifiable pigments through time. We therefore have concluded that the benthic ecosystem has been relatively stable in its qualitative makeup but reacts quantitatively to nutrient supplies from the overlying water column through time. Large excursions in both organic carbon (2-6%) and the amount of pigment-specific preservation were found and are suggested as signaling periods of higher and lower overall productivity.

Pyropheophorbide-*a*, produced from chlorophyll-*a* mainly by herbivory, was found to be transformed smoothly into cyclopheophorbide-*a*-enol within a few tens of centimeters. This reaction is a base-catalyzed Dieckman (dehydration) cyclization and gives "CYCLO" as an indicator of herbivory, most likely strongest at the sediment water interface. We have observed downhole trends in "CYCLO" *versus* pheophytin-*a* (chlorophyll-*a* lacking only the Mg atom) dominance. Correlation between these indicator pigments and organic carbon / total pigments appears to reflect not only OM supply but the degree of oxic *vs.* anoxic syndepositional conditions as well. Thus, strata with high CYCLO or high pheophytin-*a* levels would indicate oxic or anoxic conditions, which would respectively favor or retard aerobic heterotrophic activities.

Aside from the utility of pigment based chemotaxonomy in the study of Florida Bay, we report a direct (mathematical) relationship between organic carbon and water content in the upper central Florida Bay sediments studied. That is, above 1.6% C_{org} there is a direct correlation, given as decimal values (water = [0.076807] C_{org} + [0.2986]), with a linear correlation coefficient of $r = 0.91707$. We suggest that this is real and is due to a gellifaction of the bulk organic matter. That these sediments are true gels explains several phenomena. First, as one disturbs the sediment during homogenization, prior to sieving, the apparent homogeneity of the paste-like sample is destroyed and a milky water over sediment solids biphasic system is generated. Second, wave action in the bay ‘should’ resuspend these lime-marls more effectively if they were not amalgamated in some manner, such as through gellifaction. Lastly, propeller damage, akin to the smaller scale mixing in lab, is more easily understood if one considers it to be the mechanical disruption of a gel and the subsequent winnowing of the now unbound fines.

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Salinity, Nutrient and Light Requirements and Nutrient Competition Within Several Dominant Microalgal Taxa of Florida Bay.

Bill Richardson, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL.

The light, salinity and nutrient requirements of the following numerically dominant microalgal taxa of Florida Bay were examined; the blue green algae *Synechococcus elongatus,* an unidentified spherical blue green picoplankter, and the diatoms *Chaetoceros* cf. *salsugineus*, and *Cyclotella choctawhatcheeana.*

The effect of salinity on the growth rates of fully acclimated populations of these species was measured over a range of 0-50 ppt, at 25 ^{0}C, 72 uEm^{-2}sec^{-1} , under a 12:12 light:dark cycle using continuous batch culture. Distinct optima for growth were observed for *C. choctawhatcheeana (20-45 ppt) and C. cf. salsugineus* (10-40 ppt). While *S. elongatus* and the picoplankter did show optima (10-20 ppt), their growth rates were largely unaffected by salinity.

The acclimated growth rate in response to irradiance was determined for each of the four species at a salinity of 25 ppt, 25 ^{0}C, in a 12:12 light:dark cycle using semi-continuous batch culture. The saturation irradiance of both diatom species was approximately twice that of the two blue green species.

The kinetics of phosphorus (PO_4-P) dependent growth was determined for each species using batch cultures at 25 ppt, 25 ^{0}C, in a 12:12 light:dark cycle at salinities (S) of 15, 25 and 50 ppt. The results were fit to the Monod model and the maximal growth rate (U_{max}) and the half-saturation constant for growth (K_u) were determined. At S=25 the maximal growth rates for *S. elongatus*, the picoplankter, *C. cf. salsugineus* and *C. choctawhatcheeana* were 1.38, 1.37, 2.48 and 3.37 divisions day^{-1}, respectively. The half-saturation constant was 0.004 umoles liter^{-1} for the picoplankter, 0.044 umoles liter^{-1} for *C. cf. salsugineus* and 0.052 umoles liter^{-1} for *C. choctawhatcheeana.* The K_u for *S. elongatus* could not be determined as the growth rate was still maximal at the lowest concentration of phosphate measured (0.03 uM). The K_u value for *S. elongatus* was lower than all the other species at each of the three salinities. The results at S=15, S=25 and S=50 showed that each species U_{max} value was found to differ with salinity as predicted from the salinity growth curve data while each species K_u value although having wide confidence intervals, did not differ significantly with salinity.

A direct experimental test of phytoplankton resource-based competition using Tilman's equilibrium theory of competition was carried out using the same four microalgal species. Equilibrium Resource Competition (ERC-theory) predicts that under P-limitation a species that is a P-specialist by having the lowest equilibrium requirement (R*) for P, will have a competitive advantage and will in time competitively exclude all other species with higher minimal P requirements. Each species nutrient kinetic parameters, U_{max} and K_u, was used to calculate a species competitive power (R*) under phosphorus limitation at S=15, 25, and 50 ppt. The ERC model calculated R* values for each species. *S. elongatus* was ranked as the superior competitor under P-limitation at salinities of 15, 25 and 50 ppt. The superior competitive ranking of S. *elongatus* can be attributed largely to the fact that the K_u values for S. *elongatus* were so low that they could not be determined at any salinity because it maintained maximal growth rates at the lowest phosphate concentrations used (0.03 - 0.04 uM). The model ranked the picoplankter second as a phosphate competitor at all three salinities, while *C.* cf. *salsugineus* was ranked higher than *C. choctawhatcheeana* for two of the three salinities.

Competition experiments were carried out at S=15, S=25 and S=50 under P-limitation and under N-limitation. Under each of the above two nutrient regimes (P-limitation and N-limitation) were three treatments consisting of (1) a ‘steady’ supply of the limiting nutrient, (2) a periodic pulse (every 5^{th}day) of the limiting nutrient and (3) a ‘steady’ supply of the limiting nutrient coupled with a repeating oscillating salinity fluctuation (2.5 ppt decrease followed by a 2.5 ppt increase, cycle period of 10 days). All experimental flasks were maintained at D=0.2 using semi-continuous dilution which consisted of manually removing a portion of the culture and replacing it with an equal volume of medium. In competition experiments under P-limitation, approximating steady state conditions (‘steady’ nutrient supply) *S. elongatus* dominated in terms of biovolume at the end of the experiment at S= 15, 25 and 50, verifying the model's predictions. Because ERC-theory applies only to systems that approximate steady state conditions, and many natural phytoplankton communities are not usually characterized by steady state conditions for long periods of time, the potential role of a temporal disturbance on resource competition, through nutrient pulsing and a salinity fluctuation was also examined. Under each of these non-steady state conditions under P-limitation, at all salinities, *S. elongatus* dominated in terms of biovolume at the end of the experiment and the trends implied that given enough time *S. elongatus* would competitively displace all the other species. In summary, under both steady state and non-steady state conditions at all salinities *S. elongatus* was the superior competitor for orthophosphate. Competition experiments revealed that under N-limitation at S=15 and S=50, the two blue-green algae usually codominated in terms of biovolume under steady and non-steady state conditions. Under N-limitation at S=25 for all treatments, *C. choctawhatcheeana* was dominant in terms of biovolume at the end of the experiment.

Cellular quotas are being determined for both N and P for all species and will be used to determine estimates of luxury consumption for each species, which will be helpful in understanding resource competition under non steady-state conditions. Minimum cell quotas of phosphorus normalized to cell volume were comparable between all 4 species at S=25, suggesting that the increased competitive ability of *S. elongatus* was not the result of a more efficient use of phosphorus.

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Oral Abstracts

Thursday, November 4, 1999

8:00am-12:00pm

QUESTION 1

Thursday, November 4, 1999

am

7:00-8:00 **Morning Refreshments**

Question 1. ***How and at what rates do storms, changing freshwater flows, sea level rise, and local evaporation/precipitation patterns influence circulation and salinity patterns within Florida Bay and outflows from the Bay to adjacent waters?***

8:00-8:10 **Introduction to Florida Bay Circulation Projects.** ***Peter B. Ortner***, PMC Member, NOAA, Atlantic Oceanographic and Meteorological Laboratory, Miami, FL.

8:10-8:30 **First Year Results from Enhanced Observations of Circulation and Exchange Processes in Western Florida Bay and Connecting Coastal Waters, including Effects of El Nino and Hurricane Georges.** ***Thomas N. Lee*** and *Elizabeth Williams*, RSMAS/University of Miami, Miami, FL; Elizabeth Johns and Doug Wilson, NOAA/AOML, Miami, FL.

8:30-8:50 **Tidal and Non-tidal Exchanges through Seven Mile Channel.** ***Ned P. Smith***, Harbor Branch, Oceanographic Institution, Fort Pierce, FL.

8:50-9:10 **A Two-Dimensional Physics Based Numerical Hydrodynamic and Salinity Model of Florida Bay.** ***Keu W. Kim*****,** *Robert McAdory* and *Gary Brown*, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

9:10-9:30 **Responses of Salinity in Florida Bay to Changes in Freshwater Inputs and Bathymetry: Speculative Simulation Scenarios Using the FATHOM model.** ***Bernard J. Cosby***, University of Virginia, Charlottesville, VA; *William K. Nuttle* and *James W. Fourqurean*, Florida International University, Miami FL.

9:30-9:50 **An Estimate of Groundwater Flux in Florida Bay with Geochemical Tracers.** ***Zafer Top*** and *Larry Brand*, University of Miami, Miami, FL; *William Burnett*, *Jeffrey Chanton*, *Reide Corbett* and *Kevin Dillon*, Florida State University, Tallahassee, FL.

9:50-10:20 **Refreshment Break**

10:20-10:40 **An Evaluation of NEXRAD (WSR88D) Data as a Measure of Fresh Water Flux into the Florida Bay/Everglades System.** ***Paul T. Willis***, NOAA/AOML/CIMAS, Miami, FL.

10:40-11:00 **Simulations of Anthropogenically Generated Microclimates over the Florida Peninsula and their Impact on the Florida Bay Water Cycle.** ***Craig A. Mattocks***, University of Miami/CIMAS, NOAA-AOML/Hurricane Research Division, Miami, FL; *Paul Trimble*, *Matthew Hinton*, *Beheen Trimble* and *Marie Pietrucha*, South Florida Water Management District, West Palm Beach, FL.

Thursday, November 4, 1999 *(continued)*

11:00-11:20 **Reconstructing the Salinity History of Florida Bay Using Ostracode Shell Chemistry.** ***Gary S. Dwyer***, Division of Earth and Ocean Sciences, Duke University, Durham, NC; *Thomas M. Cronin*, US Geological Survey, Reston, VA.

11:20-12:00 **Panel Question and Answer Session**

12:00-1:30 **Lunch on Own**

Special Session. ***What do we know now and what do we need to know for restoration?*** *(No abstracts were solicited for these presentations.)*

Objective: This special session at the Florida Bay Science Conference invites resource managers to identify what we need to know about Florida Bay for ecosystem restoration to proceed and be successful. At the same time, scientists will describe what we now know about conditions in Florida Bay that help define ecosystem restoration goals.

Moderator: ***Tom Armentano***, National Park Service, Everglades National Park

pm

1:30-1:35 **Introduction to Synthesis in Florida Bay**
Tom Armentano, co-chair of the Florida Bay PMC

1:35-1:50 **What Do We Need to Know? — State/Regional Perspective**
Mike Collins, Chair of the South Florida Water Management District Governing Board

1:50-2:05 **What Do We Need to Know? — Federal Perspective**
To be determined

2:05-2:20 **Existing Framework for Incorporating Science into Restoration Planning**
John Ogden and ***David Rudnick***, South Florida Water Management District

2:20-2:35 **Results from Paleoecological Studies**
Ellen Prager, Consultant and Freelance Writer

2:35-2:50 **Sources of Salinity Variation and Forecasting Changes in the Bay**
Tom Lee, University of Miami

2:50-3:20 **Ecological Response to Salinity Variation**
Joan Browder, National Marine Fisheries Service and ***Bill Krucyinski***, US Environmental Protection Agency (invited)

3:20-3:50 **Refreshment Break**

3:50-4:00 **Ecological Objectives and Performance Measures for Restoration**
John Hunt, co-chair Florida Bay PMC

Thursday, November 4, 1999 *(continued)*

4:00–5:30 **Panel Discussion: Setting a Direction, What Can We Expect from Science?**

Resource managers and scientists will be asked to define questions that will be the focus of the research program in the next few years. Speakers preceding this discussion will be asked to submit a 3 to 5 bullet summary of their talks to begin the panel's discussions.

Panel Moderator: ***John Hobbie***, Chair, Science Oversight Panel

5:30 **Evening on Own**

First Year Results from Enhanced Observations of Circulation and Exchange Processes in Western Florida Bay and Connecting Coastal Waters, including Effects of El Nino and Hurricane Georges.

Thomas N. Lee and *Elizabeth Williams*, RSMAS/U. of Miami, Miami, FL; *Elizabeth Johns* and *Doug Wilson*, NOAA/AOML, Miami, FL.

The goal of this project is to study the interaction and exchange of Florida Bay waters with the connecting coastal waters of the Gulf of Mexico and the Atlantic Ocean in the Florida Keys. The research is designed to address several of the key scientific questions presented in the NOAA/COP Florida Bay Implementation Plan concerning circulation and water quality as critical to understanding the functioning of the ecosystem and its future evolution from restoration actions. Observational methods consist of a combination of bi-monthly interdisciplinary surveys, in-situ moorings, shipboard Acoustic Doppler Current Profiler (ADCP) transport transects in the major Keys flow passages and Lagrangian surface drifters, to describe and quantify the circulation and exchange pathways as related to local forcing and coupling with the waters of the Atlantic and the Gulf. These observations will also help to provide necessary boundary conditions for physical and biolo=gical models. Here we present the results of the first complete year of moored current measurements together with surface drifter observations of exchange pathways and shipboard estimates of volume flux between the Gulf and Atlantic. Spatial and temporal patterns of water mass properties are given in a companion presentation by E. Johns et al., and D. Wilson et al. reports on Shark River plume variability.

The South Florida coastal system consists of several distinct but strongly connected marine environments. There is the maze of shallow basins and mud banks making up Florida Bay that interacts with two very different continental shelves: the wide, shallow west Florida shelf with smoothly varying topography aligned in a northwest-southeast direction; and the narrow, curving coastal zone of the Florida Keys, with the complex topography of a shallow reef tract. These two shelf regions interact with Florida Bay across the mud banks along its western boundary and through the shallow tidal channels between the Keys. The two shelves also interact with each other through these tidal channels and with strong offshore boundary currents at their outer edges, the Loop Current in the Gulf and Florida Current in the Keys. The circulation and exchange of these water masses due to the interplay of local responses to different types of forcing in the different regions will determine the fate of fresh water discharges through the Everglades, Florida Bay and the west Florida shelf. Our efforts are directed at trying to observe and understand those responses to better describe the functioning of the South Florida ecosystem and forecast future changes.

The moored array was first deployed in September 1997 and will be maintained for three years. The array consists of 4 bottom mounted ADCPs equipped with nearsurface T/S sensors on the southwest Florida shelf offshore of Shark River (moorings A-D, Figure 1), a Shark River plume array of 9 T/C sensors to monitor changes in the Shark River discharge nearfield, a single current/T/C mooring near the western boundary of Florida Bay, and 3 current/T/C moorings positioned along the Florida Keys reef tract to measure interaction and exchange between the southwest shelf, Everglades discharge, Florida Bay, Keys coastal waters and the Florida Current. In addition there is a bottom pressure gauge array to measure cross- and along-shelf pressure gradients on the southwest shelf, as well as the cross-Keys pressure gradient. Satellite tracked CODE surface drifters are deployed within the Shark River discharge plume on the bi-monthly interdisciplinary surveys.

Results of the first year's observations show dramatically different circulation patterns in the two shelf regions that interact with Florida Bay. Currents on the southwest Florida shelf are dominated by strong mixed tidal forcing, with semi-diurnal tidal currents reaching 40 cm/s in the onshore-offshore direction. The shelf displays a coherent response to alongshore wind forcing with alongshore currents of 10 to 20 cm/s that have little variation with depth. There is also a significant southward mean flow, the cause of which is not yet understood, and a strong seasonal variation in stratification. In contrast, the Keys coastal waters display a relatively weak semi-diurnal current and a strong response to alongshore wind forcing and Florida Current interactions. The curving shoreline of the Keys causes regional differences in response to prevailing easterly winds and Florida Current influences. The lower Keys are normally aligned with the wind and form a downwelling coast with onshore flow in the upper layer and a westward coastal current that intensifies toward the west due to Florida Current eddies. The prevailing wind is onshore in the upper Keys with little influence on alongshore flow, whereas the Florida Current is located near the outer reefs causing strong downstream flows.

The different orientation of the two shelf regimes separated by the curving island chain of the Florida Keys causes a different circulation and sea level response to the same wind forcing, which causes a sea level slope across the Keys and drives a subtidal flow that varies with the wind forcing. Southeast winds typical of the Keys region cause a set-up of sea level in Florida Bay and set-down in the middle and northern Keys coastal waters and drive a southeast flow toward the reef tract through the Keys passages. East and northeast winds cause sea level to set-up in the Keys coastal waters and set-down in Florida Bay, driving subtidal flows toward Florida Bay through the passages.

The combined magnitude of the flow through Channels 5, 2 and Long Key Channel ranges from about 1000 m3/s toward the southeast to 200 m3/s toward Florida Bay as determined from vessel mounted ADCP transects. These subtidal flows are equivalent in magnitude to the mean river discharge onto the southeast U. S. shelf by all the rivers between Florida and Cape Hatteras. Approximately 500-700 m3/s flows through Long Key Channel alone when the flow is toward the southeast, which is about 100 times greater than the peak fresh water discharge out of the Shark River. Also, a significant number of the surface drifters deployed near the Shark River were observed to move through western Florida Bay and toward the reef track through Long Key Channel. Therefore it appears that low salinity discharge from the Shark River is advected and dispersed in the downstream direction through western Florida Bay and toward the Keys, and provides a low salinity input for the western part of the Bay that helps to regulate increasing salinities. The advective/dispersal time-scale for materials in the Shark River plume to reach the FKNMS is estimated from drifter trajectories at one to two months.

Synthesis of drifter trajectories, together with water property distributions from shipboard surveys and current measurements, indicates that the southwest Florida shelf and western Florida Bay regions are strongly connected to coastal ecosystems of the Florida Keys and west Florida shelf. The trajectories of satellite tracked surface drifters deployed in the Shark River discharge plume clearly show strong linkages between western Florida Bay and the Florida Keys out to the Tortugas. There are two typical exchange pathways coupling these regions. The most persistent route is southeastward through western Florida Bay and the Keys tidal passages, then westward along the reef tract to the Tortugas. The route through western Florida Bay is driven primarily by local wind forcing and the sea level slope between the Gulf of Mexico and the Atlantic. The westward trajectory in Hawk Channel and the reef tract is sustained by local alongshore westward wind forcing that is enhanced toward the west by recirculating gyres and eddies north of the Florida Current. It takes one to two months for drifters released in the Shark River plume to reach the Florida Keys, and then less than two weeks to reach the Tortugas region due to the increased flow in the coastal countercurrent. However, if the winds have a significant southerly component then drifters entering the Keys coastal waters through the tidal channels in the middle Keys will turn toward the north and may become entrained in the strong northward flow of the Florida Current. A more direct route between Everglades fresh water discharge and the Tortugas occurs during east and northeast wind forcing when near surface flows on the southwest Florida shelf are toward the southwest. The transport time scale to reach the Tortugas is approximately one month. This southwest route is more typical of the fall season when east and northeast winds prevail, but can occur during any season if east and northeast winds persist. A case in point is the anomalous northeast winds during the El Nino winter of 1998.

The response of South Florida coastal waters to an intense atmospheric forcing event was observed during the passage of hurricane Georges and will be discussed using data from the moored array and drifter trajectories.

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Tidal and Non-tidal Exchanges through Seven Mile Channel.

Ned P. Smith, Harbor Branch Oceanographic Institution, Fort Pierce, FL.

Current meter data from eight study sites on the Florida Bay side of Seven Mile Bridge are combined with water level records to estimate tidal and nontidal exchanges. A SonTek Argonaut-XR acoustic current meter recorded vertically averaged current speeds at a long-term study site in Moser Channel from October 22, 1998 to July 8, 1999. General Oceanics Mark II inclinometers recorded mid-depth currents at seven additional study sites, spaced approximately 1 km apart across the channel. Currents were recorded for 1-2 month periods at the short-term study sites. Linear regression is used to establish relationships between flow at the long-term station and flow at the short-term stations. Volume transport through each of the eight segments is obtained by multiplying the segment width, time-varying segment mean depth and the vertically averaged segment current speed.

Instantaneous volume transport through Seven Mile Channel commonly reaches 15 x 10^3 m^3 s^{-1} at peak flood, and it occasionally reaches -20 x 10^3 m^3 s^{-1} at peak ebb. Harmonic analysis indicates that the semidiurnal M_2 tidal constituent has an amplitude of 13.2 x 10^3 m^3 s^{-1}, and that 187 x 10^6 m^3 of water move through Seven Mile Channel during each half M_2 tidal cycle. The peak flow for the other tidal constituents is 3 x 10^3 m^3 s^{-1} or less. Low-pass filtering the instantaneous volume transport reveals an active exchange of water over time scales on the order of 3-4 days. Low-frequency exchanges commonly force water into Florida Bay at a rate of 10^3 m^3 s^{-1}, and draw water out of the bay at a rate of 2-3 x 10^3 m^3 s^{-1}. Spectral analysis of low-pass filtered wind stress and along-channel volume transport shows that nontidal volume transport is most responsive to wind forcing when the axis of the channel is 40^o to the right of the wind. Wind stress and along-channel transport are highly coherent (coherence levels between 0.7 and 0.9) over time scales of from 2.5 days to two weeks, and the phase spectrum indicates a near instantaneous response. A nontidal outflow of 7 x 10^3 m^3 s^{-1} was recorded in early November 1998 and mid March 1999. Over the entire study, the mean flow through Seven Mile Channel was an outflow of 511 m^3 s^{-1}. For comparison, the long-term average outflow through Long Key Channel is approximately 250 m^3 s^{-1}, and outflow through other channels of the Middle and Upper Keys is much less. Seasonal outflow appears to be greatest during late winter and early spring months. Periods of nontidal net inflow occur frequently throughout the record, but they generally last on the order of a week or less. An exception is the net inflow recorded from early June through early July, which may be a result of seasonally varying wind conditions.

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A Two-Dimensional Physics Based Numerical Hydrodynamic and Salinity Model of Florida Bay

Keu W. Kim, US Army Engineer Waterways Experiment Station, Vicksburg, MS; *Robert McAdory, Gary Brown*, US Army Engineer Waterways Experiment Station, Vicksburg, MS;

Objectives: The objectives of this study are: 1) to develop a physics based two-dimensional hydrodynamic and salinity numerical model of Florida Bay; 2) to use the model to study the effects of alternative freshwater releases on circulation and salinity distribution in the bay; and 3) to provide flow fields to the water quality model of the bay.

Technical Approach: The approach to the numerical modeling study of surface water of the Florida Bay system was to develop a physics based hydrodynamic and salinity numerical model of the Florida Bay system, to apply it to varying conditions of tide, inflow, and other system details, and to analyze the resulting calculations to determine the impacts of system alterations such as changing freshwater inflows. The TABS-MD system model RMA10-WES was used in this study to calculate the values of water level, current velocity, and salinity at each computational point in the numerical grid.

Field Data: In order to aid in model verification and to provide boundary conditions, a field data collection effort was conducted during March 1996 through April 1997. The Waterways Experiment Station field data effort was discussed in detail in Pratt *et al*.(1999). In addition, data from the National Park Service (NPS), Harbor Branch Oceanographic Institution, the South Florida Water management District, the U. S. Geological Survey, and the National Oceanic and Atmospheric Administration were used to develop the model.

Model Verification: The initial comparisons of the model computed and recorded, or otheriwse predicted, tides, velocities, fluxes through Keys, and salinities at stations in or near the Bay were performed for the two intensive survey periods in September 1996 and February 1997. Comparisons were then made to the longer data records. In order to understand the model tidal behavior, an harmonic analysis of the computed water levels in interior points near NPS tidal prediction sites and at selected sites near the ocean boundary was conducted.

Scenario Experiments: The scenario experiments involved calculating the hydrodynamic and salinity behavior of the Florida Bay system using different freshwater inflows. Differences in circulation and salinity distribution based on 95Base and NSM conditions will be presented. The effect of removing the Flagler Railway fill on the circulation and salinity of the Bay system will also be discussed.

Water Quality Model: Flow fields for wet, dry and average seasonal flows were calculated and used as part of an ongoing water quality study of Florida Bay.

Pratt, T. C. and Smith, N. P. (1999). "Florida Bay Field Data Report," Technical Report CHL-99-11, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Responses of Salinity in Florida Bay to Changes in Freshwater Inputs and Bathymetry: Speculative Simulation Scenarios Using the FATHOM Model.

Bernard J. Cosby, University of Virginia, Charlottesville, VA; *William K. Nuttle* and *James W. Fourqurean*, Florida International University, Miami FL.

FATHOM is a dynamic, spatially explicit, mass-balance model designed to investigate the responses water movement and salinity in Florida Bay to freshwater runoff, coastal tides, climate, and the bathymetry of the bay. The model maintains a running account of the water and salt budgets in each of 41 well-mixed basins within the bay. The boundaries of these basins follow the system of the anastomosing banks that dissect the bay. The model simulates the exchange with the coastal ocean and the mixing among the basins in the bay that results from water fluxes driven across the shallow banks by differences in water surface elevation on either side of the banks. The model solves for uniform, hydraulic flow across each bank based on the depth**,** width, and frictional roughness of the bank and water levels in the upstream and downstream basins. Manning's equation for friction flow in channels is used to calculate water velocity as a function of depth of flow on each bank. The calculated velocities are used with the cross sectional areas of water on the banks to calculate water fluxes. Salt fluxes are then calculated from water fluxes and the salinity of the water on the bank. Model adequacy and verisimilitude is assessed by comparing the temporal and spatial patterns of simulated salinity to salinity observations from a network of stations maintained in the bay by the Southeast Environmental Research Center. The comparison spans the period from 1989 to 1997. FATHOM is also used to investigate the potential outcomes for salinity of four scenarios. The first three scenarios simulated Everglades hydrology to drive runoff into Florida Bay corresponding to water management alternatives investigated in the Restudy: 95 Base, NSM and D13R. The fourth scenario uses runoff corresponding to the 95 Base scenario, removes the Flagler railroad fill between Upper and Lower Matecumbe Keys and restores those banks to the pre-railroad bathymetry. The results of each scenario are examined for both wet and dry seasons in both wet and dry years.

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An Estimate of Groundwater Flux in Florida Bay with Geochemical Tracers.

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Presence of groundwater in the coastal marine environment is known to occur, although the extent, magnitude, and ecological ramifications of this presence have been the subject of focused investigations only recently, and the number of articles in the literature is still small. One reason for the slow development may be the lack of appropriate methods of detection.

Two main approaches for the detection of groundwater are used: the direct measurements by means of various contraptions collectively called seepage meters, and indirect measurements that utilize geochemical tracers found in groundwater. Here we describe the results of the geochemical approach with the isotopes of helium and radon. The method relies upon the presence of an excess concentration of tracer of choice in the groundwater. Once the enrichment of a species in groundwater is justified, any excess tracer amount in coastal waters can then be related to the groundwater flux. The primary source for the equilibrium concentration of helium in marine waters is the atmosphere. Concentration in the water phase is determined by the equilibrium temperature and salinity. A helium excess above solubility equilibrium must therefore be supplied to the water column either by groundwater that has large dissolved helium due to exposure to uranium/thorium minerals over geologic times, or by diffusion from the seabed. The source of helium in groundwater is the radioactive decays of the uranium and thorium-chain elements (e.g. 8 α-particles emitted per U decay until it reaches stable ^{206}Pb). Most geological structures contain sufficient amounts of these elements such that over geological time-scales relatively large amounts of helium accumulate. The mechanism that incorporates helium into groundwater is leaching of helium by water. The present day production (radioactive equilibrium between the parent and the daughter) of helium from uranium (or thorium) requires exceedingly large quantities of the parent due to the half-lives on the order of 10^{10} y, hence the need for a leaching mechanism for already present helium. In other words, a large dissolved U concentration in seawater cannot cause a helium excess.

Because helium diffuses on very short time scales, its presence in excess amounts in the water column indicates that it is being supplied faster than it can escape to the atmosphere. Also because it is inert and radioactively stable, it presents an integrated picture for the study area. In Florida Bay this is especially significant, because the average water depth is only about 1m, a thin layer of water in which one expects helium to come to equilibrium with the atmosphere very fast, on a time scale of a fraction of a day. Radon-222 is also produced in the decay of U. Like helium it is an inert gas but it is radioactive with a short half-life (3.8d). Its presence in seawater is due to a flux from the seabed that can be carried by groundwater and/or diffuse out from the sediments. Its short half-life makes it suitable for more instantaneous-state studies. Because the radioactive precursor abundance in the sediments may be different from the radioactive equilibrium ratio, the production rate of ^{222}Rn in sediments needs also to be considered.

We have made in excess of 130 helium and 150 radon measurements in the water column in summer of 1997 and winter of 1997-1998. The most striking aspect of the observations is the persistence of large concentration excesses for both isotopes. The average Δ^4He, the percent concentration anomaly, is 15% with a slight seasonality. Mere presence of helium excess at this magnitude is an unmistakable indicator of groundwater input. In most coastal and open ocean areas, in the upper mixed layer, Δ^4He rarely exceeds 5%. Similarly, average ^{222}Rn activity is over 4 dpm/L, with strong seasonality. This figure is two orders of magnitude greater than that encountered in the upper layers of open ocean, again, a strong evidence of a significant groundwater input.

A quantitative estimate was made by a simple diffusive box-model that balances groundwater input, exchange with the atmosphere, and lateral exchange with waters of the Gulf of Mexico. Based on helium alone, the model yields a groundwater-input rate of 10-20 cm.d^{-1}, which represents a significant amount. Based on ^{222}Rn, the same model yields 6-8 cm.d^{-1}. With no normalization and consideration for the different behaviors of the two isotopes, this is a very good agreement. However, an advective-diffusive model with slightly different boundary conditions for ^{222}Rn alone, yields an input of 2-4 cm.d^{-1}. The difference is likely due to the different boundary conditions of the two isotopes especially with respect to their underground sources. For example, experiments with benthic chambers indicate a diffusive component for radon but none for helium. This part of the study is continuing and its results and ramifications on the apparent difference in flux figures will be further elaborated at the presentation.

Helium provides further information regarding the source of groundwater. Its lighter isotope ^{3}He, (atmospheric ^{3}He/^{4}He=1.384*10^{-6}) is also produced in the radioactive decay of tritium, ^{3}H, the legacy of the atmospheric thermonuclear tests of the early 1960s. The presence of a positive ^{3}He anomaly in the water allows one to conclude qualitatively that the water must have a component formed in the last 40 years, while the simultaneous measurement of tritium allows actual dating of the formation time. In addition to total helium (^{4}He) discussed above, we have also made corresponding ^{3}He and ^{3}H measurements. These indicate that the groundwater in Florida Bay is a mixture of the deeper, old Floridan Aquifer- and shallower, young Biscayne Aquifer waters. The mixing ratio varies from winter to summer with significant portion being from the Floridan Aquifer. Because Floridan Aquifer water at this latitude is as saline as the ambient seawater, groundwater input cannot be easily detected from salt anomalies.

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An Evaluation of NEXRAD (WSR88D) Data as a Measure of Fresh Water Flux into the Florida Bay/Everglades System

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The radar measurement of rain provides excellent spatial and temporal resolution over a large area. This is true even over water areas, where a dense gage network may be impossible, or prohibitively expensive. But, since the radar does not measure rainfall rate directly, but measures the sixth moment of the raindrop size distribution (dsd), the measurement requires a definitive relation between rainfall rate and the shape of the drop size distribution. The shape of the dsd is not uniquely related to the rainfall rate. This is a source of error, and scatter, in the radar rainfall rate measurements. A major thrust of the project has been to characterize the shape of raindrop size distributions in South Florida.

The project described herein involves the measurement of dsd's at a site at the ENP Research Center, and a comparison of the radar rain measurements to the gage measurements from the extensive gage network associated with the Florida Bay/Everglades Restoration project. The raw radar data has a spatial scale of approximately 1 x 1 km and a time resolution of 5-6 min. The NEXRAD hydrologic product (dpa) has been smoothed to a spatial scale of 4 x 4 km and a time resolution of 1 hr. This can be easily averaged to larger scales, and longer times to provide desired products.

The radar data are empirically related to the gage data using a probability matching methodology (PMM) which forces the overall match of the radar mean rainfall rate and the mean gage rainfall and also forces an empirical match in data bin intervals. From extensive data comparisons between the dpa and 1 hr gage data it is found that the radar significantly underestimates the higher rainfall rates, and overestimates the lower rainfall rates. This is true even from a smaller sample of the full resolution radar data, and high-resolution gage and disdrometer data. The match provided by the PMM is virtually the same as that from the 4 km/1 hr data. The stability of this relation is being checked with an additional year of radar and gage data, and the result will be reported.
A single gage/radar rainfall product that retains the best features of each data type is being developed using a cokriging methodology. Sample one-month mean radar data, and combined products using the empirical calibrations are presented. Planned improvements and future work are presented.

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Simulations of Anthropogenically Generated Microclimates over the Florida Peninsula and their Impact on the Florida Bay Water Cycle

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Topic Area: Meteorology and Hydrology

Objective

This project directly addresses the first central question articulated in the Strategic Plan of the Interagency Florida Bay Science Program, namely: *"How, and at what rates, do persistent and/or catastrophic storms alter freshwater input (via their associated local evaporation/precipitation patterns), thereby inducing changes in the circulation and salinity/nutrient content of Florida Bay?"*

Approach

The approach is to employ the Center for Analysis and Prediction of Storms' (CAPS) Advanced Regional Prediction System (ARPS) cloud-/mesoscale atmospheric numerical weather prediction model to simulate persistent, locally-forced weather regimes which generate thunderstorm complexes over the Everglades and coastal areas that account for roughly one-third of Florida's annual rainfall. The atmospheric model's moisture physics and surface energy parameterizations allow the prediction of both precipitation and evaporation at high resolution.

By reverting areas of urbanization and drainage to their natural state in the model, then contrasting the results of these simulations, distinct microclimates (urban heat islands and associated shifts in the rainfall distribution) which have emerged over the past century have been identified. Based on simulation results thus far, a conceptual model which describes the effects of these anthropogenically-generated microclimates on the Florida Bay water cycle has been developed which serves as a working hypothesis to guide future research.

A Conceptual Model

The Natural System

In the summer wet season, dominated by a locally forced sea breeze weather regime, the South Florida water budget can be considered a closed system. In the natural system (circa 1900), persistent standing water over the Everglades was constantly evaporated and the rising moisture-laden wetlands air formed clouds. This moisture, which was critical to the initiation of vigorous sea breeze thunderstorms, was blown to the north by the southeasterly trade winds circulating around the Bermuda High, and the majority rained down inland over the

Kissimmee River Basin and Lake Okeechobee. Once the lake filled, a critical portion of the excess water spilled over its southern rim. The ensuing sheetwater flow replenished water in the great arc of the Everglades, completing the transport cycle (Douglas, 1997).

The Anthropogenically Modified System

Drainage and diversion by canals, dikes, agriculture and commercial development have eliminated much of the wetland area, severely altered the sheetwater flow through the Everglades, depleted the Everglades moisture source and disrupted the vertical evaporative flux of water from the ground into the lower atmosphere. Isolated microclimates have formed over regional "hot spots" (dry, urban, developed areas which warm up rapidly due to a lack of thermal damping previously provided by evaporated water vapor) at the ground. "Heat island" circulations now dominate locally over the larger scale sea breeze, creating aberrant surface wind convergence patterns and concentrating rainfall along these strong, artificial horizontal gradients in surface heat and soil moisture. Thus, the local/mesoscale rain and water transport cycles have been interrupted (Pardue *et al.*, 1982). Spatially averaged accumulated precipitation over land has been reduced by 16% since 1900 (Pielke *et al.*, 1998) due to these modifications in land cover while a substantial portion of the remaining rainfall has shifted offshore.

Background

Numerous meteorological modeling studies (Pielke *et al.*, 1998; Bougeault *et al.*, 1991; Pielke, 1974; Gannon, 1978; McCumber and Pielke, 1981) have shown that land use modifications (including commercial development, agriculture, and water management practices) may have a significant impact on the spatial and temporal distribution of regional scale rainfall for selected synoptic scale meteorological conditions. In particular, small scale heterogeneities in the soil moisture, surface albedo and thermal inertia are the most dominant controlling factors involved in altering the speed and intensity of the sea breeze convergence zone and, hence, the location of attendant thunderstorm formation over the Florida peninsula.

Horizontal variations in vegetation profoundly impact evapotranspiration. Plants act like "pipes" which pull underground water out of the soil reservoir and release it into the lower atmosphere. The upward moisture transfer cools the surface and moistens the air in the planetary boundary layer (PBL). This evaporation absorbs energy and buffers the surface against further solar heating, damping the strength of the thermal/solenoidal circulations. Intricate concave/convex geographical patterns in the surface moisture gradients can generate mesoscale winds as strong as sea breezes. According to Lynn *et al.* (1998), if the scale of a wet/dry soil patch reaches a critical size, mesoscale circulations generated by landscape heterogeneities can trigger deep moist convection. In a complex feedback process involving the soil hydrology, the moist convection creates new rainfall "footprints", the largest CAPE (convective available potential energy) evolves above the wet patches, and the most intense rainfall occurs along the sea-breeze-like fronts induced by the soil moisture gradient in the internal boundary layer (IBL). The transient nature of the soil moisture patterns makes the prediction of subsequent convection difficult. If substantial areas of land remain flooded convective suppression and shallow "outflow" layers can spawn circulations analogous to lake/river breezes.

Results to Date

Preliminary land use sensitivity experiments (present day development vs. pre-colonized natural system conditions) have been run using the ARPS model to examine the environment's response to the urbanization of pristine areas. In simulations of an August 1975 Florida Area Cumulus Experiment (FACE) sea breeze case representative of the summer wet season, enhanced diurnal heating over highly developed areas, such as Naples-Fort Myers and Tampa, induced strong urban heat island circulations which concentrated and doubled the amount of simulated rainfall over heavily populated regions. Rapid evaporation and heating of the porous, cultivated land south of Lake Okeechobee caused abrupt divergent deflections of the surface winds over the lake and generated a thunderstorm complex similar to the convective cells diagnosed in real data. The crescent-shaped band of maximum rainfall, associated with the lake breeze, shifted from east of Lake Okeechobee to its southern shoreline.

The simulated evaporation pattern correlated well with the strongest divergent and initially driest surface wind fields, in the vicinity of the greatest vertical surface-to-air temperature/humidity differences. Moisture was picked up by the atmospheric flow over Lake Okeechobee and by the organized offshore downdrafts associated with the west coast sea breeze circulation, while the Florida Everglades "muck" soil in the interior of the state tended to resist evaporation due to its high water retention and strong capillary forces. Thus, a significant north-south mesoscale gradient in evaporation was simulated across Florida Bay, with a maximum occurring in the lower keys.

Methodology

In the first phase of development of a hydro-meteorological coupled model, the ARPS model grid has been completely reconfigured to closely match the grid of the Natural System Model (NSM) and the South Florida Water Management Model (SFWMM). The horizontal resolution of ARPS has been tripled, from 9 km to 3.22 km (2 miles) on a Mercator projection. High-resolution GIS soil/vegetation, land cover/use surface characteristics, and terrain elevation data from SFWMD has been reprocessed using GIS ARC-INFO "fishnet" area-weighted polygon interpolation techniques and incorporated into ARPS. This became a non-trivial, labor-intensive task because substantial data gaps had to be filled in with 200-meter resolution USGS land use data and 100-meter resolution Defense Mapping Agency (DMA) terrain elevation data.

Translation tables were derived to convert the detailed, multi-level USGS and SFWMD land use categories into the less precise ARPS vegetation types in a consistent manner. After several iterations back-and-forth between state and US government agencies, an error-free, high-resolution soil database compatible with the ARPS model grid projection was delivered by SFWMD. Still, this data set had to be supplemented with data values from 1993 LANDSAT imagery to fill in data-void regions. The soil categories were then thinned to match the less descriptive soil types used in ARPS. In order to refine the response of the surface energy budget, newly developed categories and parameters for peat (Everglades muck) soil and Mangrove forest were implemented in the ARPS model.

Future Work

These improvements in horizontal resolution, the specification of surface characteristics, and the inclusion of feedback mechanisms between the hydrologic and atmospheric systems should improve the simulation of local weather regimes driven by micro-scale features in the surface properties. Specifically, the model's new configuration will help resolve details in the shape of thunderstorm convective cells, rectify previous underpredictions of rainfall over the Florida peninsula, and quantify the spatial gradients in the precipitation and evaporation patterns.

By integrating the ARPS-simulated precipitation over the model grid domain, more reliable estimates of total freshwater input from the atmosphere into the ground/bay/ocean below can be obtained. These numerically generated estimates will be compared with observational NEXRAD radar rainfall data collected by NOAA-AOML colleagues. Evaporation estimates from the ARPS surface energy/soil module will be calibrated against results from a composite of real measurements calculated using a bulk drag aerodynamic formula, kindly provided by DeWitt Smith of the Everglades National Park Service. It should then be possible to quantify the precipitation-evaporation balance, which controls the salinity/nutrient composition of Florida Bay.

This work also lays a foundation for the development of a coupled hydro-meteorological model in the near future.

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Reconstructing the Salinity History of Florida Bay Using Ostracode Shell Chemistry.

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The salinity history of Florida Bay from the mid-1800's to present has been estimated from the metal/calcium ratios of fossil ostracode shells from sediment cores collected from central Florida Bay. The ostracode metal/Ca ratio methodology relies on two main tenets which appear to be valid: (1) metal/Ca ratios of Florida Bay waters co-vary with salinity; and (2) the metal/Ca ratios of calcite shells of ostracodes (micro-crustaceans) are controlled by the metal/Ca ratios Florida Bay waters.

Down-core results reveal a quasi-decadal scale oscillatory pattern in ostracode metal/Ca ratios that is interpreted to reflect past fluctuations in salinity. Salinity maxima occurred in the early 1920's, early 1930's, late 1940's, late 1950's to early 1960's, mid 1970's, and late 1980's, and generally correlate with multi-year intervals of low winter rainfall. Similarly, intervening intervals of estimated low salinity roughly correlate with periods of higher than normal winter rainfall. As reported by others, winter rainfall in south Florida is closely linked to ocean-atmosphere oscillations in the equatorial Pacific, and our metal/Ca -based salinity record appears to show good correspondence with the El Nino Southern Oscillation Index that describes the state of this large-scale climatic phenomenon.

These results support the hypothesis that seasonal to decadal scale salinity fluctuations in Florida Bay are a natural part of the South Florida Ecosystem, and that these fluctuations are largely a function of natural variability of regional climate (rainfall). While a clear long-term trend in salinity change is not evident in our records, beginning around 1940 there was a shift in the bay's salinity that has persisted up to the present. Our data suggest that this 60-year period was marked by large salinity oscillations and, moreover, that these oscillations generally are shifted toward higher salinity.

Thus far, the ostracode metal/Ca ratio we have focused on to reconstruct salinity is the ratio of magnesium to calcium (Mg/Ca) and the above results are based on Mg/Ca data. However, assigning absolute salinity values based on shell Mg/Ca ratios is complicated, because, in addition to the Mg/Ca ratio of the water, ostracode shell Mg/Ca ratios are also dependent on ambient water temperature. We initially operated under the assumption that water temperature effects would be minimal when considered as annual averages. However, based on the analysis of seasonally collected modern specimens, it appears that the down-core Mg/Ca ratio signal may include some temperature effects as well.

To better assess the potential influence of temperature on Mg/Ca ratios we are beginning work on shell Ba/Ca ratios. Recent (preliminary) results suggest that ostracode Ba/Ca ratios may be better suited as a salinity proxy because Ba/Ca ratios exhibit a much larger change with salinity than Mg/Ca in Florida Bay waters and there appears to be no thermodependence on ostracode shell Ba/Ca ratios. Ultimately, by coupling Ba/Ca and Mg/Ca ratio analysis on the same shells, we may be able to derive both salinity and temperature records of Florida Bay from ostracodes, possibly at seasonal time-scales.

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Poster Abstracts

QUESTION 1

Modern and Historical Bathymetry of Florida Bay.

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Detailed, high-resolution sea-floor maps of Florida Bay basins and mudbanks are needed to understand sediment dynamics and provide input into circulation model. The sea-floor of Florida Bay has not been systematically mapped in nearly 100 years, and some shallow areas have never been mapped. Because Florida Bay morphology is an intricate network of basins and mudbanks combined with extremely shallow water depths, an updated bathymetric grid is critical for implementing an accurate circulation model of the Bay. Additionally, an updated bathymetric survey of the Bay will provide a baseline for assessing future sedimentation rates and a foundation for developing a sediment budget.

The main objective of this 5-year project is to collect modern bathymetric data of Florida Bay and any other areas that have not been previously mapped. Hydrographic surveying is being conducted using the GPS based SANDS bathymetric system which has an average vertical accuracy +/- 10 cm and can collect data in water depths as shallow as 50 cm. Sounding trackline spacing for the majority of the Bay is 500 meters. All mudbanks and islands have been outlined and have closer line spacing because of the detailed intricate nature of the mudbank and island morphology. Surveying is near completion with data collected from Blackwater Sound to a line from Cape Sable to Grassy Key. Historical shorelines and hydrographic data from the 1890’s has been digitized and registered to a modern datum using a unique set of survey control data points provided by the National Ocean Service (NOAA/NOS). The historical data will serve as the basis for comparison to the modern bathymetry and shorelines of Florida Bay.

A preliminary comparison of historical bathymetric data to modern data suggests that water depths in the eastern part of the Bay have not significantly changed; although, westward from Calusa Keys (middle Bay) it appears that modern depths differ depths often by as much as +/-0.75m. The overall size and shape of the major mudbanks, e.g. Cross Bank, Ninemile Bank, have not changed since the 1890’s. However, the channels and cuts through the banks are often in different locations and appear to have been extensively dynamited in some areas. In general, the submerged portions of the mudbanks recently mapped do not have “smooth” contours as depicted on some maps, but often have undulating or “finger” shaped contours. Some “fingers” extend perpendicular to the mudbanks 50 to 100m. A detailed comparison of historical data to modern sea-floor maps will be performed when the digital maps are completed. This comparison will aid in assessing sedimentation rates and possibly gather some insight or conclusions to effects of sea-level rise on Florida Bay. Final products for this project will be historical and modern shorelines and bathymetry, digital bottom grids, and USGS 7.5 minute ortho-photo quadrangle maps overlaid with modern bathymetry.

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Freshwater Flows into Northeastern Florida Bay.

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Surface-water flow was measured at major creeks along the northeastern coast of Florida Bay as part of the South Florida Ecosystem Program. Water level, flow velocity, salinity, temperature, and periodic discharge measurements were collected at nine monitoring stations between US Highway 1 (US-1) and Terrapin Bay to determine the magnitude and spatial distribution of freshwater flow. Data were collected from October 1995 to present, and includes the El Nino event of 1997-98.

Mean monthly flows were used to evaluate surface-water flow patterns and to calculate net flow at the monitoring stations. About 80 percent of the measured freshwater flowing into the bay occurs during the May to October wet season. Increased precipitation associated with El Nino resulted in a 663 percent increase in total measured freshwater flow during the November to April dry season, increasing from 41 ft^3/s (cubic feet per second) in 1996-97 to 273 ft^3/s in 1997-98.

A comparison of flow at all monitoring stations suggests three distinct flow signatures. These flow signatures were determined as follows: (1) largest discharges occurred at Trout Creek, contributing about 60 percent of the total measured freshwater flow into northeastern Florida Bay; (2) following the El Nino event, McCormick Creek net flows were negative from October 1997 to April 1998, while the other creeks had net positive flow; and (3) net negative flows were absent at West Highway Creek during all seasons.

Evidence indicates that the greatest flow of freshwater from Taylor Slough into Florida Bay is not at Taylor River (as previously postulated), but farther east at Trout Creek. Analysis of flow data also shows that Trout Creek could be used as a long-term monitoring station to estimate total freshwater flow into northeastern Florida Bay, provided that the uncertain flow patterns at McCormick Creek and West Highway creek can be resolved.

Water level, flow velocity, salinity, temperature, and periodic discharge measurements are currently being collected at two newly installed monitoring stations that complement the existing network. The Stillwater Creek station is located in western Long Sound and the Upstream Taylor station is located about 2 miles north of an existing station at the mouth of Taylor River. Both stations will enhance the spatial resolution of flow and salinity trends and help to evaluate wind effects and storage factors in Long Sound and Taylor River.

The magnitude of discharge at Trout Creek and the water color variation along the left and right banks observed during high flows raises questions about the spatial distribution of freshwater flow entering Joe Bay. As part of a continuing effort to monitor flows in Florida Bay, discharge and salinity measurements were collected at eight creeks entering Joe Bay. Three western, one central, and four eastern creeks have been monitored on a monthly and storm-related basis since May 1999. Preliminary data suggest that greater discharges occur along the eastern and western creeks of Joe Bay as compared to the central creek. Salinity in the eastern creeks decreases rapidly and remains low after storm events or controlled-water releases; the western creeks appear to lag in salinity response time and seem to have greater fluctuations. Connection of the eastern creeks with the C-111 drainage south of structure S-18C is probable.

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Buttonwood Embankment: The Historical Perspective on Its Role in Northeastern Florida Bay Hydrology.

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The peninsula of Florida is separated from Florida Bay a coastal ridge called the Buttonwood Ridge by Craighead, (1964). The Buttonwood Embankment, averaging 0.5 m (1.5 ft) in height, was characterized as the "embankment that impounds the freshwater of the lower three counties of Florida" (Craighead, 1964). Presently, however, the creeks, lakes, and ponds adjacent to the embankment are brackish to marine. The change from fresh to brackish waters has been detrimental to the marsh. Studies have been launched to determine the best methods to return and sustain a more fresh/estuarine environment. To judiciously plan for this restoration two questions have been posed to clarify the history of the area. (1) What is the role of the "Coastal Levee" in the hydrologic (surface and groundwater) regime of southern Florida and Florida Bay? and (2) Have the environmental changes over the years resulted from rising sea-level, hydrologic management practices or both? To address these questions, we have analyzed the fauna, floral, and isotopic record in 50 cores: 8 on the embankment, 12 in the banks and basins of Florida Bay and 30 in the marsh/swamp. These data were merged with previously collected data (Davies, 1980: Cottrell, 1989). The timing of events was determined using short-lived isotopic chronological methods.

Long term development -- From these records, it is apparent that changes occurred on two time scales, 1-- major environmental changes that can be tied to global climatic variations and 2. -- The significant marine encroachment of the past fifty years. Two climatic events, during the last 2000 years have left a record in the sediments of South Florida, (1) the Medieval Warm period (800 to 1300 AD) and (2) the Little Ice Age (1500 to 1800 AD) (Willard and Holmes, 1999). Concurrent with this climate variability, or because of it, is sea-level has changed. Sea level in the Florida Bay area has been rising at ~ 3 mm per year for the past 150 years, as measured at Key West and Miami. There is a dichotomy of opinion on the nature of sea-level rise older that this record. Many investigators present evidence of a slow and continuous rise in sea-level (Scholl and others, 1966; Robbin, 1984) while others present evidence of step-type changes in sea level (Wanless and others, 1995). Some evidence also suggests a higher stand of the sea (~ 0.5 meters) occurred between 600-1000 years BP (Fairbridge, 1974; Stapor and others, 1991), during the Medieval Warm Period. Our results are consistent with the latter interpretation because brackish invertebrate taxa occur in core landward of the embankment at about 750 Yr. BP (Willard and Holmes, 1997).

A conceptual model of bank formation was developed through examination of the embankment sediment record consisting of six phases, which are tied to sea level variability during the past 2,000 years. The region underlain by the present Buttonwood Ridge was a series of fresh-water lakes and ponds, preserved as fresh-water peat admixed with freshwater marl. These basal units are overlain by estuarine carbonate mud capped by a mangrove peat. ^{14}C dates of this peat range in age from 1400 to 1700 BP. The mangrove layer is overlain by what Cottrell (1989) called a supratidal carbonate. On the Buttonwood Ridge, the supratidal sediment is very fine and devoid of any internal sedimentary structures. The scattered fossils within this layer are “terrestrial”, living on leaf litter and on the underbrush. ^{14}C dates of these fossils and organic material picked from the cores give ages between 1200 and 900 BP, corresponding to the Medieval Warm period. The process of deposition of this unit is unclear, but it is thought to resemble the processes, that are adding sediment to the area of Crocodile Point. On Crocodile Point the fringe mangrove forest filters sediment during very high water that invades a central low area. Dating of this accumulation indicates that it is accreting at the same rate as sea level is rising in the Bay.

If this model accurately describes this process, then sediments forming the Buttonwood Ridge are the result of rising sea level. 10 km inland from the coastline, the lower zone of a core contains pollen consistent with a brackish environment; the date of this zone places deposition at the end of the Medieval Warm period. This would be consistent with a higher sea level. During the Little Ice Age that followed, sea level may have dropped, exposing the supratidal mud and leading to erosion creating the Ridge as seen today.

Short-term development – During the past century, significant environmental changes have occurred in northeastern Florida Bay. Although minor vegetative changes occurred in the early part of the 20^{th} century, the most significant changes occurred during the 1950-1960 time frame. In the bay, the construction of the banks between Pass and Lake Keys and the extension of the bank south of Porjoe Key was initiated. Inland from the embankment, at least one pond began to close. Further inland, up Taylor Creek, the saw-grass plain was encroached on by mangrove forest. These events are attributed to the encroaching marine environment.

Groundwater/Surface Water Interface – In these studies, questions have been raised on the role of groundwater in the environmental changes. Fitterman (1998, personal communication) mapped the location of the fresh/salt water interface. Peat cores across this fresh/salt water boundary exhibit an increase in ^{210}Pb and ^{226}Ra at the rock/peat boundary; the highest values (10 X ambient surface values) are found in the peats on the fresh water side of the boundary. The ^{137}Cs distribution within each core is highest in the surface layers decreasing to non-detectable at the peat/rock interface. The exception to this ^{137}Cs distribution occurs in those cores at the freshwater –saltwater groundwater boundary. These cores contain detectable ^{137}Cs at the rock/peat interface. This manmade isotope, added to the atmosphere in the late 1950’s and early 1960’s, is no longer being added to environmental systems. The presence of ^{137}Cs in cores on either side of the boundary and the knowledge that ^{137}Cs in mobile in peat environments, suggest that this isotope has been transported by some groundwater transport process (perhaps upwelling along the fresh/salt water interface?).

Cores taken along the northern fringe of the bay have ^{210}Pb and ^{226}Ra subsurface distribution similar to those at the present fresh/salt water boundary inland. The highest subsurface concentrations occur in those cores taken in the thalweg of the submerged Taylor Slough. This increase is not present in other cores from the central part of the bay and is slightly recognizable in cores to the east. It is hypothesized that this increase represents “paleo-ground water” upwelling. ^{14}C dates of organic material within the sediment at the rock/sediment interface confines the timing to less than 2000 years BP. Using the radium method of dating groundwater (Swarzenski and others, 1998), a $^{228}Ra/^{226}Ra$ activity ratio (0.25) at peat/rock interface in the bottom core 5G (Whipray Basin) indicates a potential young age (<100 Years).

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Surface Salinity Variability of Florida Bay and Southwest Florida Coastal Waters.

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The surface salinity of Florida Bay and the surrounding coastal waters is highly variable, and subject to meteorological forcing influences ranging from episodic and seasonal to interannual variability due to the El Nino - La Nina cycle. Evaporation and anthropogenic activities such as flood control pumping and storage of water in Lake Okeechobee for later release, also affect the way in which precipitation patterns translate into surface salinity variability and must be taken into account as well.

As part of an ongoing program entitled "Circulation and exchange of Florida Bay and the connecting waters of the Gulf of Mexico and Florida Keys", bimonthly shipboard surveys of the triangular region bounded by northeastern Florida Bay, the Dry Tortugas, and Naples, FL have been conducted beginning in December 1995. Surface salinity data generated from a shipboard thermosalinograph (TSG) system are supplemented by TSG data for the upper Bay obtained using a smaller catamaran. To date, 18 quasi-synoptic maps have been produced using these data, and they demonstrate the highly variable nature of the regional surface salinity. The surface salinity observations will be presented chronologically in the form of regional maps, and interpreted in the context of the seasonal and interannual meteorological variability as well as the anthropogenic factors discussed above. Precipitation data for the south Florida region have been obtained from the National Climatic Data Center (NCDC), and time series of the stream and river flow out of the Everglades into northeastern Florida Bay and the southwest Florida coast have been obtained from the United States Geological Survey (USGS). These freshwater sources are very important to the variability of the surface salinity over a large region.

The surface salinity distribution is affected by precipitation and evaporation. Climatically "typical" meteorological conditions in South Florida are to have a dry season from November to April, followed by a wet season from May to October. During the dry season the average monthly precipitation is on the order of two inches, and during the wet season on the order of seven inches. In any given year the amount of rain will also be affected by hurricanes and tropical storms in the wet season, and the passage of cold fronts during the dry season. Meteorological data from the CMAN stations, which bracket the study area, are used to illustrate seasonal patterns of air/sea temperature, barometric pressure and winds, and their variability.

The four years of the observational program to date, however, have not been meteorologically "typical", but rather have been dominated first by the most extreme El Nino since at least 1950, followed by a strong La Nina, as can be seen in the "Nino-3" analysis of the National Centers for Environmental Prediction (NCEP) Center. El Nino is by definition an oceanic condition in which the waters of the equatorial Pacific are unusually warm, leading to far-ranging effects such as a reduction in the expected number of Atlantic hurricanes (which occurred in the summer of 1997) and the warm, wet "dry season" of the 1997-1998 Florida winter. La Nina is the opposite case, in which the equatorial Pacific waters are colder than usual. This was associated with the very active hurricane seasons of 1995 and 1998, and caused the record hot, dry summer of 1998.

The December 1995 cruise was the first one of the program, and showed extensive fresh water plumes off the mouths of the Shark River and the other rivers of the southwest Florida coast and anomalously fresh conditions over a broad area from Flamingo to Big Pine Key and beyond to the reef tract. Although November and December were significantly drier than average and such a large quantity of fresh water would not have been expected, the NCDC precipitation data and the USGS hydrological summary for that year showed that October 1995 had been extremely wet. This caused severe flooding in southwest Florida, and I-75, one of the primary routes across the state, was closed for several days. Over 90% of the USGS water gauges in the region hit historic high stage and discharge records. This was following the very wet summer months of 1995 during which four hurricanes and tropical storms (Allison, Erin, Jerry and Opal) brought large amounts of rain to South Florida. Much flood control pumping was necessary, and a large amount of water was stored in Lake Okeechobee. When this water was released from the lake to the Everglades and the Caloosahatchee River during the drier months of November and December, it likely caused the anomalously fresh surface salinities observed.

Cruises conducted in February and March of 1996 showed that the surface salinity of the region was increasing steadily as the dry season progressed. By the April 1996 cruise the river plumes had virtually disappeared, despite the fact that March 1996 was rainier than average. The absence of a freshwater source to the rivers of the southwest coast despite the rainfall may be attributable to the fact that releases of water to the Big Cypress area were stopped on March 1st to facilitate the Cape Sable seaside sparrow nesting season. Cruises in June and October 1996 showed the effects of a fairly typical wet season, and February and May 1997 the dry season, with little or no river plumes and a very salty (>39) upper Bay.

In December 1997, during the peak of the El Nino, there was anomalously high precipitation and this was reflected in the surface salinity, with a large plume of fresh water spreading out from all of the southwest Florida rivers and a much fresher upper Bay. As the winter rains continued, the January and April 1998 cruises showed progressively lower salinity over a larger area. The El Nino ended abruptly in May 1998, and La Nina proceeded to cause the entire summer to be extremely hot and dry. Consequently, by the June and August 1998 cruises the surface salinity had risen, the river plumes had receded, and the upper Bay had become hypersaline with salinities over 40 in the center of the Bay. Over the same time period, the April, June and August 1998 surveys also showed that a broad band of fresher water had moved into the offshore area between Naples and the Dry Tortugas. This pulse of fresher water was evident in conductivity data from moorings in the area and also, with a time delay, at moorings along the Florida Keys. It is probable that its source was rivers to the north of the study area, possibly the Mississippi River, and that it was transported southward by a mean background flow before becoming entrained by the Gulf Stream offshore of the Keys. By the October 1998 survey fresher offshore water was no longer present. Rainfall was elevated during the fall of 1998 due to the passage of hurricanes Georges and Mitch, and by the December 1998 and February 1999 cruises the upper Bay and the river plumes were all considerably fresher.

These observations demonstrate the large range of variability of the surface salinity in Florida Bay and the surrounding coastal waters, and illustrate some of the effects of the seasonal, interannual, and anthropogenic forcing. The river plumes on the southwest Florida coast may be a significant source of fresh water to Florida Bay, as the lower salinities associated with river outflow can be seen spreading south and east around Cape Sable into the western half of the Bay. This more remote source of fresh water may need to be taken into consideration in the numerical model analyses presently being developed.

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Refinement of Salinity Transfer Functions for Florida Bay to Assess C-111 Structural and Operational Modifications.

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Existing linear regression models describe the salinity at various locations in Florida Bay in terms of regional hydrologic conditions. In the southeastern part of Dade County, the C-111 water control system discharges freshwater that may be impacting the salinity in northeastern Florida Bay. During the years of system operation, the structures in the canal have had a variety of operating schedules. Additional modifications to the system are proposed by the South Florida Water Management District as part of the C-111 Project and Modified Water Deliveries to Everglades National Park. Improvements to existing salinity models are needed to better evaluate the effect of these changes on the salinity regime in parts of Florida Bay.

Hydrologic data collected since the original transfer functions were developed will be used to confirm and update the existing regional conditions model, and to evaluate the role of the C-111 system in explaining the variability in the salinity data from monitoring stations in northeast Florida Bay. Model residuals will be evaluated for correlation to flow and water levels at certain locations, such as S-174, S-175, S-176, S-18C, and possibly other stations. If measured parameters are found to be capable of explaining additional data variability, transfer functions will be suggested to describe the relationships.

New models for assessing the effects of the operation of the C-111 system, such as pump operation at S-332 and S-332D or removing portions of the existing levee will be evaluated, as well as other modeling methodologies for assessing the impact of other flow altering operational changes. The response of salinity at certain monitoring stations in Florida Bay to past operational modifications will be used to estimate the effect of the proposed improvements. Transfer functions that will be evaluated include simple linear regression models, multiple variable linear regression models, and possibly time series or non-linear regression models. If necessary, data transformations will also be evaluated. Seasonality in the data and lagged values in time will also be investigated.

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A Pump Test for Taylor Slough and Florida Bay Restoration

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Pump station S-332D is located in the L-31W canal, on the eastern boundary of Everglades National Park, near the headwaters of Taylor Slough. The structure was completed in December 1997 at a cost of $5 million. State and federal agencies are preparing an operating plan for S-332D that will (1) help rehydrate Taylor Slough and provide more natural freshwater flows to Florida Bay, (2) maintain flood control capability of up to 500 ft^3/s for the C-111 basin in agricultural south Miami-Dade, and (3) avoid impacts to the habitat of the Cape Sable seaside sparrow, an endangered specie.

As a first step toward operating the pump station, a four-week test was conducted from August 30, 1999 to September 27, 1999. The objectives of the test were to:

- Raise water levels in the L-31W canal adjacent to Taylor Slough to meet or exceed a rainfall-driven target
- Allow canal water to overflow into the Taylor Slough marsh
- Gain operational experience on the flexibility and limitations of the pump station

Intensive monitoring of hydrologic and water quality parameters was performed and the data will be summarized and presented in a report. Information obtained during the four-week test will be used for a preliminary assessment of the hydrologic and water quality impacts upstream and downstream of the pump station. Based on the four-week test, a more comprehensive 90-day test will follow.

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Sedimentation and Erosion in the Florida Bay Mangrove Transition Zone.

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Sedimentation-Erosion Tables (SETs) were placed along a north-south transect in Taylor River and an east-west transect along the Buttonwood Ridge of Florida Bay. SETs measure wetland soil elevation changes to an accuracy of plus or minus 1 mm. High accuracy is achieved by consistently suspending a flat steel table with nine pins in the exact same location during every measurement of pin distance to the sediment surface. In an erosional environment, where marker horizons disappear, these SET pins measure an increasing distance from the suspended plate. In a vertically accreting environment, the distance of the table from the sediment surface will decrease. That is, these SET pins will measure a decreasing distance from the suspended plate.

We will demonstrate how to properly construct and implement a SET device. Newer, lighter weight prototypes will be presented and cross-calibration techniques presented. In depositional environments it may be necessary to supplement SETs with feldspar marker horizons. A liquid nitrogen coring device for sampling marker horizons in wetland soils will also be presented.

Preliminary results from some seventeen SET locations sampled annually since 1997 indicate a range of both erosional and depositional environments. Most showed a 0.1-0.3 cm rise in elevation. Annual accretion rates ranged from 0.1 to 2.7 cm. Annual erosion rates ranged from 0.1 to 1.8 cm. Stations away from creek banks along the north-south transects of Taylor River appear to be losing elevation. This may be due to an imbalance between soil oxidation rates and organic deposition rates. Creek bank stations were either stable or slightly accretional. Higher plant production at creek edges may account for this. Stations away from the creek banks along the east-west Buttonwood Ridge transect were slightly accretional. Creek bank stations were generally stable. This ridge appears stable but may quickly change if sea level rise increases ridge overwash events.

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Interaction of Freshwater Riverine Discharges from the Everglades with the Gulf of Mexico and Florida Bay: Preliminary Results from a Moored Array and Shipboard Surveys.

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As part of the South Florida Ecosystem Restoration Program, a physical oceanographic study of the circulation of Florida Bay and its connection with the surrounding waters of the Gulf of Mexico, the southwest Florida shelf, and the Atlantic Ocean is presently underway. The measurement program includes moored arrays equipped with current meters, bottom pressure sensors and conductivity/temperature sensors, satellite-tracked surface drifters, a shipboard Acoustic Doppler Current Profiler (to measure volume transport through the channels between the Florida Keys), and bimonthly interdisciplinary shipboard surveys with continuous underway thermosalinograph observations of surface salinity, temperature, and fluorescence. Results from the first two years of the study (1995-1997) have shown that there is a net southeastward flow of 1 to 4 cm/s which transports waters from the Gulf of Mexico and the Everglades through western Florida Bay and the channels of the Middle Florida Keys, on a time scale of 1 to 3 months depending on local wind forcing. This net flow, with a volume transport of 1000 to 2000 m^3/s, has the potential to deliver harmful algal blooms and anthropogenic effects such as excess nutrient loading out to the environmentally sensitive coral reefs of the Florida Keys National Marine Sanctuary. The ongoing study now focuses on refining and quantifying the net flow from Florida Bay to the Atlantic and its response to seasonal and episodic meteorological forcing. In addition, new emphasis is placed on examining the fate of the freshwater discharges from the Everglades into the Gulf of Mexico via the numerous rivers of the southwest Florida coastline, and the relation of the river plume dispersion to regional wind and rainfall distributions.

The moored conductivity/temperature array consists of 20 sensors positioned from the Florida Keys reef tract, through Florida Bay and around Cape Sable, extending northward off the mouths of the Shark, Broad and Lostmans Rivers, to Indian Key just south of Marco Island, FL. The array is designed to resolve the three-dimensional structure of the river plumes, with emphasis on Shark River. In addition to the conductivity/temperature moorings, four moored upward-looking ADCPs are positioned west of Lostmans River and Cape Sable, with the offshore pair located 30 nm west of the southwest Florida coast. The ADCPs provide a continuous measure of currents, and, paired with data from the other moored instrumentation, will allow a quantitative analysis of the freshwater discharge. Bottom pressure sensors are included on the moorings 30 nm offshore of Cape Sable, adjacent to Cape Sable, in western Florida Bay, and in the Atlantic, offshore of Long Key, FL. From these instruments a continuous measurement of sea level height and the slope of the sea surface can be obtained. The bulk of the array was deployed in September 1997 and maintained since, with results at the time of the abstract available up to January to June 1999

Results from the moored array will be compared with wind fields obtained from the array of CMAN weather stations as well as rainfall gauge and river flow data, to determine the meteorological forcing mechanisms, which drive the river plume dispersion. Preliminary results of such comparisons have indicated that the dispersion is highly variable, strongly correlated with both wind and rainfall patterns, with the rainfall determining the size of the freshwater plumes on a daily-to-weekly time scale, and the wind fields determining the direction of dispersion. New data to be included in this analysis are anthropogenic flow control information and estimates of fresh water flux via evaporation. Satellite-tracked surface drifters, which are deployed in the Shark River plume during the bimonthly shipboard surveys, have corroborated the meteorologically-driven forcing of the regional circulation.

Some observations, based on CT mooring data recovered to date, include the following. They will be graphically displayed and elaborated upon in the presentation.

- The expected annual cycle of salinity variability - lower during the summer / autumn rainy season, higher during the winter / spring dry season – was disrupted in 1997/1998, presumably by the unusually high dry season rainfall that occurred, associated with El NiZo conditions. Lowest salinities throughout the region in 1998 occurred in April. Data collected during 1999 has been closer to the expected cycle, rising from a minimum in January.

- The annual cycle in the nearshore CT array – the six sensors located 2 –3 miles offshore from Lostmans River to Middle Cape – was roughly in phase, with amplitude of about 10 PSU. At ADCP moorings A and C, approximately 10 miles off shore, the amplitude was about 5 PSU. At ADCP moorings B and D, 25 – 30 miles offshore, very low frequency variability was more episodic than cyclical, with amplitudes of 2 –3 PSU and time scales of 1 – 3 months.

- Variability in the tidal to days^{-1} frequency was highest at the moorings placed near the river mouths. Shark River 2, Broad Creek, and Lostmans River, about the same distance offshore, showed in-phase variability at these frequencies, with a small (~1 PSU) S-N salinity gradient.

- Shark River 1, closest to shore, showed the freshest values at lower frequencies throughout the time period. However, maximum salinities at Shark River 1 during winter 1998, varying at 5 - 7 day synoptic weather periods, were higher than at the moorings further north, indicating more on-offshore mixing and/or larger E-W salinity gradients.

- By far the strongest event seen in the CT mooring records was the passage of Hurricane Georges in late September 1998. Salinity at the coastal sites most affected by river outflow – Shark, Broad, Lostmans – dropped 20 to 25 PSU in association with the storm’s rainfall, reaching values less than 10 PSU. Offshore moorings dropped only 1 – 3 PSU.

- The Hawk Channel mooring was the only Keys mooring to vary in phase with the Florida Bay / River moorings at synoptic time scales, indicating the preference for a southward path of fresh water from the shelf, across western Florida Bay, and out to the Atlantic through the middle Keys.

- At longer time scales, the major event in the Florida Keys moorings was the presence of fresh water (less than 34 PSU) during the July – September 1998 time period. This represented the passage of the (anomalously) fresh water from the SW Florida shelf exiting the region through the Keys.

In addition, the shipboard surveys yield measurements of temperature and conductivity continuously along the cruise track in the study area, and the mapped fields of surface salinity which can be obtained from these surveys complement the results of the moored array, which are continuous in time but not spatially continuous. To yield a three-dimensional view of the freshwater discharges, conductivity-temperature-depth (CTD) stations are taken along transects perpendicular to each river mouth, and show the extent to which the fresh water penetrates vertically into the water column. Early results from these observations have indicated that there is a high degree of variability in the vertical extent and mixing of the river plumes with the Gulf of Mexico coastal waters, probably driven by the ambient meteorological conditions and the synoptic background circulation as well as the strength of the river discharge itself.

It is expected that the moored array and the shipboard surveys will continue for at least three years, preferably longer, as there is considerable interannual variability in the larger-scale regional circulation driven by factors ranging from El NiZo cycles to interannual changes in the wind fields over the Gulf of Mexico and Atlantic Ocean, as well as large year-to-year variability in rainfall distributions over the Everglades. In order to quantify the regional circulation and river dispersion and their effects on the ecological health of Florida Bay and the Florida Keys National Marine Sanctuary, and to provide important boundary conditions and assessment of the numerical models which are presently being developed for the region, it will be necessary to make observations over the full range of interannual variability which occurs.

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Poster Abstracts

PALEOECOLOGY

Historical Salinity Effects on Microfauna in the Lower Everglades and Florida Bay.

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A multi-faceted approach examines the relationship between microfauna (ostracods and foraminifers) and salinity in Florida Bay and its environs. Several "levels" of microfaunal population variability were examined, which range from overall population characteristics to species- and individual-specific isotopic composition and morphological differences. These levels include documentation of changes in population abundance and diversity over time with variability in salinity and individual species- specific responses, which produce decipherable salinity-related records. Isotopic composition of stained individuals living in the surface sediment in each environment, as well as documentation of salinity related ostracod valve morphological change are studied. Attention is focused on those species capable of withstanding the greatest salinity fluctuations.

Core and surface microfaunal populations at Oyster Bay, Jimmy Key, and First National Bank are compared and contrasted. These three sites comprise distinct environmental regimes with well-documented salinity records. Oyster Bay has experienced the greatest salinity variability of the three sites as well as freshest overall conditions over the last 100 years. At the Jimmy Key site, in the center of the Bay, has experienced higher average salinity with less variability over this period.

Taphonomic microfaunal studies routinely utilize population characteristics as a tool for paleoenvironmental reconstruction. This study extends population work to include species and individual-specific characteristics, which may record salinity variability. In addition to the field and core collections we are culturing ostracods to examine isotopic and morphological relationships under controlled conditions. This multi-faceted approach extends our population characterization work to include documentation of physiological response of individuals within the microfaunal populations to documented changes in salinity. This data will extend the use of microfauna as indicators of modern and paleo-salinity change.

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Long-Term Florida Bay Salinity History: A Synthesis of Multi-Proxy Evidence from Sediment Cores.

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The issue of changing rates and patterns of salinity in Florida Bay is central to the question of restoration of the South Florida Ecosystem. It is critical to establish what pre-development rates and patterns of change in salinity were, and to decouple natural components of change from human-induced changes during this century.

The US Geological Survey Ecosystem History Projects, using multi-disciplinary and multi-proxy methods, have identified the long-term patterns of salinity change in seven cores taken at four sites in the central and eastern portions of Florida Bay (Bob Allen mudbank, Russell Bank, Pass Key, and the mouth of Taylor Creek). All cores were dated using ^{210}Pb geochronology. Our initial results were based on percent abundance of benthic foraminifers, ostracodes, and molluscs in down-core assemblages that were categorized based on the known preferences of a species for a specific salinity range. Evidence from the seven cores indicated that fluctuations in salinity are part of the natural cycle; however, there is a distinct difference in the patterns of fluctuation seen in the benthic salinity indicators pre-1900, compared to post-1940. Subtle shifts in the faunal distributions occur around 1910, but after 1940 the pattern of salinity fluctuation departs substantially from the pre-1900 pattern. The amplitude of shifts in salinity indicators increased from 15-20 % about the mean pre-1900 to 40-60 % post-1940. Analyses of replicate cores from three sites (Bob Allen, Russell, and Pass) were consistent with the initial data.

In conjunction with faunal analyses, stable isotopic analyses were conducted on select mollusc species (*Transennella* and *Brachiodontes*) from the same cores. These analyses indicate that between 1900 and 1940, $\delta^{18}O$ increased slightly, reflecting increased salinity and/or evaporation. These findings are in agreement with the faunal analyses. The $\delta^{13}C$ increased significantly between 1900 and 1940, which reflects decreased circulation and/or longer residence time.

To date, diatom analyses have been conducted on two of the cores (Russell and Pass) analyzed for faunal content and stable isotopes. Diatom analyses have indicated that significant changes in salinity occurred over the last century, and that periods of high salinity did exist prior to significant human-induced changes. Diatom indicators show the most significant changes in salinity after approximately 1972.

Metal/Ca ratios of ostracodes from three cores (Bob Allen, Russell, and Taylor) have indicated decadal-scale oscillations in salinity, which correlate with averaged decadal-scale fluctuations in annual and seasonal rainfall over southern Florida. These data suggest that regional climate and precipitation are important factors in controlling salinity variations in Florida Bay. Winter rainfall in southern Florida is significantly controlled by the SOI

(Southern Oscillation Index - a useful measure of ENSO, El Niño Southern Oscillation strength). Years with strong negative SOI values correspond to anomalously high winter rainfall in southern Florida, and the reverse is true for strongly positive SOI values. Periods of high rainfall correspond to salinity minima and low rainfall to salinity maxima as estimated from the ostracode shell chemistry. It is significant, however, that the highest salinity shifts recorded in metal/Ca ratios occurred in the last 50 years, a period when there is no obvious concomitant change in regional rainfall. Thus, the natural cycle of salinity fluctuations and the correspondence to ENSO and rainfall appears to be decoupled in the second half of this century, implying that other forces are influencing salinity patterns in Florida Bay. This is consistent with the hypothesis that human-induced alteration of the Everglades and the resulting altered delivery of freshwater to the Bay have changed the timing and fluctuation of salinity patterns within the Bay.

The debate over natural versus human-induced changes in the South Florida Ecosystem continues, even as restoration begins. It is critical that these questions be answered, because it is neither economically feasible nor sustainable to attempt to "fix" changes due to natural causes. However, it is feasible and sustainable to restore the components of change due to human-induced alteration of the environment. The data presented here indicate that beginning somewhere around 1935 to 1940, unprecedented changes occurred in the South Florida Ecosystem that affected the natural patterns of salinity fluctuation within Florida Bay. These data agree with results from Smith et al. (1989, Bulletin of Marine Science, v. 44, p. 274-282). Their study of fluorescence patterns in a coral from Florida Bay showed a distinct change in the late 1930’s and 1940’s, which they attributed to a change in water management practices that further reduced and disturbed the natural fresh-water flow into Florida Bay.

A logical next step in addressing the question of causes of salinity change in Florida Bay is to test the conceptual models of predevelopment seasonal salinity and hydrologic flow by using the historical data acquired from the sediment cores. Currently we are developing the technique of using ostracode (see Dwyer abstract, this volume) and mollusc shell geochemistry to refine the decadal-scale patterns developed thus far to an annual scale, and to derive data on pre-canal construction seasonal variations in salinity. These data will provide the means to test hydrologic models for predevelopment salinity within Florida Bay, and may be useful in determining whether changes in water-management practices, or climatic factors can explain the unprecedented changes of the second half of this century.

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Historical Trends in Epiphytal Ostracodes from Florida Bay: Implications for Seagrass and Macro-Benthic Algal Variability.

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We investigated living and fossil epiphytal ostracodes in Florida Bay to determine historical trends in seagrass and algal habitats during the past century. Living assemblages collected in February and July, 1998 from sites throughout Florida Bay revealed that (1) *Loxoconcha matagordensis* and *Malzella floridana* are the dominant epiphytal species living on *Thalassia*; (2) *Xestoleberis* spp. is most abundant living on macro-benthic algae such as *Chondria*; and (3) *Peratocytheridea setipunctata* prefers sandy substrates and is abundant on *Halodule*.

Temporal trends in epiphytal ostracodes were reconstructed from radiometrically-dated sediment cores from Whipray Basin, Russell Bank, Bob Allen Bank, Pass and Park Keys, the mouth of Taylor Creek and Manatee Bay. These data indicate that there have been frequent changes in the relative frequencies of *L. matagordensis*, *M. floridana*, and *Xestoleberis* over the past century. Prior to the mid-20th century, subaquatic (SAV) ostracode species were relatively rare throughout large parts of central and northeastern Florida Bay. Ostracode assemblages living between 1900 and 1940 were characterized by abundant (10->60%) *Peratocytheridea setipunctata*. This was a time when *Thalassia* and macro-benthic algal species were rare to absent at most sites. From about 1930 until 1950, *P. setipunctata* abundance declined while *L. matagordensis* and *Xestoleberis* increased progressively from 0 - 10 % to > 25 - 40 %, depending on the site. This long-term faunal shift in central Florida Bay suggests that, on average, there has been a much greater abundance and/or density of subaquatic vegetation over the past 50 years compared to the prior half century. Since 1950, central and northeastern Florida Bay has experienced high amplitude swings in the proportion of seagrass and algal-dwelling species. Some of these oscillations, such as the decline in *L. matagordensis, Xestoleberis,* and *M. floridana* during the 1970s and early 80s, appear to be synchronous across the study area and may represent large-scale dieoffs.

The most important issue regarding the interpretation of these faunal events is whether they represent a local trend at a single mudbank or whether they signify synchronous, large-scale events that characterized the entire region. If these do indeed signify regional changes in Florida Bay benthic habitats, then what is (are) their cause(s)? Both long-term decline in *P. setipunctata* and the coincident rise in *L. matagordensis*, *M. floridana* and *Xestoleberis* spp. during the mid-20th century and the decline in SAV-dwelling species during the 1970s and 1980s are most likely regional events based on the current available data. Among their many potential causes, a combination of human alteration of the hydrology and natural climatological factors seems to be the most reasonable explanation for observed trends in Florida Bay vegetation. We will discuss the idea that the influence of El Nino and decadal-scale climatological processes on Florida Bay habitats may have been altered, perhaps amplified, by anthropogenic diversion of freshwater inflow. The net result is that since the mid- 20th century, Florida Bay has been “hypersensitive” to climatic and hydrological variability.

The compelling paleoecological evidence that central Florida Bay has experienced oscillations in seagrass and macro-benthic algal habitats, including anomalously high variability during the past 30 years, is also germane to efforts to restore the bay to a natural state. Seagrass and macro-benthic algal habitats were probably very sparse in central and northeastern Florida Bay during the 19th and early 20th centuries, at least relative to the 1950s and 1960s, when epiphytal species flourished. Parts of Florida Bay also experienced diminished amounts of SAV during the 1970s and 1980s. Thus, how one defines the "natural state" of Florida Bay and the desired area of seagrass cover will depend on which time period is selected as the restoration target.

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Diatoms as Indicators of Environmental Change in Florida Bay.

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Introduction

Modern and fossil diatom assemblages in Florida Bay have been analyzed in order to make inferences concerning past changes in salinity, seagrass cover, and nutrients. Diatom analyses have been completed for two sediment cores from northeastern Florida Bay, Russell Bank core 19A (RB 19A) and Pass Key core 37 (PK 37). Ecological information from both the literature and the modern assemblages (see below) of surface sediment and epiphytic diatoms from Florida Bay was used to interpret the stratigraphic changes in the cores.

Surface sediment samples from 26 U. S. Geological Survey monitoring sites have been collected. Water quality measurements and field observations have been made at these sites since 1995 (see website at http://flaecohist.er.usgs.gov/database/ for details). Diatoms have been analyzed from a number of these surface sediment samples and their distributions were related to salinity. In addition we plan to analyze the total phosphorus (TP) content of these sediment samples and relate diatom assemblage data to TP.

Samples of sub-aquatic vegetation from these monitoring sites have also been analyzed for diatoms. This has allowed for the identification of diatoms that grow epiphytically on seagrass.

Methods

Diatoms were extracted from sediment samples by a modification of the digestion procedure described by Funkhauser and Evitt (1959). Approximately 0.5 mg dry weight was digested for each sample from core RB 19A. For core PK 37, the amount of sediment digested varied between approximately 0.7 and 2.4 mg dry weight per sample. Samples were treated with hydrogen peroxide, hydrochloric acid, and finally a nitric acid-potassium dichromate digestion. Sand particles were removed by a coarse fractionation procedure. Measured amounts of the final diatom slurries were permanently mounted in Naphrax ® (Northern Biological Supply, Ipswich, UK) (RI≅ 1.7) on microscope slides. Slides were examined with a light microscope at a magnification of 1000X. At least 300 diatom valves were counted per sample.

Pieces of live shoots of sub-aquatic vegetation samples were treated with nitric acid and potassium dichromate to extract diatoms. Diatom samples were similarly mounted on slides with Naphrax®, and approximately 200 valves per sample were counted.

Core Chronology

The ages of the sediment cores were determined radiometrically. Three cores were collected at the Russell Bank site: RB 19A, RB 19B, and RB 19C. Cores RB 19A and RB 19B were replicate cores taken alongside each other and core 19B was analyzed for lead-210 activity.

Sedimentation rates for core 19B was estimated at 1.22 cm/yr. ± 0.05 cm (Brewster-Wingard *et al*. 1997). It is assumed that core RB 19A has a similar sedimentation rate. Given this sedimentation rate, core RB 19A is approximately 115 years old, spanning the period from 1880 to 1995.

Core PK 37 was also analyzed for lead-210 activity. Details can be found in Robbins *et al.* (in press). The sedimentation rates were much higher at this site and estimated to be on the order of 2.06 cm/yr. ± 0.2. (Brewster-Wingard *et al*. 1998a).

Modern Diatom Analyses

Preliminary analyses of the modern samples show that there is a fairly diverse diatom flora in Florida Bay, and there may be new species that have not been described in the literature. Several species showed salinity preferences. For example, *Cocconeis scutellum, Grammatophora* cf. *oceanica* var. *macilenta*, and *Mastogloia corsicana* showed a preference for the higher salinity sites. *Cocconeis placentula* var. *euglypta* showed a slight preference for the lower salinity sites. Examination of sub-aquatic vegetation samples showed that *Mastogloia crucicula, Mastogloia ovalis,* and several species of *Cocconeis* were common epiphytes in Florida Bay.

Sediment Core Diatom Analyses

Diatom analyses of the sediment cores indicate fluctuations in both salinity and seagrass cover during the past 100 years. Diatoms from Russell Bank core 19A indicate that salinity was high prior to the 20th century. This is suggested by the high percentages of marine *Cyclotella* species. Between 1890 and 1920, assemblages dominated by *Mastogloia* species prevailed. These particular assemblages were dominated by two taxa that have not been identified to the species level, *Mastogloia* sp. A and *Mastogloia* sp. R. These taxa did not commonly occur in any of the modern samples analyzed to date. After 1920, there was a dramatic shift to assemblages dominated by an epipelic taxon, *Nitzschia granulata*. Increases in *N*. *granulata* suggest that there was more bare sediment with adequate light availability for colonization. This species remained common until about 1950, when epiphytic taxa including *Cocconeis placentula* var. *euglypta*, *Mastogloia crucicula* and *Mastogloia ovalis* increased. The increases in epiphytic diatom taxa indicate an increase in the abundance of seagrass. The presence of *Cocconeis placentula* var. *euglypta* suggests that salinity declined as this taxon is more common in fresh and brackish waters (e.g. Patrick and Reimer, 1966, Cooper, 1995). This taxon remains relatively common until about 1972, when other diatoms indicative of higher salinity, such as *Mastogloia corsicana*, increase. This change signals a decline in seagrass as well as an increase in salinity.

Similar trends are seen in the Pass Key core 37 (which spans approximately 35 years, between 1960-1996). Epiphytic diatoms are common during the 1970’s. There is also a general trend towards increasing salinity upcore, as indicated by marine taxa such as *Mastogloia elegans* and *Mastogloia corsicana*.

These trends in diatom indicators are consistent with the trends noted for other indicators from sediment cores from Pass Key and Russell Bank (Brewster-Wingard *et al*. 1998a, 1998b, Brewster-Wingard *et al*. 1997). Thus, a variety of indicators show that there have been significant changes in both salinity and seagrass cover during the last century in Florida Bay, with the most notable changes in salinity occurring after 1940. This suggests that increased anthropogenic disturbances in the latter half of this century have influenced salinity in Florida Bay.

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Understanding Long-Term Rainfall, Freshwater Flow and Salinity Patterns with Concomitant Responses of Benthic Microfauna, Stable Isotopes, and Pollen in Oyster and Florida Bays.

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Salinity records exhibited variability from the decadal scale to the monthly scale that can be accounted for by changing patterns in regional rainfall. Changes in salinity, both near the outflow of the Shark River Slough at Oyster Bay, and in central Florida Bay near Jimmie Key, show a direct response to regional rainfall on these time scales. Moreover, regional rainfall, represented by the 80+ year record at Homestead, Florida, proved representative of the study area and indicated high correlation with flow into Shark River Slough prior to major watershed construction instigated in the early-1960s. During subsequent periods of water management strategies, enacted from the mid-1960s to present, results indicate essentially no correlation between regional rainfall and flow during the Monthly Allocation Plan. In contrast, correlations most closely paralleled pre-construction, apparently more natural conditions, during the Rainfall Plan.

Investigated characteristics for the benthic microfaunal community (foraminifers and ostracods) such as stable isotopes, abundance and community diversity exhibited changes and trends that apparently more closely paralleled natural, rather than anthropogenic influences over the whole period of record. At both Jimmie Key and Oyster Bay, foraminifer and ostracod data indicate direct correlation to rainfall patterns for temporal scales ranging from decadal down to the limit-of-resolution of our geochronology. An exception to this natural influence was observed from the late-1940s to mid-1950s during which time a dual transition occurred in the sediments adjacent to the Shark River Slough in Oyster Bay. Organic carbon content permanently declined from above- to below-average with concurrent onset of major increases in foraminifer and ostracod abundances. These events temporally coincided with the construction of the Everglades Agricultural Area, which impounded 700,000 acres of organic-rich swampland. These effects were not observed for sediments representing the same time period at Jimmie Key.

Stable isotope ($\delta^{18}O$, $\delta^{13}C$) trends alone, for ostracods and foraminifer at Oyster Bay and Jimmie Key, showed mixed signals with most data suggesting upcore trends to less fresh, more marine conditions. However, when long-term trends for relative abundance of salinity-sensitive species were examined, for the same time periods and locations, they confirmed a statistically valid upcore trend toward less-fresh, more marine conditions at both the Oyster and Florida Bay study sites. This trend was co-incident with a weak decline in regional rainfall over the same time span.

Changes in the stable isotopic values of these microfauna indicated, to the limits of our geochronology, direct responses to regional rainfall. Such responses more closely paralleled rainfall than freshwater runoff, even adjacent to the outflow of the Shark River Slough. At Oyster Bay, ostracod stable isotope ($\delta^{18}O$) trends correlated better with variations in regional rainfall than with freshwater outflow from the adjacent Shark River Slough. Crashes in microfaunal abundances at Oyster Bay and more gradual declines at Jimmie Key were salinity related. This abundance drop was concurrent with an equally dramatic drop in community diversity. The latter was characterized by survivor-mode dominance by two microfaunal species and occurred over a period of drought at both sites and the related reduced flow from Shark River Slough.

A non-traditional use of pollen allowed evaluation of the degree of paleo-flushing from Shark River Slough that not only correlated well with existing flow and rainfall records but suggest validity as a flushing proxy for pre-record eras. Analysis of regional pollen indicated taxa associations that allowed discrimination of pollen zonations from coastal mangrove to upland slough environments. This, in turn, allowed reconstruction in the sediment record of historical periods of major to minor flushing from Shark River Slough.

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Lignin Phenols in Sediments from Florida Bay as Indicators of Seagrass History.

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Introduction

The presence of extensive seagrass beds is a key biological feature of the Florida Bay ecosystem. Seagrass beds provide habitat and nursery areas for many species of marine animals, including commercial species. Beginning in 1987, seagrass (*Thalassia testudinum*) began dying over large areas, mostly in western Florida Bay. Less extensive occurrences of *Thalassia* dieoff were observed in 1975 and 1984 in central Florida Bay (Whipray Basin), and anecdotal observations of seagrass dieoff were reported as early as the 1950's. The principal causes of the recent seagrass dieoff are unclear, but various hypotheses implicate chemical factors (nutrients, sulfide toxicity), hydrology (reduced freshwater input and resulting hypersalinity), climate (fewer severe storms to flush out the bay), and biological factors (pathogens such as *Labyrinthula* slime mold).

A major unanswered question is what is the natural variability of seagrass abundance in Florida Bay? Also, what physical or biological factors control seagrass variability? Answers to these questions are critical, as ecosystem managers need to develop target criteria for restoration and to understand the natural variability of biotic assemblages within the ecosystem. The purpose of this study is to examine historical trends in seagrass abundance in dated sediment cores from Florida Bay using lignin phenols as a proxy. We are also determining historical trends in nutrients and organic carbon in the same cores to examine linkages between nutrient load to the bay and seagrass abundance. Collaborators are examining seagrass indicator species (foraminifera, ostracodes, molluscs, and diatoms) in the same cores. This combination of geochemical and paleoecological studies of seagrass abundance provides complimentary information.

Rationale

Lignin phenols are a series of methoxy and dihydroxy phenols derived from the lignin of vascular plants. These compounds are generally absent from algae. Lignin phenols fall into families of compounds (vanillyl, syringyl, p-hydroxy, and cinnamyl phenols), based on the methoxyl and hydroxyl substituents on the aromatic ring. All vascular plants contain vanillyl phenols in their lignin structure. Angiosperms also contain syringyl phenols, while gymnosperms lack syringyl phenols. Lignin from *Thalassia* contains little or no syringyl phenol content (syringyl/vanillyl ratio $\cong$ 0.02), similar to gymnosperm lignin but distinctly different from angiosperm vegetation such as mangroves (syringyl/vanillyl $\geq$ 0.5). Thus, *Thalassia* has a lignin composition that readily distinguishes it from the other major lignin source to Florida Bay (mangroves) using the ratio of syringyl/vanillyl phenols (S/V). The composition and amount of lignin in the sediments provides an interpretable record of historical changes in seagrass abundance. Total lignin phenol content normalized to the total organic carbon content of sediments also provides information on historical trends in relative amounts of vascular plant and algal contributions to the sedimentary organic matter.

Methods

Sediment piston cores and samples of living seagrass were collected on mudbanks in June 1996 and 1997 from five sites in eastern and central Florida Bay: Pass Key, Russell Key, Bob Allen Keys, Whipray Basin NE, and Whipray Basin SW. Sediments were wet sieved into fractions (>63 and <63 μm) in order to separate coarse material (seagrass fragments and shells) from the fine-grained carbonate mud, prior to analytical procedures. After sieving, the sediment fractions and living seagrass specimens were lyophilized, weighed, and stored in glass vials.

Lignin phenols were determined using CuO controlled oxidation at 170° C in mini-bombs to release the free phenols from the lignin biopolymer. The free phenols were extracted diethyl ether, reduced to dryness, derivatized, and quantified by gas chromatography using an external standardization method. Individual lignin phenols were identified by gas chromatography/mass spectrometry using computer comparison of mass spectra of peaks in the chromatograms to those of authentic standards. Total carbon, organic carbon (pre-treated to remove carbonates) and total nitrogen were determined on lyophilized/powdered samples using a Leco 932 CHNS analyzer. Total phosphorus was determined by baking preweighed samples at 550°C, extracting the residue with 1M HCl, and determining total phosphorus concentration by colorimetric analysis. Cores were dated using ^{210}Pb geochronology for the last 100 years, and ^{14}C dating for older sediment intervals. The use of tradenames is for descriptive purposes only; no endorsement by the U.S. Geological Survey is implied.

Results

Total lignin phenol contents of sediments at the sampling sites ranged from 0.2 to 6.0 μg/mg organic carbon. Concentrations were highest at Pass Key (the site closest to land); concentrations at the most marine site (Bob Allen Keys) were about 2 to 3 times lower than those at Pass Key. The higher lignin phenol concentrations at Pass Key reflect the influence of mangrove-derived lignin transported from the nearby coastal zone mangrove forests. Downcore variability in total lignin content was relatively high over short time frames (several years) at Pass Key, probably reflecting variability in the flux of mangrove-derived lignin from the coastal zone. At Bob Allen Keys, lignin phenol concentrations were: (1) very high around 1900 (6 μg/mg organic carbon), (2) gradually decreased to concentrations of only about 1.5 μg/100 mg organic carbon in the late 1930’s, and (3) increased to concentrations of 3 to 6 μg/g organic carbon after 1950.

Values of syringyl/vanillyl phenol (S/V) ratios ranged from 0.1 to 0.6, indicating that the sediments at all sites contained a mixture of lignin derived from seagrass and mangroves. Values of S/V closer to 0.1 reflected a greater dominance by seagrass, while values closer to 0.6 indicated dominance by mangroves. Overall, S/V values were highest at Pass Key, reflecting the proximity of this site to coastal sources of mangrove-derived lignin. Downcore trends in S/V at Pass Key showed considerable variability over short time intervals, for example from 0.6 in 1990 (mangrove dominance) to 0.1 in 1993 (seagrass dominance). This may reflect short-term variability in transport of mangrove-derived lignin from the coastal zone and tidal creeks controlled by rainfall. Seagrass appears to have been abundant at this site around 1960, but declined in the late 1960's and early 1970's. Seagrass became abundant again at this site in the late 1970's and has been fairly stable since that time. At Bob Allen Keys long-term trends in seagrass abundance were observed from downcore changes in S/V. From about 1900 to the mid 1940's, S/V values were fairly constant at about 0.2, indicating a mix of both seagrass and mangrove lignin with a slight dominance by seagrass. The S/V values began to rise to about 0.4 from the mid 1940's to the early 1970's, suggesting a decline (moderate dieoff?) in seagrass abundance over this period. After the early 1970's S/V values gradually decreased to values approaching 0.1, indicating an increase in seagrass abundance over this most recent period.

Results show that historical variability in seagrass abundance has occurred during this century. No correspondence between declines in seagrass abundance and nutrient concentrations has been observed in the cores studied to date. Current work is focused on the analysis of cores from additional sites in Florida Bay.

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The Signature of Hurricane Sedimentation in the Lower Everglades/Florida Bay Ecosystem: Recognition of Sedimentologic, Geochemical and Microfaunal Indicators.

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Winter storm and hurricane resuspension and transport processes are responsible for building the bulk of the sediment sequence in the accreting bank flanks in both northwest Oyster Bay (Whitewater Bay) and Florida Bay. Repetitive resuspension by winter storms provides fine silt-sized carbonate, siliceous and organic laminae as thin event laminae, mostly a millimeter or less in thickness. As these repetitive winter storms produce similar wind and transport sequences in an area, the constituent composition and mineralogy of the laminae are similar.

Vertical profiles of excess ^{210}Pb activity in sediments from northwest Oyster Bay, Jimmie Key and First National Bank showed that sedimentation at these sites has been in steady state during the last 40 years. However, two to three discontinuities of short duration (<2 years) in the decay profiles of excess ^{210}Pb activities were observed in the sedimentary records from northwest Oyster Bay, Jimmie Key and First National Bank. Based on excess ^{210}Pb-based ages, the discontinuities occurred at about 1960, 1948 and 1935, dates coincident with major hurricanes passing through Florida Bay: Donna in September 1960 (Category 4); unnamed hurricane in September 1948 (Category 3), and the Great Labor Day Hurricane in September 1935 (Category 5).

Hurricane layers from 1935, 1948, 1960 (Donna) and 1992 (Andrew; in Oyster Bay) are identified by a sharp surface on which sand-sized shell, carbonate peloids and organic detritus are concentrated and overlain by a white, fine sand to silt layer, 0.5-2 cm in thickness. Sedimentologic and geochemical data on discontinuity surfaces show that the base of each hurricane layer is an erosional surface from which several cm of sediment was eroded. This is expectable as the upper 3-10 cm of the sediment in these accreting flanks is a very soft zone with as much as 80% water content that could easily be removed. Discontinuities in ^{210}Pb profiles and therefore erosion were more pronounced in open water sites such as Jimmie Key and First National Bank (3-20 cm thick) relative to the more protected, mangrove coastline surrounded environment of northwest Oyster Bay (~2 cm thick).

Major (category 4 and 5) hurricanes are devastating to the red and black mangrove communities, causing destruction to 50-100% of the forest in the eye wall of the storm. This loss is reflected in the organic detritus content of sediments in cores from northwest Oyster Bay and other areas surrounded by extensive mangrove coastlines. Prior to a major hurricane, the macro-organic detritus is mainly partly decayed fragments of mangrove leaves released from the adjacent forests. Defoliation, uprooting and death of the forest during and following the storm result in a change in the amount and composition of organic detritus in sediments. Organic detritus is composed of fine root hairs for a period of 5-10 years following the event. This reflects an extended period of erosion and release of root-hair detritus from the disrupted and decaying mangrove peat substrate. Organic detritus gradually decreases and becomes dominated by leaf detritus as the forest recovers.

Hurricane-related signals in the microfaunal assemblage data (benthic ostracods and foraminifers) are both site- and event-specific. The two hurricanes that significantly modified the microfaunal assemblages from Jimmie Key and northwest Oyster Bay are the Labor Day Hurricane of 1935 and Hurricane Donna (1960). Hurricane Donna resulted in peaks in relative abundance of atypical benthic foraminifer species at both sites. At Jimmie Key, the species comprising this peak were derived from elsewhere within Florida Bay. In contrast, in northwest Oyster Bay, species were comprised of continental shelf species transported from the Gulf of Mexico by Donna's last winds. An example of hurricane-specific effects can be seen in the differing signals recorded by the 1935 and 1960 hurricanes at Jimmie Key. The 1960 hurricane left a distinct lag-type deposit, whereas the 1935 hurricane sediments were essentially barren of microfauna. High organic carbon influx and subsequent oxygen depletion associated with these hurricane events appear to be recorded in the microfaunal assemblages as well.

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Impact of Hydrologic Changes on the Everglades/Florida Bay Ecosystem: A Regional, Paleoecological Perspective.

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We are investigating the response of the Everglades/Florida Bay ecosystem to hydrologic changes over the last century using floral and faunal assemblages as proxies for vegetation and environmental parameters such as hydroperiod, salinity, and substrate. Data from more than twenty cores in the Everglades and seven cores in Florida Bay provide biotic records covering the last 2,000 years. The long-term record of the Everglades is provided by peat cores, which provide century-scale resolution over the last 2,000 years. Cores from Florida Bay and Biscayne Bay have much higher sedimentation rates and provide decadal-scale resolution for the last century. Here, we present data on the natural variability of the system over the last few millennia as well as the impact of hydrologic changes on the system as a whole.

Analyses of pollen assemblages from Everglades cores from Loxahatchee NWR, Water Conservation Area (WCA) 2A, 3A, and 3B, and Everglades National Park indicate that water depths and hydroperiods have been greater than today from at least 2,000 yr. BP until about 1500 AD, with an interval of drier conditions from about 1200-900 AD. Sites in the northern Everglades were characterized by slough vegetation for most of this period, and southern Everglades sites typically consisted of sawgrass marshes and wet prairies. At the southernmost Everglades site near Florida Bay, invertebrate faunas indicate a change from fresh-water to brackish conditions at about 1200 AD. Concomitantly, vegetation shifted from fresh-water to brackish marshes. This salinity shift in the Bay and vegetational shift from sloughs to sawgrass marshes in the Everglades indicates a system-wide response to climatic changes during the Medieval Warm Period (900-1300 AD), when droughts and increased sea-surface temperatures have been recorded elsewhere in the region. Although terrestrial environments became wetter again after about 1200 AD, the site near Florida Bay never returned to fresh water and appears to have become more saline through time. Following an increase in tree-pollen abundance in the 16th century, vegetation remained stable until the mid-19th century, indicating stable, somewhat drier conditions during this time.

Biotic and environmental changes of the last century are recorded in cores from the Everglades, Florida Bay, and Biscayne Bay. In the Everglades, major changes in the vegetation occurred between the 1920s and 1940s, when water depths and hydroperiods were altered throughout the region. At most sites, these changes resulted in drier conditions and a shift from slough to sawgrass marsh vegetation. Additional, more localized changes occurred after 1950, including the increased abundance of cattails at a nutrient-enriched site in WCA 2A, shallower water depths and greater abundance of weedy annual species at sites in WCA 3A, and a shift from fresh-water and brackish marsh taxa to mangroves near Florida Bay. Correlative changes are recorded in Florida Bay salinity and seagrass abundance based on evidence from ostracodes, molluscs, benthic foraminifers, and diatoms.

The combined terrestrial and marine records indicate that the major, system-wide biotic changes occurred by 1940, which coincides with the construction of primary canals and the Tamiami Trail. The resulting disruption of sheet flow apparently had a broad regional impact, particularly when compared to the more localized impacts of changes associated with the C&SF project. These paleoecological reconstructions indicate the mid-19th century provides a reasonable approximation of the “natural” state of the Everglades ecosystem over the last few centuries and may be a realistic goal for restoration planning.

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A Century of Hydrological Variability in the Lower Everglades National Park as Interpreted from Stable Isotopes on Ostracods and Foraminifers.

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Stable isotopic analysis of selected ostracods and foraminifers were carried out from high-resolution sediment cores collected from Oyster and Florida bays. The core localities provide distinctive environmental conditions in which the effects of freshwater run-off, rainfall and consequently salinity can be assessed. Oyster bay lies at the end of the Shark River Slough, and is an area that experiences extreme salinity fluctuations due to the interaction between freshwater run-off and marine water input from the Gulf of Mexico due to tidal flow. A second core, collected near Jimmy Key, in the center of Florida Bay, provides a contrasting salinity history in which salinity has remained close to marine during this century. Stable isotope (^{13}C, ^{18}O) trends of ostracods and foraminifers at Oyster Bay and Jimmy Key suggest a general transition to more saline conditions over this time period. Relative abundance of salinity-sensitive species confirmed this observation. Moreover, stable isotopes indicate an increase in salinity variability over time, which is represented in the microfaunal assemblage by survivor-mode dominance by highly tolerant species, both in foraminifers and ostracods, that occurred during a period of drought or highly evaporative conditions during the mid to late 1980's that also lead to reduced flow from Shark River Slough. Fluctuations on stable isotope values appeared to be more a direct response to regional rainfall than freshwater run-off; however, distinct patterns can be temporally correlated to freshwater management strategies by the SFWMD.

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Oral Abstracts

Friday, November 5, 1999

8:00am-5:30pm

ADJACENT MARINE SYSTEMS

Friday, November 5, 1999

am

7:00-8:00	**Morning Refreshments**
8:00-8:10	**Introduction to Research in Adjacent Marine Systems I. *Benjamin D. Haskell***, NOAA, Florida Keys National Marine Sanctuary, Marathon, FL.
8:10-8:30	**A Spatially-Intensive Assessment of the Multispecies Reef Fishery Resources in the Dry Tortugas Region. *Jerald S. Ault***, *Steven G. Smith*, *Jiangang Luo*, *Geoffrey A. Meester* and *Guillermo Diaz*, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *James A. Bohnsack* and *Peter Fischel*, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL; *Steven Miller* and *Dione Swanson*, National Undersea Research Center, Key Largo, FL.
8:30-8:50	**Initial Responses of Exploited Organisms to No-Take Protection Zones in the Florida Keys National Marine Sanctuary. *James A. Bohnsack***, *David B. McClellan*, *Douglas E. Harper*, *Peter Fischel*, *Anne Marie Eklund*, *Stephania K Bolden* and *Joaquin Javech*, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; Jerald S. Ault, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.
8:50-9:00	**Questions**
9:00-9:20	**Modeling the Southeast Florida Coastal Ecosystem - Hydrodynamic Transport, Salinity, and Trophodynamics. *John D. Wang***, *Jerald S. Ault*, *Brian K. Haus*, *Jiangang Luo* and *Javier Rivera*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.
9:20-9:30	**Questions**
9:30-9:55	**Refreshment Break**
9:55-10:15	**Detection of Seagrass Cover and Water Clarity in Florida Bay and the Keys. *Richard P. Stumpf***, NOAA, National Ocean Service, Silver Spring MD; *Michael J. Durako*, University of North Carolina at Wilmington, Wilmington NC; *James W. Fourqurean*, Florida International University, Miami FL; *Varis Ransibrahmanakul*, TPMC, Silver Spring MD; *Megan L. Frayer*, Florida Marine Research Institute, St. Petersburg, FL.
10:15-10:35	**The Relative Influence of Florida Bay on the Water Quality of the Florida Keys National Marine Sanctuary. *Joseph N. Boyer*** and *Ronald D. Jones*, Southeast Environmental Research Center, Florida International University, Miami, FL.
10:35-10:55	**Historical Changes in Mangrove, Seagrass and Calcareous Algal Communities in South Florida. *Harold R. Wanless***, Department of Geological Sciences, University of Miami, Coral Gables, FL; *Lenore P. Tedesco* and *Bob E. Hall*, Department of Geology, Indiana University, Purdue University at Indianapolis, Indianapolis, IN.

Friday, November 5, 1999 *(continued)*

10:55-11:15 **The Origin of Variations in the Stable Oxygen, Hydrogen, and Carbon Isotopes of Waters in the Coastal Waters of South Florida.** ***Peter K. Swart*** and *Réne Price*, MGG/RSMAS, University of Miami, Miami, FL.

11:15-11:30 **Questions**

11:30-11:50 **An Environmental Information Synthesizer for Expert Systems.** ***James C. Hendee***, AOML/National Oceanic and Atmospheric Administration; Miami, FL.

11:50-12:00 **Questions**

12:00-1:30 **Lunch on Own**

pm

1:30-1:35 **Introduction to Research in Adjacent Systems II.** ***Susan Markely***, PMC Member, Miami-Dade Department of Environmental Resources Management, Miami, FL.

1:35-1:50 **Environmental History of Biscayne Bay.** ***A. Y. Cantillo***, NOAA/NOS/ National Centers for Coastal and Ocean Science, Center for Coastal Monitoring and Assessment, Silver Spring, MD; *K. Hale*, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *E. Collins*, NOAA/NESDIS/NOAA Central Library, Silver Spring, MD; *L. Pikula*, NOAA/NESDIS/Miami Regional Library, Miami, FL; *R. Caballero*, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL.

1:50-1:55 **Questions**

1:55-2:10 **A Closer Look at the Tides of Biscayne Bay, Card Sound and Barnes Sound.** ***Ned P. Smith,*** Harbor Branch Oceanographic Institution, Fort Pierce, FL.

2:10-2:15 **Questions**

2:15-2:30 **Design-Based Sampling to Assess Fish and Macroinvertebrate Populations in Biscayne Bay and the Adjacent Coral Reef System.** ***Jerald S. Ault***, *Steven G. Smith*, *Geoffrey Meester*, *Guillermo Diaz* and *Jiangang Luo*, University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *James A. Bohnsack*, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL.

2:30 –2:35 **Questions**

2:35-2:50 **Groundwater Discharge and Nutrient Loading to Biscayne Bay.** ***Michael Byrne*** and *John Meeder*, Southeast Environmental Research Center, Florida International University, Miami, FL.

2:50-2:55 **Questions**

Friday, November 5, 1999 *(continued)*

2:55-3:10 **Tidal Creek Flux Studies, Biscayne National Park.** ***John Meeder***, *Amy Renshaw* and *Michael Ross*, Southeast Environmental Research Center, Florida International University, Miami, FL.

3:10-3:30 **Refreshment Break**

3:30-3:45 **Influence of Freshwater Discharge and Ammonia Loading on Inshore Benthic Community Structure in Biscayne Bay.** ***John Meeder***, *Braxton Davis*, *Jeff Absten* and *Joseph N. Boyer*, Southeast Environmental Research Center, Florida International University, Miami, FL.

3:45-3:50 **Questions**

3:50-4:05 **The L-31E Surface Water Rediversion Project: Coastal Wetland Ecosystems and Some Initial Treatment Results.** ***M. S. Ross*,** *J. F. Meeder*, *P. L. Ruiz*, *D. Reed* and *M. Lewin*, Florida International University, Southeast Environmental Research Center, Miami, FL*; R. Alleman*, South Florida Water Management District, West Palm Beach, FL.

4:05-4:10 **Questions**

4:10-4:25 **Juvenile Jewfish Distribution and Abundance in Altered and Unaltered Habitats of the Ten Thousand Islands of Southwest Florida.** ***Anne-Marie Eklund*,** National Marine Fisheries Service, Miami, FL; *Christopher C. Koenig*, *Felicia C. Coleman* and *Todd Bevis*, Florida State University, Tallahassee, FL; *Matt Finn*, University of Maryland, College Park, MD.

4:25-4:30 **Questions**

4:30-4:45 **Multi-Taxon Analysis of the "White Zone," a Common Ecotonal Feature of South Florida Coastal Wetlands.** ***Evelyn Gaiser***, *Michael Ross*, *John Meeder* and *Matthew Lewin*, Southeast Environmental Research Center, Florida International University, Miami, FL.

4:45-4:50 **Questions**

4:50-5:05 **Seagrass Ecosystem Responses to Variable Hydrologic and Geographic Conditions: A Comparative Simulation Analysis of *Thalassia testudinum* in Florida Bay and the Caloosahatchee Estuary.** ***David F. Gruber***, Florida Center for Environmental Studies/South Florida Water Management District Key Largo, FL; *Christopher J. Madden*, South Florida Water Management District, West Palm Beach, FL; *W. Michael Kemp*, University of Maryland, Cambridge, MD.

5:05-5:10 **Questions**

5:10-5:25 **To be determined**

5:25-5:30 **Questions**

5:30 **Conference Concludes**

A Spatially-Intensive Assessment of the Multispecies Reef Fishery Resources in the Dry Tortugas Region.

Jerald S. Ault, *Steven G. Smith*, *Jiangang Luo*, *Geoffrey A. Meester*, and *Guillermo Diaz*; University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL; *James A. Bohnsack* and *Peter Fischel*, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL; *Steven Miller* and *Dione Swanson,* National Undersea Research Center, Key Largo, FL.

The Florida Keys tropical marine coral reef ecosystem is a national treasure that supports multibillion-dollar industries for fisheries and tourism. However, due to intense human population growth in south Florida, the Keys ecosystem is increasingly “at risk” from the effects of severe overfishing, pollution and habitat degradation that threaten the system’s ecological and economic integrity.

The extent of resource declines over the last several decades have been greatly mitigated by production from the Dry Tortugas, a relatively remote upstream region located at the southern end of the Florida Keys. The region possesses unique ocean circulation patterns that play an important role in the dynamics of region-wide biophysical processes and provide export of larval and adult biomass to depauperate areas. But the Tortugas’ capacity to sustain this critical support function has been rapidly eroded under traditional fishery management regimes, a trend likely to continue under current projections of population growth and persistent recreational and fleet expansions in size, range, and effective fishing power in competition for finite coral reef resources.

An innovative plan to establish a 185 mi^2 “no take” marine reserve in the Dry Tortugas has been recently proposed by the Florida Keys National Marine Sanctuary (FKNMS) and National Park Service (NPS). Success of this effort will depend greatly upon the availability of reliable data to assist both reserve design and to provide the quantitative baseline necessary to forecast changes and ultimately assess reserve efficacy. In this paper we use a systems approach to develop high precision estimates of reef fish abundance, size structure, and community composition from a collaborative spatially-intensive, fishery-independent sampling survey of reef fish and coral reef resources conducted during late May to early July, 1999, with sponsorship from the National Undersea Research Center, Center for Marine Conservation, NOAA/FKNMS, and NPS.

A reliable non-destructive stationary visual SCUBA diver census method was used in conjunction with digital laser video cameras, limited deployments of a remotely operating submersible vehicle with mounted camera arrays, and use of split-beam hydroacoustics. We used a two-stage stratified random design configuration to guide selection of about 450 survey stations, where we obtained an average of 2 replicate diver samples plus a number of physical and habitat variables. While we found substantial evidence of overfishing in the Tortugas region during our survey, we also encountered rich biodiversity, and “discovered” two new areas of luxuriant coral coverage: a large area of ‘Sherwood Forest’-type habitat that extends about 25 x 2 miles along the western Tortugas; and ‘Loggerhead Forest’ located between the National Park and Tortugas Bank.

We summarize by showing how explicit modeling of the linkages between fish community distribution, abundance and size structure in relation to key “habitat” characteristics can provide critical guidance for future cost-effective sampling and resource assessment efforts.

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Initial Responses of Exploited Organisms to No-Take Protection Zones in the Florida Keys National Marine Sanctuary.

James A. Bohnsack, *David B. McClellan*, *Douglas E. Harper*, *Peter Fischel*, *Anne Marie Eklund*, *Stephania K Bolden*, and *Joaquin Javech*, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; *Jerald S. Ault*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.

The Florida Keys National Marine Sanctuary (FKNMS) Management Plan became effective on July 1, 1997. It prohibited fishing and other extractive uses in one 30 km^2 Ecological Reserve and 18 Sanctuary Protected Areas (SPAs) along the Upper, Middle, and Lower Florida Keys. The Southeast Fisheries Science Center (SEFSC, NOAA Fisheries) in cooperation with the FKNMS is conducting extensive monitoring to document initial changes and compare biotic changes in the no-take zones with nearby reference areas open to extractive activities. In the first year, data were collected from 919 stationary visual samples and approximately 230 predatory surveys from 85 reef sites. These data were compared between sites and to an historical database obtained continually since 1979. Although much too soon to evaluate all the impacts of this added protection, dramatic effects were observed for many exploited species. Spiny lobster (*Panulirus argus*) abundance and frequency-of-occurrence greatly increased in protected areas. For the first time, large spiny lobster were observed on reefs moving in the open during the day and during the spiny lobster fishing season at SPAs and on fished reefs near the Western Sambos Ecological reserve in the Lower Keys. In 20 years of monitoring, the highest observed average densities were recorded in no-take zones for the following species of economic importance: gray snapper (*Lutjanus griseus*), hogfish (*Lachnolaimus maximus*), yellowtail snapper (*Ocyurus chrysurus*), and combined large grouper (*Serranidae*). In comparison, average densities were lower in exploited reference areas. Average densities of species not exploited were within historical performance bounds. Results demonstrate a strong initial positive response to protection from exploitation. The magnitude of the response suggests that human extractive activities have much more pronounced impacts on abundance of exploited species than ambient differences in water quality.

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Modeling the Southeast Florida Coastal Ecosystem - Hydrodynamic Transport, Salinity, and Trophodynamics.

John D. Wang, *Jerald S. Ault, Brian K. Haus, Jiangang Luo,* and *Javier Rivera,*
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The major water bodies of the Southeast Florida coastal ecosystem consist of Biscayne and Florida Bays and the continental shelf. These coastal shelf waters sustain a rich tropical marine ecosystem with the only living coral reefs in North America. Besides nurturing productive and economically important multispecies fisheries, it is the natural habitat of several endangered or threatened species such as rare sea turtles and crocodiles, and supports a megalopolis with a billion dollar tourism and recreational boating industry. Efforts are underway to resolve resource conflicts arising from these often opposing interests to arrive at a sustainable long term solution. For example, a comprehensive multi-purpose water resources project has been proposed for the region (USCOE, 1999), which will divert freshwater from the estuaries to the Everglades. Due to serial overfishing, another important issue is whether the creation of marine protected areas can help establish sustainable fisheries. A sound scientific knowledge base of the hydrodynamic transport which links inshore with offshore waters is needed to resolve these management issues and to understand the influence of circulation on the biological communities, corals, seagrasses, and fish, that are part of the regional ecosystem. Because of the controlling function imposed by salinity on marine life, it is also of particular importance to be able to predict the changes in salinity that may arise from planned water diversions.

With support from the US Army Corps of Engineers and NOAA's Coastal Ocean Program we have developed numerical hydrodynamic models of Biscayne Bay (BB) and of part of the Southeast Florida shelf (SEFS). The models are based on the vertically integrated equations of motion for hydrodynamics dynamically coupled with the advection-diffusion equation for salinity. This type of model was selected in consideration of the shallow waters (< 4 m for most of Biscayne Bay, and < 20 m for the shelf) and complex bottom topography making good horizontal resolution more important than resolving vertical structure. Future enhancement of the model to include vertical variations can be contemplated if needed when sufficient data become available to force and validate a fully 3-D model. As a consequence of the one-layer nearly horizontal flow approximation, near field dynamics of canal mouths and inlet outflow plumes cannot be modeled faithfully, although mass flows can be conserved.

Model forcing is derived from historic data and existing monitoring stations. Tides for the BB model were obtained from the Virginia Key NOAA/NOS tide gage and supplemented by short term tide observations along the open boundary of the bay. Hourly wind observations were obtained from the offshore CMAN station at Fowey Rocks. Runoff estimates were derived from SFWMD records of canal structure discharges for all the canals at the edge of the Bay. The high intermittency in canal discharges were smoothed by forcing the model with hourly averaged discharges. For the SEFS model additional data were obtained from the Molasses Reef CMAN station, and water depth recordings at Tennessee Reef.

Model bottom topography was interpolated from digital databases gridded at 0.25 minutes (ca 460 m) in Biscayne bay and at 0.002 degrees (ca 222 m) for the shelf. The model allows the shallowest portions of the bay to drain and reflood as the water surface moves down and up. Rainfall, evaporation, and groundwater seepage can also be included in the model. The SEFS model presently does not include Florida Bay but can be coupled to a model for that water body when available. The Waterways Experiment Station of the US Army Corps of Engineers is developing such a model.

A 4-year hindcast using the present version of the BB model, based on a triangular finite element grid with 6364 elements and 3407 nodes and providing the flows and salinity in the bay at resolutions that approach 500 m in some locations, has been made for the years 1995-1998. For the simulation, the computed wind stress over the bay waters was reduced by 50% to account for a combination of internal boundary layer effects (transition from land to water) and smaller roughness from depth and fetch limited waves.

Comparisons of an earlier model version with current meter observations have previously been made. Because of the present emphasis on transport we have carried out additional model validation using observed flows in the inlets and long term salinity monitoring data. Comparison of vertically averaged observed and computed salinities at 34 stations in the bay gave an overall coefficient of determination (r-squared) of 0.54 and fitting a line to a scatter plot of all observed vs. computed salinities yielded a regression slope of 0.97 very close to the ideal 1.0. Aside from adjustments made to the amount of freshwater entering Little Manatee Bay and Barnes Sound in order to include effects of exchange with Florida Bay, these results were obtained without specific calibration of the model to observed salinities.

Although the purpose of the SEFS model is to describe the circulation in the shelf, it extends 60 km seaward from the Keys and stretches from Palm Beach to Key West in order to reduce the influence of (uncertain) boundary conditions on the domain of interest. This model also includes Biscayne Bay at a lower grid resolution and therefore can provide improved boundary conditions of salinity and water level for the more detailed BB model.

Comparison of the SEFS model with moored current meters, shipboard ADCP measurements and two Ocean Surface Current Radar observation periods show the mid and inner shelf responding predictably to local wind and tides. At the edge of the shelf, the Florida Current (FC) is a prominent feature and is potentially important for the shelf circulation and exchange with the adjacent deep waters.

In a research application the physical model is coupled with a generalized age-structured predator-prey model of multistock production dynamics to analyze a key trophodynamic linkage between an important predator (spotted seatrout, Cynoscion nebulosus) and prey (pink shrimp, Penaeus duorarum) in Biscayne Bay. The model numerically tracks the spatial and temporal dynamics of cohorts of pink shrimp and spotted seatrout from spawning, through settling and recruitment and across the seascape as they grow. This integrated model framework provides opportunity to assess effects of changes in salinity and water quality regimes and to appraise key indicators of ecosystem productivity and functioning.

USCOE, 1999: Central and Southern Florida Project Comprehensive Review Study, Final Integrated Feasibility Report and Programmatic Impact Statement. US Army Corps of Engineers.

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Detection of Seagrass Cover and Water Clarity in Florida Bay and the Keys.

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REMOTE SENSING OF CHANGES IN WATER CLARITY AND SEAGRASS COVER IN FLORIDA BAY.

Previously we have reported on turbid water and benthic cover changes in Florida Bay from 1985 to 1997 using Advanced Very High Resolution Radiometer (AVHRR) imagery. The imagery confirmed the increase in turbidity starting in late 1987, as well as a decrease in the extent of bottom cover in the Bay. The bay continued to show decreased cover and increased turbidity through 1997.

In 1997, the imagery indicated reduced turbidity and increased bottom cover in the northwest Bay southwest of Flamingo. We found extensive *Halodule* along Dave Foy Bank in winter 1998. Field sampling from 1998 showed some recovery of seagrass in the NW region.

In late 1997, the SeaWiFS (Sea Wide Field-of-View) instrument was launched. SeaWiFS provides the same resolution as AVHRR (1 km pixel), with coverage about every two days. It offers a key improvement over AVHRR, as it was designed to monitor ocean chlorophyll as well as water clarity. With optical remote sensing, there is no fundamental distinction between seagrass chlorophyll and phytoplankton chlorophyll. Areas of dense seagrass in shallow water show relatively high chlorophyll, areas of sparse seagrass show low chlorophyll. SeaWiFS offers an additional data set for refinement of the methods applied to AVHRR for monitoring of seagrass. Using depth information and field data from 1998 and 1999, we are able to determine the sensitivity of the SeaWiFS method for monitoring seagrass in Florida Bay and the Keys, and monitor for seagrass in shallow water.

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The Relative Influence of Florida Bay on the Water Quality of the Florida Keys National Marine Sanctuary.

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The water quality of the Florida Keys National Marine Sanctuary (FKNMS) is characterized by complex patterns at both spatial and temporal scales due to local and regional circulation regimes and nutrient loading sources. The FKNMS is directly influenced by the Florida Current, the Gulf of Mexico Loop Current, currents of the Southwest Shelf, and by tidal exchange with Florida Bay and Biscayne Bay. Advection from these external sources has significant effects on the physical, chemical, and biological composition of waters within the FKNMS, as does internal nutrient loading and freshwater runoff from the Keys themselves. Therefore, the geographical boundary of the FKNMS must not be thought of as enclosing a distinct ecosystem but as being one of political/regulatory definition. Our ongoing quarterly sampling of 200 stations in the FKNMS and Shelf, as well as monthly sampling of 100 stations in Florida Bay, Biscayne Bay and the mangrove estuaries of the SW coast, has provided us with a unique database to explore the spatial component of water quality variability. By stratifying the sampling stations according to regional geography, distance from shore, proximity to tidal passes, and influence of Shelf waters we have come to some preliminary conclusions as to the relative importance of internal vs. external factors on the water quality within the FKNMS.

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Historical Changes in Mangrove, Seagrass and Calcareous Algal Communities in South Florida.

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Seagrass and mangrove communities have undergone dramatic changes during he past century. For most of south Florida, those changes can be documented between 1927 and the present by analysis of sequential aerial photographs. Other photographs, historical descriptions, and analysis of sediment cores supplement sequential aerial photograph observations.

Seagrass Communities. In central Florida Bay, there has been a progressive colonization of mud banks since the January 1935 aerial photographs. Sequential aerial photograph analysis and coring indicates that many of the remaining barren mud patches on the leeward flanks of banks are simply areas that have not yet colonized by seagrass during that period. Barren mud patches on other banks are the result of low relief mud waves that are deposited and migrating across the bank crest. The progressive increase in seagrass cover has led to an increase in the benthic infaunal and epifaunal communities and extensive bioturbation of the upper 30-50 centimeters of the banks. Bank areas that have remained barren are layered, low-permeability, carbonate mud containing 2-4 per cent organic carbon. The increase in seagrass cover is in spite of the two major and several moderate hurricanes that have crossed the Bay during the period. Decreased seasonal freshwater stress in central Florida Bay in the early 1900s is thought to have provided the setting for this phase of seagrass invasion and colonization.

Mud banks bordering the seaward margin of Central Biscayne Bay (Safety Valve) and seaward of southern Biscayne Bay (Caesar's Creek Bank) have been repeatedly severely stressed by hurricanes. Seagrass banks on the interior of the Safety Valve were extensively eroded by the minor hurricane of 1928 (Harlem, 1976) and by category 3 Hurricane Betsy in 1965. Both were slow moving storms that expended considerable time with strong wave and current agitation on the bank crest and interior. Recolonization across the bank interiors is mostly from surviving seagrass patches and occurs as coalescing convex-outward circles, which advance at 10-25 cm per year. Calcareous algae usually is the pioneer colonizer followed by *Syringodium* and then *Thalassia.* The different rates of lateral expansion of these species appear to control the succession. Repeated storm erosion of seagrass communities from the Safety Valve bank is related to the more exposed setting and the sandier mud substrate as compared to the mud banks in central Florida Bay.

The Hurricane of 1935 smothered much of Caesar's Creek Bank with sediment discharged from Biscayne Bay, resulting in a layer of carbonate mud and silt 15-25 cm in thickness (Warzeski, 1976). This widespread layer was only gradually recolonized. By 1960, the bank had regained a seagrass cover and by 1990 the layer had been largely bioturbated and occurred about 15 cm below the sediment surface.

In northern Biscayne Bay, the artificial opening of Baker's Haulover inlet in 1925 initiated more marine water conditions that has led to the widespread colonization of *Thalassia testudinum* (turtle grass) in the shallower bottoms. Extensive deepening of the bay bottom by dredging prior to that time, however, left much of northern Biscayne Bay too deep to for seagrass colonization and bottom stabilization. Resuspension from these unstabilized flocculent bottoms by tides and waves has resulted in excessive turbidity in northern Biscayne Bay, a result that has further reduced light and restricted seagrass cover. Miami-Dade County has made serious efforts to refill many of these deep dredged areas. This has resulted in improved water clarity and expanded seagrass cover.

Calcareous Algal Communities. The green calcareous algae *Halimeda opuntia* grows profusely on the mud banks of northern, central and southern Biscayne Bay. Within and on the protected flanks of banks, it can form monospecies mounds as much a 1 m in height as 20 m across on bank interiors and 2 m in thickness on protected flanks. Beneath the living surface is an accumulation of skeletal algal plates. This community aggressively overgrows *Thalassia* beds.

Hurricane waves and currents tend to completely erode both the living *Halimeda* mound and the underlying skeletal plates from the banks, widely dispersing the easily transported calcareous plates. Following Hurricane Andrew in 1992, the Safety Valve mud bank was dotted by large barren depressions in the seagrass where *Halimeda* mounds had previously been. The brief, strong currents of this fast moving storm left the adjacent seagrass community largely undamaged.

Mangrove Communities. The mangrove communities of south Florida have undergone dramatic changes in past 75 years. Four types of mangrove community change are noted. These changes are in response to (1) the increase in rate of relative sea level rise, (2) human modification of inland wetland water levels and coastal wetland salinity, (3) major storm and freeze events, and/or (4) changing substrate conditions.

The dramatic increase in the rate relative sea level rise that began about 1930 has resulted in about 25 cm of sea level rise to date. This has destabilized the coastal mangrove communities and resulted in significant landward migration of the red, black and white mangrove ecotones and made recovery difficult following times of hurricane damage. Along the eastern margin of Cape Sable, an area unaffected by human modification, the landward margin of the red mangrove community has advanced 100-300 meters landward since the 1927 aerial photographs.

Elsewhere around south Florida, there is clear evidence for significant landward invasion of red, black and white mangrove communities, but in most areas the cause is complicated by historically lowered fresh water levels, reduced freshwater flow and deeply penetrating artificial canals. These have worked in conjunction with the dramatic rise in sea level to cause minor to dramatic landward expansion in the mangrove community. Included is widespread replacement of freshwater marsh and salt marsh communities with mangrove.

Lateral extent and community composition is commonly dependent on extent of hurricane surges and seed types dispersed during hurricanes.

Hurricanes, especially those of category 4 and 5 strength (Labor Day Hurricane of 1935, Hurricane Donna in 1960 and Hurricane Andrew in 1992), have caused widespread destruction of the south Florida's mangrove forests in the area of the storm's eye wall. In areas with a dominantly mangrove peat substrate, post-storm decay products commonly kill off surviving mangroves and severely inhibit the recovery of the mangrove community in the area. In addition, rapid subsidence of the decaying peat substrate beneath the destroyed mangrove forest lowers the substrate through the intertidal zone (2-4 cm/year). Unless the damaged site is very well flushed by tidal waters, the mangrove community will not effectively recover. Interior mangrove forests behind Highland Beach, Big Sable Creek, Gopher Creek, and Oyster Bay are in increasing stages of marine transgression from this storm initiated loss. In contrast, mangrove communities, such as the islands adjacent to lower Shark River Slough and along the mainland shore of western Biscayne Bay, are well flushed and tend to recover quickly.

The dramatic colonization of mangroves on the intertidal mud banks in central Florida Bay since the mid 1960s occurred during a period free from hurricanes, thought during a rapidly rising sea level. Conditioning and shallowing of the substrate by seagrass colonization may have played an important role.

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The Origin of Variations in the Stable Oxygen, Hydrogen, and Carbon Isotopes of Waters in the Coastal Waters of South Florida.

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An understanding of the behavior of the stable oxygen ($^{18}O/^{16}O$), hydrogen (D/H), and carbon ($^{13}C/^{12}C$) isotopic composition of waters in South Florida is an essential prerequisite for (1) the utilization of these isotopes as proxy indicators for ascertaining the history of water usage in South Florida, (2) understanding factors which govern the control of salinity in coastal environments, (3) constraining the origin of waters entering the coastal regime. Based on a six-year time series of the analyses of H, C, and O isotopes from Florida Bay as well as shorter time series from Whitewater Bay, the Thousand Islands area, Biscayne Bay, and the Everglades, it is clear that 'normal' isotopic behavior which occurs in conventional estuaries is not applicable. In South Florida isotopic compositions are controlled by a series of complex interrelationships between run off, evaporation, degradation of organic material, and mixing with marine waters. During periods of greater than normal precipitation, water entering the coastal environment is isotopically depleted in the heavier isotopes of oxygen and hydrogen. This produces what is considered to be a normal condition in estuaries, a positive covariance between salinity and the oxygen and hydrogen isotopic composition of the water. During periods of normal precipitation freshwater entering the coastal areas as runoff produces an inverse correlation between salinity and oxygen/hydrogen. This arises because the freshwater water in the Everglades is always subject to high amounts of evaporation causing the water to become isotopically enriched in the heavier isotopes of hydrogen and oxygen. Hence areas affected by runoff, exhibit negative correlations between salinity and oxygen isotopic composition. Areas that are not influenced by runoff show positive covariance between oxygen and salinity, driven by evaporation and precipitation. During periods of low rainfall, changes in salinity usually arise through evaporation and precipitation and produce positive correlations between salinity and oxygen/hydrogen. An absence of correlation between salinity and oxygen/hydrogen arises as a result of mixing of waters, which have experienced different amounts of evaporation, or mixing with freshwater which has experienced moderate amounts of evaporation.

Carbon isotopic variations arise through the degradation of organic material, photosynthesis, and mixing with marine fluids. Freshwaters emanating from the Everglades are usually highly depleted in ^{13}C, the degree of which is inversely proportional to the amount of rainfall. Within the coastal waters themselves significant amounts of ^{12}C can be added to the waters through the remineralization of organic carbon, however this process results in no correlation between the carbon isotopic composition and salinity. These processes are recorded in the carbon and oxygen isotopic composition of calcareous organisms living in these environments and are documented in a six year time series of isotopic compositions of waters collected from Florida Bay, Whitewater Bay, Thousand Islands, and Biscayne Bay conjunction with SERP.

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An Environmental Information Synthesizer for Expert Systems.

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As an enhancement to the SEAKEYS environmental monitoring network, software called the Environmental Information Synthesizer for Expert Systems (EISES) has been constructed which synthesizes knowledge from near real-time acquired meteorological and oceanographic data. This knowledge is acquired in the form of “facts” which can be used by expert systems designed to monitor and match environmental parameters as they meet criteria generally thought to be conducive to certain biological events. The initial expert system constructed to use the facts from EISES, which we have dubbed the Coral Reef Early Warning System (CREWS), represents a first step in the construction of a larger coral reef specific expert system. When environmental conditions are conducive to coral bleaching, according to different bleaching theories or models, CREWS produces “alerts” which are automatically posted to the Web and emailed to researchers so they can verify and study bleaching events as they might happen. The models are refined using feedback from field data on bleaching recorded after alerts from the expert system. CREWS has now been implemented not only for the Florida Keys National Marine Sanctuary, but also for the Great Barrier Reef Marine Park Authority, and will hopefully be developed in the future for other coral reef sanctuaries or parks throughout the world.

In addition to CREWS, expert systems for Florida Bay are being developed with collaborators to model juvenile pink shrimp and fish spawning migrations (with UM/RSMAS and NOAA/NMFS), and conditions conducive to harmful algal blooms (with NOAA/NESDIS). Some other example events that might be monitored or predicted from EISES expert systems include good diving and/or fishing conditions (e.g., clear water, low winds) at remote locations, phytoplankton blooms, hypo- or hypersaline influxes from Florida Bay, and excessive dissolved nutrient encroachment (inferred from high fluorometry values).

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Environmental History of Biscayne Bay.

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Biscayne Bay is surrounded on the north by the growing urban areas of Dade County which include Miami and Miami Beach, and on the south by the sparsely inhabited Homestead area and the northern Florida Keys. Its environmental history is closely related to the development of the Greater Miami area. Urban development of the northern part of the Bay during the 1920s began the decline that remained largely unchecked until the early 1970s. Recently has its environmental degradation of the Bay has reversed. This work describes the major events impacting the Bay's ecosystem and how it has changed over time.

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A Closer Look at the Tides of Biscayne Bay, Card Sound and Barnes Sound.

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A 1997-98 Army Corps of Engineers Waterways Experiment Station (WES) field study of Biscayne Bay and adjacent waters provided water level data from 12 locations between North Miami Beach and Barnes Sound. Combining the WES data with results of National Ocean Service studies in the early 1970s and Harbor Branch studies in the middle 1990s, harmonic constants of the principal tidal constituents are available from 43 locations.

The seasonal rise and fall of the bay water level, defined by the Sa and Ssa tidal constituents, includes a primary minimum 11 cm below the annual mean in mid February and a primary maximum 16 cm above the annual mean in mid October. Secondary maximum and minimum water levels, -3.6 and -4.5 cm below the annual mean, respectively, occur in mid May and Mid June.

Co-amplitude and co-phase charts for the principal tidal constituents describe the movement and decay of tidal waves, entering through the Safety Valve and spreading northward and southward into Biscayne Bay and adjacent waters. The M_2 constituent amplitude in shelf waters is 33 cm. The M_2 tidal wave reaches the middle of Biscayne Bay three and a half-hours later, and the amplitude has decreased to 22 cm. The southward moving M_2 tidal wave reaches northern Barnes Sound with an amplitude of 8 cm after another hour and a half, and it is moving through Jewfish Creek with an amplitude of 3.5 cm 40 minutes later.

Combining tidal ranges at each location with the bay surface areas they represent, one can calculate the mean tidal inflow and outflow associated with the principal tidal constituents and the extremes at times of spring and neap tide.
Results can be used for model validation, as well as for flushing estimates in water quality studies.

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Design-Based Sampling to Assess Fish and Macroinvertebrate Populations in Biscayne Bay and the Adjacent Coral Reef System.

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A key step towards understanding human impacts on marine fishes and macroinvertebrates and their habitats is obtaining high-precision empirical information on animal abundance and size-age structure in time and space. We developed a sampling design-based approach using fishery-independent surveys to assess populations of ecologically and economically important species in Biscayne Bay and the adjacent coral reef system. We present results for pink shrimp and several reef fish species in the snapper-grunt complex. Sampling within Biscayne Bay was conducted with roller-frame trawls, which primarily target shrimp, but also effectively capture many fishes including young-of-the-year juvenile snappers and grunts. The coral reef environment was sampled by SCUBA divers using the stationary visual census method according to a two-stage design, where the primary sampling unit is a reef site and the secondary unit is a visual sample location within a reef site. Pilot studies were carried out in both the bay and reef systems over a several-year period to collect baseline data on animal density (numbers per m^2), size structure, and biophysical habitat features (e.g., bottom substrate, temperature, salinity, depth, etc.). We then analyzed animal-habitat associations using a broad array of statistical tools. Pink shrimp as well as several snappers and grunts exhibited striking habitat preferences; moreover, we observed multiple ontogenetic shifts in these preferences encompassing the entire bay-reef seascape for each species. To improve the accuracy of future surveys, these results were used to conduct post-stratification analyses that evaluated the utility of stratifying the bay and reef sampling domains by relevant habitat covariates. Stratified random surveys were subsequently implemented in the bay and reef environments, achieving significant reductions in variance of population abundance estimates for pink shrimp and reef fishes. We summarize our findings by demonstrating how statistical sampling designs employing habitat-based stratification schemes can yield high-precision abundance estimates at relatively low cost, and also provide a robust quantitative methodology for identifying habitats essential to ecosystem function and fisheries production.

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Groundwater Discharge and Nutrient Loading to Biscayne Bay.

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Excess nutrients entering Biscayne Bay are producing ecosystem wide problems associated with eutrophication and no data exists on the relative importance of groundwater versus canal discharges and nutrient loads. The primary purpose of this research is to quantify groundwater discharge and nutrient loads into the near-shore waters of Biscayne Bay.

This study is significant for several reasons. First, water quality has declined in response to land use changes (Parker et al., 1955, U.S.G.S. 1255, 965 p.). Second, agriculture lands surround the study area, which may increase nutrient concentration in the ground and surface waters (Johannes, 1980, Mar. Ecol. Prog. Ser. **3** 365-373). Third, the South Florida Water Management District (Alleman et al., 1995, Biscayne Bay SWIM, SFWMD) is attempting to increase groundwater flow into Biscayne Bay.

Groundwater flows into estuaries are believed to make up a small part of the total water budget, however, the nutrient concentrations are often significantly higher than local rivers and streams (Johannes, 1980). The only previous work in Biscayne Bay suggests groundwater discharges influence benthic community zonation (Kohout and Koplipinski, 1967, Estuaries **5** 488-499).

Two transects of wells were drilled between the outlets Military and Mowry Canals. Nutrient concentrations were determined by sampling groundwater in wells drilled in the near-shore estuary. The wells and surface water were sampled during the dry and wet season. Comparisons were made upon distance from shore, depth of well and seasonality.

Groundwater discharge was determined by seepage meter measurement (Lee, 1977, Limnol Ocean. **22** no 1, 140-147) and traditional computations using Darcy's equation. Seepage meters were installed in the near-shore environment along three transects. The meters were measured during the wet and dry seasons and throughout a full tidal cycle. The traditional Darcy's computation was done using field measured hydraulic gradients.

Seepage meters discharge rates averaged 10 m^3 per liner m of shoreline per day. Total discharge for the study area with 2100 m of shoreline is 21,000 $m^3\ d^{-1}$. Darcy's equation yielded a maximum and minimum discharge depending on hydraulic conductivity. Maximum discharge value is 18,286 $m^3\ m^{-1}\ d^{-1}$ and 38,400,000 $m^3\ d^{-1}$ for the entire study area. Minimum discharge is 7,300 $m^3\ m^{-1}\ d^{-1}$ and 15,400,000 $m^3\ d^{-1}$ for the entire study area.

Total phosphorus concentration in the groundwater is 0.031 ppm. Total nitrogen concentration is 1.11 ppm and total organic carbon concentration is 10.80. This is not significantly different than the nutrient concentrations of Mowry Canal. In Mowry Canal the nutrient concentrations are as follows, total phosphorus 0.032 ppm, total nitrogen 0.920 ppm and total organic carbon is 12.50 ppm (Scheidt et al 1993, Report SFRC-83/06, ENP).

Groundwater nutrient loading ranges from 0.7 to 1,190 g d^{-1} for total phosphorus. Total nitrogen ranges from 23 g d^{-1} to 43,000 g d^{-1} and total organic carbon 227 g d^{-1} to 3,840,000 g d^{-1}. Due to different estimates of discharge, estimates of loads vary greatly.

Completion of this study will yield a more reliable discharge estimate along with better estimates of nutrient loading. Upon completion, managers should be able to determine the overall importance of groundwater discharge to the estuary. Water managers can than use these data to plan the most effective policies concerning Biscayne Bay revitalization. Water managers currently plan to increase groundwater discharge without knowing the current discharge and nutrient concentrations. This research will yield the baseline information needed to make the best possible decision.

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Tidal Creek Flux Studies, Biscayne National Park.

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Coastal wetlands are generally considered to be sources of organic materials which are responsible, in part, for increased estuarine productivity; this process is frequently referred to as "outwelling". Outwelling of organic carbon and nutrients occurs when the amount of nutrients exported from the coastal wetland exceeds the amount stored (both short term in tissue and long term in soils) and imported from marine sources. In most coastal ecosystems the terrestrial or freshwater source may be more significant than autochthonous coastal wetland or marine sources. In these cases, coastal basin topography and physical processes (such as tidal range, volume and timing of discharge, etc.) greatly influences the amount of freshwater derived nutrients exported to the estuary.

Export from coastal mangroves in the South Florida region has been addressed in several studies and an average of 1.0 g C/m^2/day is estimated (Odum et al. 1982). Most previous studies used a modeling approach based upon litter production and decomposition rates. Two tidal creek basins along the western shore of Biscayne Bay between Military and Mowry Canals in the Biscayne National Park were studied. Two gauging stations in each tidal creek system; one 50 m from the mouth and one approximately 250 m inland at the boundary between the scrub and mixed mangrove communities were established. Stage-discharge relationships for all four sites under conditions of both tidal ingress and egress were developed. Discharge was determined by measuring creek cross sectional area and water current velocity profiles at successive tide stages. Water samples for nutrient analysis (including dissolved organic carbon) were collected every two hours and nets collected all particulate organic carbon larger than 3 mm in diameter for one hour every other hour throughout two consecutive tidal cycles in Dec 1996 and December 1997 at all stations simultaneously. Both sample periods were during spring tide cycles. In contrast to most other studies, we documented a net influx of organic carbon of 0.5 g/m^2/day assuming an even distribution throughout our study sites.

For each tidal cycle, a net movement of water inland was measured. This water can be accounted for by loss from evaporation, transpiration and resaturation of soils. The major difference between flux measurements in December and April is a function of tidal height. December tidal height was considerably higher than in April. Tidal incoming waters were always higher in TP, N+N, and NH_4 in December than in April and TOC higher in April. This relationship is the result of the Mowry Canal water discharged into coastal area is a magnitude higher in December than in April. Considerably more water was exchanged at the fringing sites (50 m) than at the interior sites (250 m). The control site (the northernmost site) is slightly higher in elevation and does not have a very large topographic basin with scrub vegetation and exhibited less tidal exchange than did the treatment site. Interestingly, NH_4 (an anaerobic decay product) usually associated with mangrove waters and outwelling was actually found to be imported into the both tidal creek basins.

This study documents that a net influx of organic carbon and nutrients into the coastal wetlands occurs during spring tides. These findings have important implications to land managers. These findings may be explained by two major circumstances both anthropogenic in origin: 1) nearshore Biscayne Bay waters are nutrient enriched because of freshwater delivered by the Mowry Canal and groundwater, and 2) freshwater sheetflow has been entirely removed from both of these watersheds by the construction of the L-31E levee. Presently, BNP managers are faced with nutrient loading along the shoreline by groundwater and canal delivery, which result in the stress of nearshore benthic communities. In contrast, the coastal ecosystem, which should be the natural source of most estuarine nutrients in the Biscayne Bay ecosystem, is functioning as an inefficient nutrient trap because of the loss of freshwater delivery via tidal creeks. The differences documented between these two closely spaced tidal creek basins emphasizes the necessity of studying each coastal basin in some detail prior to making management decisions affecting water quantity and quality in the nearshore area.

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Influence of Freshwater Discharge and Ammonia Loading on Inshore Benthic Community Structure in Biscayne Bay.

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Biscayne National Park is located adjacent to a very large population and agricultural center. Over the past 100 years of land development, Biscayne Bay's circulation patterns have been highly altered, freshwater sheet flow discharge eliminated, and freshwater discharge by canals has increased. In addition, the timing of freshwater discharge is highly altered and inshore water quality has declined. Much of the estuarine zone of Biscayne Bay has been eliminated by the loss of a "natural" volume and timing of freshwater sheetflow along the western shore of Biscayne Bay. Also, the nearshore aquatic environment is highly impacted by nutrient loading, which has increased productivity and filamentous algae.

The quality of both canal and groundwater inputs has declined as urbanization and agriculture have dominated the landscape. Numerous landfill and other contaminated sites influence groundwater that enters Biscayne Bay. Initial nutrient loading figures from the Mowry Canal and groundwater to Biscayne Bay are very high compared to our typically low regional levels (oligotrophic conditions). Groundwater nutrient levels obtained 50m from shore along Biscayne Bay from the Dinner Key to Mowry Canal have ammonia concentrations 30 or more times greater than those of overlying surface waters. In addition, the highest groundwater concentrations were found at Black Point and decreased by nearly half both northwards and southwards. The location of the highest concentrations off Black Point was no surprise because the site is located close to the old and present Dade County landfills. Our groundwater nutrient loading values suggest that Biscayne Bay may be undergoing considerably more nutrient loading than previously though. This poses not only an environmental degradation problem, but also potentially one of ammonia toxicity.

Coastal mangroves are highly productive systems that are known to export ammonia because of anaerobic decomposition processes. Ammonia production in the coastal mangrove system is limited to a fraction of the biomass turnover on an annual basis and is therefore fixed within rather narrow bounds at any site. In addition, most mangrove swamps along the western shore of Biscayne Bay overlie a carbonate marl soil about l m thick, which overlies the bedrock (and groundwater). The mud layer is impermeable and serves to separate the surficial interstitial soil and tidal water from the freshwater groundwater of terrestrial origin. This is an important point because mangrove-derived ammonia is separate from anthropogenic-derived ammonia in groundwater until they are discharged into the Bay. An exception to this may be the thin fringing mangrove zone along the water's edge, which frequently is not underlain by the marl soil horizon. This is the zone of highest productivity, greatest physical export of detritus, greatest below ground biomass production (actually accretion), and soils with the best gas exchange.

Only limited data on Biscayne Bay ammonia concentrations is available for inshore areas.

The need to understand the distribution of ammonia in Biscayne National Park was necessary to establish pollution load reduction goals based upon actual spatial and temporal distributions and their impacts to Bay ecology. To this end we conducted a survey of total ammonia concentrations (soil, sediment, surface water, and groundwater) in the coastal mangroves and adjacent Bay waters along the western shore of Biscayne National Park. Benthic community characteristics (species composition, structure, cover, biomass) and physical parameters were measured at each sampling site. Data from this survey are presented to: 1) determine ammonia distribution in the Park, 2) correlate benthic community characteristics with freshwater sources and ammonia concentration, and 3) locate “hot spots” where ammonia levels are above background levels and may pose an environmental degradation or toxicity problem.

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The L-31E Surface Water Rediversion Project: Coastal Wetland Ecosystems and Some Initial Treatment Results.

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A pilot project to reestablish sheetflow through coastal mangrove systems from the L-31E canal was initiated in 1993. The objectives were to reduce point source canal discharges into southern Biscayne Bay, and to restore to the degree feasible the coastal ecosystems that prevailed prior to canal construction. The initial years of the project were spent in designing and implementing the water delivery system, obtaining baseline physiographic, hydrologic, and biologic information about the wetlands to be treated, and initiating a monitoring design to track ecological changes associated with the diversion treatment. Water delivery to the wetlands began in August 1997, and has continued through the present. However, because of the design of the delivery system, low stages in the canals do not permit significant delivery between mid-October and mid-May. Following the first full year of treatment, ecosystem effects resulting from diversion were difficult to discern, especially in comparison to the wide spatial variation in background wetland attributes. As fresh water delivery becomes more prolonged, we expect to see significant changes in ecosystem function, including a gradual invasion of graminoids into the scrub mangrove community, development of a seasonally persistent periphyton mat, and substantial changes in pore water chemistry.

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Juvenile Jewfish Distribution and Abundance in Altered and Unaltered Habitats of the Ten Thousand Islands of Southwest Florida.

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The largest of the western North Atlantic groupers is the jewfish, *Epinephelus itajara*. This species was heavily overexploited until 1990, when a total ban was implemented on all harvest in US waters, and the species was designated as a candidate for the US Endangered and Threatened Species List. Although little is known about the life history of juvenile jewfish, historical anecdotal evidence suggests that the juveniles are most abundant along the mangrove shorelines of the southwest Florida coast. The objectives of this study were to estimate the abundance of juvenile jewfish in the Ten Thousand Islands region of southwest Florida, to determine their utilization of particular habitats, and to test for the effect that habitat alterations have had on juvenile jewfish distributions. Using commercial blue crab traps and modifications of these traps, we caught and tagged several hundred juveniles along 6 unaltered tidal passes and 3 canal systems. Each jewfish caught was weighed, measured, and tagged with an internal anchor tag. Jolly-Seber mark/recapture analysis was conducted on each of the 9 areas. Preliminary data has demonstrated that there are fewer jewfish in the altered canal habitats, than there are in the natural tidal passes. The jewfish are associated with depressions in the middle of the channels or along the shoreline where the mangrove islands are deeply undercut. The canal systems are much more uniform, lacking the depressions and the shoreline undercuts characteristic of the natural passes. In addition, the canal systems may be receiving greater freshwater pulses than the unaltered rivers receive. Tidal currents may also be good predictors of jewfish abundance, since the rivers that receive less tidal flow contain fewer jewfish. Although overfishing of adults on offshore reefs and wrecks was the primary cause of population decline of jewfish, it is important to understand what habitat is most valuable to all life history stages. During the next phase of our study, we will compare catch-per-unit effort of jewfish in more altered habitats near Marco Island, in natural passes and rivers in Everglades National Park's mangrove shoreline and also along the east coast of Florida, in Biscayne Bay.

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Multi-Taxon Analysis of the "White Zone," a Common Ecotonal Feature of South Florida Coastal Wetlands.

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A common feature of many South Florida coastal areas is a zone of low plant cover, clearly recognizable as a white band on black and white or color infrared photos, sandwiched between more densely vegetated fringing mangrove and interior ecosystems. This "white zone" could be an excellent indicator of the balance between sea level and freshwater discharge, a common concern in South Florida. Over the past 50 years, the interior boundary of the white zone has encroached inland by an average of 1.5 km; maximum shifts occurred in areas cut off by canals from upstream fresh water input. To determine the physical and biological nature of the "white zone" we examined the distribution of plants, diatoms and mollusks in relation to several environmental parameter along a single coastal transect adjacent to Biscayne Bay and south of Turkey Point Power Plant. We found the white zone to be a region of low productivity characterized by low vegetation cover and canopy height (< 50% and < 1 m, respectively). Plant, diatom and mollusk species assemblages correlate strongly with the coastal gradient, and may be separated into coastal, transitional and interior units. Diatom distribution is also correlated strongly with salinity, while plants and mollusks integrate a variety of environmental variables correlated to distance. The position of the white zone and coverage of the coastal, transitional and interior compositional units of plants, diatoms and mollusks may provide an indirect assessment of wetland status. These relationships could be used in goal setting through paleoecological applications and in long-term monitoring of hydrologic restoration.

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Seagrass Ecosystem Responses to Variable Hydrologic and Geographic Conditions: A Comparative Simulation Analysis of *Thalassia testudinum* in Florida Bay and the Caloosahatchee Estuary.

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An exploratory model is being developed to simulate and analyze responses to variations in hydrologic conditions for shallow ecosystems containing the seagrass, *Thalassia testudinum*. The structure of this model distinguishes six major forcing functions, twelve state variables and three auxiliary processes and constraints.

External properties (nutrients, organic matter, heat, salt) are delivered to the study site via freshwater flow and tidal exchange, which, combined with two climatic variables (sunlight-PAR, air temperature), drive the simulated ecosystem dynamics.

The estuarine ecosystem state is defined by four water column variables (dissolved inorganic nitrogen, DIN; dissolved inorganic phosphorus, DIP; phytoplankton; dissolved and particulate organic matter, DOM, POM), four sediment variables (porewater DIN; porewater DIP; porewater sulfide; detrital organic matter), two seagrass variables (leaves; roots/rhizomes), and two attached algal variables (epiphytes; benthic algae).

Four autotrophic units (seagrass, phytoplankton, epiphytes, and benthic algae) compete for nutrients and light, with light attenuation (shading) providing indirect interactions.

The model equations use standard formulations for nutrient, light and temperature kinetics, and for bioenergetic balances in biotic variables. Fundamental diagenetic relations describe sediment respiration, nutrient cycling and sulfur dynamics.

Where appropriate, the model code uses functions described in previously published simulation studies. Plant biomass is partitioned between photosynthetic (above-sediments) and non-photosynthetic tissues (below-sediment) pools. Organic matter and inorganic nutrients are exchanged between these two plant pools at daily and seasonal time-scales via translocation functions, which are controlled by environmental conditions and plant growth cycle.

The model also examines alternative schemes by which plant propagation/ reproduction, bottom cover and geographic position can be simulated without explicit use of conventional demographic, and fine-scale spatial approaches.

This model is being calibrated for four contrasting sites: two in the Caloosahatchee Estuary (San Carlos Bay, Pine Island Sound) and two in Florida Bay (Little Madeira Bay, Rankin Key). For both systems the two sites were selected to represent contrasting levels of influence from adjacent watershed. Data are being compiled to describe annual cycles for forcing functions in a relative high-flow year and a relatively low-flow year. We are attempting to calibrate the same basic model for each site and year (2 systems, 2 sites in each, 2 years), and conduct simulation experiments to infer differences in model ecosystem dynamics associated with differences in environmental conditions.

Simulation studies are being used to analyze data and consider alternative hydrologic scenarios, contrasting differences in responses among seasons and estuaries. These simulations can also be used to test hypotheses concerning the influence of fresh water inputs on seagrass productivity and survival.

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Poster Abstracts

ADJACENT MARINE SYSTEMS

Update of Results of the Mussel Watch Project in South Florida and the Caribbean.

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This presentation is a summary of the Mussel Watch Project findings regarding concentrations of contaminants in South Florida and Puerto Rico. At some sites, there are currently the NS&T results were compared with those obtained in the Caribbean by the International Mussel Watch Program. The Mussel Watch Project determines the concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) congeners, several pesticides, butyltins, and selected trace elements in sediment and mollusk samples from US coastal waters. Mollusks and sediments are collected at each Mussel Watch Project site. Several species of mollusks are collected: eastern oysters (*Crassostrea virginica*) from the South Atlantic and the Gulf of Mexico; smooth-edge jewelbox (*Chama sinuosa*) from the Florida Keys; and Caribbean oyster (*C. rhizophorae*) from Puerto Rico. The results at the South Florida and Caribbean sites are shown and compared to the nationwide levels of several contaminants.

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The Fate of Wastewater-borne Nutrients in the Groundwaters of the Florida Keys.

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We designed experiments to evaluate the fate of the addition of wastewater-borne nutrients injected into the shallow subsurface in the Florida Keys. During three different experiments, either bulk unlabeled phosphate, 32PO43-, or bulk unlabeled nitrate was added simultaneously with a conservative tracer (sulfur hexafluoride) into a low volume wastewater injection well on Long Key. Relative concentration changes monitored over time indicated that both phosphate and nitrate acted non-conservatively in the subsurface. Phosphate showed an initial rapid uptake followed by a slower removal, possibly caused by adsorption-desorption reactions.

Based on our observations, we estimate that approximately 95% of the phosphate injected into the subsurface could be removed in 20 to 50 hours. There was also evidence for removal of nitrate due to denitrification. Approximately 65% of the nitrate was removed over several days, suggesting a denitrification rate of 2700 µmoles m-3 groundwater hr-1, comparable to estimates of denitrification in other groundwater systems.

Collectively, our results from Long Key suggest that nutrients injected in the subsurface can be removed rapidly from solution and thus may not have a significant impact on surface waters at this location. However, these experiments were conducted at a relatively small facility (2.6 m3 wastewater injected per day). More recent experiments are focusing on a much larger facility in Key Colony Beach that injects as much as 750 m3 per day. Ongoing work at this site suggest that phosphate adsorption and denitrification are rapidly removing a large portion of these nutrients from the dissolved inorganic nutrient pool. Saturation of available phosphate adsorption sites may limit the efficiency of wastewater-borne phosphate removal under such high nutrient loading conditions. Denitrification assays from this site suggest that potential denitrification rates at this location may be much higher than the rates calculated for the Long Key site.

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Seagrass Status and Trends Monitoring Program in the Florida Keys National Marine Sanctuary.

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The general objective of seagrass monitoring in the Florida Keys National Marine Sanctuary (FKNMS) is to measure the status and trends of seagrass communities to evaluate progress toward protecting and restoring the living marine resources of the Sanctuary. The scope and depth of this monitoring effort are without precedent or peer for seagrass ecosystems throughout the world. Specific objectives are: 1) To provide data needed to make unbiased, statistically rigorous statements about the status and temporal trends of seagrass communities in the Sanctuary as a whole and within defined strata; 2) To help define reference conditions in order to develop resource-based water quality standards; and 3) To provide a framework for testing hypothesized pollutant fate/effect relationships through process-oriented research and monitoring. To reach these objectives, four kinds of data are being collected in seagrass beds in the FKNMS: 1)Distribution and abundance of seagrasses using rapid assessment Braun-Blanquet surveys; 2) Demographics of the seagrass communities using leaf-scar counting and population demographics techniques; 3) Seagrass productivity of the dominant species of seagrass in the FKNMS (*Thalassia testudinum*) using the leaf-mark and harvest method; and 4) Seagrass nutrient availability using tissue concentration assays.

When the results from these EPA-funded surveys are combined with comparable data from Florida Bay funded by the South Florida Water Management District and Everglades National Park, it is possible to make regional maps of seagrass distribution for the entire south Florida Region. Combining all projects, we sampled 1207 randomly-selected stations in the area from Cape Romano to the Dry Tortugas to North Key Largo; 87.5% of all sites supported seagrasses. When projected to an areal basis, 75.4% of the survey area, or 14,662 km^2, supported seagrasses.

Density & Standing Crop Estimates: Short shoot density, standing crop, and leaf mass of *Thalassia testudinum* were estimated from seagrasses harvested from the 6 quadrats used in our productivity studies. Short shoot densities ranged between 66 - 1025 SS m^{-2}. Standing crop ranged between 5 - 93 g m^{-2}. Leaf mass exhibited a high degree of variation, with values ranging between 21-415 mg SS^{-1}.

Productivity: Productivity of *Thalassia testudinum* was calculated on a short shoot (SS), mass-specific (MS), and areal basis. Short shoot productivity ranged between 0. 18 - 8.31 mg SS^{-1} d^{-1}, with higher values recorded for seagrasses in Florida Bay (FKNMS segments 4 and 6) relative to seagrasses on the ocean-side (FKNMS segments 5, 7, and 9). Mass-specific productivity ranged between 3.21 - 49.47 mg g^{-1} d^{-1}, with the highest value recorded at site 271 in 97-3. Areal productivity ranged between 0.07 - 3.37 g m^{-2}. Strong seasonal patterns were observed for all three measures of productivity, especially for shallower sites in Florida Bay; where high, negative residuals were calculated for winter and spring, and high positive residuals were calculated for summer and fall.

Leaf C:N:P Ratios: The elemental content of the leaves of *Thalassia testudinum* from the FKNMS varied greatly in the FKNMS. In fact, 95% of the total range in published seagrass nitrogen and phosphorus contents from all seagrasses from around the world was found within samples of *T. testudinum* from the Sanctuary. The C:N ratio ranged from 15.6 to 38.6, with a grand mean of 23.1. These values indicate that, on average, there is sufficient N available to support the growth of T *testudinum* in the Sanctuary. C:N was generally higher in summer-fall than in winter-spring, which reflects the role of seagrass growth rate in determining N demand, and therefore N availability in the environment. C:P ratios varied form 41 to 1823. The grand mean of all samples processed to date was 860, which indicated the important role that P availability had in determining seagrass distribution in the FKNMS.

Relationships between seagrasses and water quality: Water quality, water depth, and the composition of the substratum are the primary factors determining the composition of the benthic communities in shallow water marine systems. In the south Florida hydroscape, the shallow water benthos is a mosaic of seagrass-dominated habitats, coral reefs, and other hard bottomed habitats. Strong spatial pattern in the species composition, density, and N and P content of seagrasses correspond to patterns in water quality in these areas. The distributions of the four major species of seagrasses (*Thalassia testudinum, Syringodium filiforme, Halodule wrightii* and *Halophila decipiens*) are independent of one another, suggesting that the distributions of the species may be controlled independently or that biotic interactions may be important. Water quality varies, as a consequence of the relative importance of the different sources of nutrients in the hydroscape. PCA indicates that there are six main influences on water quality: concentration of DIN; TN:TP; concentration of DIP, continental runoff, attenuation of light, and organic N in surface water. Light penetration to the bottom is strongly correlated to the seagrass community in the FKNMS, with the distribution of *T. testudinum*, the dominant seagrass species, limited to areas where greater than 10% of surface light reaches the bottom. If less than 10% of incident light reaches the bottom, seagrass communities are dominated by *Halophila decipiens*. In areas receiving more light, *S. filiforme* density is correlated to P availability, and *T. testudinum* is the dominant seagrass in N-rich environments.

Demographics of seagrass populations indicate mostly stable seagrass populations: An examination of the population age structure of 131 populations of *Thalassia testudinum* over the extent of the Florida Keys National Marine Sanctuary (FKNMS) over a two year period revealed significant spatial variation in short shoot demographic characteristics and population dynamics. The yearly mean plastochron interval was 34.4 ∀ 3.8 (d $leaf^{-1}$) and the mean population age was approximately 3 years. A significant relationship between asexual reproductive output and gross recruitment ($r^2 = 0.15$, $p = 0.001$) and mortality and gross recruitment ($r^2 = 0.72$, $p < 0.001$) existed. Overlapping spatial patterns of high gross recruitment and mortality were nearly synchronous. Thus, the greatest risk of mortality occurred in areas where gross recruitment was highest. The net population growth for *T. testudinum* within the boundaries of FKNMS was stable (mean = $-0.007y^{-1}$ ∀ $0.087y^{-1}$).

However, areas within FKNMS fluctuated between positive and negative net growth rates (-0.20y^{-1} to 0.50y^{-1}). The power of such large scale observations is in its ability to identify areas of management concern and frame questions addressing the controlling mechanisms influencing these regions of fluctuating population growth.

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SEAKEYS 1999: Florida Keys Monitoring Initiative.

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The Sustained Ecological Research Related to the Management of the Florida Keys Seascape (SEAKEYS) program was organized in 1991 by the Florida Institute of Oceanography (FIO) with initial funding from the John D. and Catherine T. MacArthur Foundation, and continuing funding from the South Florida Ecosystem Restoration, Prediction and Monitoring (SFERPM) program, administered by the National Oceanic and Atmospheric Administration (NOAA). The SEAKEYS environmental monitoring program, which is basically an oceanographic extension to the meteorologically-oriented Coastal-Marine Automated Network of NOAA, has accumulated an unparalleled long-term database of meteorological and oceanographic data from the Florida Straits and Florida Bay.

During 1998 the SEAKEYS network was upgraded with more precise oceanographic sensors, and selected stations were augmented with fluorometers, transmissometers, and water-level sensing equipment. A seventh monitoring station, a cooperative effort between FIO and the University of South Florida's Department of Marine Science (USF/DMS), was completed in Northwest Florida Bay at 25° 05' 00" N, 81° 05' 30" W during summer, 1998. This station also contains a full suite of meteorological and oceanographic instrumentation and also transmits its data hourly via a NOAA GOES satellite. The Northwest Florida Bay station is the northwestern most station in the SEAKEYS network, as well as the southernmost link in the West Florida Coastal Ocean Monitoring and Prediction System of USF/DMS.

Turbulent weather was prominent during 1998 in the Florida Keys. Severe conditions reported by the SEAKEYS stations included the Ground Hog Day Storm, Hurricane Georges, and Tropical Storm Mitch. In most cases the SEAKEYS stations contained the only instruments to measure the meteorological and oceanographic measurements accompanying these events in the Florida Keys. The Long Key station measured the highest winds (119 mph) in South Florida during the Ground Hog Day Storm of February 2, 1998. On September 25, 1998 the eye of Hurricane Georges passed over Key West at 1150 EDT as wind speeds dropped from 85.2 mph to 9.6 mph. The eye moved across the Dry Tortugas station at 1610 EDT with barometric pressures dropping to 974.4 mb. Winds gusted to hurricane force only after the eye passed at 2100 EDT. Georges' most severe winds in the Florida Keys gusted to 113 mph at Sombrero Reef, with a sustained wind speed of 94 mph. Long Key, Molasses Reef, and Fowey Rocks received gusts of tropical storm force. The tide station at Sombrero Reef reported a storm water level of 2.87 feet above mean lower low water. This contrasted with below normal levels reported at a station on Florida Bay. Hurricane Mitch passed northwest of the Florida Keys on the evening of November 4, 1998, bringing peak winds of 62.4 mph at Molasses Reef and sustained gale force winds until the following afternoon. Numerous localized tornadoes spawned by this storm caused extensive damage in the Upper Keys.

Daily near real-time SEAKEYS data are available to researchers via NOAA's Coral Health and Monitoring Program (CHAMP) Web site at http://www.coral.noaa.gov, while historical data are available at http://www.neptune.noaa.gov. The Coral Reef Early Warning System (CREWS), which utilizes the near real-time data from six SEAKEYS stations, is an online expert system which monitors environmental conditions on the reef that are theoretically conducive to coral bleaching. If these conditions occur, alerts are sent via email to researchers and posted to the Web at http://www.coral.noaa.gov/sferpm/seakeys/es.

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Florida Bay Watch: Results of Four Years of Nearshore Water-Quality Monitoring in the Florida Keys

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Florida Bay Watch is a volunteer-based program of The Nature Conservancy in which trained volunteers collect seawater samples and environmental data using standard scientific methods. It is designed to augment and assist scientific studies conducted by universities, agencies, and other institutions. This poster presents results of a monitoring project of water-quality parameters in nearshore waters at fixed stations in Florida Bay and along the Florida Keys for the four-year period November 1994 - October 1998. These nearshore data complement offshore data collected in Florida Bay and along the Keys by Florida International University (FIU); chemical analyses for this project were performed by the water-quality laboratory at FIU's Southeast Environmental Research Program (SERP).

The nearshore water-quality stations were located at the homes and workplaces of Florida Bay Watch volunteers. Stations were distributed from Key Largo to Key West and included sites both bayside and oceanside of the Florida Keys. The addition of new stations and the termination of others occurred over the four years; four stations were active for the entire period. Sampling occurred at both developed (residential canals and boat basins) and natural/unobstructed shorelines.

Florida Bay Watch volunteers were trained in basic water-quality sampling methods, which included instruction on filling out data forms, techniques for calibrating field equipment, and emphasis on careful handling of water samples to ensure the integrity of the data. Periodic evaluations were conducted to ensure consistency, and all data went through a quality-control check to identify possible sampling errors. Volunteers were instructed to sample each week during a low tide; data sets for most stations followed this routine, with some exceptions. The following information was recorded on a standardized data form: date, time, tide, Beaufort number for wind and sea state, wind direction, current strength, current direction, Secchi depth, time of Secchi reading, sea-surface temperature, specific gravity, and rainfall in the previous 24 hours. In addition, volunteers collected and froze a water sample for analysis of total nitrogen (TN) and total phosphorus (TP). For determination of chlorophyll-*a* (Chl-*a*) concentrations, two 60 mL aliquots of seawater were drawn into a syringe and then squirted through a filter unit containing a Whatman glass microfiber filter, GF/S, 25 mm diameter. The filter paper was placed in a vial, closed within a brown opaque bottle, and frozen.

Water samples and data forms were collected from the volunteers monthly and the samples were sent to the water-quality laboratory at SERP, FIU. Total nitrogen, total phosphorus, and chlorophyll-*a* concentrations were determined using standard methods.

To examine possible patterns through time in concentrations of these three water-quality parameters, four stations with four-year data sets were employed. Three of the stations were in the Upper Keys and one was in the Middle Keys. Two stations were at developed shorelines and two were at natural/unobstructed shorelines; all were bayside of the Keys.

Monthly station means were used in analyses of variance to compare nutrient and chlorophyll-*a* levels among the four years.

To examine water-quality parameters for possible patterns across space, stations were categorized by the three criteria noted above: region of the Keys, developed vs. natural shorelines, and oceanside vs. bayside of the Keys. Developed shorelines included various kinds of canals (dead-end, open-ended, aerated, non-aerated) and boat basins. Natural shorelines often included a dock from which samples were collected. One-year periods between November 1994 and October 1998 were used in one-way analyses of variance to compare the levels of the water-quality parameters within each of the three categories of stations.

Small-scale variations in nearshore water-quality parameters were a striking feature of this data set, as reported in Florida Bay Watch Quarterly and Annual Reports. Values often fluctuated considerably both at a particular station from week to week and among nearby stations; these fluctuations sometimes were on a scale of one or two orders of magnitude. We will present the results of the four-year analysis of nearshore water-quality parameters and the comparisons within station categories.

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Comparative Studies of Seagrass and Epiphyte Communities in Florida Bay and Two Other South Florida Estuaries in Relation to Freshwater Inputs.

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Three of the primary coastal ecosystems receiving freshwater inputs from Lake Okeechobee and the Everglades hydrologic system are St. Lucie River estuary, Caloosahatchee River estuary and Florida Bay. A comparative study was undertaken to contrast responses of seagrass, epiphyte and sediment communities to variations in hydrologic influence. Four transects were established (two in Florida Bay and one each in the other two estuaries) to examine variations in plant biomass and morphology, as well as pigment and chemical composition of seagrasses (submersed plants), and communities associated with epiphytic and benthic microalgae. Artificial substrates were deployed to collect epiphyte communities in time-courses, and these were compared with samples taken directly from seagrass leaves.

For each transect, stations were positioned along salinity gradients radiating away from respective freshwater sources. Stations in Florida Bay were sampled in the dry and wet seasons, while the other two estuaries were visited only during the dry season. Recent observations on hydrologic and water quality variables were assembled to characterize general environmental conditions at each site. The two Florida Bay transects were initiated from Little Madeira and Terrapin Bays, respectively, and five of the six total stations contained the seagrass, *Thalassia testudinum*, while the other station was sparsely colonized with *Halodule wrightii*.

Although four of five stations in the Caloosahatchee estuary were vegetated, species composition was mixed, including *Valisneria americana*, *Halodule wrightii, and Thalassia testudinum*. Only two of five stations in the St. Lucie River estuary were vegetated, one with *Ruppia maritima* the other with *Halophila johnsonia.* Patterns of seagrass abundance, morphology and pigment concentrations and C:N:P ratios generally reflected and integrated responses to nutrient and light conditions. Species compositions were directly related to mean salinity conditions, and plant abundance and character were related to both mean and variability of salinity levels. Patterns in the accumulation of epiphytic material appeared to follow gradients of nutrient concentrations in the St. Lucie estuary, but were more closely related to ambient light conditions in the Caloosahatchee.

In both Florida Bay transects, maximum levels of epiphytic material occurred at stations with intermediate salinity, nutrient and light conditions along respective gradients. There was generally good agreement between the epiphytic communities on artificial and natural substrates, but several interesting exceptions were noted. Time courses of epiphyte accumulation suggested saturation after 4 weeks at some but not all sites. Grazing may have been a factor with longer deployments. Several interesting relationships were suggested among seagrasses, epiphyte and sediment variables observed in this study. Overall, contrasts in patterns among the four transects indicate that light, nutrients and salinity are reasonably good predictors of plant and epiphytic communities; however, relationships differ substantially among systems, presumably because of complex ecological interactions.

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Preliminary Data and Document Rescue of Material Relevant to the South Florida Ecosystem.

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There are significant amounts of unpublished documents and data on the marine and estuarine environment of Florida that are so far unavailable to the scientific community, academia and the general public. These data and documents are important because they represent the Florida coastal ecosystems in times past, and are the basis for comparing past with current conditions.

Currently an innovative prototype data and document rescue effort is underway that combines the expertise of a senior scientist with that of librarians. Its main purpose is to inventory unpublished documents and data, perform a quality assurance review of the scientific content, convert the material to electronic and printed form, and make it available through printed and online resources. If the data and documents are not rescued, they will be lost as printed material physically deteriorates, personnel retire and corporate memory disappears. Examples of rescued documents relevant to the South Florida ecosystem are presented and the data and document rescue approach discussed.

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Linking Ecotoxicity and Risk Management to Sustainable Restoration of South Florida Ecosystems- Summary of Workshop.

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A workshop was held at FIU in October, 1998 to bring together research investigators and regulatory officials to identify and discuss toxic substance issues in South Florida affecting ecological receptors and develop a strategic plan to address problems which require further action. The findings through scientific consensus and recommendations for further action are summarized below.

1. There is a limited database on the concentrations of chemical and non-chemical stressors in different environmental compartments and their potential ecological effects in South Florida. However, there is some evidence of exposure and adverse ecological effects to chemical contaminants that is geographically and trophically widespread. For example, certain ecological receptors (e.g., pink shrimp, largemouth bass, wading birds and top predators) are at risk and are not being adequately protected from pesticides. Other species have not been well investigated.

A screening level (preliminary) ecological risk assessment is needed to tabulate, organize, summarize and interpret all available existing studies including on-going monitoring on exposure and toxicological effects conducted in the area which encompasses South Florida and should include freshwater, estuarine, saltwater, wetland and terrestrial habitats. This assessment should be one of the short-term goals of the South Florida Restoration effort. This initial assessment should include, but not be limited to:

- distribution of exposure in different compartments including concentrations and areas
- fate and effects data from different sources
- ecotoxicity and biological effects information relevant to South Florida
- define contaminants of concern (COC)
- define target ecological receptors
- pesticide usage data in different locations
- rank priorities on the basis of hazard

The screening level assessment should place specific attention to determining data adequacy and defining data gaps where additional information is needed for assessment, and include all uncertainties in the report. The screening level assessment will ultimately optimize future monitoring but it will also define research and development priorities like:

- sampling of contaminants of concern
- in situ biomonitoring as well as laboratory and simulated ecosystem studies (e.g., microcosm, mesocosm) of dose-response relationships

- fate and transport modeling to establish cause and effect relationships to confirm causative agents

All exposure, fate and ecotoxicity data should be continuously updated in a database at a centralized location for data sharing on a web site. The database should also include information on newly registered pesticides and ecological incident reports. The Restudy objectives may or may not be consistent with priorities based on risk to ecological receptors. Therefore, the preliminary screening level risk assessment is vital to assess restoration priorities, frame new ecosystem restoration policies based on existing risk information, focus monitoring objectives and define priorities for synoptic investigations of exposure and biological effects. Other investigations need not be delayed until completion of the screening level risk assessment (see below).

2. Some data gaps are already known and require immediate investigations and monitoring. This should not be delayed until completion of the screening level ecological risk assessment. This may include studies on:

- sampling critical areas to provide a more consistent picture of pesticide exposure (some areas will require continuous chemical monitoring and may include biomonitoring)
- acute and chronic effects (e.g., growth, development, reproduction, endocrine system) toxicity testing of water, sediment and soil in critical urban and agricultural areas (e.g., Everglades National Park)

3. A complete ecological risk assessment (retrospective) is needed with diagnostic studies to test various management scenarios, answer questions raised by the public and to develop scientific hypotheses for investigation. This should be a short-term goal and include all aquatic, terrestrial and wetland ecosystems. It will ultimately define the specific stressors and interactive stressors that should be the highest priorities for the restoration. The following studies should be considered as part of the ecological risk assessment process for South Florida:

- Determine the magnitude, frequency, form and distribution of exposures in different compartments. Information is needed on the exposure of chemical stressors as a result of their fate (i.e., through degradation/persistence, metabolism, transport, accumulation, etc.) in environmental compartments characteristic of the South Florida geochemistry
- Defining the form and processes that constitute critical food webs (and relationships) to delineate the risk of contaminants that bioaccumulate.
- Exposure and effects investigations in the laboratory and under field and simulated field conditions. It should be emphasized that in many locations, organisms may already be compromised with background concentrations of organochlorine compounds (e.g., DDT and metabolites) and that exposures to pesticides (i.e., from agriculture and mosquito control) are often frequent, short-term pulses during several months. Different pesticides are also used at the same time potentially producing acute and/or chronic interactive effects. These exposure scenarios/phenomena should be considered in all aquatic and terrestrial toxicity

studies to define cause-effect relationships. Toxicity studies should place specific attention on realistic, low level exposure concentrations and potential chronic effects. Emphasis should be on assessing effects on growth, development, reproduction and the endocrine system.

• Use transport and fate models and validate in South Florida ecosystems to define and predict exposure patterns. There are several exposure models available that can be applied to South Florida ecosystems and which should be used in the retrospective ecological risk assessment.

During the different phases of the risk assessment there should be meetings/workshops between investigators and regulatory officials to discuss results and modify, if necessary, any upcoming work based in recent findings. This will ensure that all studies in the assessment take advantage of the most up-to-date results for an effective assessment.

4. A prospective ecological risk assessment may be conducted after restoration of severely impacted elements of the ecosystem are repaired to forecast probabilistic risks expected under various management scenarios. This assessment should be part of the primary long-term goal of the restoration effort and may include studies on:

• exposure-effects (acute and chronic toxicity)
• fate and transport simulations of exposure and effects

5. Develop a Science Panel of experts in ecological risk assessment and risk management to review and advise on:

• all future studies and ecological risk assessments
• coordinating state and federal monitoring programs

Since a qualified advisory board was already selected with the above expertise it will be in the best interests of the restoration effort and time to adopt the same panel of experts as the Science Advisory Panel.

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The Effect of Salinity Stress on the Wound Healing Rate of *Plexaurella* Sp?, A Soft Coral from the Near Shore Waters of The Florida Keys.

Charles Shaffer and *Charles Bigger*, Florida International University, Miami, FL; *Christina Beck* and *Adam Shope*, Wittenberg University, Springfield, OH.

The notion that environmental stress can compromise defense mechanisms is well established. The first purpose of this study was to examine in detail the tolerance limits of *Plexaurella* sp?, a gorgonian coral from the near shore waters of the Florida Keys, to changes in salinity. Secondly we examined the effect of maintaining this species at either margin of its tolerance range (i.e. a stress but not lethal state) on the rate of at which it heals coenchymal wounds.

During a thirty day observation period, we found that there clearly is a salinity survival curve for *Plexaurella*, which ranges from 15 ppt to 43 ppt. In order to measure the effect of variations in salinity on the rate of wound healing we maintained specimens at 15, 25, 35 and 435 ppt. Salinity, created a 4.5 cm wound in the coenchyme and measured the rate at which these wounds healed. Data will be presented demonstrating that a marked impairment in wound healing rate occurred at either end of the salt tolerance range of *Plexaurella*.

Our data suggests that wound healing, an important parameter of innate immune defense in this coral species, is compromised by extremes of salinity. These results may have significant implications for decision making processes in coastal situation where human have some control of estuarine water flow (as in the case of the Everglades and Florida Bay).

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Physical Forcings and Vegetation Patterns Across Mangrove / Marsh Ecotones in Southwest Florida.

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Mangrove forests dominate the world's tropical and subtropical coastlines. Along coasts with very low topographic relief mangroves often gradually give way to brackish and freshwater marsh vegetation communities. This is characteristic of regions like the Gulf of Carpentaria (northern Australia), the Sunderbans (Bangladesh), and the Florida Everglades. Analysis of historical aerial photographs of the southwest coast of Everglades National Park reveal that the position of the mangrove / marsh ecotone has moved substantially in some locations and hardly at all in others. Several causal factors have been advanced to account for the encroachment of mangroves into the adjacent marshes, including: sea level rise and reduced freshwater inflow from upstream. Additional influences may include drought, fire and freezes.

I have conducted detailed studies along a 300m transect on the Harney River, on the southwest coast of Everglades National Park. The area was chosen specifically because it has shifted inland by >150m since 1940. The transect begins in the tall mangrove forest adjacent to the river and runs southward, ending in a sawgrass plain (*Cladium jamaicense*). Permanent vegetation monitoring plots and porewater salinity sampling wells were established at five sites along the transect. At each end of the transect hydrological sampling wells have been established to measure surface and ground water elevations and salinities. Site 1 is 15m from the river and consists of tall (25m) mangrove forest with all three species present (*Avicennia germinans*, *Laguncularia racemosa* and *Rhizophora mangle*). Site 2 is 50m further inland. All three mangroves are present and the forest canopy is some 20m high. Site 3 is 70m further inland. *Rhizophora* and *Laguncularia* are common, *Avicennia* is uncommon and *Conocarpus erectus* is present. *Laguncularia* is the dominant tree at Site 4, which is another 70m inland. *Rhizophora* and *Conocarpus* are present here and sawgrass forms an understory beneath the open canopy. Site 5 is 300m from the Harney River and is dominated by sawgrass. Scattered individuals of *Myrica cerifera* and *Persea borbonia* are present.

Sediment porewater salinity has been measured in replicate wells (n=3) from two depths (30 and 60cm) at each site at approximately bi-weekly intervals since April 1997. Two permanent vegetation monitoring plots were established in 1997 at each site (10 total) and have been remeasured annually. Seventy-three plots have been monitored to record mangrove seedling establishment and growth since the fall of 1997. For each plot, individual tree stems were identified, measured for Diameter at Breast Height (DBH), permanently tagged and mapped.

Similar patterns in the variation of sediment porewater salinity have been observed over time at each site, however the magnitude of variation is different among sites. In general salinity is highest nearest the Harney (.15o/oo) and decreases inland. However the lowest salinity was at site 4, with the sawgrass marsh having slightly increased salinities. Porewater salinity tended to be highest at all sites in the late dry season (May-June). This dry season high varied between years. For example, highest salinities at site 1 were 30o/oo in May-June of 1997 and only 20o/oo in May-June 1998. During this late dry season period, salinities were highest at 30cm depth and less at 60cm depths. This difference was almost 10o/oo at site 1 (30 vs. 20o/oo). This depth difference was observed at all sites and in all years. The magnitude of the difference decreased from the river to the sawgrass marsh and the differences also varied among years of observation. With the onset of summer rains, sediment salinities dropped quickly at all sites. Furthermore, surface salinities (30cm) dropped to lower levels than measured for deeper (60cm) sediments.

Mangrove stem density increased moving inland and was greatest at sites 3 and 4. Stem density then dropped to zero at site five. Stem size however was greatest near the Harney River. Sites 3 and 4 were dominated by small very sized (<3cm DBH) *Laguncularia racemosa*. Various measures of vegetation structure such as stem density, species richness and basal area were found to be uncorrelated with patterns of salinity or salinity variation. At present, vegetation dynamics across this mangrove / sawgrass ecotone appear to be more affected by episodic events or long term forcings. For example, a hard freeze in January 1997, "top-killed" many *Laguncularia* along the ecotone, moving it towards the river. However, the root stocks of these plants survived and resprouted. Observations at other ecotonal areas in southwest coastal Everglades indicate that fire plays an important role, particularly for mangrove-sawgrass and mangrove-*Spartina* ecotones. Long-term shifts in the position of these ecotones may be related to sea-level rise and upstream water management practices.

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Modeling the Southeast Florida Coastal Ecosystem - Hydrodynamic Transport, Salinity, and Trophodynamics.

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The major water bodies of the Southeast Florida coastal ecosystem consist of Biscayne and Florida Bays and the continental shelf. These coastal shelf waters sustain a rich tropical marine ecosystem with the only living coral reefs in North America. Besides nurturing productive and economically important multispecies fisheries, it is the natural habitat of several endangered or threatened species such as rare sea turtles and crocodiles, and supports a megalopolis with a billion dollar tourism and recreational boating industry. Efforts are underway to resolve resource conflicts arising from these often opposing interests to arrive at a sustainable long term solution. For example, a comprehensive multi-purpose water resources project has been proposed for the region (USCOE, 1999), which will divert freshwater from the estuaries to the Everglades. Due to serial overfishing, another important issue is whether the creation of marine protected areas can help establish sustainable fisheries. A sound scientific knowledge base of the hydrodynamic transport which links inshore with offshore waters is needed to resolve these management issues and to understand the influence of circulation on the biological communities, corals, seagrasses, and fish, that are part of the regional ecosystem. Because of the controlling function imposed by salinity on marine life, it is also of particular importance to be able to predict the changes in salinity that may arise from planned water diversions.

With support from the US Army Corps of Engineers and NOAA's Coastal Ocean Program we have developed numerical hydrodynamic models of Biscayne Bay (BB) and of part of the Southeast Florida shelf (SEFS). The models are based on the vertically integrated equations of motion for hydrodynamics dynamically coupled with the advection-diffusion equation for salinity. This type of model was selected in consideration of the shallow waters (< 4 m for most of Biscayne Bay, and < 20 m for the shelf) and complex bottom topography making good horizontal resolution more important than resolving vertical structure. Future enhancement of the model to include vertical variations can be contemplated if needed when sufficient data become available to force and validate a fully 3-D model. As a consequence of the one-layer nearly horizontal flow approximation, near field dynamics of canal mouths and inlet outflow plumes cannot be modeled faithfully, although mass flows can be conserved.

Model forcing is derived from historic data and existing monitoring stations. Tides for the BB model were obtained from the Virginia Key NOAA/NOS tide gage and supplemented by short term tide observations along the open boundary of the bay. Hourly wind observations were obtained from the offshore CMAN station at Fowey Rocks. Runoff estimates were derived from SFWMD records of canal structure discharges for all the canals at the edge of the Bay. The high intermittency in canal discharges were smoothed by forcing the model with hourly averaged discharges. For the SEFS model additional data were obtained from the Molasses Reef CMAN station, and water depth recordings at Tennessee Reef.

Model bottom topography was interpolated from digital databases gridded at 0.25 minutes (ca 460 m) in Biscayne bay and at 0.002 degrees (ca 222 m) for the shelf. The model allows the shallowest portions of the bay to drain and reflood as the water surface moves down and up. Rainfall, evaporation, and groundwater seepage can also be included in the model. The SEFS model presently does not include Florida Bay but can be coupled to a model for that water body when available. The Waterways Experiment Station of the US Army Corps of Engineers is developing such a model.

A 4-year hindcast using the present version of the BB model, based on a triangular finite element grid with 6364 elements and 3407 nodes and providing the flows and salinity in the bay at resolutions that approach 500 m in some locations, has been made for the years 1995-1998. For the simulation, the computed wind stress over the bay waters was reduced by 50% to account for a combination of internal boundary layer effects (transition from land to water) and smaller roughness from depth and fetch limited waves.

Comparisons of an earlier model version with current meter observations have previously been made. Because of the present emphasis on transport we have carried out additional model validation using observed flows in the inlets and long term salinity monitoring data. Comparison of vertically averaged observed and computed salinities at 34 stations in the bay gave an overall coefficient of determination (r-squared) of 0.54 and fitting a line to a scatter plot of all observed vs. computed salinities yielded a regression slope of 0.97 very close to the ideal 1.0. Aside from adjustments made to the amount of freshwater entering Little Manatee Bay and Barnes Sound in order to include effects of exchange with Florida Bay, these results were obtained without specific calibration of the model to observed salinities.

Although the purpose of the SEFS model is to describe the circulation in the shelf, it extends 60 km seaward from the Keys and stretches from Palm Beach to Key West in order to reduce the influence of (uncertain) boundary conditions on the domain of interest. This model also includes Biscayne Bay at a lower grid resolution and therefore can provide improved boundary conditions of salinity and water level for the more detailed BB model.

Comparison of the SEFS model with moored current meters, shipboard ADCP measurements and two Ocean Surface Current Radar observation periods show the mid and inner shelf responding predictably to local wind and tides. At the edge of the shelf, the Florida Current (FC) is a prominent feature and is potentially important for the shelf circulation and exchange with the adjacent deep waters.

In a research application the physical model is coupled with a generalized age-structured predator-prey model of multistock production dynamics to analyze a key trophodynamic linkage between an important predator (spotted seatrout, Cynoscion nebulosus) and prey (pink shrimp, Penaeus duorarum) in Biscayne Bay. The model numerically tracks the spatial and temporal dynamics of cohorts of pink shrimp and spotted seatrout from spawning, through settling and recruitment, and across the seascape as they grow. This integrated model framework provides opportunity to assess effects of changes in salinity and water quality regimes and to appraise key indicators of ecosystem productivity and functioning.

USCOE, 1999: Central and Southern Florida Project Comprehensive Review Study, Final Integrated Feasibility Report and Programmatic Impact Statement. US Army Corps of Engineers.

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Recruitment of Mangroves Following Catastrophic Disturbance by Hurricane Andrew.

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Hurricane Andrew passed over South Florida on August 24, 1992, with sustained winds of 230 kph causing significant damage to the mangroves of the southwestern Everglades National Park. We established six permanent plots within the path of the hurricane's eye wall. Over the last seven years we have taken annual surveys of these plots. We have permanently tagged all stems over 1.4 meters tall. When a new stem reaches this height it is added into our survey and followed annually. This has allowed us to follow the recruitment pattern of new stems into the plots. We found differential cumulative recruitment by species at a $p<0.10$ level. The plots differ significantly in the amount of damage sustained by the hurricane. Such that the greater the percentage of basal area removed by the storm indicates a trend in increased cumulative recruitment. *Laguncularia racemosa* recruited slightly better than *Avicennia germinans*; however, there were no other differences. Looking on a per plot basis there is a trend that *Avicennia* recruitment is low but consistent at all plots. At the plots with moderate damage *Laguncularia* is the prominent species recruiting into the plots early; then *Rhizophora mangle* becomes the dominant species recruiting into the plot. This patterns does not hold for plots with little or extremely heavy damage. There has been little mortality of new recruits due to shading/suppression by more established individuals. Also there has been no peaking of recruitment. Each year the amount of stems recruiting into the plots has not decreased significantly.

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