GEER Program
& Abstracts

Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem

"From Kissimmee to the Keys"

April 13-18, 2003

Westin Innisbrook • Palm Harbor, Florida

SOUTH FLORIDA ECOSYSTEM RESTORATION
TASK FORCE / WORKING GROUP

SCIENCE COORDINATION TEAM

Welcome to the GEER 2003 Science Conference!

Yes, the tradition is continuing. We had a very successful GEER-2000 Science Conference in Naples, Florida, with over 500 colleagues participating in the Conference. Now, I would like to welcome you to the GEER-2003 Science Conference. Please note: this tradition will continue; we are currently planning for our next GEER Conference in December 6-10, 2004 – so mark your calendar.

The GEER Science Conference this year is special in several ways. First, colleagues involved in the Florida Bay Science Conference and the GEER Science Conference are meeting jointly. What an excellent opportunity for learning and sharing science that deals with the entire Greater Everglades ecosystem; hence, the theme for this conference – ***from Kissimmee to the Keys.*** Plus, we infused a novel idea in the Plenary Session as well as throughout the conference. We have invited the ***'managers'*** to participate in the Conference and have challenged them to clearly articulate ***'management questions and decisions requiring science.'***

For all of you involved in the many meetings dealing with CERP and GEER project planning and implementation, you realize that most of our work lies ahead of us. Now it is more important than ever to clearly understand ***what science*** is critical for answering restoration and resource management questions and ***when*** the information is needed to be timely relevant to the decision process. How can we be sure that what we design and build will indeed contribute to successful restoration of the greater Everglades? We still have challenges ahead of us – challenges that only good science can help us meet successfully. And, only good science can ensure that what we design and what we build will, in fact, work.

Herein lies the challenge to our conference presenters. How do ***you*** make sure that ***your*** science is understood, is timely, is relevant, and will ultimately be used to inform decision-making? The answer can rely, in part, on your style of delivery. When you give your oral or poster presentation, first tell us ***what** you are doing, **why** you are doing it, and how your science is **relevant** to understanding the greater Everglades ecosystem*. Then, after delivering the body of your presentation, close by reminding us of 'what' and 'why', but *most importantly, you must tell us your **key findings** and **critical additional research needs***.

Each of us, whether we are presenting or listening, should keep the following questions in mind:

- How does our science explain the physical, hydrological and biological features that created and sustained the pre-drainage Everglades? Does that information help us address key management questions as well as in laying the foundation for *informed decisions* relevant to restoring the Greater Everglades within the context of compatible integration with humanity?
- How have recent studies and modeling strengthened our understanding of interrelationships between resource demands and critical physical and biological linkages, identified intervening trends which may impede restoration progress, and/or shed light on measuring restoration success from an ecological, social, cultural and economic perspective?

We look forward to the next few days of interaction and presentations, and to the opportunity for learning more about the Greater Everglades *from Kissimmee to the Keys*. You have my

Best Wishes,

G. Ronnie Best, Ph.D., PWS
Conference Chair & SCT Co-Chair
U.S. Geological Survey

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We kindly acknowledge the ***South Florida Water Management District*** *for providing several of the cover photos, and we thank* ***John LeClair*** *of Miami, Florida for sharing his photo of the Roseate Spoonbill.*

GEER Science Conference Program Committee

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Laura Brandt, U.S. Fish and Wildlife Service, Biology Division, Boynton Beach, FL

Stan Bronson, University of Florida, Palm Beach County Cooperative Extension Service, West Palm Beach, FL

Joan Browder, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL

David Colangelo, South Florida Water Management District, Kissimmee Division, West Palm Beach, FL

Wayne E. Daltry, Director, Smart Growth Department, Lee County Administration, Ft. Myers, FL

Donald DeAngelis, U.S. Geological Survey, Florida Integrated Science Centers, Coral Gables, FL

Robert F. Doren, Ecologist, U.S. Department of Interior at Florida, International University, Miami, FL

Michael Duever, South Florida Water Management District, Lower West Coast Service Center, Ft. Myers, FL

H. Carl Fitz, South Florida Water Management District, Everglades Division, West Palm Beach, FL

Aaron Higer, U.S. Geological Survey, Boca Raton, FL

Todd Hopkins, U.S. Fish and Wildlife Service, South Florida Ecological Services, Vero Beach, FL

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Roy Sonenshein, U.S. Geological Survey, Center for Water and Restoration Studies, Miami, FL

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Lou Toth, South Florida Water Management District, Kissimmee Watershed Management Team, West Palm Beach, FL

South Florida Ecosystem Restoration Task Force, Working Group and Supporting Organizations

Broward County Department of Environmental Protection
City of South Bay
Everglades National Park
Florida Department of Agriculture and Consumer Services
Florida Department of Community Affairs
Florida Department of Environmental Protection
Florida Department of Transportation
Florida Fish and Wildlife Conservation Commission
Florida Governor's Office
Florida Keys National Marine Sanctuary
Miami-Dade County
Miccosukee Tribe of Indians of Florida
Museum of Discovery & Science
National Oceanic and Atmospheric Administration
National Park Service
Palm Beach County Planning Department
Palm Beach County Water Utilities Department
Seminole Tribe of Florida
Smart Growth Department, Lee County Administration
Southeast Environmental Research Center
South Florida Water Management District
University of Florida/IFAS, Soil and Water Science Department
University of Florida/IFAS, Center for Natural Resources – South Florida
U. S. Army Corps of Engineers
U. S. Attorney's Office
U. S. Department of Agriculture
U. S. Department of the Army
U. S. Department of Commerce
U. S. Department of Interior
U. S. Department of Interior, Bureau of Indian Affairs
U. S. Department of Justice
U. S. Department of Transportation
U. S. Environmental Protection Agency
U. S. Fish and Wildlife Service
U. S. Geological Survey
Water Resources Advisory Commission (WRAC)

Conference Overview

The Everglades ecosystem is an invaluable ecological and economic resource and it is the subject of one of the most ambitious restoration efforts ever undertaken. The restoration goals stated by the South Florida Ecosystem Restoration Task Force are broad in context and short on specifics. Since our first GEER Conference in December 2000, there have been a number of advances in our understanding of the ecology and history of the Everglades. In addition, as we move forward with implementing the Comprehensive Everglades Ecosystem Plan (CERP) and other Greater Everglades restoration programs, we are realizing there are as many management questions as there are answers. So, as we move toward implementing Everglades restoration, we need to define more specifically what the restored system will be and how we will attain it. At this conference, we have challenged the *'managers'* to clearly articulate their *'management questions and decisions requiring science.'* What an excellent venue for scientists to hear from managers and for managers to hear about and communicate with scientists about the science relevant to the challenge of Greater Everglades Ecosystem Restoration. It is important for managers to be challenged to continuously improve the articulation of their management questions and decisions requiring science. And, it is also important for managers to challenge scientists to bring their results into the management arena in a productive and useful manner.

Conference Purpose

The purpose of this conference is to provide a forum for physical, biological and social scientists to share their knowledge and research results concerning Everglades restoration. The objectives are to define specific restoration goals, determine the best approaches to meet these goals and provide benchmarks that can be used to measure the success of restoration efforts over time. This conference recognizes:

- There is a need to synthesize information gathered since the GEER 2002 Conference,
- The interdisciplinary nature of Everglades restoration, and
- The need to adapt scientific understanding to management action.

Conference Structure

The conference includes invited presentations by an outstanding array of experts as well as selected oral and poster presentations of research conducted on various aspects of Everglades restoration. Concurrent sessions include presentations grouped by topic.

Not only will the conference provide an opportunity for exchange of information between scientists, resource managers and decision-makers, the conference will also provide an opportunity for all of us to look to the future.

Restatement of Questions

How can we be sure that what we design and build will indeed contribute to successful restoration of the greater Everglades? We still have challenges ahead of us – challenges that only good science can help us meet successfully. And, only good science can ensure that what we design and what we build will, in fact, work.

Herein lies the challenge to our conference presenters. How do ***you*** make sure that ***your*** science is understood, is timely, is relevant, and will ultimately be used to inform decision-makers? The answer can rely, in part, on your style of delivery. When you give your oral or poster presentation, first tell us ***what*** *you are doing,* ***why*** *you are doing it, and how your science is* ***relevant*** *to understanding the greater Everglades ecosystem*. Then, after delivering the body of your presentation, close by reminding us of the 'what' and 'why', *and most importantly, emphasize your* ***key findings*** *and* ***critical additional research needs****.*

Each of us, whether we are presenting or listening, should keep the following questions in mind:

- How does our science explain the physical, hydrological and biological features that created and sustained the pre-drainage Everglades? Does that information help us in implementing CERP and GEER as well as in laying the foundation for *measuring success* of restoration?
- How does our research contribute to understanding the interrelationships between resource demands and the greater Everglades physical and biological components, to identifying trends which may impede restoration progress, and, to measuring restoration success from an ecological, social, cultural and economic perspective?

Abstract Book Organization

This abstract book is organized in alphabetical order by presenting author. A detailed author index appears at the back of this book to assist you with finding a particular author's work.

This publication will be available online after the conference through the following web site: **http://conference.ifas.ufl.edu**

For more information about G.E.E.R., contact the Conference Chair:

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Email: Ronnie_Best@usgs.gov

Discussion Periods

As one of the primary purposes of the Greater Everglades Ecosystem Restoration 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.

SOFIA IMS Demonstration and Website Usability Testing

9am-5pm, Tuesday-Thursday (April 15-17)

South Florida Information Access (SOFIA) is an interdisciplinary service that provides coherent information access in support of research, decision-making, and resource management for the South Florida ecosystem restoration effort. Sponsored by the USGS Place Based Science Program, SOFIA offers a suite of information systems and tools enabling the selection, organization, documentation, dissemination and storage of data and other information products.

We are announcing the introduction of a new product (SOFIA IMS) and you are invited to join us for an informal demonstration. The SOFIA IMS is geospatial interface using ArcIMS software, and provides a means of accessing information stored in the SOFIA database through a geospatial query. The spatial data will be served using the ArcSDE software, which provides a mechanism for storing spatial data in a relational database.

We will be conducting interactive sessions using the IMS demo site from 9am-5pm on Tuesday-Thursday (April 15-17). Be sure to sign up for a one-on-one demonstration session at the conference. Available times will be posted outside the demo room (Salons G & H) located in the Stirling Hall Conference Center at the Westin Innisbrook.

We hope you will stop by the demo room and join us for an informal preview of our new product.

Greater Everglades Information Systems & Services on the Web

Everglades Online Database
Florida International University/Florida Center for Library Automation
http://everglades.fiu.edu/eol/index.html

Coastal and Estuarine Data/Document Archeology and Rescue *(CEDAR)*
NOAA Miami Regional Library
http://www.aoml.noaa.gov/general/lib/CEDAR.html

Reclaiming the Everglades: South Florida's Natural History 1884-1934
Florida International Univ., Univ. of Miami, Historical Museum of South Florida, Florida Ctr. for Library Automation
http://everglades.fiu.edu/reclaim/index.html

South Florida Information Access (SOFIA)
USGS South Florida Ecosystem Program
http://sofia.usgs.gov/

Water Resources of South Florida – Real Time data
USGS Water Resources Division
http://www-sflorida.er.usgs.gov/realtime.html

Aquatic Cycling of Mercury in the Everglades (ACME)
USGS Mercury Project
http://orxddwimdn.er.usgs.gov/servlet/page?_pageid=363,367,383&_dad=portal30&_schema=PORTAL30

Across Trophic Level System Simulation (ATLSS)
USGS Biological Resources Division
http://atlss.org/

Big Cypress Basin Regional Research Database
Florida Marine Research Institute and Florida Gulf Coast University
http://ocean.fmri.usf.edu/bcb/default.htm

The Everglades Landscape Model (ELM v2.1)
South Florida Water Management District
http://www.sfwmd.gov/org/erd/esr/elm.html

Everglades Litigation Collection
University of Miami School of Law Library
http://www.law.miami.edu/library/everglades/

Everglades Village - An Electronic Community for South Florida
http://www.evergladesvillage.net/

Everglades Restoration
Archives of COMMONS-EVERGLADES@LISTS.SIERRACLUB.ORG
http://lists.sierraclub.org/Archives/commons-everglades.html

Technical Publications Search
South Florida Water Management District
http://sfwmd.ces.fau.edu/techpub/display_browse.ihtml

Extension Digital Information Source (EDIS)
University of Florida /Institute of Food and Agricultural Sciences
http://edis.ifas.ufl.edu/

Caloosahatchee Documents Collection
Florida Gulf Coast University Library
http://library.fgcu.edu/Forms/caloosa.asp

PLEASE NOTE: Web addresses are subject to change without notice.

Program Agenda

Sunday, April 13, 2003

3:00pm - 6:00pm	Conference Registration Opens [STIRLING HALL SALONS A, B & C] Florida Bay Poster Presenters set up Displays [EDINBURGH BALLROOM]
6:00pm - 7:00pm	Early Bird Social with Welcome Address and Overview by John Hunt [EDINBURGH BALLROOM]
7:00pm	Social Adjourns to "Unofficial Networking" in Bamboo's Restaurant

Monday, April 14, 2003

7:00am - 5:00pm	Conference Registration Office Open [STIRLING HALL SALONS A, B & C]
7:00am - 5:00pm	Early Morning Refreshments in the Florida Bay Poster Presentations Display Area [EDINBURGH BALLROOM]
8:00am - 5:00pm	**Plenary Session on Florida Bay** [STIRLING HALL EAST BALLROOM] *(See Florida Bay Published AGENDA for detailed schedule)*
8:00am - 5:00pm	**ATLSS Training Workshop: Across Trophic Level System Simulation (ATLSS)**, is a spatial query and visualization GIS tool that provides the capability of retrieving, displaying, and analyzing ATLSS model data by means of a user-friendly graphical interface. A certified ArcView instructor will provide instruction. [STIRLING HALL SALONS O, P & Q]
12:10pm - 1:30pm	Lunch on Own
6:30pm - 9:00pm	Florida Bay Poster Session & Reception [EDINBURGH BALLROOM]

Tuesday, April 15, 2003

7:00am - 5:00pm	Conference Registration Office Open [STIRLING HALL SALONS A, B & C]
7:00am - 8:30am	Early Morning Refreshments [EDINBURGH BALLROOM]
8:00am - 5:40pm	**Plenary Session on Florida Bay** [STIRLING HALL EAST BALLROOM] *(See Florida Bay Published AGENDA for detailed schedule)*
8:30am - 5:20pm	**Concurrent Sessions:** Greater Everglades Ecosystem Restoration (GEER)

TUESDAY, APRIL 15, 2003 – CONCURRENT SESSION 1
GEER SESSION: HYDROLOGIC DATA AND MODELING [STIRLING HALL SALONS O, P & Q]

MODERATOR: ***Jayantha Obeysekera,*** Hydrologic Systems Modeling Division, Water Supply Department, South Florida Water Management District, West Palm Beach, FL

9:00am - 9:20am	**Management Questions and Decisions Requiring Science** **Invited Manager:** ***Tom Van Lent,*** Ph.D., P.E., Deputy Director for Science, South Florida Natural Resources Center, Everglades National Park, Homestead, FL
9:20am - 9:40am	**Weather Station-based Potential Evapotranspiration Computation Model and Database for Central and South Florida -** ***Wossenu Abtew,*** *J. Obeysekera, A. Reardon* and *N. Duerr,* South Florida Water Management District, West Palm Beach, FL (p. 3)

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 1
GEER SESSION: HYDROLOGIC DATA AND MODELING (CONTINUED)

9:40am - 10:00am	**Evapotranspiration Rates from Two Different Sawgrass Communities in South Florida During Drought Conditions -** ***Edward R. German*** and *David M. Sumner*, U.S. Geological Survey, Altamonte Springs, FL (p. 204)
10:00am - 10:20am	**Recharge and Discharge Measurements in the Everglades using Short-lived Radium Isotopes -** ***James M. Krest*** and *Judson W. Harvey*, U.S. Geological Survey, Reston, VA (p. 327)
10:20am - 10:40am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
10:40am - 11:00am	**Integration of Local Hydrology into a Regional Hydrologic Simulation Model -** ***Randy Van Zee***, *Eric Flaig* and *Wasantha Lal*, South Florida Water Management District, West Palm Beach, FL (p. 556)
11:00am - 11:20am	**Application of the Regional Simulation Model to Southwestern Florida -** ***David E. Welter***, *Wasantha Lal*, *Clyde Dabbs* and *Rama Rani*, South Florida Water Management District, West Palm Beach, FL (p. 582)
11:20am - 11:40am	**Watershed Hydrologic Model Development for Loxahatchee Ecosystem Restoration -** ***M. Clay Brown***, *Yongshan Wan*, *Randy VanZee* and *Wasantha Lal*, South Florida Water Management District, West Palm Beach, FL (p. 49)
11:40am - 12:00pm	**Thoughts on the Modeling of Human Operational Influences on Regional Hydrologic Models -** ***Wasantha Lal***, *Randy Van Zee* and *Joseph Park*, South Florida Water Management District, West Palm Beach, FL (p. 332)
12:00pm - 12:20pm	**Multi-Disciplinary Research and Modeling to Support The Nature Conservancy's FLOW Initiative for the Kissimmee-Okeechobee Watershed -** ***Douglas T. Shaw,*** The Nature Conservancy and University of Florida, Gainesville, FL; *Jora Young*, The Nature Conservancy, Altamonte Springs, FL (p. 483)
12:20pm - 1:30pm	Lunch on Own

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 1
GEER SESSION: HYDROLOGIC DATA AND MODELING (CONTINUED)
[STIRLING HALL SALONS O, P & Q]

MODERATOR: ***María M. Irizarry***, Center for Water and Restoration Studies, Florida Integrated Science Center, U.S. Geological Survey, Miami, FL

1:30pm - 1:40pm	**Management Questions and Decisions Requiring Science Invited Manager:** ***Dennis Duke***, P.E., Program Manager, Ecosystem Restoration, U.S. Army Corps of Engineers, West Palm Beach, FL
1:40pm - 2:00pm	**Modeling Changes in Flow Induced by Anisotropy of Vegetation Patches and Topographic Features -** ***Stuart Stothoff***, Southeast Environmental Research Center, Miami, FL; and *Sherry Mitchell-Bruker*, Everglades National Park, Homestead, FL (p. 531)

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 1
GEER SESSION: HYDROLOGIC DATA AND MODELING (CONTINUED)

2:00pm - 2:20pm	**USDA-Everglades Agro-Hydrology Computer Model (EAHM) -** ***M. R. Savabi,*** USDA-ARS, SHRS, Miami, FL; and *D. Shinde,* University of Florida, Gainesville, FL (p. 461)
2:20pm - 2:40pm	**Groundwater Monitoring and Modeling in an Agricultural Area Adjacent to the ENP -** ***Rafael Muñoz-Carpena***, *Martin Morawietz* and *Yuncong Li,* Tropical Research and Education Center, University of Florida, Homestead, FL (p. 386)
2:40pm - 3:00pm	**Management of Large Inflow and High Water Levels in Lake Okeechobee -** ***Paul Trimble****, Jayantha Obeysekera, Luis Cadavid, Walter Wilcox, Everett R. Santee* and *Calvin Neidrauer,* South Florida Water Management District, West Palm Beach, FL (p. 547)
3:00pm - 3:20pm	**Water Allocation in Lake Okeechobee during Periods of Shortage and Drought -** ***Walter M. Wilcox,*** *Luis G. Cadavid, Jayantha T. B. Obeysekera, Lehar M. Brion* and *Paul J. Trimble,* South Florida Water Management District, West Palm Beach, FL (p. 595)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Modeling the Upper Kissimmee Chain of Lakes for Operational Hydrology -** ***Angela M. Montoya****, Paul Trimble, Alaa Ali, Luis Cadavid, Jayantha Obeysekera* and *Steve Lin,* South Florida Water Management District, West Palm Beach, FL (p. 382)

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 2
GEER SESSION: THREATENED AND ENDANGERED SPECIES [STIRLING HALL SALONS D, E & F]

MODERATOR - ***Todd Hopkins***, US Fish and Wildlife Service, Vero Beach, FL

8:30am - 9:00am	**Management Questions and Decisions Requiring Science** **Invited Manager:** ***James "Jay" Slack***, Field Supervisor, U.S. Fish and Wildlife Service, South Florida Field Office (SFFO), Vero Beach, FL
9:00am - 9:20am	**Landscape-scale Conservation Planning for the Florida Panther -** ***Randy Kautz*** and *Robert Kawula,* Florida Fish and Wildlife Conservation Commission, Tallahassee, FL; *Thomas Hoctor,* University of Florida, Gainesville, FL; *Jane Comiskey,* University of Tennessee, Knoxville, TN; *Deborah Jansen,* Big Cypress National Preserve, Ochopee, FL; *Dawn Jennings* and *John Kasbohm,* U.S. Fish and Wildlife Service, Jacksonville, FL; *Frank Mazzotti,* Fort Lauderdale Research and Education Center, Davie, FL; *Roy McBride,* Livestock Protection Company, Ochopee, FL; *Larry Richardson,* U.S. Fish and Wildlife Service, Naples, FL; *Karen Root,* Bowling Green State University, Bowling Green, OH (p. 298)

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 2
GEER SESSION: THREATENED AND ENDANGERED SPECIES

9:20am - 9:40am	**Minimizing Ecological Impacts During the Siting of Comprehensive Everglades Restoration Plan Project Features: The Development of an Ecological Surface Value Model for the Lake Okeechobee Watershed Project -** ***David E. Hallac*** and *Brian Luprek,* U.S. Fish and Wildlife Service, South Florida Ecological Services Office, Vero Beach, FL (p. 237)
9:40am - 10:00am	**Multi-species/habitat Ecological Evaluation Modeling -** *Leonard Pearlstine,* ***Frank J. Mazzotti*** and *Gareth Mann,* University of Florida, Davie, FL; *Laura Brandt* and *Dawn Jennings,* U.S. Fish and Wildlife Service, Boynton Beach and Jacksonville, FL (p. 359)
10:00am - 10:20am	**Vegetative Habitats of Water Conservation Area-3A: Hydrologic Impacts of IOP -** ***Wiley M. Kitchens,*** U.S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL; *Paul Wetzel* and *Erik Powers,* University of Florida, Gainesville, FL (p. 312)
10:20am - 10:40am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
10:40am - 11:00am	**Habitat Related Growth in the Juvenile Florida Applesnail,** ***Pomacea paludosa* - *Robert B.E. Shuford, III*** and *Jennifer Magson,* South Florida Water Management District, West Palm Beach, FL; *Paul V. McCormick,* A.R.M. Loxahatchee National Wildlife Refuge, Boynton Beach, FL (p. 488)
11:00am - 11:20am	**Population Dynamics of the Snail Kite in Florida -** ***Julien Martin*** and *Wiley M. Kitchens,* U.S. Geological Survey, University of Florida, Gainesville, FL; *W.M. Mooij,* Netherlands Institute of Ecology, Nieuwersluis, The Netherlands (p. 355)
11:20am - 11:40am	**Projecting Future Population Dynamics of the Florida Snail Kite in Relation to Hydrology by Means of a Suite of Models -** ***W. M. Mooij,*** Netherlands Institute of Ecology, Centre for Limnology, Nieuwersluis, The Netherlands; and *D. L. DeAngelis,* U.S. Geological Survey, Center for Water and Restoration Studies, University of Miami, Coral Gables, FL (p. 384)
11:40am - 12:00pm	**Status and Conservation of the American Crocodile in Florida: Recovering an Endangered Species While Restoring an Endangered Ecosystem -** ***Michael S. Cherkiss*** and *Frank J. Mazzotti,* University of Florida, Fort Lauderdale, FL (p. 78)
12:00pm - 12:20pm	**Habitat Selection and Home Range of American Alligators in the Greater Everglades -** ***Michael L. Phillips,*** University of Florida, Department of Wildlife Ecology and Conservation, Ft. Lauderdale, FL; *Kenneth G. Rice,* U.S. Geological Survey, Center for Water and Restoration Studies, Ft. Lauderdale, FL; *Cory R. Morea,* Florida Fish and Wildlife Conservation Commission, Tallahassee, FL; *H. Franklin Percival* and *Stanley R. Howarter,* University of Florida, Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL (p. 425)
12:20pm - 1:30pm	Lunch on Own

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 2
GEER SESSION: ECOLOGICAL MODELING [STIRLING HALL SALONS D, E & F]

MODERATOR: ***H. Carl Fitz***, Everglades Division, South Florida Water Management District, West Palm Beach, FL

1:30pm - 1:40pm	<u>Introduction and Session Overview</u>**:** ***H. Carl Fitz***, Everglades Division, South Florida Water Management District, West Palm Beach, FL
1:40pm - 2:00pm	**Overview of the Across Trophic Level System Simulation (ATLSS) Program: Model Development, Field Study Support, Validation, Documentation, and Application** - ***D. L. DeAngelis,*** U.S. Geological Survey, Center for Water and Restoration Studies, University of Miami, Coral Gables, FL (p. 128)
2:00pm - 2:20pm	**Progress and Future Direction in Topographic Modeling for ATLSS Models -** ***Scott M. Duke-Sylvester*** and *Louis J. Gross,* University of Tennessee, Knoxville, TN (p. 162)
2:20pm - 2:40pm	**Evaluation and Calibration of ATLSS SESI Models -** ***Louis Gross****, Jane Comiskey*, *Mark Palmer,* University of Tennessee, Knoxville, TN; and *Donald DeAngelis,* U.S. Geological Survey, Center for Water and Restoration Studies, University of Miami, Coral Gables, FL (p. 218)
2:40pm - 3:00pm	**The ATLSS American Alligator Population Model: Results from Restoration Alternatives -** ***Daniel H. Slone,*** USDA Forest Service, Southern Research Station, Pineville, LA; ***Kenneth G. Rice***, U.S. Geological Survey, Center for Water and Restoration Studies, Fort Lauderdale, FL; *Jon C. Allen,* Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA; *H. Franklin Percival*, U.S. Geological Survey, Florida Cooperative Fish and Wildlife Unit, Gainesville, FL (p. 439)
3:00pm - 3:20pm	**ATLSS Vegetation Succession Model Project -** ***Scott M. Duke-Sylvester*** and *Louis J. Gross*, University of Tennessee, Knoxville, TN; *Paul R. Wetzel,* Smith College, Northampton, MA (p. 158)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 2
GEER SESSION: ECOLOGICAL MODELING (CONTINUED) [STIRLING HALL SALONS D, E & F]

MODERATOR: ***Don DeAngelis***, U.S. Geological Survey, Center for Water and Restoration Studies, University of Miami, Coral Gables, FL

3:40pm - 4:00pm	**Everglades Landscape Model: Advances in Integrated Ecological Assessment -** ***H. Carl Fitz,*** *Jason Godin, Fred Sklar, Beheen Trimble* and *Naiming Wang*, Everglades Division, South Florida Water Management District, West Palm Beach, FL (p. 177)
4:00pm - 4:20pm	**Habitat Suitability Indices for Evaluating Alternative Water Management Strategies -** ***Kenneth C. Tarboton****, Michelle M. Irizarry-Ortiz, Steven M. Davis* and *Jayantha T. Obeysekera,* South Florida Water Management District, West Palm Beach, FL; and *Daniel P. Loucks,* Cornell University, Ithaca, NY (p. 537)

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 2
GEER SESSION: ECOLOGICAL MODELING (CONTINUED)

4:20pm - 4:40pm	**Spatial Decision Support Systems for Ecological Restoration and Management - *Leonard G. Pearlstine*** and *Frank J. Mazzotti*, Department of Wildlife Ecology and Conservation, University of Florida, Ft. Lauderdale, FL; and *Donald L. DeAngelis*, U.S. Geological Survey, University of Miami, Coral Gables, FL (p. 421)
4:40pm - 5:00pm	**Design Models for Treatment Wetland Systems at Low Phosphorus Concentrations: DMSTA - *William Walker*** and *Robert Kadlec* (p. 574)
5:00pm - 6:30pm	Florida Bay Poster Presenters to Remove Displays
6:30pm - 9:00pm	**Joint Conference Networking Reception** [POOLSIDE AT LOCHNESS LAGOON]

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 3
GEER SESSION: WATER QUALITY AND ECOLOGY IN AGRICULTURAL AREAS
[STIRLING HALL SALONS L, M & N]

MODERATOR: *Lewis Hornung*, South Florida Water Management District, West Palm Beach, FL

1:30pm - 1:40pm	**Introduction and Session Overview: *Pamela A. Telis***, U.S. Geological Survey, c/o U.S. Army Corps of Engineers, Jacksonville, FL
1:40pm - 2:00pm	**Invited Manager: *Paul Gray***, Manager, Lake Okeechobee Audubon Sanctuary, Audubon of Florida, Lorida, FL
2:00pm - 2:20pm	**Invited Manager: *Sonny Williamson,*** President, Williamson Cattle Co., Okeechobee, FL
2:20pm - 2:40pm	**Integration of Science and Engineering with Federal and State Policies and Regulations and Public Opinion in Planning for the Lake Okeechobee Watershed Project, Comprehensive Everglades Restoration Program - *Lewis I. Hornung***, South Florida Water Management District; and *Chuck Sinclair*, HDR Engineering, Inc. (p. 264)
2:40pm - 3:00pm	**Policy and Management Strategies for the Restoration of Lake Okeechobee - *Kim Shugar***, Florida Department of Environmental Protection, West Palm Beach, FL; and *Benita Whalen*, South Florida Water Management District, West Palm Beach, FL (p. 490)
3:00pm - 3:20pm	**UF/IFAS Roles in the Lake Okeechobee Protection Program Highlighting Demonstration of Water Quality Best Management Practices for Beef Cattle Ranching in the Lake Okeechobee Basin -** *Wendy Graham* and ***Mitch Flinchum,*** University of Florida/IFAS, Gainesville and Belle Glade, FL, respectively; and ***Sanjay Shukla,*** University of Florida/IFAS, Southwest Florida Research and Education Center, Immokalee, FL (p. 180)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 3
GEER SESSION: WATER QUALITY AND ECOLOGY IN AGRICULTURAL AREAS (CONTINUED)

3:40pm - 4:00pm **Contributions of Beef Cattle Ranches to Surface Water Quality in the Lake Okeechobee Basin - *Patrick J. Bohlen*** and *Hilary Swain*, Archbold Biological Station, Lake Placid, FL; *Kenneth L. Campbell* and *Donald A. Graetz*, University of Florida, Gainesville, FL; and *John C. Capece*, Southern Datastream, Inc., LaBelle, FL (p. 30)

4:00pm - 4:20pm **Characterizing Flow and Phosphorus Loads for Lake Okeechobee Watershed using WAM - *Barry M. Jacobson*** and *Adelbert (Del) B. Bottcher*, Soil and Water Engineering Technology, Inc., Gainesville, FL; and *Jeffrey G. Hiscock*, Palm Beach Gardens, FL (p. 284)

4:20pm - 4:40pm **Fish Communities in Rice Fields of the Everglades Agricultural Area - *Wendy M. Bear***, *Michelle L. Casler*, *Elise V. Pearlstine*, and *Frank J. Mazzotti*, University of Florida, Ft. Lauderdale, FL (p. 21)

4:40pm - 5:00pm **Wading Birds, Shorebirds, and Waterfowl in Rice Fields of the Everglades Agricultural Area -** *Sara Townsend*, ***Elise V. Pearlstine*** and *F. J. Mazzotti*, University of Florida, Ft. Lauderdale, FL; and *C. W. Deren*, University of Arkansas, Stuttgart, AK (p. 420)

5:00pm - 5:20pm **BMPs and Water Quality in Miami-Dade County - *Yuncong Li*** and *Rafael Muñoz-Carpena*, Tropical Research and Education Center, University of Florida, Homestead, FL (p. 342)

5:20pm - 6:30pm Florida Bay Poster Presenters to Remove Displays

6:30pm - 9:00pm **Joint Conference Networking Reception**
[POOLSIDE AT LOCHNESS LAGOON]

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 4
GEER SESSION: ARTHUR R. MARSHALL LOXAHATCHEE NATIONAL WILDLIFE REFUGE
[STIRLING HALL SALONS I, J & K]

MODERATOR: ***H. Franklin Percival***, U.S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL

1:30pm - 1:40pm **Management Questions and Decisions Requiring Science**
Invited Manager: *Mark Musaus,* Refuge Manager, Arthur R. Marshall Loxahatchee National Wildlife Refuge, Boynton Beach, FL

1:40pm - 2:00pm **Cooperative Ecological Studies at the Arthur R. Marshall Loxahatchee National Wildlife Refuge: An Academic/Government Partnership for Linking Science, Management and Education - *Laura A. Brandt*** and *Mark J. Musaus*, U.S. Fish and Wildlife Service, Boynton Beach, FL; *G. Ronnie Best*, *H. Franklin Percival* and *Kenneth G. Rice*, U.S. Geological Survey, Miami, Gainesville, and Davie, FL; and *Frank J. Mazzotti*, University of Florida, IFAS, Ft. Lauderdale, FL (p. 41)

2:00pm - 2:20pm **Use of Chloride Concentration to Assess Conservative and Non-Conservative Properties of Everglades Surface-Water Constituents - *Michael G. Waldon*** and *Paul McCormick*, DOI Everglades Program Team, Boynton Beach, FL (p. 569)

TUESDAY, APRIL 15, 2003 - CONCURRENT SESSION 4
GEER SESSION: ARTHUR R. MARSHALL LOXAHATCHEE NATIONAL WILDLIFE REFUGE (CONTINUED)

2:20pm - 2:40pm	**Landscape Analysis of Gramminoid Habitats to Water Quality and Hydrology in Arthur R. Marshall Loxahatchee National Wildlife Refuge - *Wiley M. Kitchens*,** U.S. Geological Survey/Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL (p. 311)
2:40pm - 3:00pm	**Everglades Tree-Island Response to Hydrologic Change - *Debra A. Willard***, *William H. Orem* and *Christopher Bernhardt*, U.S. Geological Survey, Reston, VA; and *Charles W. Holmes*, U.S. Geological Survey, St. Petersburg, FL (p. 597)
3:00pm - 3:20pm	**The Loxahatchee Impoundment Landscape Assessment (LILA) Facility: a Macrocosm Approach to Experiments with Microtopography, Water Depth and Flow Rate - *Dale E. Gawlik***, *Fred H. Sklar, Sue Newman, Zaki Moustafa* and *Shili Miao*, Everglades Division, South Florida Water Management District, West Palm Beach, FL; *Arnold van der Valk*, Iowa State University, Ames, IA; and *Paul Wetzel*, Smith College, Northampton, MA (p. 199)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Effects of the Exotic Old World Climbing Fern on the Ant Diversity of Tree Islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge - *A. Camille Darby*** and *Jim K. Wetterer*, Florida Atlantic University, Boca Raton, FL; *Laura A. Brandt*, U.S. Fish and Wildlife Service, Boynton Beach, FL; and *Frank J. Mazzotti*, University of Florida/IFAS, Ft. Lauderdale, FL (p. 120)
4:00pm - 4:20pm	**Body Condition Analysis for the American Alligator for Use in Everglades Restoration - *Christa L. Zweig*** and *Frank J. Mazzotti*, Department of Wildlife Ecology and Conservation, University of Florida, Ft. Lauderdale, FL; *Kenneth G. Rice*, U.S. Geological Survey, Center for Water and Restoration Studies, Fort Lauderdale, FL; *Laura A. Brandt*, U.S. Fish and Wildlife Service, A.R.M. Loxahatchee National Wildlife Refuge, Boynton Beach, FL; *Clarence L. Abercrombie*, Wofford College, Spartanburg, SC (p. 617)
4:20pm - 4:40pm	**Northern Everglades Canals: Alligator Population Sources or Sinks? - *Matthew D. Chopp*,** Florida Fish and Wildlife Conservation Commission, Lake Panasoffkee, FL; *H. Franklin Percival*, U. S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL; and *Kenneth G. Rice*, U. S. Geological Survey, Center for Water and Restoration Studies, Ft. Lauderdale, FL (p. 81)
4:40pm - 5:00pm	**Session Summary and Discussion - *Laura A. Brandt***, A.R.M. Loxahatchee NWR, Boynton Beach, FL
5:00pm - 6:30pm	Florida Bay Poster Presenters to Remove Displays
6:30pm - 9:00pm	**Joint Conference Networking Reception** [POOLSIDE AT LOCHNESS LAGOON]

Wednesday, April 16, 2003

7:00am - 5:00pm	Conference Registration Office Open [STIRLING HALL SALONS A, B & C]
7:00am - 8:30am	Early Morning Refreshments in Poster Display Area [EDINBURGH BALLROOM]
7:00am - 8:30am	GEER Poster Presenters to put up Displays [EDINBURGH BALLROOM]

WEDNESDAY, APRIL 16, 2003
GEER PLENARY SESSION (8:30AM - 12:00PM) [STIRLING HALL BALLROOM EAST & WEST]

Management Questions and Decisions Requiring Science: The goal for this Plenary Session is for Key Managers to clearly articulate those Major Management Questions and Information Needs that will guide their restoration-related Decisions over the next several years.

8:30am - 8:40am	**Introductions and Plenary Session Overview - *G. Ronnie Best,*** Co-Chair, Science Coordination Team, U.S. Geological Survey, Miami, FL
8:40am - 9:05am	***Ann R. Klee***, Chair, South Florida Ecosystem Restoration Task Force and Counselor to Secretary of the Department of the Interior, Washington, DC
9:05am - 9:30am	***COL Greg May***, District Engineer, U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, FL
9:30am - 9:55am	***Henry Dean***, Executive Director, South Florida Water Management District, West Palm Beach, FL
9:55am - 10:20am	***Kenneth D. Haddad***, Executive Director, Florida Fish & Wildlife Conservation Commission, Tallahassee, FL
10:20am - 10:40am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
10:40am - 11:05am	***Michael V. Martin***, Vice President for Agriculture and Natural Resources, University of Florida, Gainesville, FL
11:05am - 11:30am	**"How Can 'Science' Meet These Challenges?"- *Charles (Chip) Groat***, Director, U.S. Geological Survey, Reston, VA
11:30am - 12:00pm	Panel Q & A
12:00pm - 1:30pm	Lunch on Own

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 1
GEER SESSION: SOUTH EASTERN COASTAL ECOSYSTEMS [STIRLING HALL SALONS O, P & Q]

MODERATOR: ***Richard E. Dodge,*** Nova Southeastern University, Oceanographic Center, National Coral Reef Institute, Dania, FL

1:30pm - 1:40pm	**Management Questions and Decisions Requiring Science Invited Manager: *Greg A. Graves,*** Environmental Manager, Surface Water Quality Section, Florida Department of Environmental Protection, Port St. Lucie, FL
1:40pm - 2:00pm	**An Integrated Modeling System for Forecasting the Response of Indian River Lagoon and Tampa Bay to Anthropogenic and Climatic Changes - *Y. Peter Sheng***, Civil & Coastal Engineering Department, University of Florida, Gainesville, FL (p. 485)

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 1
GEER SESSION: SOUTH EASTERN COASTAL ECOSYSTEMS (CONTINUED)

2:00pm - 2:20pm	**Prevalence of Abnormal Fish as an Indicator of Environmental Quality in the St. Lucie Estuarine System - *Joan A. Browder***, *C. Mindy Nelson, M. Kandrashoff, W. Kandrashoff* and *J. W. Bernstein,* Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL (p. 46)
2:20pm - 2:40pm	**Wading Bird Use of Managed Wetland Habitats for Foraging in the Northern Indian River Lagoon System - *Eric D. Stolen***, *Dave R. Breininger* and *Rebecca B. Smith*, Dynamac Corp., Kennedy Space Center, FL (p. 524)
2:40pm - 3:00pm	**Vegetation Community Changes along the Loxahatchee River in Southeastern Florida: Examination along a Salinity Gradient - *John G. Zahina,*** South Florida Water Management District, West Palm Beach, FL (p. 614)
3:00pm - 3:20pm	**Environmental Indicators as Performance Measures in the Management of Coastal Ecosystems - *M. J. Hameedi,*** National Oceanic and Atmospheric Administration, Silver Spring, MD (p. 241)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Relative Importance of Tripton, Chlorophyll_a, and Dissolved Organic Matters in Affecting Light Attenuation in Florida Estuaries - *Y. Peter Sheng*** and *David Christian*, Coastal and Oceanographic Engineering Program, University of Florida, Gainesville, FL (p. 487)
4:00pm - 4:20pm	**Linking Development to the Status of Benthic Communities: Challenges and Lessons from the Florida Keys - *Ricardo N. Calvo*** and *Debra C. Woithe*, URS Corporation, Tampa, FL; *Deborah H. Peterson*, U.S. Army Corps of Engineers, Jacksonville, FL (p. 63)
4:20pm - 4:40pm	**Florida Keys Carrying Capacity Study--Process and Lessons Learned - *Deborah H. Peterson,*** U.S. Army Corps of Engineers, Jacksonville, FL; *Ricardo N. Calvo*, URS Corporation, Tampa, FL (p. 424)
4:40pm - 5:00pm	**Relating Water Flow to Wetland Processes and Everglades Restoration: Getting the Water REALLY Right in the River of Grass - *Daniel L. Childers***, *David Iwaniec, Damon Rondeau, Gustavo Rubio* and *Adam Wood*, Florida International University, Miami, FL; *Lynn Leonard*, University of North Carolina-Wilmington, Wilmington, NC; *Christopher Madden*, SFWMD, West Palm Beach, FL; *Sherry Mitchell-Bruker*, SFNRC, Everglades National Park, Homestead, FL; *Helena Solo-Gabriele*, University of Miami, Miami FL (p. 80)
6:00pm - 8:00pm	**GEER Poster Session & Reception** [EDINBURGH BALLROOM]

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 2
GEER SESSION: ROLE OF FLOW IN THE GREATER EVERGLADES [STIRLING HALL BALLROOM EAST]

MODERATOR: ***Nick Aumen***, Everglades National Park, Boynton Beach, FL

1:30pm - 1:40pm	**Management Questions and Decisions Requiring Science** **Invited Manager:** ***Kimberley A. Taplin,*** Project Manager, South Florida Restoration Branch, U.S. Army Corps of Engineers, West Palm Beach, FL
1:40pm - 2:00pm	**Self-assembly of Slough-Ridge-Tree Island Landscapes in the Central Everglades: A Model for the Integration of Hydrological and Ecological Processes - *Thomas J. Givnish,*** University of Wisconsin, Madison, WI; *John C. Volin*, Florida Atlantic University, Davie, FL (p. 206)
2:00pm - 2:20pm	**Landscape Mapping of Ridge and Slough Topography: Integration of Hydrology and Biological Processes - *John C. Volin*[1]**, *Thomas J. Givnish*[2], *Jordan D. Muss*[1], *Dianne Owen*[1], *Valeria C. Volin*[1] and *Paul H. Glaser*[3;] [1] Florida Atlantic University, [2]University of Wisconsin-Madison, [3] University of Minnesota (p. 561)
2:20pm - 2:40pm	**Picturing Pre-Drainage Everglades Hydrology: How Fuzzy Is It? - *Jayantha Obeysekera***, *Christopher McVoy, Winifred Park Said, Joel VanArman, Randy VanZee* and *Jenifer Barnes*, South Florida Water Management District, West Palm Beach, FL (p. 404)
2:40pm - 3:00pm	**Quantifying the Current Landscape Patterns of the Everglades Ridge and Slough - *Martha K. Nungesser***, *Christopher McVoy, Yegang Wu* and *Naiming Wang*, South Florida Water Management District, West Palm Beach, FL (p. 403)
3:00pm - 3:20pm	**Role of Flow-related Processes in Maintaining the Ridge and Slough Landscape - *Elizabeth Crisfield***, Daniel Beard Research Center, Everglades National Park, Homestead, FL; *Christopher McVoy*, Everglades Division, South Florida Water Management District, West Palm Beach, FL (p. 109)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Development and Stability of the Everglades Ridge and Slough Landscape - *Christopher E. Bernhardt*** and *Debra A. Willard*, U.S. Geological Survey, Reston, VA; *Charles W. Holmes*, U.S. Geological Survey, St. Petersburg, FL (p. 27)
4:00pm - 4:20pm	**A Tool for Measuring Landscape Changes (Ridge and Slough) in the Everglades - *Yegang Wu,*** *Martha K. Nungesser, Naiming Wang* and *Christopher McVoy*, South Florida Water Management District, West Palm Beach, FL (p. 609)
4:20pm - 4:40pm	**Pre-drainage Relation of Lake Okeechobee to the Everglades - *Christopher McVoy*** (Everglades Division) and *Winifred Park Said* (Hydrologic Systems Modeling Division), South Florida Water Management District, West Palm Beach, FL (p. 373)
4:40pm - 5:00pm	Session Summary and Discussion
6:00pm - 8:00pm	**GEER Poster Session & Reception** [EDINBURGH BALLROOM]

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 3
GEER SESSION: THE MARINE ECOSYSTEMS OF THE FLORIDA KEYS
[STIRLING HALL SALONS D, E & F]

MODERATOR: ***Brian D. Keller***, NOAA/Florida Keys National Marine Sanctuary, Marathon, FL

1:30pm - 2:00pm	**Management Questions and Decisions Requiring Science** **Invited Manager: The Role of Science in Framing and Answering Management Questions - *Billy D. Causey,*** Superintendent, NOAA/Florida Keys National Marine Sanctuary, Marathon, FL
2:00pm - 2:20pm	**Influence of Eddies on the Transport of Pre-settlement Stages into Florida Bay - *Cynthia Yeung***, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA; *David L. Jones*, *Maria M. Criales* and *Monica R. Lara*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; and *Thomas L. Jackson*, *John T. Lamkin*, and *William J. Richards*, NOAA Fisheries, Southeast Fisheries Science Center, Miami, FL (p. 611)
2:20pm - 2:40pm	**Determination of Caffeine, a Specific Marker for Wastewater Contamination, in Coastal Environments from the Florida Keys - *Piero R. Gardinali**[*1,2]*, *Arlette Azua*[1] *and Joseph Boyer*[2]; [1]Department of Chemistry, and [2]Southeast Environmental Research Center (SERC), Florida International University, University Park, Miami, FL (p. 196)
2:40pm - 3:00pm	**Seagrass Monitoring in the Florida Keys National Marine Sanctuary: Seasonal Pattern and Long-term Trends at Permanent Monitoring Sites - *James W. Fourqurean***, *Leanne M. Rutten* and *Susie P. Escorcia*, Department of Biological Sciences and Southeast Environmental Research Center, Florida International University, Miami, FL; *Michael J. Durako*, Center for Marine Science, University of North Carolina at Wilmington, Wilmington, NC; and *Joseph C. Zieman*, Department of Environmental Sciences, University of Virginia, Charlottesville, VA (p. 185)
3:00pm - 3:20pm	**Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project: Long-term Status and Trends - *Walter C. Jaap,*** *Michael K. Callahan*, *Keith E. Hackett*, *James Kidney*, *Matthew Lybolt*, *Selena Kupfner* and *Jennifer Wheaton*, Florida Marine Research Institute, FWC, St. Petersburg, FL; *James Porter* and *Katherine Patterson*, University of Georgia, Athens, GA (p. 275)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**A Post Mortem Analysis of Coral Mortality in the Lower Florida Keys, Florida - *Keith E. Hackett*** and *Michael K. Callahan*, Florida Marine Research Institute, St. Petersburg, FL; *Chuanmin Hu*, College of Marine Science, University of South Florida, St. Petersburg, FL; *James Porter*, University of Georgia, Athens, GA (p. 232)

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 3
GEER SESSION: THE MARINE ECOSYSTEMS OF THE FLORIDA KEYS (CONTINUED)

4:00pm - 4:20pm **The Etiology of White Pox, a Lethal Disease of the Caribbean Elkhorn Coral, *Acropora palmate* - *Kathryn P. Sutherland*** and *James W. Porter*, University of Georgia, Athens, GA; *Kim B. Ritchie*, Scripps Institution of Oceanography, La Jolla, CA, MicroGenomics, Carlsbad, CA; *Shawn W. Polson*, Clemson University, Clemson, SC; *Erich Mueller*, Mote Marine Laboratory, Center for Tropical Research, Summerland Key, FL; *Esther C. Peters*, Tetra Tech, Inc., Fairfax, VA; *Deborah L. Santavy*, Gulf Ecology Division, U.S. EPA, Gulf Breeze, FL; *Garriet W. Smith*, University of South Carolina, Aiken, SC (p. 533)

4:20pm - 4:40pm **Pulley Ridge - the US's Deepest Coral Reef? - *Robert B. Halley,*** *Virginia E. Garrison, Katherine T. Ciembronowicz* and *Randy Edwards*, U.S. Geological Survey, FISC, St. Petersburg, FL; *Walter C. Jaap*, Florida Marine Research Institute, St. Petersburg, FL; *Gail Mead* and *Sylvia Earle,* Sustainable Seas Expedition; *Albert C. Hine, Bret Jarret, Stan D. Locker, David F. Naar* and *Brian Donahue,* Center for Coastal Ocean Mapping, College of Marine Science, University of South Florida, St. Petersburg, FL; *George D. Dennis*, U.S. Geological Survey, FISC, Gainesville, FL; and *David C. Twichell*, U.S. Geological Survey, Woods Hole, MA (p. 238)

4:40pm - 5:00pm **Effects of No-Take Zones on Reef Fish Populations after Five Years of Protection in the Florida Keys National Marine Sanctuary - *James A. Bohnsack***, *David B. McClellan* and *Douglas E. Harper*, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL; *Jerald S. Ault* and *Steven G. Smith*, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; *Billy Causey*, Florida Keys National Marine Sanctuary, Marathon, FL (p. 32)

5:00pm - 5:20pm **Do Marine Reserves in Florida Keys National Marine Sanctuary Protect Spiny Lobsters? - *Carrollyn Cox***, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Marathon, FL (p. 106)

6:00pm - 8:00pm **GEER Poster Session & Reception** [EDINBURGH BALLROOM]

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 4
GEER SESSION: WETLAND TREATMENT SYSTEMS [STIRLING HALL SALONS L, M & N]

MODERATOR: *Jennifer Jorge*, Lower East Coast Division, South Florida Water Management District, West Palm Beach, FL

1:30pm - 1:40pm **Management Questions and Decisions Requiring Science**
Invited Manager: *Patricia Strayer*, PE, Director, Southern District Restoration Department, South Florida Water Management District, West Palm Beach, FL

1:40pm - 2:00pm **Can Stormwater Treatment Areas be Managed to Optimize Total Phosphorus Concentration Reductions for Everglades Restoration? - *Martha K. Nungesser***, South Florida Water Management District, West Palm Beach, FL (p. 401)

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 4
GEER SESSION: WETLAND TREATMENT SYSTEMS (CONTINUED)

2:00pm - 2:20pm	**Capabilities and Limitations of Stormwater Treatment Areas for Reducing Phosphorus Loads to the Water Conservation Areas: A Biogeochemical Perspective - *Thomas A. DeBusk*** and *Forrest Dierberg*, DB Environmental, Inc., Rockledge, FL (p. 131)
2:20pm - 2:40pm	**Phosphorus Removal Performance of Native and Exotic Submerged Aquatic Macrophytes in South Florida - *Scott Jackson,*** *Patrick Owens, Thomas A. DeBusk* and *Forrest Dierberg*, DB Environmental, Inc., Rockledge, FL (p. 278)
2:40pm - 3:00pm	**Analysis of Water Quality in a Constructed Treatment Wetland Designed to Reduce Nutrients in Everglades Agricultural Area Runoff - *Binhe Gu***, *Jana Newman, Martha Nungesser* and *Michael J. Chimney*, South Florida Water Management District, West Palm Beach, FL (p. 230)
3:00pm - 3:20pm	**Stormwater Treatment Area Optimization Research: The Result of Pulsed Loading and Depth Changes on Half-acre Research Treatment Wetlands in South Florida - *Jana Majer Newman*** and *Kimberleigh Cayse,* South Florida Water Management District, West Palm Beach, FL (p. 395)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Large Scale Treatment Wetlands for Everglades Restoration: Baseline Comparisons and First Year of Operation of STAs 5 and 6 - *Jana Majer Newman***, *Christy Combs* and *Kathy Pietro,* South Florida Water Management District, West Palm Beach, FL (p. 393)
4:00pm - 4:20pm	**Phosphorus Removal Performance By Submerged Aquatic Vegetation-Dominated Wetlands in Response to Hydraulic Loading Pulses - *Kevin A. Grace***, *Thomas A. DeBusk* and *Forrest E. Dierberg,* DB Environmental, Inc., Rockledge, FL (p. 214)
4:20pm - 4:40pm	**Relationships Between Hydraulic Efficiency and Phosphorus Removal in a Submersed Aquatic Vegetation-Dominated Treatment Wetland - *Forrest Dierberg***, *John Juston* and *Thomas A. DeBusk*, DB Environmental, Rockledge, FL; *Taufiqul Aziz*, Florida Department of Environmental Protection, Tallahassee, FL (p. 141)
4:40pm - 5:00pm	**Evaluation of a Periphyton-based Stormwater Treatment Area (PSTA) in the Margin of the C-111 Canal and the Everglades National Park (ENP): Results of a Two-Year Investigation (2001-2002) - *Serge Thomas***, *Evelyn E. Gaiser, Miroslav Gantar, Aga Pinowska, Leonard J. Scinto* and *Ronald D. Jones,* SERC/FIU, Periphyton Group, Miami, FL (p. 540)

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 4
GEER SESSION: WETLAND TREATMENT SYSTEMS (CONTINUED)

5:00pm - 5:20pm **Periphyton Stormwater Treatment Areas Demonstration Project: Results of Three Years of Monitoring** - *Jana Majer Newman* and ***Lori Wenkert***, South Florida Water Management District, West Palm Beach, FL (p. 583)

5:20pm - 5:40pm **Applying the Success of the Stormwater Treatment Areas to the Greater South Florida Restoration Effort of the Comprehensive Everglades Restoration Plan -** *Jana Majer Newman* and ***Kathleen Collins***, South Florida Water Management District, West Palm Beach, FL (p. 93)

6:00pm - 8:00pm **GEER Poster Session & Reception** [EDINBURGH BALLROOM]

WEDNESDAY, APRIL 16, 2003 - CONCURRENT SESSION 5
GEER SESSION: SOCIAL AND HUMAN SYSTEMS [STIRLING HALL SALONS I, J & K]

MODERATOR: ***Bonnie Kranzer***, Lead Planner, South Florida Water Management District, Lower West Coast Service Center, Ft. Myers, FL

1:30pm - 1:40pm **Introduction and Session Overview:** ***Wayne E. Daltry,*** Director, Smart Growth Department, Lee County Administration, Ft. Myers, FL

1:40pm - 2:00pm **Projected (2000-2025) Residential and Nonresidential Development for Central and Southern Florida -** ***Robert W. Burchell***, Rutgers University, New Brunswick, NJ; and *William R. Dolphin*, Rutgers University, New Brunswick, NJ (p. 53)

2:00pm - 2:20pm **Miami-Dade Agriculture as an Ecosystem Buffer: Will it Survive Economics, Urban Development Pressure and Pestilence? -** ***Robert L. Degner***, *Thomas J. Stevens, III.* and *Kimberly L. Morgan*, University of Florida, Gainesville, FL (p. 133)

2:20pm - 2:40pm **Gladesmen Cultural Landscapes and Community Engagement: A Case Study -** ***Laura A. Ogden,*** University of Florida, Gainesville, FL (p. 405)

2:40pm - 3:00pm **Water Pricing as a Conservation Tool: An Economic Analysis of the Lower East Coast of South Florida Water Utilities -** ***Carolina Rivera*** and *Mahadev Bhat,* Florida International University, Miami, FL (p. 451)

3:00pm - 3:20pm **Land-Use Planners and Regulators and the Multi-Species Recovery Plan: Exposure, Awareness, and Motivations -** ***Janas Sinclair***, Florida International University, North Miami, FL; *Frank Mazzotti* and *Jocie Graham*, University of Florida, Davie, FL (p. 496)

3:20pm - 3:40pm **An Assessment of Public Engagement in the Everglades Restoration Projects -** ***Lara Taylor*** and *Mahadev Bhat,* Florida International University, Miami, FL (p. 538)

Thursday, April 17, 2003

7:15am - 5:00pm	Conference Registration Office Open [STIRLING HALL SALONS A, B & C]
7:15am - 8:15am	Early Morning Refreshments in Poster Display Area [EDINBURGH BALLROOM]

THURSDAY, APRIL 17, 2003
GEER PLENARY SESSION: RESTORATION SCIENCE SUCCESSES AND CHALLENGES FOR SOUTHWEST FLORIDA [STIRLING HALL BALLROOM EAST & WEST]

MODERATOR: ***Michael Savarese*,** Division of Ecological Studies, Florida Gulf Coast University, Ft. Myers, FL

8:15am - 8:35am	**Management Questions and Decisions Requiring Science** **Invited Speaker: Restoration Issues and Coordinated Planning in Southwest Florida -** ***James W. Beever***, Biological Scientist IV, Florida Fish and Wildlife Conservation Commission, Punta Gorda, FL
8:35am - 8:55am	**Evaluation of Hydrology and Plant Community Changes Resulting from Alternative Restoration Scenarios in the Southern Golden Gate Estates of Southwest Florida -** ***Michael J. Duever*,** South Florida Water Management District, Fort Myers, FL (p. 156)
8:55am - 9:15am	**Oyster Physiology and Ecological Distribution as an Indication of Environmental Health and as a Performance Measure of Restoration Effectiveness of Southwest Florida's Estuaries -** ***Michael Savarese***, *Aswani Volety* and *Greg Tolley*, Florida Gulf Coast University, Ft. Myers, FL (p. 464)
9:15am - 9:35am	**Freshwater Fishes as Indicators of Wetland Hydrology and Function in South Florida -** ***David W. Ceilley***, Environmental Science, The Conservancy of Southwest Florida, Naples, FL (p. 71)
9:35am - 9:55am	**The Caloosahatchee Estuary: Applied Research to Determine Freshwater Inflow Limits -** ***Robert H. Chamberlain*** and *Peter H. Doering*, South Florida Water Management District, West Palm Beach, FL (p. 73)
9:55am - 10:15am	**Restoration Science Successes and Challenges for Southwest Florida: Charlotte Harbor -** ***Stephen A. Bortone***, Marine Laboratory, Sanibel-Captiva Conservation Foundation, Sanibel, FL (p. 34)
10:15am - 10:40am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 1
GEER SESSION: RESTORATION NEEDS & PRIORITIES IN SOUTHWEST FLORIDA AND COASTAL ECOSYSTEMS: FROM SCIENCE TO MANAGEMENT [STIRLING BALLROOM EAST]

MODERATORS: ***Heather Rein*** and ***Michael Savarese***, Division of Ecological Studies, Florida Gulf Coast University, Ft. Myers, FL

10:40am - 11:00am	**Management Questions and Decisions Requiring Science** **Invited Manager: Restoration Science and Management in Southwest Florida -** ***Carol Wehle***, Regional Director of the Lower West Coast Service Center, South Florida Water Management District, Ft. Myers, FL

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 1
GEER SESSION: RESTORATION NEEDS & PRIORITIES IN SOUTHWEST FLORIDA AND COASTAL ECOSYSTEMS: FROM SCIENCE TO MANAGEMENT (CONTINUED)

11:00am - 11:20am	**An Integrated Approach for Evaluating CERP Projects: Linking Science and Management in the Southwest Florida Feasibility Study - *Tomma Barnes*** and *Janet Starnes*, South Florida Water Management District, Fort Myers, FL; *Frank J Mazzotti* and *Leonard G. Pearlstine*, University of Florida, Davie, FL; *Donald L. DeAngelis*, U.S. Geological Survey, Coral Gables, FL (p. 15)
11:20am - 11:40am	**Southwest Florida Feasibility Study Development of Hydrologic Targets for the Caloosahatchee Estuary - *Robert H. Chamberlain*** and *Tomma Barnes*, South Florida Water Management District, West Palm Beach and Ft. Myers, FL (p. 76)
11:40am - 12:00pm	**Big Cypress Basin-Estero Bay Regional Research Database/Web Site - *Jill Trubey,*** Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, FL (p. 551)
12:00pm - 12:20pm	**Consensus Building for Defining and Prioritizing Restoration Science and Restoration Project Needs in Southwest Florida - *Heather Rein***, Florida Gulf Coast University, Ft Myers, FL; *Mike Bauer*, Audubon of Florida, Ft. Myers, FL (p. 435)
12:20pm - 1:30pm	Lunch on Own

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 1
GEER SESSION: SOUTHWEST FLORIDA COASTAL [STIRLING BALLROOM EAST]

MODERATOR: ***Tomma Barnes***, South Florida Water Management District, Ft. Myers, FL

1:30pm - 1:40pm	**Session Introduction and Overview: *Tomma Barnes,*** South Florida Water Management District, Ft. Myers, FL
1:40pm - 2:00pm	**Florida Panther Conservation and Genetic Restoration - *Darrell Land***, Florida Fish and Wildlife Conservation Commission, Naples, FL (p. 333)
2:00pm - 2:20pm	**Southwest Florida Amphibian Monitoring Network - *John R. Cassani*** and *Ellen Lindblad*, Southwest Florida Amphibian Monitoring Network, Fort Myers, FL (p. 70)
2:20pm - 2:40pm	**The Geographical Signature of Tidal Rivers in Southwest Florida as Ecological Guiding Views for Restoring the Caloosahatchee River - *Ernest D. Estevez,*** Mote Marine Laboratory, Sarasota, FL (p. 171)
2:40pm - 3:00pm	**Water Quality and Physical Features of Goliath Grouper Nursery Habitat in the Ten Thousand Islands - *Anne-Marie Eklund***, *Steve Wong* and *Jennifer Schull*, NOAA-Fisheries, Southeast Fisheries Science Center, Miami, FL; *Matt Finn*, Huckleberry Fisheries, Goodland, FL; *Chris Koenig* and *Felicia Coleman*, Florida State University, Tallahassee, FL (p. 168)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 1
GEER SESSION: SOUTHWEST FLORIDA COASTAL (CONTINUED)

3:00pm - 3:20pm	**Modeling Circulation and Transport in Charlotte Harbor Estuarine System - *Y. Peter Sheng*** and *Kijin Park*, Coastal and Oceanographic Engineering Program, University of Florida, Gainesville, FL (p. 486)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Discharge from Caloosahatchee River that Enters Estero Bay - *Michael J. Byrne***, U.S. Geological Survey, Fort Myers, FL (p. 54)
4:00pm - 4:20pm	**An Ecological Model to Predict *Vallisneria americana* Michx. Densities in the Upper Caloosahatchee Estuary - *Melody J. Hunt,*** South Florida Water Management District, West Palm Beach Florida, FL (p. 270)
4:20pm - 4:40pm	**Establishing Minimum and Maximum Freshwater Inflows to the Caloosahatchee Estuary, FL - *Peter H. Doering*** and *Robert H. Chamberlain*, South Florida Water Management District, West Palm Beach, FL (p. 144)
4:40pm - 5:00pm	**Modeling Manatee Response to Restoration in the Everglades and Ten Thousand Islands - *Bradley M. Stith***, *Jim Reid, Dean Easton* and *Susan Butler,* U.S. Geological Survey, Center for Aquatic Resources Studies, Sirenia Project, Gainesville, FL (p. 521)
5:00pm - 5:20pm	Session Summary and Discussion
6:00pm - 8:00pm	**GEER Poster Session & Reception** [EDINBURGH BALLROOM]

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 2
GEER SESSION: SPECIES, HABITATS AND LANDSCAPES [STIRLING HALL SALONS D, E & F]

MODERATOR: *Robert Sobczak*, Big Cypress National Preserve, Ochopee, FL

10:40am - 11:00am	<u>**Management Questions and Decisions Requiring Science**</u> <u>**Invited Manager**</u>**: Science Needs of Big Cypress National Preserve – *Robert Sobczak***, on behalf of *Ron Clark*, Chief of Resource Management, Big Cypress National Preserve, Ochopee, FL
11:00am - 11:20am	**Functional Response of Three Wading Bird Species to Prey Density - *Erynn M. Call***, South Florida Water Management District, West Palm Beach, FL; *Dale E. Gawlik*, South Florida Water Management District, West Palm Beach, FL (p. 58)
11:20am - 11:40am	**A Test of the Prey Size Hypothesis as an Explanation for Decreased Wading Bird Nesting in the Southern Everglades - *Dale E. Gawlik***, Everglades Division, South Florida Water Management District, West Palm Beach, FL (p. 202)
11:40am - 12:00pm	**Avian Response to Nutrient Enrichment in the Northern Everglades - *Gaea E. Crozier*** and *Dale E. Gawlik*, South Florida Water Management District, West Palm Beach, FL (p. 113)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 2
GEER SESSION: SPECIES, HABITATS AND LANDSCAPES (CONTINUED)

12:00pm - 12:20pm	**Patterns of Movement of Florida Gar (*Lepisosteus platyrhincus*) in the Everglades Revealed by Radio Telemetry - *Lawrence F. Wolski*** and *Joel C. Trexler*, Florida International University, Miami, FL; *Jason Knouft*, Washington University, St. Louis, MO; *Carl Ruetz III*, Annis Water Resources Institute, Muskegon, MI; and *William F. Loftus*, U.S. Geological Survey, Center for Water and Restoration Studies, Miami, FL (p. 604)
12:20pm - 1:30pm	Lunch on Own

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 2
GEER SESSION: SPECIES, HABITATS, AND LANDSCAPES (CONTINUED)
[STIRLING HALL SALONS D, E & F]

MODERATOR: *Frank Mazzotti*, University of Florida, IFAS, Fort Lauderdale Research and Education Center, Ft. Lauderdale, FL

1:30pm - 1:40pm	**Management Questions and Decisions Requiring Science Invited Manager: Science Needs of Everglades National Park - *Robert Johnson***, Everglades National Park, National Park Service, Homestead, FL
1:40pm - 2:00pm	**The Role of Seasonal Hydrology in the Dynamics of Fish Communities Inhabiting Karstic Refuges of the Florida Everglades - *Robert M. Kobza*** and *William F. Loftus*, U.S. Geological Survey, Center for Water and Restoration Studies, Homestead, FL (p. 316)
2:00pm - 2:20pm	**Use of Long-term Monitoring Data for Fishes and Macroinvertebrates in the Development of Performance Measures for the Modified Water-Delivery Project - *Joel C. Trexler***, Florida International University, Miami, FL; *Frank Jordan*, Loyola University New Orleans, LA; *Carl Ruetz*, Grand Valley State University, Muskegon, MI; *John Chick*, Illinois Natural History Survey, Champaign, IL; *William F. Loftus*, U.S. Geological Survey, Miami, FL; *Sue Perry*, Everglades National Park, Homestead, FL (p. 545)
2:20pm - 2:40pm	**Spatial and Temporal Patterns of Fish Population Dynamics in the Everglades - *Carl R. Ruetz III,*** Annis Water Resources Institute, Grand Valley State University, Muskegon, MI; *Joel C. Trexler*, Department of Biological Sciences, Florida International University, Miami, FL; *Frank Jordan*, Department of Biological Sciences, Loyola University, New Orleans, LA; *William F. Loftus*, U.S. Geological Survey, Florida Center for Watershed and Restoration Studies, Everglades National Park Field Station, Homestead, FL; *Sue Perry*, Natural Resources Center, Everglades National Park, Homestead, FL (p. 456)
2:40pm - 3:00pm	**Abundance and Diet of *Rana grylio* across South Florida Wetlands - *Cristina A. Ugarte***, Department of Biological Sciences, Florida International University, Miami, FL; *Kenneth G. Rice*, U.S. Geological Survey, Center for Water and Restoration Studies, Fort Lauderdale, FL (p. 553)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 2
GEER SESSION: SPECIES, HABITATS AND LANDSCAPES (CONTINUED)

3:00pm - 3:20pm	**Distribution, Abundance, and Population Structure of a Broadly-Distributed Indicator Species, the Diamondback Terrapin (*Malaclemys terrapin*), in the Mangrove-dominated Big Sable Creek Complex of Southwest FL, Everglades National Park - *Kristen M. Hart,*** U.S. Geological Survey, Center for Coastal and Watershed Studies, and Duke University, Nicholas School of the Environment Marine Laboratory, Beaufort, NC; *Carole C. McIvor*, U.S. Geological Survey, Center for Coastal and Watershed Studies, St. Petersburg, FL; *Gary L. Hill,* U.S. Geological Survey, Center for Coastal and Watershed Studies, St. Petersburg, FL (p. 244)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Using Proportion of Area Occupied to Estimate Abundance of Amphibians in Everglades National Park and Big Cypress National Preserve - *Kenneth G. Rice,*** U.S. Geological Survey, Center for Water and Restoration Studies, Ft. Lauderdale, FL; *J. Hardin Waddle* and *H. Franklin Percival*, U.S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL (p. 441)
4:00pm - 4:20pm	**Environmental Fluctuation and Population Dynamics of Two Species of Freshwater Crayfish (*Procambarus* spp.) in the Florida Everglades -** *William F. Loftus*, U.S. Geological Survey, Florida Center for Water and Restoration Science, Homestead, FL; *Joel Trexler*, Florida International University, Miami, FL; ***A. Noble Hendrix***, University of Washington, Seattle, WA (p. 257)
4:20pm - 4:40pm	**Preliminary Results on the Effects of Environmental Parameters on Food-Web Complexity in the Florida Everglades - *Alissa J. Williams*** and *Joel C. Trexler*, Florida International University, Miami, FL (p. 559)
4:40pm - 5:00pm	**The Effects of Desiccation Duration on Periphyton Mat Community Structure and Function after Rewetting - *Andrew D. Gottlieb,*** Florida International University, Miami, FL (p. 213)
5:00pm - 5:20pm	**Session Summary and Discussion - *Frank Mazzotti,*** University of Florida, Fort Lauderdale Research and Education Center, Davie, FL
6:00pm - 8:00pm	**GEER Poster Session & Reception** [EDINBURGH BALLROOM]

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 3
GEER SESSION: IMPLEMENTING GREATER EVERGLADES ECOSYSTEM RESTORATION
[STIRLING HALL SALONS O, P & Q]

MODERATOR: ***John Ogden***, South Florida Water Management District, West Palm Beach, FL

10:40am - 10:50am	**Introduction and Session Overview: *John Ogden***, South Florida Water Management District, West Palm Beach, FL

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 3
GEER SESSION: IMPLEMENTING GREATER EVERGLADES ECOSYSTEM RESTORATION (CONTINUED)

10:50am - 11:00am	**What is "Total" Greater Everglades Ecosystem Restoration? -** ***G. Ronnie Best,*** Co-Chair, Science Coordination Team, U.S. Geological Survey, Miami, FL and ***Laura A. Brandt,*** U.S. Fish and Wildlife Service, Boynton Beach and Jacksonville, FL
11:00am - 11:20am	**Invited Manager: Implementing CERP within Total Ecosystem Restoration -** ***Dennis Duke,*** P.E., Program Manager, Ecosystem Restoration, U.S. Army Corps of Engineers, West Palm Beach, FL
11:20am - 11:40am	**Ecosystem Response as a Dynamic Guide to the Design and Operation of CERP: Major Considerations and Challenges for the RECOVER Monitoring and Assessment Plan -** ***Steve Davis***, South Florida Water Management District, West Palm Beach, FL; *Laura Brandt* and *Betty Grizzle*, U.S. Fish and Wildlife Service, Boynton Beach and Vero Beach, FL (p. 125)
11:40am - 12:00pm	**Developing Systemwide Performance Measures for the Comprehensive Everglades Restoration Plan -** ***Brenda Mills*** and *Kim Jacobs*, South Florida Water Management District, West Palm Beach, FL (p. 376)
12:00pm - 12:20pm	**A Total System Conceptual Ecological Model for South Florida -** *John C. Ogden*, South Florida Water Management District, West Palm Beach, FL; ***Tomma Barnes***, South Florida Water Management District, Fort Myers, FL; and *Steve M. Davis*, South Florida Water Management District, West Palm Beach, FL (p. 17)
12:20pm - 1:30pm	Lunch on Own

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 3
GEER SESSION: BISCAYNE BAY COASTAL SYSTEMS [STIRLING HALL SALONS O, P & Q]

MODERATOR: ***Joan Browder***, Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL

1:30pm - 1:40pm	**Management Questions and Decisions Requiring Science Invited Manager:** ***Susan M. Markley,*** Natural Resources Division Chief, Miami-Dade Department of Environmental Resources Management, Miami, FL
1:40pm - 2:00pm	**Ecosystem History of Central Biscayne Bay Based on Sediment Core Analyses -** ***G. L. Wingard***, *T.C. Cronin, D.A. Willard, J.B. Murray, R. Stamm*, U.S. Geological Survey, Reston, VA; *C.W. Holmes*, U.S. Geological Survey, St. Petersburg, FL; *G.S. Dwyer*, Duke University, Durham, NC; *S.E. Ishman, C. Williams*, Southern Illinois University, Carbondale, IL (p. 602)
2:00pm - 2:20pm	**Coupling of Hydrodynamic and Spatial Ecosystem Models to Assess Spotted Seatrout Population Risks from Exploitation and Environmental Changes -** ***Jerald S. Ault,*** *Jiangang Luo* and *John D. Wang*, University of Miami, Miami, FL (p. 12)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 3
GEER SESSION: BISCAYNE BAY COASTAL SYSTEMS (CONTINUED)

2:20pm - 2:40pm **An Ecological Risk Assessment of the Effects of the Everglades Restoration Project and Climate Variability on Biological Endpoints of Biscayne Bay and Everglades Ecosystems -** ***Mark Harwell,*** Florida A&M University, Tallahassee, FL; *Jerald Ault, Diego Lirman, David Letson, Jiangang Luo, John Wang,* University of Miami, Miami, FL; *John Gentile,* Harwell, Gentile & Assoc., Brewster, MS; *Wendell Cropper*, University of Florida, Gainesville, FL; *Don DeAngelis,* U.S. Geological Survey, Miami, FL; *Jayantha Obeysekera,* SFWMD, West Palm Beach, FL (p. 254)

2:40pm - 3:00pm **Assessment of the Effects of the Everglades Restoration Project and Climate Variability on the Growth and Survivorship of Seagrasses and Sponges of Biscayne Bay -** ***Diego Lirman,*** *Jiangang Luo, John Wang*, University of Miami, Miami, FL; *Wendell P. Cropper Jr.*, University of Florida, Gainesville, FL (p. 343)

3:00pm - 3:20pm **Airborne Lidar Sensing of Coral Reef Topographic Complexity in Biscayne National Park, Florida -** ***John C. Brock***, *Tonya D. Clayton* and *Amar Nayegandhi*, U.S. Geological Survey, Center for Coastal and Watershed Studies, St. Petersburg, FL; *C. Wayne Wright*, NASA Goddard Space Flight Center, Wallops Flight Facility, Wallops Island, VA (p. 43)

3:20pm - 3:40pm Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

3:40pm - 4:00pm **Paleoecological Determination of the Western Biscayne Bay Coastal Zone Salinity Regime Prior to Anthropogenic Alterations to the System and Estimates of Freshwater Discharge Required to Reproduce an Estuarine Condition -** ***J. Meeder,*** *P. Harlem* and *A. Renshaw*, Southeast Environmental Research Center, Florida International University, Miami, FL (p. 375)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 3
GEER SESSION: COASTAL MANGROVE ECOSYSTEMS [STIRLING HALL SALONS O, P & Q]

MODERATOR: ***Thomas Smith III,*** U.S. Geological Survey, Center for Water & Restoration Studies, c/o Center for Coastal Studies, St. Petersburg, FL

4:00pm - 4:20pm **Fish Assemblages of Tidally-Flooded Mangrove Forested Habitat along a Salinity Gradient in Shark River -** ***Carole C. McIvor,*** U.S. Geological Survey, Center for Coastal and Watershed Studies, St. Petersburg, FL; *Noah Silverman, Gary L. Hill* and *Katie Kuss*, U.S. Geological Survey, Center for Coastal and Watershed Studies, St. Petersburg, FL (p. 369)

4:20pm - 4:40pm **SELVA-MANGRO: Integrated Landscape and Stand-level Model of Mangrove Forest Response to Sea-level Rise and Hydrologic Restoration of the Everglades -** ***Thomas W. Doyle***, U.S. Geological Survey, Lafayette, LA (p. 148)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 3
GEER SESSION: COASTAL MANGROVE ECOSYSTEMS (CONTINUED)

4:40pm - 5:00pm	**The Utility of Mangrove Unit Models (FORMAN and HYMAN) in Support of the Comprehensive Everglades Restoration Plan -** ***Victor H. Rivera-Monroy****, Robert R. Twilley, Kishore Pudipeddi,* University of Louisiana-Lafayette, Center for Ecology and Environmental Technology, Lafayette, LA (p. 453)
5:00pm - 5:20pm	**Historic Conditions of Coastal Biscayne Bay and the Results of Anthropogenic Alterations on the Mangrove Ecosystem -** ***P. Harlem,*** *J. Meeder* and *A. Renshaw*, Southeast Environmental Research Center, Florida International University, Miami FL (p. 243)
6:00pm - 8:00pm	**GEER Poster Session & Reception** [EDINBURGH BALLROOM]

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 4
GEER SESSION: CONTAMINANTS AND BIOGEOCHEMICAL CYCLES IN THE GREATER EVERGLADES [STIRLING HALL SALONS L, M & N]

MODERATOR: ***Robert A. Frakes***, U.S. Fish and Wildlife Service, South Florida Field Office (SFFO), Vero Beach, FL

10:40am - 11:00am	**Management Questions and Decisions Requiring Science Invited Manager: Mercury in Florida's Environment -** ***Tom Atkeson,*** Mercury Coordinator, Florida Department of Environmental Protection, Tallahassee, FL
11:00am - 11:20am	**Sulfur Contamination and Geochemistry of the Everglades -** ***William Orem****, Harry Lerch, Anne Bates, Margo Corum* and *Marisa Beck,* U.S. Geological Survey, Reston, VA (p. 409)
11:20am - 11:40am	**Interactions of Dissolved Organic Matter with Mercury in the Florida Everglades -** ***George Aiken,*** U.S. Geological Survey, Boulder, CO (p. 5)
11:40am - 12:00pm	**Unraveling the Complexities of Mercury Methylation in the Everglades: The Use of Mesocosms to Test the Effects of "New" Mercury, Sulfate, Phosphate, and Dissolved Organic Carbon -** ***David P. Krabbenhoft,*** U.S. Geological Survey, Middleton, WI; *William H. Orem*, U.S. Geological Survey, Reston, VA; *George Aiken*, U.S. Geological Survey, Boulder, CO; *Cynthia Gilmour,* Academy of Natural Sciences, St. Leonard, MD (p. 323)
12:00pm - 12:20pm	**Impact of Photooxidation and Cometabolism on Petroleum Degradation by Bacteria from Pristine and Oil-contaminated Sites -** ***Milton Clarke,*** *Richard Gragg* and *Jennifer Cherrier*, Florida Agricultural and Mechanical University, Tallahassee, FL; *Jeff Chanton*, Florida State University, Tallahassee, FL (p. 85)
12:20pm - 1:30pm	Lunch on Own

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 4
GEER SESSION: CONTAMINANTS AND BIOGEOCHEMICAL CYCLES IN THE GREATER EVERGLADES (CONTINUED) [STIRLING HALL SALONS L, M & N]

MODERATOR: ***David P. Krabbenhoft***, U.S. Geological Survey, Middleton, WI

1:30pm - 1:40pm	**Introduction and Session Overview:** ***David P. Krabbenhoft***, U.S. Geological Survey, Middleton, WI
1:40pm - 2:00pm	**Biogeochemical and Hydrologic Controls on Food Web Structure in the Everglades -** ***Carol Kendall***, *Bryan E. Bemis*, and *Scott D. Wankel*, U.S. Geological Survey, Menlo Park, CA; *Ted Lange*, Florida Fish and Wildlife Conservation Commission, Eustis, FL; *David P. Krabbenhoft*, U.S. Geological Survey, Middleton, WI (p. 300)
2:00pm - 2:20pm	**Spatial and Temporal Patterns of Mercury Bioaccumulation in Largemouth Bass in the Everglades -** ***Ted R. Lange***, *Doug A. Richard* and *Bethany E. Sargent*, Florida Fish and Wildlife Conservation Commission, Eustis, FL (p. 335)
2:20pm - 2:40pm	**Using Nitrogen and Carbon Isotopes to Explain Mercury Variability in Largemouth Bass -** ***Bryan E. Bemis*** and *Carol Kendall*, U.S. Geological Survey, Menlo Park, CA; *Ted Lange*, Florida Fish and Wildlife Conservation Commission, Eustis, FL; *Linda Campbell*, National Water Research Institute, Environment Canada, Burlington, ONT, Canada (p. 24)
2:40pm - 3:00pm	**The Rise and Fall of Mercury Contamination in Everglades Biota, 1890 - 2003: A Retrospective Study of Wading Bird Museum Specimens -** ***Peter C. Frederick***[1], *Becky Hylton*[1], *Julie A. Heath*[1] and *Marilyn G. Spalding*[2]. (1. Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL; 2. Department of Pathobiology, School of Veterinary Medicine, University of Florida, Gainesville, FL (p. 188)
3:00pm - 3:20pm	**Is Food Web Structure a Main Control on Mercury Concentrations in Fish in the Everglades? -** ***Carol Kendall*** and *Bryan E. Bemis*, U.S. Geological Survey, Menlo Park, CA; *Joel Trexler*, Florida International University, Miami, FL; *Ted Lange*, Florida Fish and Wildlife Conservation Commission, Eustis, FL; *Q. Jerry Stober*, U.S. Environmental Protection Agency, Athens, GA (p. 303)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Occurrence and Transport of IRGAROL 1051, a New Antifouling Herbicide, and Its Major Metabolite in Coastal Waters from Biscayne Bay and the Florida Keys -** ***Piero R. Gardinali***[*1] and *Charles Maxey*[1]; [1]Department of Chemistry, and [2]Southeast Environmental Research Center (SERC), Florida International University, University Park, Miami, FL (p. 198)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 4
GEER SESSION: CONTAMINANTS AND BIOGEOCHEMICAL CYCLES IN THE GREATER EVERGLADES (CONTINUED)

4:00pm - 4:20pm **Screening Level Probabilistic Aquatic Ecological Risk Assessment of Canal C-111 and Adjacent Coastal Areas - *G. M. Rand*** and *J. F. Carriger*, Southeast Environmental Research Center, Florida International University, Miami, FL (p. 428)

4:20pm - 4:40pm **Variation of Soil Topography and Soil Forming Factors between Ridge and Slough Communities - *M. W. Clark***, *K. R. Reddy, E. Jorczak* and *C. Lewis*, Wetland Biogeochemistry Laboratory, University of Florida, Gainesville, FL (p. 83)

4:40pm - 5:00pm **Interactions of Vegetation, Hydrology, and Soils in Everglades National Park Tree Islands: Phosphorus Biogeochemistry of Soils - *Krish Jayachandran,*** *Seema Sah, Jay Sah* and *Mike Ross*, Department of Environmental Studies and Southeast Environmental Research Center, Florida International University, Miami, FL (p. 288)

5:00pm - 5:20pm **Using Multivariate Statistics to Identify Sensitive Biogeochemical Indicators in the Northern Everglades - *R. Corstanje*** and *K. R. Reddy,* Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida-IFAS, Gainesville, FL; *K. M. Portier,* Statistics Department, University of Florida, Gainesville, FL (p. 101)

5:20pm - 5:40pm **Effects of Microhabitats on Stable Isotopic Composition of Biota in the Florida Everglades - *Scott D. Wankel*** and *Carol Kendall*, U.S. Geological Survey, Menlo Park, CA; *Paul McCormick* and *Robert Shuford*, South Florida Water Management District, West Palm Beach, FL (p. 578)

6:00pm - 8:00pm **GEER Poster Session & Reception** [EDINBURGH BALLROOM]

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 5
GEER SESSION: INVASIVE EXOTIC SPECIES: MODELING AND REGIONAL PERSPECTIVE
[STIRLING HALL SALONS I, J & K]

MODERATOR: *Robert F. Doren*, Ecologist, U.S. Department of Interior at Florida, International University, Miami, FL

1:30pm - 1:40pm <u>**Introduction and Session Overview**</u>**: *Robert F. Doren,*** Ecologist, U.S. Department of Interior at Florida International University, Miami, FL

1:40pm - 2:00pm **Detecting Invasive Exotic Plants - Synoptic Summary of February 2003 Workshop - *Robert F. Doren,*** Ecologist, U.S. Department of Interior at Florida International University, Miami, FL

2:00pm - 2:20pm **Modeling the Spread and Control of *Lygodium microphyllum* in A.R.M. Loxahatchee NWR - *Scott M. Duke-Sylvester*** and *Louis J. Gross,* University of Tennessee, Knoxville, TN (p. 160)

2:20pm - 2:40pm **The Life History Patterns of the Invasive Fern, *Lygodium microphyllum,* at the Whole-plant, Community and Landscape Scale - *John C. Volin***, *Michael J. Lott*, *Jordan D. Muss, Dianne Owen* and *Joy E. Stewart*, Florida Atlantic University, Davie, FL (p. 562)

THURSDAY, APRIL 17, 2003 - CONCURRENT SESSION 5
GEER SESSION: INVASIVE EXOTIC SPECIES: MODELING AND REGIONAL PERSPECTIVE (CONTINUED)

2:40pm- 3:00pm	**Conceptualizing *Melaleuca quinquenervia* Invasion: A Feedback System between the Plant and Its Soil Biota - *Dorota L. Porazinska,*** *Monica L. Elliot* and *Robin M. Giblin-Davis,* University of Florida, Fort Lauderdale, FL; *Paul D. Pratt*, USDA/ARS, Fort Lauderdale, FL (p. 427)
3:00pm - 3:20pm	**Everglades Plant Community Invasibility and Facilitation of Invasion by Native Plant Species - *Jennifer Richards***, Florida International University, Miami, FL (p. 444)
3:20pm - 3:40pm	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]
3:40pm - 4:00pm	**Statistical Tests for Effects of Introduced Fishes on Native Fish Communities Inhabiting Wet Prairie and Mangrove Habitats in South Florida - *Joel C. Trexler,*** Florida International University, Miami, FL; *Jerome J. Lorenz,* National Audubon Society, Tavernier, FL; *William F. Loftus*, U.S. Geological Survey, Miami, FL (p. 543)
4:00pm - 4:20pm	**Non-Indigenous Fishes in Restored and Natural Wetlands on the Big Cypress Seminole Indian Reservation - *Kristine J. Dunker*** and *John C. Volin,* Florida Atlantic University, Davie, FL; *William Loftus,* U.S. Geological Survey, Center for Water and Restoration Studies, Miami, FL (p. 164)
4:20pm - 4:40pm	**Changes in the Fish Fauna of the Kissimmee River Basin, Peninsular Florida: Non-Native Additions - *Leo G. Nico,*** U.S. Geological Survey, Gainesville, FL (p. 399)
4:40pm - 5:00pm	Session Summary and Discussion
6:00pm - 8:00pm	**GEER Poster Session & Reception** [EDINBURGH BALLROOM]

Friday, April 18, 2003

7:30am - 12:00pm	Conference Registration Office Open [STIRLING HALL SALONS A, B & C]
7:30am - 8:30am	Early Morning Refreshments in Poster Display Area [EDINBURGH BALLROOM]

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 1
GEER SESSION: KISSIMMEE RIVER [STIRLING HALL BALLROOM EAST]

MODERATOR: *David J. Colangelo*, South Florida Water Management District, West Palm Beach, FL

8:30am - 8:40am	**Management Questions and Decisions Requiring Science Invited Manager: Helping Achieve Kissimmee River Restoration Success with Science-Based Operational Decisions - *Shawn P. Sculley, Sr.,*** P.E., Director, Kissimmee Division, South Florida Water Management District, West Palm Beach, FL

Friday, April 18, 2003 - Concurrent Session 1
GEER Session: Kissimmee River (continued)

8:40am - 9:00am	**Reestablishing the Hydrogeomorphic Habitat Templet in the Kissimmee River - *David H. Anderson,*** Kissimmee Division, South Florida Water Management District, West Palm Beach, FL (p. 8)
9:00am - 9:20am	**Dissolved Oxygen in the Kissimmee River: Baseline Condition and Initial Response to Restoration - *David J. Colangelo***, South Florida Water Management District, Kissimmee Dept., West Palm Beach, FL (p. 92)
9:20am - 9:40am	**Total Phosphorus Trends in the Greater Everglades Headwaters: Upper Kissimmee Chain-of-Lakes - *Nellie Morales,*** South Florida Water Management District, West Palm Beach, FL (p. 385)
9:40am - 10:00am	**Benefit of Kissimmee River Restoration to Lake Okeechobee Phosphorus Control - *Bradley L. Jones,*** South Florida Water Management District, West Palm Beach, FL (p. 293)
10:00am - 10:20am	**Water Quality Considerations in the Study of the Groundwater - Surface Water Interactions Occurring During the Kissimmee River Restoration - *Paul R. McGinnes,*** *Cynthia Gefvert*, *Brad Jones* and *Steve Krupa*, South Florida Water Management District, West Palm Beach, FL (p. 368)
10:20am - 10:40am	Refreshment Break in Poster Display Area [Edinburgh Ballroom]
10:40am - 11:00am	**The Effects of Cattle Grazing on Flora and Fauna in the Kissimmee River Valley, Florida - *Peter G. David*** and *David Black,* South Florida Water Management District, West Palm Beach, FL (p. 122)
11:00am - 11:20am	**Initial Responses of In-Channel Littoral Vegetation to Restored Flow in The Kissimmee River - *Stephen G. Bousquin,*** Kissimmee Division, South Florida Water Management District, West Palm Beach, FL (p. 39)
11:20am - 11:40am	**A Summary of Baseline Vegetation Data for Phase I of the Kissimmee River Restoration Project and Expectations for Wetland Vegetation Recovery in the Restored System - *Laura Carnal,*** South Florida Water Management District, West Palm Beach, FL (p. 67)
11:40am - 12:00pm	**Using Aquatic Invertebrates to Assess Restoration of the Kissimmee River Ecosystem - *Joseph W. Koebel Jr.,*** South Florida Water Management District, West Palm Beach, FL (p. 319)
12:00pm - 12:20pm	**Importance of Floodplain Wetlands to Restoration of the Kissimmee River Fishery - *J. Lawrence Glenn III,*** South Florida Water Management District, West Palm Beach, FL (p. 212)
12:20pm - 1:00pm	GEER Poster Presenters to Remove Displays
1:00pm	Conference Concludes

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 2
GEER SESSION: SPECIES, HABITATS AND LANDSCAPES [STIRLING HALL SALONS D, E & F]

MODERATOR: ***Nat Frazer***, Chair, Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL

8:30am - 8:40am	**Introduction and Session Overview:** ***Nat Frazer,*** *Chair,* Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL
8:40am - 9:00am	**Spatial Pattern and Scale of Everglades Macroinvertebrate Communities along Nutrient and Hydroperiod Gradients -** ***Shawn E. L. Smith*** and *Joel C. Trexler*, Florida International University, Miami, FL (p. 500)
9:00am - 9:20am	**The Pollination Ecology of Everglades Sawgrass, *Cladium jamaicense* (Cyperaceae) -** ***Jenise M. Snyder*** and *Jennifer H. Richards,* Florida International University, Miami, FL (p. 514)
9:20am - 9:40am	**The Response of Everglades Tree Species to Simulated Hydrologic Regimes: An Experimental Study -** ***Michael S. Ross,*** *David T. Jones, Bernice Hwang, Joshua Walters*, Southeast Environmental Research Center, Florida International University, Miami, FL; *Steve Oberbauer,* Department of Biological Sciences, Florida International University, Miami, FL; *Krish Jayachandran,* Southeast Environmental Research Center and Department of Environmental Studies, Florida International University, Miami, FL (p. 454)
9:40am - 10:00am	**What We Know and Should Know about Tree Islands -** ***Fred H. Sklar***, South Florida Water Management District, West Palm Beach, FL (p. 499)
10:00am - 10:20am	**Effect of Hydropattern Changes on Ecological and Biological Properties of Forested Wetlands Located in the Central Everglades: A Tree Island Monitoring Program -** ***C. Coronado-Molina***, *M. Korvela, L. Bauman, A. Gras* and *F. Sklar*, South Florida Water Management District, West Palm Beach, FL (p. 99)
10:20am - 10:40am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 2
GEER SESSION: FIRE IN THE GREATER EVERGLADES ECOSYSTEM

MODERATOR: ***James R. Snyder***, U.S. Geological Survey, Ochopee, FL

10:40am - 11:20am	**Assuring the Role of Fire in the 2050 Greater Everglades Ecosystem -** ***Michael J. Duever,*** South Florida Water Management District, Fort Myers, FL (p. 152)
11:20am - 11:40am	**The Role of Invasive Plants in Restoring Fire to the Greater Everglades System -** ***Judy Haner,*** Florida Department of Environmental Protection, Rookery Bay National Estuarine Research Reserve, Naples, FL (p. 242)
11:40am - 12:00pm	**The Role of Fire in Maintaining Wet Prairies within the DuPuis Management Area -** ***David W. Black***, South Florida Water Management District, West Palm Beach, FL (p. 28)

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 2
GEER SESSION: FIRE IN THE GREATER EVERGLADES ECOSYSTEM (CONTINUED)

12:00pm - 12:20pm	**Fuel Loads in the Understory of Florida Keys Pine Forests along a Chronosequence of Time Since Last Fire - *Jay P. Sah,*** *Michael S. Ross, Suzanne Koptur, Chris Borg* and *Hong Liu*, Florida International University, Miami, FL; *James Snyder*, U.S. Geological Survey, Ochopee, FL (p. 457)
12:20pm - 12:40pm	**The Role of Fire in the Restoration of Everglades Wetland Communities - *James W. Pahl*** and *Curtis J. Richardson*, Duke University Wetland Center Nicholas School of the Environment and Earth Sciences, Durham, NC (p. 414)
12:40pm - 1:00pm	GEER Poster Presenters to Remove Displays
1:00pm	Conference Concludes

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 3
GEER SESSION: WATER QUALITY: SOILS AND BIOTIC INTERACTIONS
[STIRLING HALL SALONS O, P & Q]

MODERATOR: ***Mark Clark***, Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida, IFAS, Gainesville, FL

8:30am - 8:40am	**Management Questions and Decisions Requiring Science Invited Manager: *Melissa L. Meeker***, Florida Operations Manager, Foster Wheeler Environmental Corporation {Formerly: Director of District Management, Florida DEP, Southeast District Office}, Stuart, FL
8:40am - 9:00am	**Linking Historic, Present and Future Spatial Variability of Soil Attributes in the Greater Everglades Ecosystem - *S. Grunwald*,** *T.F.A. Bishop* and *K. R. Reddy*, Soil and Water Science Department, University of Florida, Gainesville, FL and *S. Newman*, South Florida Water Management District, West Palm Beach, FL (p. 227)
9:00am - 9:20am	**Predicting Trophic Level Responses To Phosphorus Concentrations In The Everglades - *Curtis J. Richardson***, Duke University Wetland Center, Durham, NC (p. 450)
9:20am - 9:40am	**Responses of Midges (Diptera: Chironomidae & Ceratopogonidae) to Canal Inflows, and to Phosphorus-dosing in Flume Arrays, in Everglades National Park - *Richard E. Jacobsen*** and *Sue A. Perry*, South Florida Natural Resources Center, Everglades National Park, Homestead, FL (p. 281)
9:40am - 10:00am	**Microbial Trophic Levels within the Carbon Cycle in Oligotrophic and Nutrient Impacted Regions of Water Conservation Area 2-A - *Andrew Ogram*,** *Ashvini Chauhan, Hector Castro, Ilker Uz* and *K. R. Reddy*, University of Florida, Gainesville, FL (p. 407)
10:00am - 10:20am	**Litter Quality Versus Environmental Conditions: What Regulates Decomposition? - *Sue Newman,*** *C. Ryan Penton, Italia Gray* and *Megan Jacoby*, Everglades Division, South Florida Water Management District, West Palm Beach, FL (p. 397)
10:20am - 10:40am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 3
GEER SESSION: WATER QUALITY: SPATIAL AND TEMPORAL PATTERNS IN SELECT WATERSHEDS

MODERATOR: ***Sue Newman***, South Florida Water Management District, West Palm Beach, FL

10:40am - 11:00am	**Characterization of Solute and Fine-Particle Transport in Shark Slough, Everglades National Park by a Tracer Release in the FIU *In Situ* Flumes - *Judson W. Harvey*[1]**, *James E. Saiers*[2], *James M. Krest*[1], *Steven Mylon*[2], *Jessica T. Newlin*[1], *Christine Taylor*[3] and *Evelyn E. Gaiser*[3;] [1]U.S. Geological Survey, Reston, VA; [2]Yale University, New Haven, CT; [3]Florida International University, Miami, FL (p. 249)
11:00am - 11:20am	**Spatial and Temporal Patterns of Surface Water Quality on the Big Cypress Seminole Indian Reservation - *Dianne Owen*** and *John C. Volin,* Florida Atlantic University, Davie, FL; *William A. Dunson*, Pennsylvania State University, University Park, PA (p. 412)
11:20am - 11:40am	**Changes in Ecosystem Macronutrient Budgets, Microbial Characteristics, and Vegetation Patterns, along Phosphorus-enrichment Gradients in Everglades Wetlands - *Leonard J. Scinto,*** *Daniel L. Childers*, *Evelyn E. Gaiser*, *Ronald D. Jones*, *Michael Rugge* and *Joel Trexler*, Florida International University (FIU), Miami, FL; *Robert F. Doren*, Department of the Interior, Miami, FL; *Gregory B. Noe*, United States Geologic Survey, Reston, VA; *William A. VanGelder*, Southwest Florida Water Management District, Bartow, FL (p. 479)
11:40am - 12:00pm	**Experimental Phosphorus Enrichment in Everglades National Park: I. Approach and Methods - *Evelyn E. Gaiser,*** *Adrienne Edwards, Krish Jayachandran, Ronald Jones, David Lee, Thomas Philippi, Jennifer Richards, Leonard Scinto, Joel Trexler*, Florida International University, Miami, FL (p. 190)
12:00pm - 12:20pm	**Experimental Phosphorus Enrichment in Everglades National Park: II. Results -** *Evelyn E. Gaiser, Adrienne Edwards, Krish Jayachandran, Ronald Jones, David Lee, Thomas Philippi,* ***Jennifer Richards****, Leonard Scinto, Joel Trexler,* Florida International University, Miami, FL (p. 447)
12:20pm - 12:40pm	**Experimental Phosphorus Enrichment in Everglades National Park: III. Application to Large-scale Pattern of Enrichment in Everglades Marshes - *Evelyn E. Gaiser***, *Daniel Childers, Krish Jayachandran, Ronald Jones, David Lee, Greg Noe, Thomas Philippi, Jennifer Richards, Leonard Scinto, Joel Trexler,* Florida International University, Miami, FL (p. 193)
12:40pm - 1:00pm	GEER Poster Presenters to Remove Displays
1:00pm	Conference Concludes

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 4
GEER SESSION: INVASIVE EXOTIC SPECIES: ORGANISM CASE STUDIES
[STIRLING HALL SALONS L, M & N]

MODERATOR: ***Joel Trexler***, Florida International University, Miami, FL

8:30am - 8:40am	<u>**Introduction and Session Overview**</u>**:** ***Joel Trexler***, Florida International University, Miami, FL
8:40am - 9:00am	**Snakehead Fishes and Florida Waters -** ***Walter R. Courtenay, Jr.***, U.S. Geological Survey, Center for Aquatic Resources Studies, Gainesville, FL (p. 105)
9:00am - 9:20am	**Molecular Forensics of Introduced Swamp Eels (Synbranchidae) -** ***Timothy Collins***, *Matthew Osentoski*, Department of Biological Sciences, Florida International University, Miami, FL; *Leo G. Nico*, Florida Caribbean Science Center, U.S. Geological Survey, Gainesville, FL (p. 95)
9:20am - 9:40am	**Variation among *Melaleuca quinquenervia* (Myrtaceae) Populations in Florida and Its Influence on Performance of the Biological Control Agent *Oxyops vitiosa* (Coleoptera: Curculionidae) -** ***F. Allen Dray Jr.***, USDA, ARS Invasive Plant Research Laboratory; Fort Lauderdale, FL (p. 151)
9:40am - 10:00am	**The Effects of the Cuban Treefrog (*Osteopilus septentrionalis*) on Native Treefrog Populations within Everglades National Park -** *Kenneth G. Rice*, U.S. Geological Survey, Center for Water and Restoration Studies, Ft. Lauderdale, FL; *J. Hardin Waddle*, U.S. Geological Survey, Big Cypress Field Station, Ochopee, FL; ***Marquette E. Crockett*** and *Amber D. Dove*, U.S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, Everglades Field Station, Homestead, FL (p. 111)
10:00am - 10:20am	Refreshment Break in Poster Display Area [EDINBURGH BALLROOM]

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 4
GEER SESSION: INVASIVE EXOTIC SPECIES: ORGANISM CASE STUDIES (CONTINUED)

MODERATOR: ***Tim Collins***, Florida International University, Miami, FL

10:20am - 10:40am	**Biological Control of Invasive Plants in Everglades Ecosystems -** *Ted D. Center* and ***F. Allen Dray Jr.***, USDA, ARS Invasive Plant Research Laboratory; Fort Lauderdale, FL (p. 150)
10:40am - 11:00am	**It's the End of the World As We Know It - *Lygodium microphyllum* is Strangling the Everglades Restoration Project -** ***Patrick Gleason***, *Amy Ferriter* and *Ken Rutchey*, South Florida Water Management District, West Palm Beach, FL; *Antionio Pernas* and *Bob Doren*, Department of Interior, Miami, FL; *Bob Pemberton*, United States Department of Agriculture, Davie, FL; *John Volin*, Florida Atlantic University, Davie, FL; *Ken Langeland*, University of Florida, Gainesville, FL (p. 210)

FRIDAY, APRIL 18, 2003 - CONCURRENT SESSION 4
GEER SESSION: INVASIVE EXOTIC SPECIES: ORGANISM CASE STUDIES (CONTINUED)

11:00am - 11:20am	**The Growth and Physiological Ecology of Two Invasive Non-indigenous Fern Species, *Lygodium microphyllum* and *Lygodium japonicum* - *Michael S. Lott*** and *John C. Volin*, Florida Atlantic University, Davie, FL (p. 350)
11:20am - 11:40am	**Recent Fish Introductions into Southern Florida Freshwaters, with implications for the Greater Everglades Region - *William F. Loftus*** and *Leo G. Nico*, U. S. Geological Survey, Florida Integrated Science Center, Miami and Gainesville, FL; *Jeffrey Kline* and *Sue A. Perry*, Everglades National Park, Homestead, FL; *Joel C. Trexler*, Florida International University, Miami, FL (p. 347)
11:40am - 12:00pm	Session Summary and Discussion
12:00pm - 1:00pm	GEER Poster Presenters to Remove Displays
1:00pm	Conference Concludes

GEER Poster Directory

All GEER Posters will be on display from 8:30am, Wednesday, April 16 through 12noon, Friday, April 18. Two formal poster sessions are scheduled on Wednesday and Thursday evenings from 6pm – 8pm. Presenters will be stationed at their posters from 7pm-8pm.

(Please see the Florida Bay Abstract Book for a list of Florida Bay poster presentations.)

41........**Long-Term Data from the USGS/BRD Mangrove Hydrology Sampling Network in Everglades National Park - *Gordon H. Anderson,*** U.S. Geological Survey, Center for Water & Restoration Studies, Homestead, FL; *Thomas J. Smith III*, U.S. Geological Survey, Center for Water & Restoration Studies, St. Petersburg, FL (p. 9)

101......**The Role of Flow in the Everglades Ridge and Slough Landscape - *Nicholas G. Aumen*** (for the Science Coordination Team), Everglades National Park, Homestead, FL (p. 13)

97........**Water Velocity and Suspended Solids Concentrations in the Proximity of Tree Islands in Everglades National Park - *Jose Bazante*** and *Helena M. Solo-Gabriele,* University of Miami, Dept. of Civil, Arch., and Environmental Engineering, Coral Gables, FL; *Michael Ross* and *Daniel L. Childers,* Southeast Environmental Research Center, Florida International University, Miami, FL; *Sherry Mitchell*, Everglades National Park, Homestead, FL; and *Lynn Leonard*, University of North Carolina at Wilmington, Department of Earth Science and Geology, Wilmington, NC (p. 19)

56........**Isotopic Evidence for Spatial and Temporal Changes in Everglades Food Web Structure - *Bryan E. Bemis*,** *Carol Kendall* and *Scott D. Wankel*, U.S. Geological Survey, Menlo Park, CA; *Ted Lange,* Florida Fish and Wildlife Conservation Commission, Eustis, FL; *David P. Krabbenhoft*, U.S. Geological Survey, Madison, WI (p. 22)

20........**Late Holocene History of Oyster Reef Development in Estero Bay, Southwest Florida: Implications for Management and Future Coastal Environmental Change - *Todd Bost,*** *Harry Phillips, Heather Rein, Michael Chichester, Gayle Boyle, Christal Glinka, Carrie Moore, Dustin Cartee, Randy Hutto* and *Michael Savarese*, Florida Gulf Coast University, Ft. Myers, FL (p. 36)

82........**Alligator Surveys at A. R. M. Loxahatchee National Wildlife Refuge - *Laura A. Brandt,*** U.S. Fish and Wildlife Service, Boynton Beach, FL; and *Frank J. Mazzotti,* University of Florida, Davie, FL (p. 40)

84........**Preliminary Results on Crayfish Populations in The Freshwater Marshes/Coastal Mangrove Ecotones of the C-111 Basin, Everglades National Park - *M. C. Bruno,*** *O. Beceiro* and *S.A. Perry,* South Florida Natural Resources Center, Everglades National Park, Homestead, FL (p. 50)

19........**Monitoring and Mapping Salinity Patterns in Estero Bay, Southwestern Florida - *Michael J. Byrne,*** U.S. Geological Survey, Fort Myers, FL (p. 56)

28........**Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project: Integration of Bioeroding Sponge (Genus *Cliona*) Survey - *Michael K. Callahan,*** Florida Marine Research Institute, St. Petersburg, FL; *Christine A. Ward-Paige* and *Michael J. Risk,* McMaster University, Hamilton, Ont., Canada (p. 61)

GEER Abstracts

- Listed alphabetically by presenting author.
- Presenting author appears in **bold**.

Weather Station-Based Potential Evapotranspiration Computation Model and Database for Central and South Florida

Wossenu Abtew, *J. Obeysekera*, *A. Reardon* and *N. Duerr*
South Florida Water Management District, West Palm Beach, FL

Evapotranspiration is one of the major parameters in south Florida hydrology. As a major component of the hydrologic cycle, there is a need for reasonably accurate estimates of evaporation from water bodies and evapotranspiration from vegetation. It is a parameter whose measurement or estimation had been a challenge. Evapotranspiration depends on the availability of energy, on the mechanism of mass transfer, energy transfer and the availability of water. Evaporation and evapotranspiration are functions of solar radiation, temperature, wind speed, vapor pressure deficit, atmospheric pressure, characteristics of the surrounding environment and type and condition of vegetation. South Florida is an area of high rainfall, high humidity and generally low wind speed. Air temperature is high with relatively warm winter months. Solar radiation is abundant with seasonal and daily variation. Most of the variation of daily ET is explained by solar radiation.

There are 25 weather stations in the South Florida Water Management District monitoring network. Solar radiation, humidity, wind speed and air temperature sensors are common equipment in the weather stations. Some are equipped with net radiometers to measure net solar radiation. At the South Florida Water Management District, a computer program, ET_SF, was developed to directly access a meteorological database holding fifteen minute interval field observations and then compute potential ETp using each of the six methods with varying complexity. The program can access data from all the weather stations in the network and computes ETp for the respective site. Figure 1 depicts graphic interface of the ETp computation program. Daily potential ETp data is stored in the corporate hydrometeorologic database, DBHYDRO, which is accessible through the Web. Areal estimates of ETp can be generated from the point estimates at the weather stations.

Annual average air temperature is 23.1 ^{o}C with monthly average temperature increasing from 17.9 ^{o}C in January to 27.4 ^{o}C in August. The average wind speed is 3.1 m s^{-1}. The annual average relative humidity is 80.7% with annual average minimum and maximum values of 67% and 92%, respectively. The area has significant sunshine with an annual average solar radiation flux rate of 0.1908 kw m^{-2}. Table 1 depicts the monthly average meteorological parameters as computed from weather stations with varying lengths of record from 1988 to 2002. The areal average annual ETp is 130.1 cm.

A network of weather stations and an ETp computation software developed in-house is currently being used to develop a daily ETp database at the South Florida Water Management District. A simple ETp estimation model that was previously calibrated with lysimeter data is being applied.

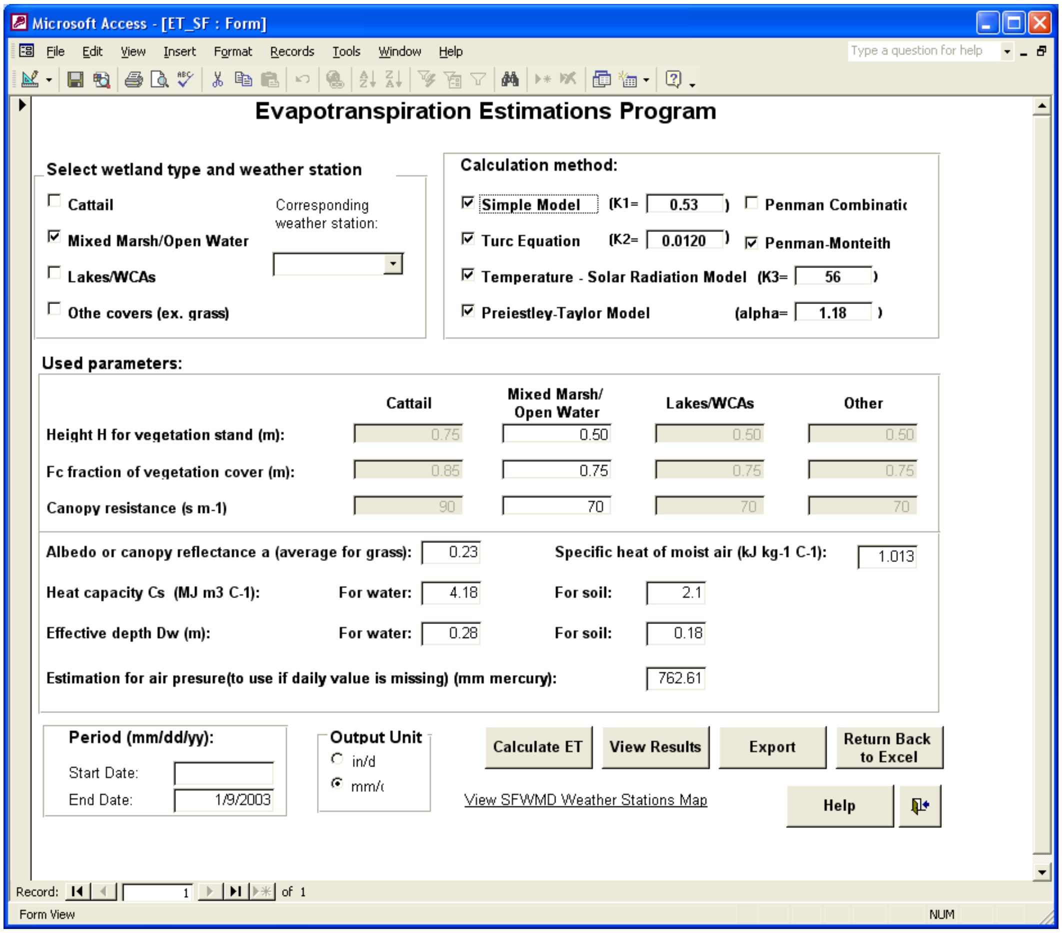

Figure 1. Graphic Interface of the ETp Computation Program, ET_SF.

Table 1. District-wide average monthly weather parameters.

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tmean (oC)	17.9	19.0	20.6	22.7	25.0	26.6	27.3	27.4	26.3	24.8	21.5	18.8
Tmax (oC)	23.2	23.3	24.8	25.9	27.3	28.5	29.2	29.2	28.0	27.5	25.2	23.3
Tmin (oC)	9.7	12.0	14.7	18.0	21.8	24.3	24.7	24.5	23.8	20.3	16.1	10.5
Rhmin (%)	62.8	63.9	60.9	58.3	65.2	71.6	73.1	74.3	74.3	67.1	67.0	65.9
Rhmax (%)	94.0	92.2	91.3	89.6	90.1	90.9	90.8	91.2	92.7	92.5	93.9	95.0
WS@10m (m/s)	3.22	3.42	3.66	3.56	3.18	2.73	2.53	2.53	2.69	3.18	3.31	3.11
Rs (MJ M^{-2} d^{-1})	11.87	14.62	18.14	20.44	21.40	19.43	19.15	18.58	16.06	14.69	12.34	10.91
ETp (mm/d)	2.57	3.16	3.93	4.42	4.63	4.20	4.14	4.02	3.47	3.18	2.67	2.36
Rainfall (cm)	5.59	5.99	7.45	6.55	11.84	19.94	17.73	17.86	18.36	11.99	5.84	4.83

References:

Abtew, W., 1996, Evapotranspiration Measurements and Modeling for Three Wetland Systems in South Florida. Journal of the American Water Resources Association. 32 (3): 465-473.

Reardon, A. and Abtew, W., 2002, Evapotranspiration Estimation for South Florida-Documentation for Program ET_SF. Environmental Monitoring and Assessment Department. South Florida Water Management District, West Palm Beach, FL.

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Interactions of Dissolved Organic Matter with Mercury in the Florida Everglades

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Interactions of mercury (Hg) with dissolved organic matter (DOM) are hypothesized to play important roles in controlling the reactivity, bioavailability and transport of Hg in the Everglades. Little is known, however, about how Hg interacts with DOM or how strong these interactions are. The questions being addressed by this research are: 1) By what mechanisms and how strongly does Hg interact with DOM, and 2) What role do these mechanisms play in controlling the effects that Hg has on organisms. This research is driven by the hypothesis that the chemistry and structural characteristics of the DOM in the Everglades strongly influence the processes that control Hg cycling and bioavailability in the environment. A combined field/laboratory approach designed to characterize DOM in the Everglades and to relate the structural characteristics of the DOM to its reactivity with Hg is being used to test this hypothesis.

Most of the DOM in the Everglades originates from the degradation and leaching of organic detritus derived from the algae, bacteria and macrophytes living within the wetland environment. In addition, organic matter is also transported to the Water Conservation Areas of the Everglades in the canals that drain the Everglades Agricultural Area. Areas strongly influenced by the Everglades Agricultural Area had higher dissolved organic carbon (DOC) concentrations, had a greater amount of hydrophobic acids and hydrophobic neutrals, and the DOM was more aromatic than samples collected from less impacted areas. Pore waters were found to contain greater DOC concentrations than overlying surface waters, with the highest DOC concentrations in pore waters from the more eutrophic study areas. DOC concentrations and the contributions of aromatic organic molecules to the pool of molecules comprising the DOM were lower in those areas with higher concentrations of methylmercury. The amount and nature of DOM in the Everglades was found to be dependent on the dominant vegetation types, hydroperiod, interactions of surface water with peat pore waters, and interactions with canal water.

To better define the nature and strength of interactions between DOM and Hg, the hydrophobic acid fraction (HPOA), hydrophilic acid fraction (HPIA), hydrophobic neutral fraction (HPON), fulvic acid and humic acid were isolated from various surface waters in the Florida Everglades. Using these isolates, Hg-DOM binding constants were determined over a wide range of Hg(II) to DOM concentration ratios by means of a modified equilibrium dialysis ligand exchange method. Very strong interactions ($K_{DOM}' = 10^{23.2\pm0.5}$ L kg^{-1} at pH = 7.0 and I = 0.1), indicative of Hg-thiol bonds, were observed at Hg(II)/DOM ratios below approximately 1 μg Hg(II) per mg DOM. Hg(II)/DOM ratios above approximately 10 μg Hg(II) per mg DOM gave much lower K_{DOM}' values ($10^{10.7\pm0.5}$ L kg^{-1} at pH = 4.9 to 5.6 and I = 0.1), consistent with Hg(II) binding mainly to oxygen functional groups. These results suggest that the binding of Hg(II) to DOM under natural conditions (very low Hg(II)/DOM ratios ranging from 0.01 to 10 ng of Hg/mg of DOM) is controlled by a small fraction of DOM molecules containing reactive thiol functional groups. Similar strong Hg-DOM binding constants were obtained in studies of the partitioning of Hg(II) between DOM and particulate organic matter (POM). In this work, the HPOA isolate from F1, a northern, eutrophic site, was more effective at competing with POM for Hg(II) than the sample from 2BS, a more pristine site.

Under most environmental conditions, therefore, it can be expected that only the strongest DOM sites will interact with Hg(II). In the case of fully oxygenated Everglades water (sulfide-free), the binding of Hg(II) by DOM should dominate Everglades' dissolved inorganic mercury speciation. However, even for the case of strong binding sites ($K_{DOM}' = 10^{23.2\pm0.5}$), Hg-sulfide complexes are predicted to dominate dissolved inorganic Hg solution speciation in the presence of small concentrations (nanomolar) of sulfide because of the strong sulfide affinity for Hg. Where measurable total sulfide concentrations are present in the surface water and pore water of the Everglades, therefore, Hg-sulfide complexes likely predominate.

A chemical equilibrium approach does not completely explain the behavior of Hg(II) in the presence of DOM, however. For instance, chemical speciation models indicate that pore waters in the Everglades, especially in the eutrophic areas, are supersaturated with respect to cinnabar (mercuric sulfide, HgS); however, no cinnabar has been found in the peat soils of the Everglades. Therefore, to better define the geochemical interactions between DOC, Hg(II) and sulfide, experiments were designed using the organic matter isolates and whole water samples to study interactions of DOC with Hg in cinnabar dissolution and precipitation experiments. Cinnabar is a relatively insoluble solid ($\log K_{sp} = -52.4$) under most environmental conditions, but, in the presence of DOM, particularly the humic fractions (HPOA, humic acid, and fulvic acid), a significant amount of Hg (up to 1.7 μM/mg C) was released from cinnabar over a period of seven days at pH 6.0. The amount of Hg dissolved by various fractions of organic matter followed the order: humic acid > HPOA ≅ fulvic acid >> HPIA. The hydrophobic and hydrophilic neutral fractions dissolved insignificant quantities of Hg from cinnabar. Model compounds such as cysteine and thioglycolic acid dissolved small amounts of Hg from the cinnabar surface, while other model compounds such as acetate, citrate, and EDTA dissolved no detectable Hg. There was a positive correlation ($R^2 = 0.84$) between the amount of Hg released and the aromatic carbon content of the DOM.

Precipitation and aggregation of metacinnabar (black HgS) was inhibited in the presence of low concentrations of humic fractions of DOM isolated from the Florida Everglades. At low Hg concentrations ($\leq 5\times10^{-8}$ molar (M)), DOM prevented the precipitation of metacinnabar. At moderate Hg concentrations (5×10^{-5} M), DOM inhibited the aggregation of colloidal metacinnabar (Hg passed through a 0.1 μm filter, but was removed by centrifugation). At Hg concentrations greater than 5×10^{-4} M, mercury formed solid metacinnabar particles that were removed from solution by a 0.1 μm filter. Organic matter rich in aromatic moieties was preferentially removed with the solid. HPOA, humic and fulvic acids inhibited aggregation better than HPIA. Inhibition of metacinnabar precipitation appears to be the result of strong DOM-Hg binding. Prevention of aggregation of colloidal particles appears to be caused by adsorption of DOM and electrostatic repulsion.

A general observation that can be drawn from all of our studies of Hg(II)-DOM interactions is that the amount of dissolved Hg(II) present in a given system is greater in the presence of reactive DOM. This is significant because many of the processes (both abiotic and biotic) involved in Hg cycling in the Everglades are hypothesized to be strongly dependent on the concentration of total dissolved Hg. Preliminary results of ongoing wetland enclosure (mesocosm) experiments in the Everglades are consistent with this hypothesis. In these experiments, mesocosms amended with the most reactive organic matter from the Everglades, the HPOA fraction of the DOM obtained from site F1, contained higher concentrations of total dissolved Hg than control enclosures containing less reactive, native DOM. The DOM amended enclosures also were found to have enhanced methylation (both biotic and abiotic pathways) of

Hg(II) and enhanced photo-oxidation of methylmercury relative to the controls. Future research will address the mechanisms by which DOM influences these important reactions.

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Reestablishing the Hydrogeomorphic Habitat Templet in the Kissimmee River

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The foundation for ecosystem restoration in the Kissimmee River is the reestablishment of hydrologic and geomorphic characteristics, which interact to create a physical habitat templet. This habitat templet will guide the assemblage of biological communities in the restored system and influence ecosystem processes such as energy flow and biogeochemial cycling. River channel geomorphic studies in the Kissimmee River are quantifying changes in the habitat templet associated with the restoration of flow.

This habitat templet was disrupted by channelization of the river during the 1960s as part of the Central and Southern Flood Control Project. Channelization involved excavation of the C-38 canal, which destroyed portions of the natural river channel and isolated the remaining channel remnants. While remnant river channels contained water, they no longer conducted flow. Before restoration, 86 transects in remnant river channels were sampled to characterize baseline conditions for river channel morphology and substrate characteristics. In the absence of flow, remnant river channels experienced relatively minor changes in shape. However, the natural channel sand substratum was buried under a layer of recent (post-channelization) deposition that was composed primarily of fine organic detritus. This deposition layer averaged 14 cm (±0.71 SE) in thickness. For these transects, the percentage of samples on a transect without deposition averaged only 3%, and deposition thickness at the thalweg averaged 21 cm (±2.17 SE).

During Phase 1 of the restoration project, 12 km of the C-38 canal were filled by replacing spoil, and new river channels were carved to connect remnants of the historic river channel to create 24 km of continuous river channel. Phase 1 was completed in February 2001, and continuous flow has been maintained through the reconnected channel since June 2001. After 10 months of continuous flow, 24 transects were resampled, and mean thickness was found to have decreased to 4 cm (±0.76 SE), which is a reduction of 71% from the baseline value. The average percentage of samples on a transect without a deposition layer increased from the baseline value of 3% to 64%, and average thickness at the thalweg decreased by 81% to an average of 4 cm (±1.69 SE). Other evidence for the reestablishment of natural sediment transport and deposition processes includes the formation of point bars on sixty-three meander bends. These observed changes in substrate characteristics are approaching the expected changes that were based on reference data, but they are happening much faster than anticipated. The magnitude and rapidity of these changes is consistent with stream power calculations, which suggest that during this 10 month period stream power exceeded a theoretical threshold for the movement of sand for >90%, and thus should have been competent to transport the lighter organic material.

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Long-Term Data from the USGS/BRD Mangrove Hydrology Sampling Network in Everglades National Park

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In 1992, under the guidance and support of the USGS Global Change Research Program (GCRP), The "Groundwater-surface water interactions and sea-level rise in southern Florida study" was initiated. The principle focus of the study was to develop a systematic network of shallow groundwater well and surface water monitoring sites to evaluate the hydrodynamic changes across the transition zone or ecotone between the freshwater Everglades and coastal mangrove estuaries. Located on the southwestern coast of Florida, within Everglades National Park, transects were established along the three principal tidal rivers: Shark, Lostman, and Chatham River (Fig. 1). Shark River slough and its estuary were selected as the primary study area, because of their significance to the freshwater Everglades system. Each transect is ~30 km in length (the meso-scale) and has three permanent, continuously recording hydrologic monitoring stations. On the Shark River transect, Shark 1 (SH1) represents the upland non-tidal freshwater region; Shark 2 (SH2), the transitional ecotonal area between the two hydrologic systems; and Shark 3 (SH3) the coastal mangrove estuary region. Two additional hydrology stations (SH4 and SH5) were set up to monitor hydrologic changes across the fringe mangrove/coastal marsh ectone ~ 300m in length (the micro-scale). Shallow ground and surface water levels, temperature and specific conductance, and rainfall are the principal parameters measured at each monitoring site.

Hydrologic data from the Shark River Transect has been compiled for seven water years: 1996-2002 (Fig. 2). Daily surface water from SH1 shows the wet tropical summer (June-October) weather and drier cooler winter (November-May) climate patterns of south Florida. The non-tidal, freshwater marshes respond quickly to local rainfall and evaporation, surface-water discharge from upstream. Water levels in Shark Slough were significantly higher in 1995 and 1999. Hurricane Irene in October 1999 was the largest single event recorded at SH1 since 1995. SH2 is located on the terminus of the freshwater slough, at the ecotone with downstream tidal systems. Principally, SH2 showed a tidal signal in the daily surface water, however, it was dampened by the overland flow of surface water during the summer months, primarily June and in September. Tropical storm Harvey in September 1999 was the largest single event recorded at SH2 since 1995. SH3 is located on a red mangrove delta island near the mouth of the Shark River estuary. It is overwhelmingly a tidally influenced site, receiving a tidal influx twice daily. Tropical Storm Harvey in September 1995 was the single largest event recorded at SH3 since 1995.

The project is developing a common vertical reference for the southwest coast to provide greater comparative analysis of hydrologic data (DeWitt et al., this volume). The Shark River hydrologic network is centrally positioned to provide essential baseline empirical physical data needed for numerous research efforts and modeling involved with Everglades restoration. Such projects include the Tides and Inflows in the Mangroves of the Everglades (TIME) and a variety of inter-related USGS hydrological, ecological, geological and mapping investigative studies. These data provide valuable integration with South Florida National Parks resource management; the Comprehensive Everglades Restoration Plan (CERP); and the Florida Coastal Long Term Ecological Research (LTER) project.

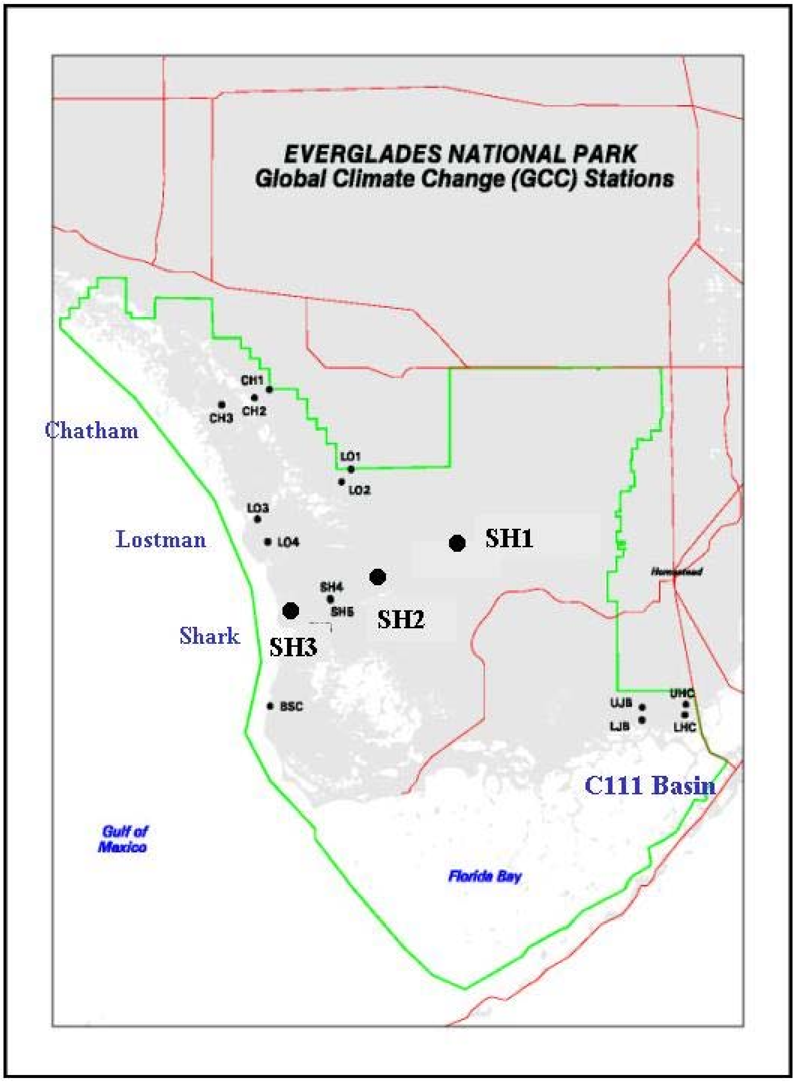

Figure 1. Locations of hydrologic sampling sites within Everglades National Park.

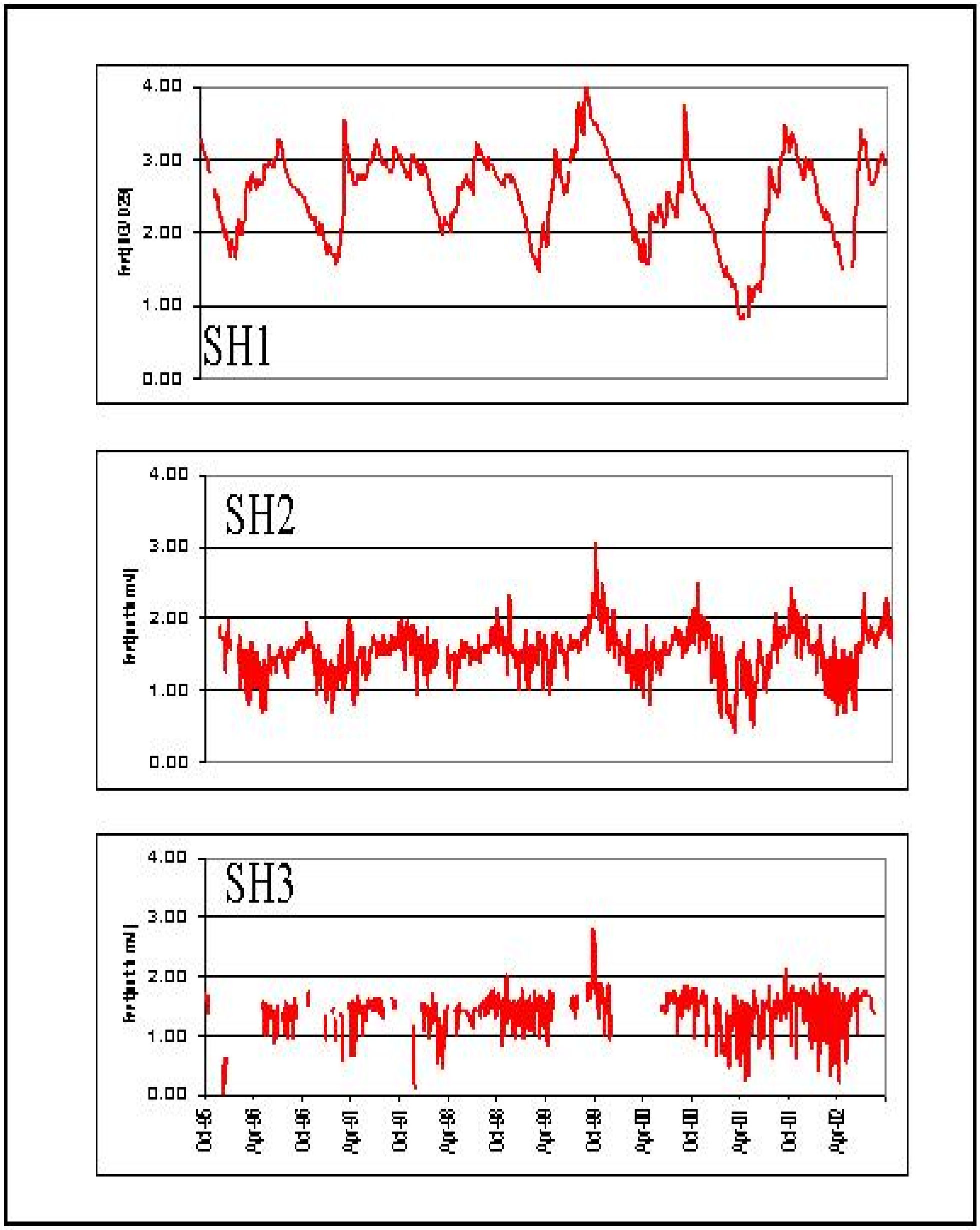

Figure 2. Period of record for surface water stage along the main Shark River transect.

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Coupling of Hydrodynamic and Spatial Ecosystem Models to Assess Spotted Seatrout Population Risks from Exploitation and Environmental Changes

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Traditionally, water quality, critical habitats, and fish stocks have each been treated as separate management issues. However, pervasive resource declines and widespread habitat destruction have emphasized the importance of taking a more holistic view to resource management. Clearly, we need innovative predictive tools to help evaluate mechanisms for effective spatial fishery management. Explosive regional human population growth, overfishing and habitat degradation in south Florida has stimulated system restoration projects that are redefining the quality and functioning of the coastal ecosystem. Success of Everglades restoration and other targeted fishery management strategies will be reflected in changes in the size and abundance structure of fisheries and species composition of the marine resource communities. Because spotted seatrout are sensitive indicators of system environmental changes, we developed a spatial age structured predator-prey model to assess seatrout population risks from exploitation and environmental changes. The model couples the production dynamics of a higher trophic level age-structured population (e.g., seatrout, Cynoscion nebulosus) to a key prey (e.g., pink shrimp Farfantepeneaus duorarum) through a dynamic array of biophysical processes. The model is based on fundamental principles of bioenergetics, population ecology, and community trophodynamics linked to a well calibrated Biscayne Bay hydrodynamic model (Wang 1978, Wang et al. 1988, 2002). This is done by mathematically linking bioenergetic principles of fish physiology, population ecology, fish-habitat relationships, and community trophodynamics to a regional hydrodynamic circulation and mass transport model. We focused on an important model application on issue of expected ecosystem transitions from changes in freshwater to "tide" under the comprehensive Everglades restoration plan. Specifically, we evaluated impact to seatrout population productivity, fishery yields, and ecosystem performance resulting from two alternative water management scenarios associated with Everglades restoration, which are expected to affect the timing, location and quantities of freshwater delivered to Biscayne Bay, Florida.

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The Role of Flow in the Everglades Ridge and Slough Landscape

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The Everglades has at the core of its identity the slow movement of water across the vast, low gradient, wetland landscape. Marjory Stoneman Douglas eloquently immortalized this identity in her descriptions of the "River of Grass" (Douglas 1947). Drainage and compartmentalization efforts during the 20^{th} century for flood control and water supply purposes interrupted this flow, as well as altering water levels, distribution, and seasonal timing. Water flows are closely linked to water levels, and their alterations have caused environmental damage. Efforts to restore the Everglades have focused on re-establishing more natural hydropatterns – the appropriate water levels, and the location, timing, and duration of these water levels. While these natural hydropatterns are widely recognized as being extremely important, much less attention has been paid to the importance of the actual movement of water, the physical and ecological roles that movement of this water plays, and how management activities have altered that flow. Thus, the Science Coordination Team has chosen understanding the science of the role of flow in the Everglades as one of its priorities. The purpose of this paper is to provide a stimulus for increasing the level of understanding and awareness of the role of flow in restoration activities, and to highlight the urgent need for research in this area.

Pre-drainage Everglades hydrology was dominated by a remarkable flow regime – a 30-mile-wide expanse of water moving down the low-gradient wetland landscape from north to south. Surprisingly, although Everglades hydrology has flow as one of its defining characteristics, most discussions of hydrology in the Everglades exclude mention of the role of water movement. The movement of water in aquatic ecosystems such as wetlands is a fundamental construct of ecosystem structure and function, and its ecosystem role is well-established. It is likely that water movement plays a similar vital role in the Everglades.

The ridge and slough landscape, one of several major habitat types in the Everglades, originally consisted of a peat-based system of dense sawgrass ridges interspersed with adjacent and relatively open sloughs. These parallel ridges and sloughs existed in an organized pattern, oriented parallel to the flow direction, on a slightly sloping peatland. Unfortunately, compartmentalization and related water management activities are resulting in the loss of this ridge and slough landscape. This loss is evidenced by replacement of the characteristic ridge and slough landscape with a landscape that is more topographically and vegetationally uniform. It is clear that 1) the Everglades ridge and slough landscape has changed, and is continuing to change significantly; and 2) the landscape changes are having detrimental ecological effects on Everglades plants and animals. It is likely that these changes are the result of altered water flow and hydropattern caused by human-made barriers and shunts, interacting with corresponding changes in water depth and water level fluctuations.

The mechanisms causing the loss of ridge and slough landscape likely are complex, are occurring over a time scale of decades or more, and restoration decisions will have to be made on a time frame shorter than decades. A number of mechanisms for the formation and maintenance of the ridge and slough landscape are proposed, including: sediment transport; changes in water depth under managed conditions; differential rates of peat accumulation and decomposition; erosional formation; extreme hydrological events; fire; underlying bedrock patterns; and microhabitat differences in water chemistry. The presence of flow is necessary for almost all of these mechanisms to operate, and it is likely that a combination of several of these mechanisms operating together is responsible for formation and maintenance of the ridge and slough landscape.

The mechanisms of ridge and slough landscape degradation are not fully understood. However, it is likely that barriers to flow, including levees and canals, contribute significantly to the conversion of the ridge and slough wetland mosaic to more uniform stands of sawgrass. Conversion of the ridge and slough landscape pattern to uniform sawgrass stands has had, and will continue to have, deleterious impacts on Everglades plants and animals. An Everglades landscape increasingly dominated by dense sawgrass stands supports fewer numbers of animals and a lower diversity of animals. The control of vegetation over wading bird ecology is strong enough that Kushlan (1989) states, “Whatever determines vegetation patterns will also, to a large degree, determine bird use of wetlands.” Wading birds are an important component of the Everglades ecosystem. Their foraging and nesting success often are used as indicators of the overall health of the system, and they are one of the most visible and highly regarded fauna of the Everglades. The conversion of ridge and slough landscape to dense sawgrass stands has had a negative impact on wading birds and other important birds of the Everglades. Negative impacts of these landscape changes extend throughout the Everglades food web, including fish, which are important food for wading birds. In addition to altering flow patterns and wetland landscape patterns, barriers to flow serve as barriers to movement of aquatic animals.

Very few research studies have been conducted specifically to determine the role of flow in the Everglades ecosystem. Most of the research projects from which data are presented in this paper, while relevant to the role of flow, were not designed to determine the role of flow. It is precisely for this reason that the Science Coordination Team chose the topic of flow as one of its priorities. Recommendations for future research are prioritized, and include: a multidisciplinary paleoenvironmental study; a thorough geomorphic review; sediment transport studies; synoptic and time series measurements of flow; development of a carbon balance model; remote sensing; and others.

Finally, additional performance measures are recommended for the ridge and slough landscape for the monitoring and assessment of the Comprehensive Everglades Restoration Plan (CERP) progress. These measures, largely based on expanded collection and analysis of remotely sensed images, include: aerial extent and temporal trends of sawgrass ridge, slough, and tree island polygons; edge-to-area ratios for landscape types; average length-to-width ratio and temporal trends of sawgrass ridges or sloughs for a defined area; and spatial orientation of the three landscape types as compared to their historic orientations.

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An Integrated Approach for Evaluating CERP Projects: Linking Science and Management in the Southwest Florida Feasibility Study

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The Southwest Florida Feasibility Study (SWFFS) is a component of the Comprehensive Everglades Restoration Plan (CERP). The SWFFS will result in an independent but integrated implementation plan for CERP projects in southwest Florida. The SWFFS will provide a framework to address the health and sustainability of natural systems, including water quantity and quality, flood protection, and ecological integrity. The SWFFS was initiated to address additional water resource issues (needs, problems, and opportunities) within southwest Florida that were not being addressed directly by CERP. The purpose of the SWFFS is to identify alternatives that address those issues in the study area and to evaluate the effects of those alternatives on the natural systems of southwest Florida.

The objectives of the integrated approach for evaluation of alternatives for the SWFFS are to: 1) Gather available (historic to current) data on natural systems of SWF, and develop appropriate data management and manipulation procedures. 2) Develop conceptual models and performance measures for natural systems of SWF. 3) Using selected performance measures develop and apply forecasting models to evaluate alternatives as they are being developed. 4) Identify information gaps, and critical uncertainties that require research and experimentation. 5) Based on the performance measures develop a system-wide monitoring program to measure restoration success and 6) Integrate the information obtained from objectives 1-5 into a decision support system (DSS) for the SWFFS. In this talk we discuss our overall approach to achieving the objectives of this project.

Large, complex, regional, ecosystem restoration projects should have a means to evaluate how well the actions of the projects achieve the desired goals. Learning from experience, this project builds on procedures being applied as part of CERP. Conceptual models are being used to identify the critical linkages between ecosystem stressors, indicators, and performance measures. Regional hydrological and ecological models have been used to evaluate alternative scenarios and the results have been applied to modify alternatives. An adaptive assessment strategy is being developed apply the performance measures in developing a system- wide monitoring program to measure and interpret ecosystem responses. These steps will be integrated into a DSS to inform the process of developing and evaluating restoration alternatives.

An Applied Science Strategy was adopted to effectively link science and management during all phases of CERP. The federal authorization (Water Resources Development Act of 2000) for CERP calls for adaptive management of ecosystem restoration. However, except for the development of conceptual models the steps in the process for evaluating (pre-project) and assessing (post-project) restoration projects and for adapting management decisions have yet to been specified. As part of the SWFFS we have developed an integrated process (Figure 1) for linking science with management that can serve as a system-wide template for evaluating CERP projects.

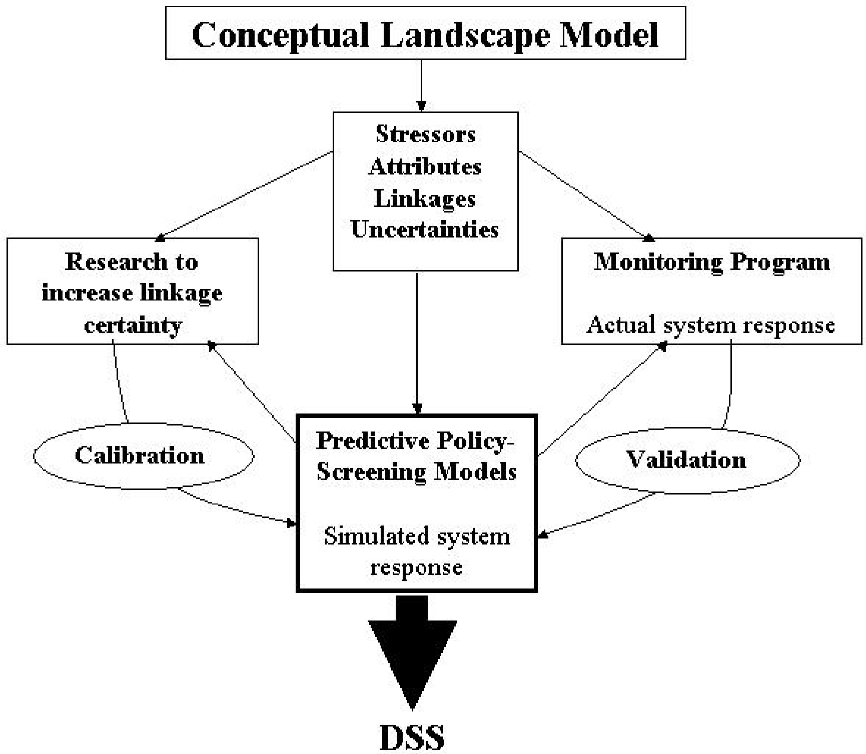

Figure 1. An integrated approach for adaptive management of CERP projects.

Adaptive management is a learning process designed to increase the certainty that management decisions will reach the desired outcomes. Our approach links the conceptual model process with policy screening models (project evaluation) and monitoring (project assessment). This completes a loop that provides a passive, iterative approach to adaptive ecosystem restoration. We complement this process with an active adaptive management loop involving research and experimentation. Together this provides an integrated approach to doing science but does not directly link the science being done to the decision making process.

We link science to management with a decision support system. DSS's are broadly defined as computer-based systems used to aid decision makers using data and models to solve unstructured problems. They do not make decisions or set policy, rather they help decision makers to organize, sort, and display decision variables and parameters, and to appreciate the impacts of potential policy actions. This approach will enable the SWFFS to carry out the tasks of formulation, evaluation, and modification of alternatives to develop a effective and feasible plan. This project will supply the information required by the SWFFS to meet its objectives of: conserving and protecting water resources to ensure the sustainability of (other) natural resources, improving and protecting, quality, heterogeneity, and natural biodiversity in freshwater, upland, estuarine, and marine ecosystems, and to protect and recover listed species.

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A Total System Conceptual Ecological Model for South Florida

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The Central and Southern Florida Project Comprehensive Review Study included an Applied Science Strategy that has been adopted as a process for effectively linking science and management during all phases of the Comprehensive Everglades Restoration Plan (CERP). The Applied Science Strategy is a total systems and multi-disciplinary process that can be used as a planning tool for designing the restoration plan and for determining the most appropriate restoration targets, and the best measures for each of these targets, during and following the implementation of the restoration programs. An essential step in the Applies Science Strategy is the creation of a set of conceptual ecological models of the major physiographic regions in south Florida that will be directly affected by the Comprehensive Everglades Restoration Plan. The purpose of these models is to show how ecosystems are stressed, to identify the sources of this stress, and to be used as a guideline for establishing performance measures for stressors and attributes identified in the process.

These simple, non-quantitative models are an effective planning tool for developing a consensus regarding a set of causal hypotheses, which explain the affects that the major anthropogenic stressors have on the ecosystem. Each model identifies the attributes in the natural systems that are the best indicators of the changes that have occurred as a result of the stressors. Each model also delineates the ecological linkages between the stressors and the attributes and the most appropriate measure for each of the attributes.

Originally, nine conceptual models were developed for physiographic regions in south Florida. These include Florida Bay, Biscayne Bay, St. Lucie/Indian River Lagoon, Caloosahatchee Estuary, Big Cypress Basin, Lake Okeechobee, Everglades Ridge and Slough, Everglades Marl Prairie, and Everglades Mangrove Transition Zone. More recently, a conceptual model for the Total Greater Everglades System was developed.

The Total System Conceptual Model is designed to show the ecological linkages among the major working hypotheses and cause and effect relationships that explain the important effects of system-wide stressors on the South Florida Ecosystem. These stressors, which include sea level rise, water management practices, and changes in land use patterns, certainly echo those seen in the set of regional conceptual models that were previously developed. Our purpose in creating the Total System Model was to identify the working hypotheses that explain the major ecological changes that have occurred at the larger scale of the South Florida Ecosystem. The Total System Model integrates these major, system-wide working hypotheses that are common to several or all of the regional conceptual models, along with ecological linkages that are working across multi-landscape boundaries and therefore are not adequately addressed with a regional model. One additional question addressed by the Total System Model is whether there are major stressors and ecological effects that, because they are operating at such a large scale, have not been adequately characterized by the regional models.

Some important stressors have been omitted from the Total System Model. This may be because the effects of the stressor on a region's internal ecology have specific, regional effects and are better characterized in the appropriate regional model.. Six stressors, altered hydrology, exotics and invasives, excess nutrients, mercury contamination, compartmentalization, and loss of spatial extent, have been identified for the Greater Everglades Ecosystem.

Therefore, the Total System Model looks at the bigger picture, to pick up where regional models leave off, to look at the interactions among regional models, including the upstream and downstream effects of what happens across boundaries. Many of the attributes chosen as indicators of these system-wide events are similar to those seen in other models. Here, however, they indicate more broad scale effects. Five ecological attributes identified in the Total System Model include wading birds; endangered and keystone species; fish and invertebrate communities; upland and wetland vegetation; and aquatic vegetation.

In CERP, the Total System Model will be used to create a new set of total system performance measures and to add a total system component to the Monitoring and Assessment Plan. In addition, it will provide the opportunity to simplify regional models by shifting certain system-wide issues to the Total System Model.

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Water Velocity and Suspended Solids Concentrations in the Proximity of Tree Islands in Everglades National Park

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The overall goal of this study is to determine the importance of water flow in the formation and preservation of tree islands in the Florida Everglades. The study quantifies water velocities and determines sediment characteristics in the vicinity of 3 tree islands situated in the Shark Valley Slough in the Everglades National Park. Spatially intensive velocity data are being taken along 3 transects that are perpendicular to the main North-South axis of each island, using a Sontek handheld flowmeter. The first and northern-most transect is located by the island's tropical hardwood hammock (head), the second transect is located near the middle and the third is located close to the tail of the island. Each transect has its origin to the west of the tree island and has a station every 5 meters. One Sontek Argonaut ADV autonomous velocity meter has been installed near each tree island to obtain temporally intensive velocity in three dimensions. Suspended sediment studies are also conducted along the transects. Samples are collected without filtration for turbidity, particle size distribution and number of particles analyses. The latter two are performed with a Coulter Counter Particle Size Analyzer. The gravimetric analysis of total suspended solids, volatile suspended solids and non-volatile suspended solids is being conducted by sampling with an in-line filtration system. Most of the work to-date has been done on the tree island known as Gumbo Limbo, an island situated near the center of the Shark Valley Slough. Thus, the results presented below correspond to this particular island. Water velocity measurements along the transects varied between less than 1 cm/s to more than 6 cm/s. The highest velocities occurred at those stations exhibiting little vegetative cover in all three transects. High velocity peaks were also measured inside the tree line at transects 1 and 2. In contrast, water velocities decreased dramatically inside the tree line in transect 3. The fact that transects 1 and 2 have hard wood tree cover that does not allow underwater vegetation to grow, appears to play a major role in controlling flow velocity. Wind velocity and direction are highly variable. Water flow is protected from wind influences inside the tree line at transects 1 and 2 but not at transect 3. Water depth was variable in all transects but there is a clear tendency for depth to decrease as the center of the island is approached in transects 1 and 2. Since transect 3 is located at the tail of the island, this tendency was not observed. Turbidity was relatively low along all 3 transects with most values being in the 0.45 ntu to 0.55 ntu range. The particle size distribution of most samples was exponential in nature with the largest number of particles having a smaller average diameter. Mean particle size was relatively constant, varying from 2.5 to 4.0 microns. Gravimetric analysis of total suspended solids was performed at 7 stations at transect 1. Results were relatively constant between stations. Total suspended solids were on the order of 1.0 mg/L. As expected, most of the total suspended solids were volatile due to the high organic content of suspended solids in a wetland environment. Results suggest that that water velocity appears to be most strongly influenced by presence and/or absence of vegetation and the type of vegetation through which it flows. Velocities were high outside the tree line in open areas of sawgrass die-off, and in some parts along transects 1 and 2 inside the tree line where the tree canopy prevents the growth of underwater vegetation. Future work will consist of data collection along the transects of the other two tree islands and analysis of the data that is being continuously recorded by the autonomous Sontek Argonaut ADV velocity meters in all 3 tree islands. Additionally, we plan to develop a method to evaluate the affect of wind on water flow. We expect to find important correlations between the variables under study that will allow us to better understand the relationship between water flow and the creation and preservation of tree islands.

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Fish Communities in Rice Fields of the Everglades Agricultural Area

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The Everglades Agricultural Area (EAA) was created from former Everglades wetlands to provide land for farming of sugarcane and other crops. About 6% of the area is rotated into rice annually. Rice has been found to support wetland species in some areas although it is not a surrogate for natural wetlands. One goal of this project was to determine the abundance and types of aquatic species to be found in the ditches and canals neighboring the flooded rice fields and in the fields themselves. The rice fields are flooded from May through October. As soon as rice reaches a certain height, water is pumped from the neighboring canal into a man-made ditch which flows into the rice fields. Seventeen species of fish were observed. We used minnow traps of 1/8" mesh size for most species; for the larger species we used visual counts or dip nets. The traps were placed at dawn and at the surface since the majority of fish fed at the surface during dawn and early morning hours. Each trap was placed for approximately 10-15 minutes at the edge of the field, in the middle of the field about 20 feet from the main road, and in the ditch, canal or dike within varying distances from the main road but always at the edge. Traps were placed to take advantage of water flow from the ditch to fields and in areas of good rice coverage. Fish abundance and diversity seemed to be correlated with the growth and maturation of the rice crop. At first, when the rice was about 10 cm high, all that was found in the traps were small predatory water beetles and the occasional eastern mosquitofish. But as the rice grew, the abundance and diversity of species increased. At the initial stages of rice cultivation, fish seemed to be present and moving between the ditch and field but never staying long enough to be caught in large numbers. But as the rice matured and the canopy closed, the fish were more frequently caught and observed in the fields. The rice fields, because they obtain their water from permanent water bodies such as canals, are readily inoculated with a diversity of fish. However, it isn't until the rice matures and the food sources increase in the fields that the fish are regularly found there.

Table 1. Species and numbers of fish caught in the EAA

Armored Catfish	*Pterygoplicththys multiradiatus*	1
Banded Sunfish	*Leporinus fasciatus*	2
Bluefin Killifish	*Lucania goodei*	74
Bluegill	*Lepomis macrochirus*	5
Bluespotted Sunfish	*Enneacanthus gloriosus*	3
Brook Silverside	*Labidesthes sicculus*	1
Eastern Mosquitofish	*Gambusia holbrooki*	6810
Flagfish	*Jordanella floridae*	662
Golden Topminnow	*Fundulus chrysotus*	2
Redear Sunfish	*Lepomis microlophus*	7
Tilapia	*Tilapia sp.*	10
Least Killifish	*Heterandria formosa*	338
Marsh Killifish	*F. confluentus*	5
Mayan Cichlid	*Cichlasoma uropthalmus*	17
Oscar	*Astronotus ocellatus*	3
Sailfin Molly	*Poecilia latipinna*	699
Taillight Shiner	*Notropis maculatus*	2

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Isotopic Evidence for Spatial and Temporal Changes in Everglades Food Web Structure

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Trophic structure within a food web is often implicated as a control on how mercury is distributed and transferred throughout an aquatic ecosystem. Methyl mercury bioaccumulates in the food web, with higher concentrations typically found in tissues of organisms that occupy higher trophic positions. Reducing mercury contamination in the ecosystem is a major focus of restoration efforts in the Everglades. Therefore, knowledge about Everglades trophic structure is critical for making management decisions about how to effectively minimize mercury concentrations in biota.

The nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) isotopic composition of tissues is a tracer of diet that can be used in many aquatic ecosystems to distinguish the relative trophic positions of organisms. We use measured $\delta^{15}N$ and $\delta^{13}C$ values of Everglades biota to investigate spatial and temporal variability in food web structure. Plants, invertebrates, and fish were collected from 16 well-studied ACME (Aquatic Cycling of Mercury in the Everglades) sites during 1995-1999 as part of a collaboration between the USGS and the Florida Fish and Wildlife Conservation Commission (FFWCC). These collections provided more than 350 site-date sampling groups.

Within this massive data set, we focus on several sites with multiple collection periods during 1996-1998 that have a sufficient number of organisms to investigate spatial and temporal differences in food web structure. The organisms analyzed for tissue $\delta^{15}N$ and $\delta^{13}C$ represent a broad range of trophic positions within the food web, from primary producers to top-tier predator fish. $\delta^{15}N$ and $\delta^{13}C$ values of primary producers reflect those of the water chemistry, modified by isotopic fractionations associated with nutrient uptake and growth. The isotopic compositions of invertebrates and fish are integrated measures of diet, with an expected relative enrichment of the heavier isotope (i.e., higher $^{15}N/^{14}N$ and $^{13}C/^{12}C$) at each trophic level.

We use $\delta^{15}N$ versus $\delta^{13}C$ plots to identify relative trophic positions of biota within the food web for each site and collection date. Based on laboratory and field studies, the expected pattern of trophic enrichment is increasing $\delta^{15}N$ and $\delta^{13}C$ toward higher trophic positions (e.g., site U3, September 1997) (fig. 1). The magnitude of $\delta^{15}N$ and $\delta^{13}C$ ranges varies among sites and collection dates. This is not entirely surprising, given the large range of consumer-diet isotopic fractionations reported for different species (e.g., McCutchan, 1999). However, the statistically significant, yet different, $\delta^{15}N$:$\delta^{13}C$ slopes for the biota analyzed in each site-date group suggest that processes influencing consumer-diet isotopic fractionations within a food web are spatially and temporally unique. The $\delta^{15}N$:$\delta^{13}C$ slope differences likely indicate spatial and temporal differences in the food web base and/or complexity of trophic interactions.

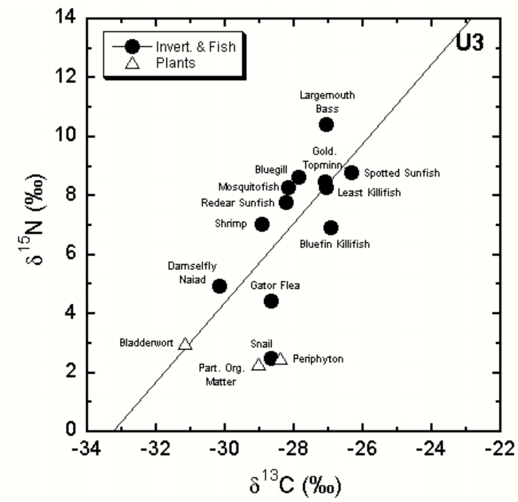

Figure 1. $\delta^{15}N$ versus $\delta^{13}C$ at site U3 during September 1997. The $\delta^{15}N$:$\delta^{13}C$ slope for invertebrates and fish is +1.3 (n = 12; p = 0.02; R^2_{adj} = 0.37). Symbols are median values.

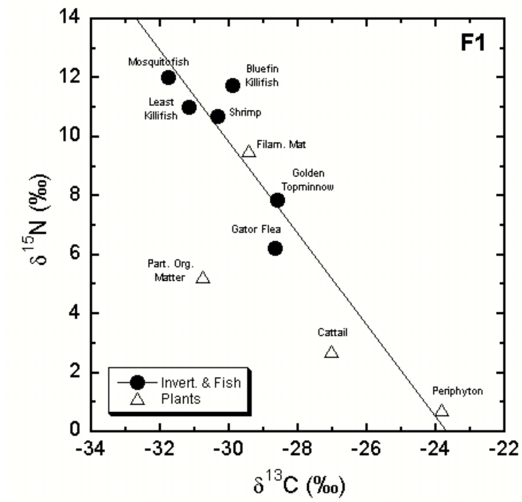

Figure 2. $\delta^{15}N$ versus $\delta^{13}C$ at site F1 during September 1997. The $\delta^{15}N$:$\delta^{13}C$ slope for invertebrates and fish is –1.5 (n = 6; p = 0.03; R^2_{adj} = 0.66). Symbols are median values.

$\delta^{15}N$:$\delta^{13}C$ slopes are typically positive, as expected (fig. 1). However, rare negative slopes (e.g., site F1, September 1997) suggest the unlikely possibility that consumers are relatively depleted in the heavier isotope of carbon than their diets (fig. 2). Although this pattern has been observed for individual species in controlled growth experiments (e.g., DeNiro and Epstein, 1978), an alternative explanation for the multiple-species pattern plotted here is that the biota isotopes reflect the presence of multiple food web bases with distinct $\delta^{13}C$ and $\delta^{15}N$ values. For example, if mosquitofish, bluefin killifish, least killifish, and shrimp are components of one food chain at site F1 and golden topminnow and gator flea utilize another food web base (fig. 2), then this could explain the appearance of a single, "reversed" trophic hierarchy in carbon isotope space.

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Using Nitrogen and Carbon Isotopes to Explain Mercury Variability in Largemouth Bass

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We investigate whether variations in the nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) isotopic composition of largemouth bass (*Micropterus salmoides*) tissue can explain a significant amount of the variation in mercury concentrations in this top predator fish. The $\delta^{15}N$ and $\delta^{13}C$ values of tissues are integrated measures of diet assimilated over time, with consumers enriched in the heavier isotope relative to their diet. This stepwise isotopic increase toward higher trophic positions has been used for decades to reconstruct relative food web structure in a variety of ecosystems, with a focus on intercomparison of northern temperate lakes. Relatively few studies have applied this technique to wetlands.

One of the goals of restoration efforts in the Everglades is to better understand the sources and distribution of mercury in the food web, in order to develop management strategies to minimize mercury contamination of the ecosystem. Because bioavailable methyl mercury is retained in tissues of Everglades biota, successive trophic levels within the food web accumulate higher mercury levels. Mercury concentrations in top predators such as the sport fish largemouth bass typically exceed EPA safety limits. Isotopic estimates of diet and energy flow within the food web are expected to provide potential information about the sources and pathways of mercury bioaccumulation in Everglades marshes.

Stepwise multiple regression is used to identify parameters that explain a significant amount of variance in largemouth bass total mercury (THg) at 12 marsh and canal sites throughout the Everglades representing a variety of hydropatterns (extremely short to long). The five predictor variables include: latitude of collection site (i.e., spatial influence), collection year (1996-1998; i.e., temporal influence), total fish length (a size estimate), $\delta^{15}N$, and $\delta^{13}C$. In addition, we repeat the regressions for individual sites to identify locally important influences.
Of the twelve marsh and canal sites we investigate, seven have complete data for the years 1996-1998. When data for these seven sites are combined, spatial differences (i.e., latitude) explain the most THg variance in largemouth bass tissue (~38%), which is consistent with locally differing influences (Kendall et al., 2001). Fish length explains an additional ~15% of THg variance, with relatively minor contributions by $\delta^{15}N$ (~5%) and interannual differences (~3%). $\delta^{13}C$ is not a significant influence at this landscape scale. The spatial differences may reflect differences in hydropattern, available methyl mercury concentrations (Gilmour et al., 1998), or other environmental variables such as dissolved organic carbon (DOC) concentration or water pH. Future addition of these data to the regression models may help identify the sources of the intersite differences.

When the data are analyzed separately for the twelve collection sites, fish length explains the most THg variance (approximately 34-77%) for ten of the twelve sites (fig. 1). Length is the second most important predictor in another site, explaining ~11% of THg variations. The importance of fish size on THg found here is consistent with the results of the site-grouped analysis in this study, as well as previous studies (Lange et al., 1999); larger fish are typically older and have had more time to accumulate mercury in their tissues.

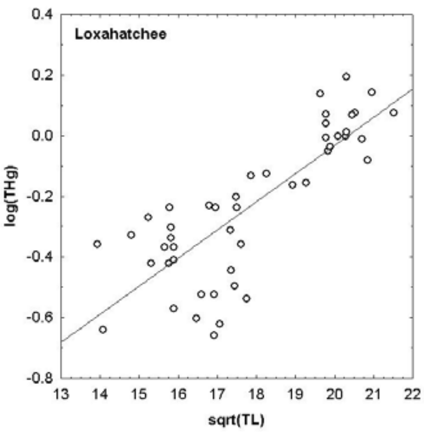

Figure 1. Correlation of the log_{10} of total mercury concentration (THg as μg/g ww) with the square root of total fish length (TL in mm) for largemouth bass at Loxahatchee. Symbols represent individual fish.

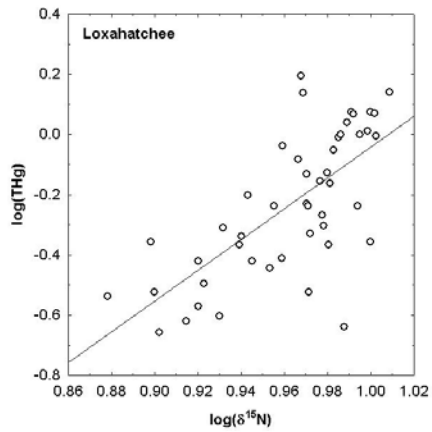

Figure 2. Correlation of the log_{10} of total mercury concentration (THg as μg/g ww) with the log_{10} of δ^{15}N (‰) for largemouth bass at Loxahatchee. Symbols represent individual fish.

In contrast with the findings for the site-grouped analysis, the site-specific analyses indicate that δ^{15}N, δ^{13}C, and temporal variations can be locally important predictors of THg in largemouth bass (fig. 2). δ^{15}N is a significant predictor of THg variation in four sites (~16-27% variance explained), and explains the most variance in two of these (likely an indicator of relative trophic level differences among largemouth bass within a site). δ^{13}C is a significant predictor of THg in three sites. In one of these sites, δ^{13}C is the best predictor of THg variation (~23%), whereas in the other two it explains only ~2-6% of THg variation. The small expected consumer-diet enrichment of ^{13}C (compared to ^{15}N) and large δ^{13}C spatial variations (Kendall et al., 2001) suggest that δ^{13}C is tracking something other than trophic position (perhaps micro-environmental variations). Interannual variations are a significant influence in ten of the twelve sites, where they explain ~5-31% of variation in THg. The importance of these predictor variables in explaining largemouth bass mercury does not appear to correlate with marsh versus canal sites.

In summary, δ^{15}N and δ^{13}C can provide locally important information about mercury variations in largemouth bass tissue in the Everglades. However, fish size and temporal changes in the ecosystem are typically much more important influences that may mask information that could contribute to better understanding the transfer of mercury within food webs.

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Development and Stability of the Everglades Ridge and Slough Landscape

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In the Everglades, the Ridge and Slough landscape is a widespread habitat type characterized by a system of dense sawgrass ridges separated by relatively open water-lily sloughs. The ridges run approximately parallel to each other, oriented on the direction of flow. We use pollen and chronological analyses of sediment cores to test the hypothesis that 20th century compartmentalization and water-management practices have altered the ridge and slough landscape and that ridges are expanding.

We first analyzed a suite of surface samples collected in different sub-environments of the landscape to determine which vegetation types were distinguishable in the pollen record. These include: dense *Cladium* (sawgrass) with scattered *Cephalanthus* (buttonbush) in the central ridge; less dense, shorter *Cladium*, with abundant *Cephalanthus* and occasional *Crinum* and *Sagittaria* in the ridge-slough transition zone; and *Nymphaea*, *Utricularia*, *Panicum*, *Pontederia*, and *Eleocharis* in the slough. Using Mann-Whitney tests and cluster analyses, we determined that ridge and slough assemblages differ significantly, primarily in abundance of *Cladium* pollen. Incorporation of these data into the existing database of 170 sites and eight vegetation types provide tools to reconstruct past vegetation and its response to hydrologic changes based on pollen analysis of sediment cores.

Transects of sediment cores were collected across ridges and sloughs in Water Conservation Area (WCA) 3A and 3B; these transects include cores collected in the central part of the dense sawgrass ridge, the ridge-slough transition zone, and central slough. The central ridges and sloughs appear to have been stable over long time scales. Analysis of the slough core indicates that slough vegetation occupied the site for >2,000 years; however, increased abundance of sawgrass pollen during the 20th century indicates the onset of drier conditions. Likewise, the central ridge site was occupied by sawgrass for ~2,000 years. At the ridge-slough transition site, however, slough vegetation was present for >2,000 years before expansion of sawgrass ridge sometime in the last 200 years. Completion of geochronological analyses will document the timing of the expansion more precisely.

These preliminary data provide evidence that sawgrass ridges have expanded laterally into sloughs. Future coring strategies will address the issue of north-south stability of ridges and sloughs and will expand into WCA 2A to determine whether the ridge and slough landscape previously occupied more northerly sites and, if so, when it shifted to predominantly sawgrass vegetation.

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The Role of Fire in Maintaining Wet Prairies within the DuPuis Management Area

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The 8600 ha DuPuis Management Area (DMA) lies within the Everglades drainage basin, straddling the Palm Beach – Martin County line about 6 km east of Lake Okeechobee. Along its southwestern boundary the DMA includes a 9.7 km strip of remnant Everglades marsh along with the vegetatively complex northern edge of the marsh. Sandy soils on the DMA slope down to the edge of the Everglades marsh, falling 2 m in elevation over 6 km. Although a drainage system was installed by previous owners, a hydrologic restoration project carried out by the South Florida Water Management District has re-established an approximation of natural water conditions over much of the property. Several hundred depressional wetlands overflow into broad flow-ways that carry water by sheet flow in a southwesterly direction to the Everglades marsh. The DMA is a mosaic of vegetation types supporting more than 800 species of vascular plants.

The term “wet prairie” is here applied to non-forested short hydroperiod wetlands on mineral soils dominated by grasses and sedges. Adjacent less elevated areas support either marsh (on organic soil) or cypress swamps. Slightly elevated areas adjacent to wet prairie are typically slash pine flatwoods. More than 300 species of vascular plants occur in wet prairies at DMA. A single 1m x 1m quadrate often includes more than 20 native vascular plant species. The following plant species listed as threatened (T) or endangered (E) by the Florida Department of Agriculture and Consumer Services have been noted in wet prairies at the DMA:

Calopogon barbatus	T
Calopogon multiflorus	E
Eulophia alta	T
Lilium catesbaei	T
Nemastylis floridana	E
Pinguicula caerulea	T
Pinguicula lutea	T
Platanthera nivea	T
Pogonia ophioglossoides	T
Pterogloaspis ecristata	T
Spiranthes longilabris	T
Spiranthes torta	E
Zephyranthes simpsonii	T

Wet prairies in poorly drained parts of the DMA thrived under the frequent burning practiced by ranchers. Immediately following public acquisition in 1987, however, burn intervals in the wetter areas were extended to about 7 years and changes began to occur. Taller graminoid species formed dense growth that began to crowd out and suppress flowering of low species. Bushes such as *Myrica cerifera*, *Ilex glabra*, and *Lyonia lucida* spread into previously open prairies. *Pinus elliottii* seedlings invaded in large number, and there was some observation of *Taxodium ascendens* spreading into wet prairies. An aggressive burning program was instituted with intervals of 3-4 years and vegetation changes are being reversed.

Changes to the wet prairies were addressed before serious damage was done. However, the processes observed have the potential to eliminate wet prairie habitat. With this concept in mind, an attempt was made to interpret existing vegetation patterns in the western part of the J. W. Corbett Wildlife Management Area, which adjoins the DMA and was acquired by the State in 1947. Observations from a helicopter show extensive stands of larger *Pinus elliottii* and *Taxodium ascendens* with nearby areas free of large trees suggesting that they were once open prairies. Many such areas, however, are now densely forested with medium sized pine or mixed pine and cypress with a brushy understory. This pattern is consistent with what would be expected if fire were reduced in frequency for an extended period of time and processes observed at DMA were allowed to continue. Although such brushy mixed forests were undoubtedly part of the natural mix of habitat types in the Everglades region, continued loss of wet prairie seems unfortunate. Apparently, frequent or very frequent fire is required to maintain wet prairie, although the precise frequency needed may depend on hydrologic and soil characteristics so a kind of adaptive management is called for.

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Contributions of Beef Cattle Ranches to Surface Water Quality in the Lake Okeechobee Basin

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Reducing nutrient loads in surface runoff from the extensive acreage of beef cattle ranches in the Lake Okeechobee basin is a key aspect of ecosystem restoration efforts in the Greater Everglades. State agencies are working together with the University of Florida and non-profit research organizations to conduct research on the effectiveness of various best management practices for water quality on cattle ranches. One component of this effort is a large-scale research project at the MacArthur Agro-ecology Research Center, located at a 4,170-hectare cattle ranch, which is a division of Archbold Biological Station in south-central Florida. This project, now entering its fifth year, is examining the effect of cattle stocking density on nutrient concentrations and loads in surface runoff from cattle pastures. Support for this project comes mainly from the South Florida Water Management District (SFWMD) ration with Archbold Biological Station, the University of Florida Institute of Food and Agricultural Sciences (UF-IFAS) the Florida Department of Environmental Protection (FDEP), the Florida Department of Agriculture and Consumer Services (FDACS) and the Florida Cattlemen's Association (FCA). A major goal of the project is to help develop Best Management Practices (BMPs) that will help reduce phosphorous loads in surface runoff into Lake Okeechobee, while maintaining the economic viability of Florida cattle ranches.

The experiment consists of 16 field-scale plots that are separately fenced, ditched and instrumented so that all surface water runoff from each pasture can be quantified, sampled and analyzed. The 16 plots include 8 x 50-acre improved summer pastures, which are grazed May-October, and 8 x 80 acre semi-improved winter pastures, which are grazed November-April. Improved summer pastures are Bahia grass (*Paspalum notatum*) and are fertilized annually with approximately 50 lbs. acre^{-1}and historically (up until 1987) were fertilized also with phosphorus. Semi-improved winter pastures consist of a mixture of introduced Bahia grass and native grasses and are not fertilized. The initial experiment examines the effect of four different cattle stocking densities (control, low, medium, and high) on nutrient (NH_4^+, NO_3^-, TKN, SRP, TP) concentrations and loads in surface runoff. Stocking rates are 0, 1.4, 2.5, and 3.3 acres/cow-calf unit on improved summer pastures and 0, 2.3, 4.0, and 5.3 acres/cow-calf unit on semi-improved winter pastures. The cattle stocking rate treatments were started in autumn 1998. Runoff in the first 4 years of the project (1998-2001) varied with annual rainfall, which ranged from a near normal amount of 54.4" in 1998 to a record low of 29.2" in 2000. The improved summer pastures show much higher total phosphorous concentrations, and loads were much greater in improved summer pastures than in semi-improved winter pastures. Total phosphorus loads for 1998, 1999, 2000 and 2001 were 0.65, 0.73, 0.07 and 3.31 lbs/acre in improved pastures and 0.10, 0.13, 0.05 and 0.45 lbs/acre in semi-improved pastures, respectively. The ratio of soluble reactive phosphorus to total phosphorus (SRP:TP) was also much greater in improved pasture (0.72) than in semi-improved pasture (0.23) runoff, indicating that improved pasture exported a greater portion of biologically active phosphorus. Loads of TKN and ammonium were greater from improved pastures than from semi-improved pastures in 1999 and 2001 but not in the other two years. Inter-annual variability in nutrient concentration was large, especially due to higher nutrient concentrations in runoff from semi-improved pastures during a drought year (2000) relative to the other years. Cattle stocking density did not influence the concentration or load of any nutrient in surface runoff during the first four years of the experiment.

Ancillary isotopic data from our pastures indicates that the excess phosphorus in surface runoff from improved pastures at our location is likely due to accumulation of fertilizer phosphorus during past fertilization practices. These excess phosphorus levels have persisted for more than 16 years after phosphorus fertilizer use was discontinued, suggesting that many years will be required for this accumulated phosphorus to leach from these systems. Nutrient loads in surface runoff from the pastures were correlated positively with concentrations of water-soluble phosphorus (WSP) in the surface soils. Most of the WSP was concentrated in the upper 5 cm of soil where more than 60% of total phosphorus was in an organic form.

Our results indicate that adjustments in cattle stocking density are not likely to have a significant effect on nutrient loads in surface runoff from cattle pastures in the short term, but that pasture type has a large effect on phosphorus loads. Efforts to attenuate phosphorus runoff from cattle ranches should probably focus on those areas of the landscape with higher phosphorus accumulation in soils and with other characteristics, such as rapid drainage, that may contribute to increased nutrient runoff. We are currently considering future experiments to test various treatments that may reduce phosphorus runoff from improved pastures.

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Effects of No-Take Zones on Reef Fish Populations after Five Years of Protection in the Florida Keys National Marine Sanctuary

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On July 1, 1997, the Florida Keys National Marine Sanctuary (FKNMS) Management Plan became effective which prohibited all fishing and other extractive uses in 23 sites:, four research only zones,18 Sanctuary Protected Areas (SPAs) dispersed along the Florida Keys, and in a 30 km^2 Ecological Reserve near Key West. In order to assess impacts of no-take protection of reef fish populations inside and outside of protected zones, the Southeast Fisheries Science Center (SEFSC, NOAA Fisheries) and the University of Miami in cooperation with the FKNMS has conducted extensive monitoring of reef fish populations before and after new regulations became effective. A possibility existed that no-take protection would have minimal or no impact on reef fishes due to any of the following factors: lack of compliance and inability to enforce regulations, high emigration rates of reef fishes moving out of small zones, or the existence of fishing regulations that potentially provided adequate protection for exploited populations.

Non-destructive visual sampling was used to assess reef fish composition, abundance (density), and size structure in randomly selected circular 15m diameter plots. After listing all species observed during the first five minutes, individuals were then counted and their size estimated. Habitat features and depth were recorded. During analyses, the reef habitat was classified as one of 5 categories and all individuals of exploited species were classified as either as exploitable-sized (i.e. at or above minimum legal size or reproductive adults for species not covered by fishing regulations) or juveniles (below minimum legal size; below the size of reproduction).

Sample points were selected using a two-stage stratified random sampling design in which the Florida Keys were first divided into a grid of 200 x 200 m cells. The first stage randomly selected cells to be sampled based on the known presence of reef habitat according to maps. The second stage randomly selected two sample units with reef habitat within a cell. Each sample unit consisted of two (or more) circular 15 m diameter plots sampled by individuals of a buddy team which were combined to make one sample for analyses. Stratification was based on habitat type and protection level.

Changes in no-take and fished zones were assessed system-wide and compared to a four-year baseline (1994-1997) monitored before new regulations were established. Results indicate that although no-take zones comprise only 0.5% of the FKNMS, they include ~5.5% of the reef habitat because no-take zones were preferentially selected to include reefs. Also, density of exploitable sized fishes was higher in no-take zones than in fished strata from the outset in1997 because no-take zones were preferentially selected to include good reef habitat. Preliminary analyses showed a significant and dramatic increase in mean density of exploitable-sized individuals but no significant changes for two species not targeted by fishing. In no-take zones within 5 years (1998-2002), abundance of economically important exploitable phased yellowtail snapper (*Ocyurus chrysurus*) and combined grouper (Serranidae) increased 36 times over the baseline, gray snapper (*Lutjanus griseus*) increased over 10 times, and black grouper

(*Mycteroperca bonaci*) increased over 20 times! In comparison, average abundances of species not exploited, striped parrotfish (*Scarus croicensis*) and stoplight parrotfish (*Sparisoma viride*), were within historical performance bounds.

Although the average observed density of exploitable species was significantly higher in no-take zones than in similar fished areas, mean density tended to increase in both strata apparently in response to a systemwide recruitment increase during the 5-yr period. In one case, combined grouper, average density also increased significantly in fished areas in 2001 and 2002 compared to the baseline period. This response may also reflect influences in increased minimum size limits for grouper and the prohibition of fish traps in 1990. Overall, the increased mean density in no-take zones was much greater than in fished zones. Reserves as a whole are performing as expected. Further analyses will examine relative performance of individual reserves.

This study shows the impact of fishing on reef fish populations targeted by fishing. The presence of no-take zones provide valuable reference areas with minimal extractive influence from which to assess impacts of changing hydrology in Florida Bay associated with the Everglades Restoration. The magnitude of the population response to relaxed fishing pressure suggests that human extractive activities have much more pronounced impacts on abundances of exploited species than ambient differences in water quality.

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Restoration Science Successes and Challenges for Southwest Florida: Charlotte Harbor

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The Charlotte Harbor restoration effort has different program plans for each of the major basins within its watershed. Each of these plans, however, is integrated into a total program of restoring habitat, flowways, and maintaining ecosystem integrity.

In the Caloosahatchee Basin, oxbows in the river will be monitored to assess the effect of restoration on water quality and biodiversity. The restoration plan calls for removing exotics plants from spoil islands created as part of dredge and fill activities. Additional activities call for removal of the spoil piles themselves to restore the hydrological profiles to pre-dredging conditions.

The Charlotte Harbor Basin restoration plan includes exotic plant (chiefly Brazilian pepper) removal from nearshore buffer areas surrounding the bay as well as establishing a Charlotte Harbor State Buffer Preserve that includes the acquisition and management of over 38,000 acres. Broader restoration plans for the harbor area call for expanding and replacing septic systems in Charlotte County and removal of mosquito ditches whenever possible. Site-specific projects in the Charlotte Harbor Basin call for restoring Alligator Creek and Coral Creek. The upper portion of the Charlotte Harbor system (i.e., Lemmon Bay) will soon have a long-term, large-scale plan developed for its restoration.

In the Estero Bay Basin an extensive effort is planned to acquire and restore lands that have been altered as a result of large-scale agricultural activities. Proximate to this area is the Southwest Florida Regional Airport (RSW). Construction is currently underway to expand the airport and restoration plans call for an expansion of the flowway involving removal of exotic vegetation and maintenance of hydrological connections through ditch removal. Additional surface water drainage connections are planned for several areas surrounding the airport and FGCU-associated properties. The proximity of the airport to valuable wood stork habitat makes this activity paramount. Site-specific activities involve the Benson Property, Tesone Property, and Bluejack Oak Parcel. Most restoration activities in the Estero Bay Basin are associated with opening, creating, or maintaining flow ways for surface and ground water. Areas near Bunche Beach, Corkscrew Swamp, Cow Slough, Halfway Creek, Alico Road, Florida Rock Industries, Hendry Creek, Imperial River, Lakes Park, Leitner Creek, Bonita Springs, Spring Creek, and Six-Mile Cypress, and Osprey Village are portions of a larger plan to increase flowways while reducing local, short-term flooding in the Estero Basin. Concomitant with this activity is a project on Lover’s Key State Recreational Area to widen the hydrologic flowway from Estero Bay to the Gulf.

Across the entire system plans are being prepared to assess and restore various VEC (Valued Ecosystem Component) species such as oyster beds, submerged aquatic vegetation, and mangroves.

Dominating the coastal zone will be the reconstruction of the Sanibel Causeway. Associated with this project are actions that will assure broader hydrologic flowways under the causeway that will reduce tidal flow and river discharge restrictions.

Overall, the Charlotte Harbor restoration plan is in its infancy. It is significant to note that the plan is directed to the multiple basins within the system. More importantly, the planned activities are coordinated at large and small scales in both time and space to achieve the desired end result of ecosystem restoration for a variety of interest groups that most importantly includes the natural environment.

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Late Holocene History of Oyster Reef Development in Estero Bay, Southwest Florida: Implications for Management and Future Coastal Environmental Change

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Oyster reefs are critical to both the health and historic development of Southwest Florida's estuaries. Consequently, their status is of great concern to environmental managers of our coastal systems. Like sea grass beds, oyster reefs are vital ecological components of estuarine systems, making their health pivotal to the estuary as a whole. Oyster physiology and ecological distribution, however, are sensitive to changes in water quality, particularly salinity. Oyster physiology, growth, and recruitment are maximized within brackish water salinities, where the freshwater – marine water mixing zone predominates within an estuary. Unfortunately, water management practices in Southwest Florida have severely altered the location and duration of the mixing zone. Management practices are being reevaluated and restoration projects designed to improve oyster physiology and reef distribution.

The dependency of estuarine health on oyster reefs is a consequence of the historic development of reefs through the late Holocene, an interval of time spanning the last 5000 years. The right conditions of sea level rise, climate (i.e., precipitation and temperature), and sedimentation converged through this interval to promote reef development. The coastal geomorphology Southwest Florida exhibits today, a network of coastal bays and numerous mangrove-covered islands adjacent to river mouths, is a product of that reef development.

Best management practices of Southwest Florida's estuarine health require an understanding of the history of oyster reefs. As sea level continues to rise and society continues to manipulate water resources, oyster health and reef distribution will alter. Predicting the system's response is a major environmental management objective. Late Holocene history of reef development provides the data necessary to predict the system's potential behavior in the future. The purpose of this research is to determine the paleoenvironmental conditions under which late Holocene reefs developed in Southwest Florida and to compare those to the conditions prevalent among modern oyster reefs.

Three sediment vibracores were taken from a modern oyster reef in the Horseshoe Keys in north-central Estero Bay. Two of these were located along the crest of a linear reef, separated by 100 meters along the reef's axis. A third core was taken from the backreef flank of the reef, approximately 10 meters landward of one of the cores taken from the crest. Facies within the cores were differentiated and described. Sedimentologic, faunal, and taphonomic analyses were conducted on all facies. The reef cores were also correlated with two on-/offshore coring transects taken previously, one within the Hendry and Mullock Creek watershed in northern Estero Bay (5 cores) and a second taken in the Estero River watershed in central Estero Bay (10 cores). The ecologic and environmental characteristics of modern brackish water oyster reefs in Estero Bay and relict, marine vermetid gastropod reefs in the Ten Thousand Islands were used to further infer paleoenvironmental conditions of late Holocene reef facies.

Horseshoe Keys' reef cores show similar facies transitions in response to late Holocene transgression. Early Holocene or Pleistocene (age indeterminate) supratidal sands are overlain by intertidal mangrove peats. The peats demark the onset of marine flooding and date at approximately 4300 ybp within central Estero Bay. These sediments are followed in most cores by a shallow subtidal estuarine facies, dominated by euryhaline molluscs. Reef boundstones develop as the marine transgression culminates. Vermetiform gastropods, belonging to the families turritellidae and vermetidae, dominate early in the history of reef development. Regression then follows with oyster boundstones gradually replacing vermetiform boundstones as more estuarine conditions return in response to coastal progradation.

Vermetiform boundstones, located at the base of the reef sequence, are inferred to have a more normal marine origin. The fauna associated with the vermetiform gastropods is more stenohaline in character; the taphonomic features of the shells (e.g., abundance of biocorroders and encrusters; poor taphonomic grades) are more consistent with a normal marine environment; and sedimentary textures are indicative of higher energy, wave-dominated settings. Additionally, modern vermetids and turritellids are found in environments less influenced by freshwater. A preliminary radiocarbon date from vermetiform gastropods from the middle of the reef boundstone facies approximates 3100 years before present, suggesting that reef initiation occurred just prior to this time.

The abundance of vermetiform gastropods decreases while shells from the eastern oyster, *Crassostrea virginica*, become more abundant upsection within the reef sequence, further suggesting that conditions became more estuarine through time. Maximal oyster productivity and reef development today occur in brackish, more protected estuarine settings. The concomitant occurrence of other estuarine taxa, the improvement in shell taphonomic grade, the loss of many shell biocorroding and encrusting species, and the finer-grained, more poorly sorted sediments all support an inferred paleoenvironmental shift to greater freshwater influence. The precise timing of this environmental shift during the late Holocene is presently unknown.

Parkinson (1989), working within the Ten Thousand Islands, hypothesized that vermetiform gastropod reefs form the underpinning of mangrove-forested, coastal outer islands (longshore drift-formed barrier islands are absent from the Ten Thousand Islands). Our results are consistent with these observations. If true throughout the Southwest Florida coast (preliminary supportive data now exist for the Ten Thousand Islands, Henderson Creek, Estero Bay, and the Caloosahatchee River), we pose that the formation of coastal vermetiform reefs was responsible for enclosing and protecting the coast, thereby creating the estuarine bay environments best suited for subsequent oyster reef development. Development of vermetiform reefs would have triggered an autogenic succession that grossly influenced coastal geomorphology and evolution.

Latest Holocene oyster-dominated reef formation is dependent upon a slow sea level rise rate (< 10 cm / 100 y). Oyster reefs experience high rates of sedimentation, rates that match or exceed sea level rise. This permits the persistence of protected estuaries and leads to the progradation of the coast. The relative timing of reef successional change seen in our cores is consistent with a reported deceleration in sea level rise approximately 3200 ybp. If the accelerated sea level rise rate which began at the onset of the industrial revolution (increase by an order of magnitude when compared to the prior 3000 years) is maintained in the immediate future, oyster reef development will eventually cease and the current Southwest Florida geomorphology will quickly degrade. Because Southwest Florida’s estuarine ecology is so dependent upon the oyster reef ecosystem, the character of our future estuaries may be radically different from what we currently experience. The implications this has for future environmental management and restoration are outstanding.

This research was conducted as a collaborative student project within M. Savarese's upper division undergraduate course in Geobiology during the fall, 2002 semester.

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Initial Responses of In-Channel Littoral Vegetation to Restored Flow in the Kissimmee River

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Prior to channelization, the extent and species composition of littoral plant communities in the Kissimmee River were typical of a low-gradient lotic environment. Aquatic vegetation was limited, likely primarily by flow, to narrow littoral zones dominated by emergent species. With the dredging of canal C-38 and diversion of flow to the canal, remnant channels became nonflowing pools. Littoral vegetation beds expanded in width towards mid-channel areas, and cover of floating and mat-forming species increased relative to cover of emergent species. Extensive vegetation beds, typically dominated by floating exotic species, often completely spanned channels. To monitor responses of littoral vegetation to restored flow, we collected data twice annually (winter and summer) from 1998-2002 at 91 permanent transects in remnant channels of Pools B and C of the Kissimmee River. Means were estimated for each of three time intervals: a baseline period (February 1998-June 1999), an initial response period following backfilling (August 1999-September 2000), and a post construction period (January 2001-September 2002). Mean vegetation bed widths, mean relative cover of floating and mat-forming plant species, and mean percentage of channel that was vegetated all declined in each time interval.

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Alligator Surveys at A. R. M. Loxahatchee National Wildlife Refuge

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Alligators are a conspicuous feature of the Arthur R. Marshall Loxahatchee National Wildlife Refuge and are considered a keystone species in the Everglades. Relative abundance of alligators is an attribute that will be measured as a means of tracking the responses of the Everglades to restoration activities. The natural variability and the appropriate temporal and spatial scale for assessing responses of an attribute must be known in order for the attribute to be useful in measuring responses. Evaluation of historic and current data provides the basis for understanding natural variability and predicting future responses.

Historic data on alligators at the refuge consists of narrative accounts in annual reports, sporadic alligator surveys conducted in the canals during the 1960s, regular surveys conducted in the canals from 1979-1987, and regular paired surveys conducted in canal and marsh habitats from 1998 to the present.

Preliminary results of the paired surveys indicate that water level air temperature and water temperature are important in explaining relative abundance of alligators in the marsh and water levels is important in the canal.

A power analysis was run on marsh and canal data to determine appropriate sampling regimes for detecting at least a 10% or 5% decrease in alligators/Km with an alpha of 0.25. Using the current survey methods of 1 transect with 2-4 surveys per year results in only an approximate 30-40% chance of detecting a 10% decrease in 5 years in the marsh or canal. Increasing the number of marsh transects to 2 or 3 and the number of surveys per year to 4, increases the power to 85% and 100% respectively with and alpha of 0.25.

These data will be used to help design future surveys being implemented to evaluate both local and system-wide impacts of CERP and other restoration efforts.

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Cooperative Ecological Studies at the Arthur R. Marshall Loxahatchee National Wildlife Refuge: An Academic/Government Partnership for Linking Science, Management, and Education

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Loxahatchee) is 59,646 ha of northern Everglades habitats. It includes the 58,176 ha Water Conservation Area 1, 649 ha of the Strazzulla marsh, a 162 ha cypress swamp, and 821 ha of freshwater marsh impoundments. The refuge is an important part of the Everglades system and provides habitat for over 700 vertebrate species, 63 of which are considered as imperiled, and an unknown number of plant and invertebrate species. The vision for Loxahatchee is to "To serve as an outstanding showcase for ecosystem management that restores, protects and enhances a portion of the unique northern Everglades biological community…"

The refuge faces three major challenges to fulfilling this vision: water quality, water quantity, and exotics. Successful management of the refuge requires an applied science framework that addresses maintenance and restoration of the habitats and wildlife in the face of these challenges.

Key features of this framework are identification of management issues and the articulation of these management issues into specific scientific questions and testable hypotheses. Often a management issue cannot be addressed through a single study, but requires integration of many pieces of information. Therefore, any individual research study may appear irrelevant to a manager, because the linkage to the management issue is not clear. Establishing these linkages prior to the initiation of a study is critical to ensuring it's relevance to management.

At Loxahatchee we are taking a cooperative approach to both identifying and addressing management related science needs in an effort to ensure the science to support management is available. Refuge staff are developing an inventory, monitoring, and research plan which identifies management issues and specific science questions related to the management issues. The science questions then can be developed into specific management relevant studies by or with the assistance of scientists from USGS, other agencies, and universities.

Over the last four years a combination of strategies have been used to initiate research to address management needs. Strategies include monitoring and research efforts conducted by refuge staff, work conducted through cooperative and grant agreements, the use of interns and graduate students, work conducted on the refuge because the refuge was able to provide logistical support in the form of housing, transportation, or fuel, and work conducted under the issuance of Special Use Permits. The most beneficial of these studies to the refuge have been the ones where there has been clear communication of needs and expectations. Communication of this type takes commitment of time for both the scientists and managers, but is critical for ensuring that projects provide relevant information. We have found that generally, neither scientists nor managers are trained in such types of interactions. Therefore, in addition to continuing to foster partnerships for addressing science needs, we also will be initiating an effort to provide future scientists with the opportunity to develop a better understanding of management needs. Such education and training will ensure that we have a core of people with the experience to facilitate communication between scientists and managers and provide better linkages between science and management.

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Airborne Lidar Sensing of Coral Reef Topographic Complexity in Biscayne National Park, Florida

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Variability in vertical relief, or rugosity, combined with diversity of substratum type, creates habitat complexity, a factor that both reflects and governs the spatial distribution and density of many reef organisms. The NASA **E**xperimental **A**dvanced **A**irborne **R**esearch **L**idar (EAARL) is designed to measure the topographic complexity of shallow reef substrates. The EAARL is a narrow beam divergence, high pulse repetition frequency, **t**emporal **w**aveform-**r**esolving, **a**irborne **g**reen wavelength **l**idar (TWRAGL) mounted on an aircraft platform whose position is determined by carrier phase differential GPS techniques. This unique instrument has cross-environment coastal surveying capabilities over beaches, vegetated land, and especially, the clear water settings of most shallow coral reefs.

During early August 2002, 8 EAARL flights were conducted over the northern Florida Keys reef tract. EAARL lidar coverage was acquired by at least 2 flight passes over all of a broad swath extending from north of Turtle Reef to south of Carysfort Reef. In order to insure acquisition of dense lidar coverage for optical rugosity analysis of reefs in Biscayne National Park, the August 4, 2003 and August 5, 2003 missions each repeated a single flightline positioned to survey several bank reefs and numerous patch reefs, respectively.

Five sites selected for optical rugosity analysis (ORA) match sites of recent field monitoring of coral cover and species richness. The remainder of the 15 ORA sites were selected based on an inspection of recently acquired AISA airborne hyperspectral and QuickBird satellite images. Lidar temporal waveform data sets were extracted for the ORA sites, and processed to create a voluminous set of submarine topographic transects for each site referenced to the NAVD88 vertical datum and the NAD83 horizontal datum. This step involved the use of algorithms that examine each lidar temporal waveform to determine the range to the sea surface and the water column thickness.

Each lidar topographic transect was evaluated separately to determine at each point the direct geometric distance (D_{geom}*) to the transect origin point, the transect-following distance (*D_{tran}*) to the transect origin point, and the elevation difference relative to the adjacent point closer to the transect origin point* (δE_{ap}*). At each point, partial transect optical rugosity (*Ro_{part}*) was calculated as:*

$$Ro_{part} = \frac{D_{tran}}{D_{geom}}$$

The optical rugosity assigned to the entire transect (Ro_{tran}) was set equal to the peak partial transect rugosity obtained for that transect :

$$Ro_{tran} = \max(Ro_{part})$$

In addition, the average and maximum adjacent point elevation change, Av(δE_{ap}) and Mx(δE_{ap}), respectively, were calculated for each transect. Finally, the *whole-site* mean and maximum values of Ro_{tran} and Av(δE_{ap}) for the entire population of transects at each ORA site, along with their standard deviations, were calculated.

The optical rugosity analysis revealed a distinct geographic pattern of variation in whole-site measures of TWRAGL-based topographic complexity that matches previous *in situ* assessments of the relative habitat complexity of bank reefs and patch reefs in the northern Florida Keys reef tract. Three groupings of sites, Pacific Reef sites, Ajax Reef sites, and patch reef sites, are clearly evident along a curvi-linear trend towards increasing topographic complexity on a plot of whole-site mean Ro_{tran} versus site mean Av(δE_{ap}) (Figure 1). This result is consistent with field observations of higher stony coral cover, octocoral cover, and coral species richness on patch reefs relative to shallow bank reefs within the study area. Further, both the north Pacific Reef sites and the south Ajax Reef sites form tight clusters, revealing subtle but highly reproducible morphological differences between these quite similar bank reef regions. An analogous pattern of variation between bank and patch reefs is evident on a plot of the standard deviation of whole-site mean Ro_{tran} versus the standard deviation of whole-site mean Av(δE_{ap}) (Figure 2). Both the north Pacific Reef and south Ajax Reef sites form tight clusters at low relative standard deviation of both measures of topographic complexity, with variability slightly higher at Ajax Reef. All but one of the patch reef sites fall along a rough trend line toward higher internal-site variability in both Ro_{tran} and Av(δE_{ap}).

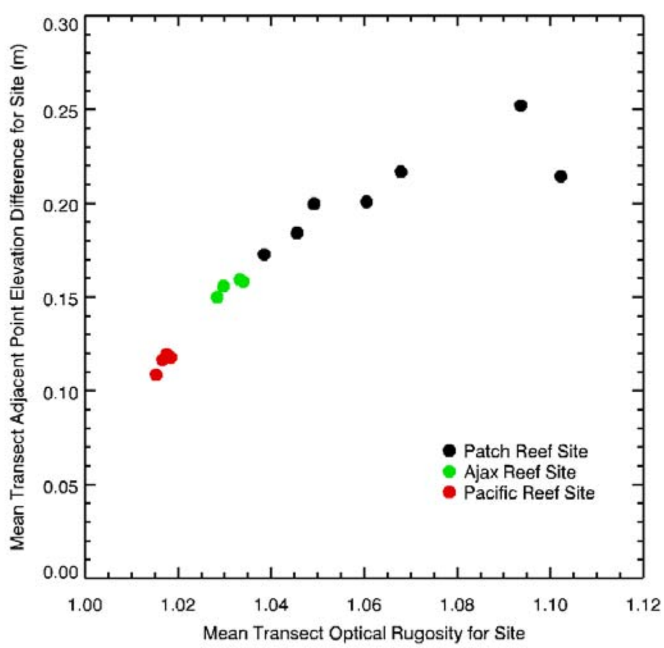

Figure 1.

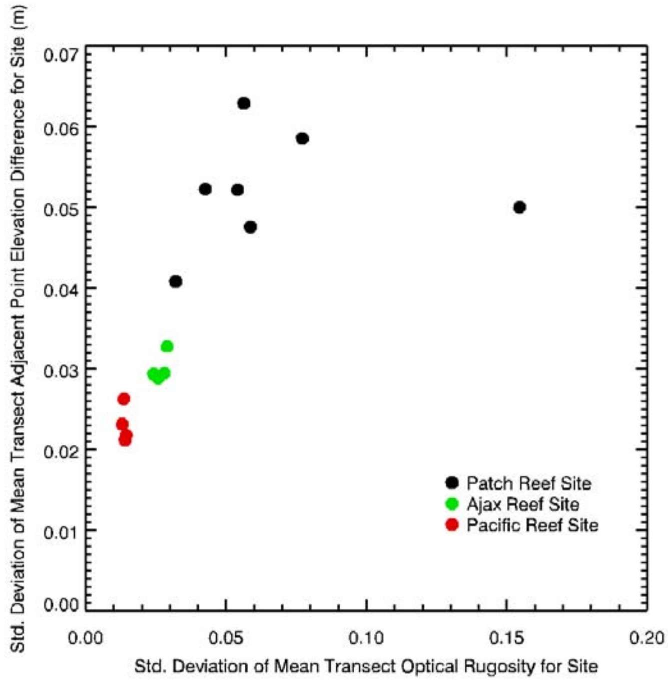

Figure 2.

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Prevalence of Abnormal Fish as an Indicator of Environmental Quality in the St. Lucie Estuarine System

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Indices of environmental integrity are needed to evaluate the quality of habitat in South Florida estuaries that have been affected by water management and may be changed by the Comprehensive Everglades Restoration Project. Changes could occur in the volume and timing of freshwater inflow and the nutrients and contaminants it carries. Chemical concentrations in waters, sediments, and even the biota are, by themselves, inadequate indicators of environmental quality because they do not reeflect biological effects. Furthermore, stressors other than chemicals (e.g., temperature, salinity, salinity variation, presence of pathogens or harmful algae, turbidity, etc.) might affect faunal health. The health of the fish community is the ultimate indicator of quality of fish habitat. The prevalence of abnormalities in wild fish populations provides a readily measurable index of fish health and the quality of fish habitat. High prevalence levels suggest that fish populations are under stress. Long-term changes in prevalence suggest a change in stressors. The prevalence of abnormal fish reflects the combined effects of all stressors and can serve as an indicator of relative ecological health of an estuarine system. Trends in the prevalence of abnormal fish can provide a means to assess the progress and success of restoration efforts.

NOAA Fisheries (Southeast Fisheries Science Center) has sampled in the St. Lucie estuarine system from November 1996 to the present time to determine the prevalence of abnormal fish (the term "prevalence" is used to denote the percent of abnormal individuals in the total fish catch). The project has three components: (1) quantitative field sampling to determine prevalence of abnormal fish, (2) biological analysis and characterization of abnormalities, and (3) statistical analysis of abnormality prevalence in relation to potential causal factors. Sampling was conducted in the lower estuary and nearby reef (SLIN) in all years. Substantial sampling was conducted in the middle estuary (SLES) during years 1, 5, and 6. Sampling was conducted at the first reference site, Jupiter Inlet (JUP), in year 5 and in the second reference site, the tidal Loxahatchee River, in year 6. Sampling is primarily with hook and line baited with dead shrimp. All captures are recorded by species and total length, and each fish is classified as normal or having one or more specific type of gross abnormality.

Fish sampled in this study include most of the species and sizes of fish caught recreationally in the area. These include estuarine species, which are caught in both the middle and outer estuary, and reef-fish species, which are caught in both the outer estuary and nearshore reef. Irish pompano (*Diapterus auratus*), spottail pinfish (*Diplodus holbrooki*), and gray snapper (*Lutjanus griseus*) are the most numerous species in current samples. Abnormalities were found in roughly half of the more than 50 species caught. Fifteen distinct types of abnormalities were separately enumerated. Abnormalities observed in the St. Lucie include primarily those associated with skin or fin erosion, ulceration, or hemorrhaging (LUHE), structural anomalies associated with skeleton or fins (DEF), chromatophore clusters (CC), scale disorientation (SD), lateral line anomalies (LL) and parasite infestations (P). Wounds from obvious mechanical injury and apparent healed lesions are separately recorded. LUHE, as a group, is the predominant abnormality seen in the St. Lucie system and is most frequent in the middle estuary. Fin erosion is the more prominent component of LUHE and is, in fact, the principle abnormality observed in the St. Lucie system. Almost all cases of hemorrhaging are at the base of an eroding fin. The caudal fin is the most commonly observed site of fin erosion. Raised red spots of various sizes (< 5 mm to > 15 mm in cross section), determined to be areas of inflammation or congestion, are another common component of LUHE. Scale disorientation, characterized by patches of miss-aligned scales, is another common abnormality seen in St. Lucie fish. Skeletal and fin anomalies that suggest developmental problems also occur in St. Lucie fish, especially in the inlet/reef area. The most common of these is missing, stunted, or twisted dorsal spines, sometimes in association with a depression in the dorsal profile.

Most types of abnormalities occur across a spectrum of species. LUHE and skeletal and fin deformities occur in all three major species. But species differ somewhat not only in prevalence of abnormalities but also in the type of abnormalities occurring most frequently. Fin erosion accounts for almost all LUHE cases in gray snapper, whereas skin lesions make up the largest component of LUHE in spottail pinfish. Of the three species, Irish pompano has exhibited the widest spectrum of abnormalities. The consistently highest prevalence of abnormalities observed in any species in this study has been in the sheepshead (*Archosargus probatocephalus*).

The long-term abnormality prevalence data are being analyzed for variation by species, quarter of the year, year, and area. Proportions were transformed ($\arcsin \sqrt{p}$) before analysis. General linear modeling and analysis of variance of a data set limited to the St. Lucie Inlet/reef area and St. Lucie Estuary indicated that species explained 54.58% of variation in the prevalence of abnormal fish, quarter of the year explained 2.02%, calendar year explained 0.84%, and area explained 0.13%. The records used in the analysis varied substantially in the number of fish they covered. To compensate, a weighted analysis was performed in which each record was weighted by the number of fish it included. The full weighted model was highly significant (p=0) and explained 57.57% of variance in the prevalence of abnormal fish. An unweighted model was also highly significant (p=0) but explained only 28.55% of total variance. Figure 1 provides an annual index of the prevalence of fish with abnormalities from the weighted model. These estimates differ from the raw data because they take into account the effect of species composition. Prevalence of fish with abnormalities is being examined in relation to freshwater inflow from the Lake Okeechobee-C44 basin and the C23, C24, and Ten Mile Creek basins and in relation to other environmental variables. The working hypothesis, based on observations during sampling, is that a higher prevalence of abnormalities is associated with episodic turbidity events. Results will be presented.

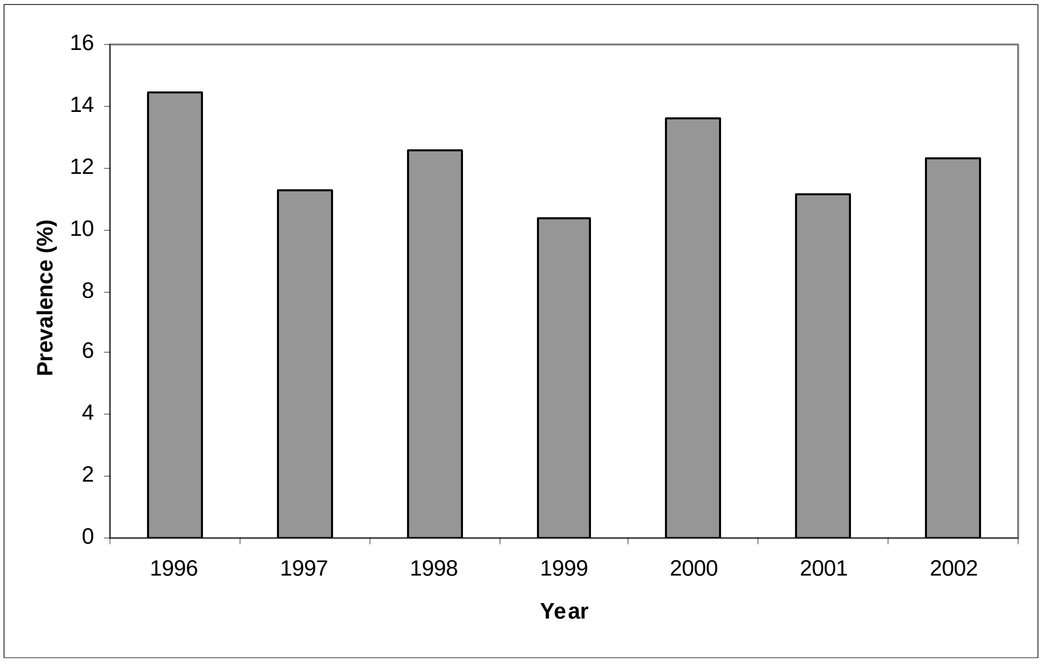

Figure 1. Annual index of prevalence of fish with abnormalities from the weighted model.

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Watershed Hydrologic Model Development for Loxahatchee Ecosystem Restoration

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The Loxahatchee River and Estuary located on the East Coast of South Florida, supports unique ecological resources and biological habitats that are greatly impacted by both sea level rise, estuary inlet dredging and watershed hydrologic alteration. The Loxahatchee watershed hydrologic model is one of the modeling tools being developed by the South Florida Water Management District (SFWMD) for Loxahatchee Ecosystem restoration. The model is built on a new generation model, Hydrologic Simulation Engine, that simulates 2-D overland flow, 3-D ground water flow, 1-D channel flow, and flow in and out of lakes in an integrated manner. A semi-implicit finite volume scheme is used for computational engine, allowing for unconditionally stable solutions of the simulated system. The initial step in developing the model is to design a natural system model (NSM) that simulates the hydrologic response of the natural or pre-drained watershed to today's hydrologic input (e.g., rainfall and ET from 1965 to 2001). Using unstructured triangular grids, the model domain covers the extent of the historic watershed including the original Loxahatchee slough. The NSM version of the Loxahatchee watershed model, using the historic ocean tide as the downstream boundary condition, simulates what the surface and ground water flow into the estuary would be if the watershed remained under pre-drained conditions. This information is critical in setting up the hydrologic restoration target, which, in turn, determines the target salinity regimes in the estuary and the floodplain. The second step in the model development is to use todays and future landuse and hydrography in the watershed to simulate the hydrology of the developed watershed. This modeling approach will provide meaningful comparisons between the two systems, and the results will be used to formulate alternatives to restore the hydrology for a healthy and stable Loxahatchee Ecosystem.

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Preliminary Results on Crayfish Populations in the Freshwater Marshes/Coastal Mangrove Ecotones of the C-111 Basin, Everglades National Park

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Under present water management operations, the wetlands that fringe northeastern Florida Bay fluctuate between freshwater and marine conditions within the annual wet/dry cycle, experiencing higher salinities, longer periods of saline intrusion, and shorter hydroperiods than would have occurred in a non-managed system. Restoration could re-establish natural salinity gradients through the overland sheet flow, restoring the freshwater/oligohaline coastal wetland.

The freshwater marshes/coastal mangrove ecotones in northeast Florida Bay are important, since they are more directly influenced by discharge flow from Taylor Slough and C-111 canals than the mangrove habitats. Due to lower salinity, the freshwater faunal component is higher.

The crayfish *Procambarus alleni* Faxon is a major trophic component in Everglades wetlands, and will be used as an indicator species for monitoring the progress of restoration programs. The potential impact of restoration strategies on population dynamics of this key trophic species has been investigated for ENP marl prairies. Our research extends crayfish studies in the mangrove-marsh ecotone, to the southwest of Acosta and Perry's earlier study, to assess crayfish responses to salinity gradients.

METHODS

We selected three north-south transects in the panhandle of the C-111 basin, named from west to east 59, 60, and 61. Each transect included three stations, named N (north), C (central), S (south), about 0.5 mi distant from each other, representing different habitats: sawgrass for the northern stations, dwarf mangroves for the central stations, and creeks in the mangrove fringe for the southern stations. We set 6 minnow traps at each site, retrieved them after 24 hours, and measured water depth at each trap, water temperature, salinity, conductivity, and oxygen percent saturation in the field.

Samples were collected after the sampling areas reflooded, on June 18-20, 2002, July 25-26, 29-30, September 17-18, 19, and November 12-13, 2002. In November two of the northern sites were dry (60N and 61N), and water levels were so low at 59N and 61C that we were able to set only 5 and 3 traps respectively.

RESULTS

Salinity varied among sites and over time, from values of 0.2 p.p.m., as typically measured in the surface water of the interior of ENP, to a maximum value of 4.1 p.p.m. The northern sites had an average salinity of 0.35 p.p.m., the central sites 0.53 p.p.m., and the southern sites 1.15 p.p.m., thus identifying a gradient that corresponds to the shift in plant communities. Transect 59, which is closer to Taylor Slough, had the widest variation in salinity, especially at the central and southern sites. Transect 61 was less variable and had lower values, when compared with the corresponding stations of the remaining two transects. At transect 61 salinity varied very little at the northern and central site around freshwater values and varied more, with higher values (average: 1.275 p.p.m), at the southern site. Salinity was higher and more variable in June and

November (average 1.1 and 1.0 respectively) than in July and September (average 0.3 for both months).

Water depth was less variable at transects 59 and 60. At transect 61 the central station had depths lower than the northern site, and depth at the southern site was much lower than the southern sites of the other two transects, and was comparable to the values for the northern sites. Water depth decreased over time, and values were more variable in June and November.

We standardized for different numbers of traps set at different months and calculated the relative number of crayfish collected at each site (total number of crayfish collected/ number of traps set). Relative numbers were higher in June (40%), and lower in the remaining months (18, 22, and 200% for July, September, and November respectively). Along the north-south gradient, the highest percent of individuals was collected at the northern stations (42%), and along the east-west one, at transect 61 (43%). When comparing the total number of crayfish collected for all months, the southern transect differed (p=0.003) from central and south transects, and transect 61 differed (p=0.003) from transects 59 and 60. The southern sites differed because only at 61S high number of crayfish were collected, and collection in November had high numbers of individuals only at 61S, and 0 individuals at 59S and 60S. Sites 59N, C, and S differed, probably because high numbers of crayfish were collected at 59N and C, and low numbers at 59S.

Large adult crayfish (>18 mm) predominated at the central transect at all months, whereas the northern transect had mostly large adults in June and July, and the southern transect had mostly large adults in July and September. For the east-west transect, crayfish population size structure at transect 61 differed significantly from that at transect 59 (p=0.0357) and at transect 60 (p=0.0068). At transects 59 and 60 the length of individuals generally decreased from north to south, whereas at transect 61 the lengths were higher at the southern sites than at 61C and 61N. At all transects the monthly average values varied from small adults emerging from burrows in June, larger individuals present in July and September, and smaller individuals in November. Juveniles represented 45% of the total individuals collected in June, 10% in July, 24% in September, and 48% in November. They were mostly collected at transect 59, and in the north sites.

The linearized growth curves of length-weight data and linear regression on male and female crayfish differed between sites. For males, the growth slopes were significantly less steep at 61S, 60S and 60N than at the other sites, for females at 59N.

DISCUSSION

Variation in salinity and water depth characterize a north-south and an east-west gradient of increased salinity and water depth. As a consequence, high numbers of *P. alleni* were collected at transect 61, which was more similar to freshwater sites, and mainly at 61S which is more similar in water levels and salinity to the northern sites at transects 59 and 60.

The lower growth rates at 59N and 60N may be due to the adverse impact of locally shortened hydroperiods and associated habitat quality, as already shown for marl prairies wetlands of ENP.

Small adults of *P. alleni* dominate in non-optimal habitats, such as short hydroperiod habitats. In this study they were mostly present at the southern sites, where salinity values are higher and their variation is greater.

Overall, results from our research suggest:

- Crayfish can disperse at the beginning of the wet season to colonize new habitats where resources are abundant. As a consequence, crayfish may occupy the habitats on the basis of local salinity optimal values, which were not reflected in major changes in vegetation composition during that time frame.
- The wide monthly variations in salinity and water depth in the proximity of Taylor Slough have an adverse impact on *P. alleni* growth and densities. When water levels become too great, *P. alleni* can migrate to shallower areas, to avoid fish predation, as observed for *P. alleni* populations in deep water sloughs (Jordan et al., 1996).

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Projected (2000–2025) Residential and Nonresidential Development for Central and Southern Florida

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This study of projected development for fifty central and southern Florida counties is of vital importance for those planning for the protection of lands and natural habitats in these areas. The study involves a 25-year projection of population, households, and employment by county for each county in central and south Florida grouped by regional planning agencies specific to these areas.

Since growth in Florida, Texas, and California will constitute one-third of the nation's growth over the next several decades, the scale of growth in each of these states must be understood and dealt with.

Projections of households and jobs will be converted to projections of housing units and nonresidential structures. The incidence of forthcoming housing units and nonresidential structures will be converted to the demand for land, water and sewer infrastructure, roads and public services.

These projections will indicate the scale of development for the next 25 years as well as the development hardware/software necessary to service this development.

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Discharge from Caloosahatchee River that Enters Estero Bay

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Estero Bay is a State aquatic preserve located about 3 miles south of the Caloosahatchee River along the coast of southwestern Florida. Five major tributaries flow into this long and shallow body of water including Hendry Creek, Mullock Creek, Estero River, Spring Creek, and Imperial River (fig. 1). Most water exchange between Estero Bay and the Gulf of Mexico is through four inlets through a chain of barrier islands; Matanzas Pass, Big Carlos Pass, New Pass, and Big Hickory Pass. Lands surrounding Estero Bay, including the barrier islands, are highly developed.

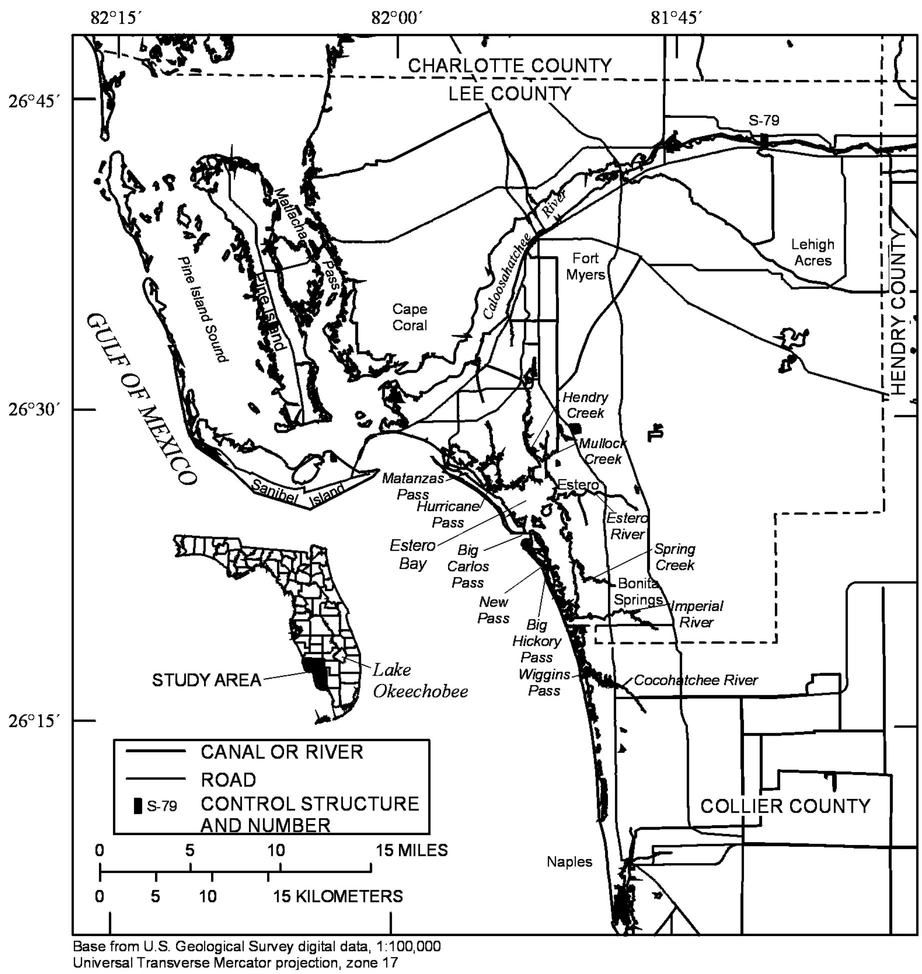

Figure 1. The Estero Bay watershed.

The hydrologic relation between the Caloosahatchee River and Estero Bay is poorly understood. The quantity and timing of freshwater flow into the Caloosahatchee River estuary has been altered due to anthropogenic activities. Principal discharge of water from the Caloosahatchee River into Estero Bay is through Matanzas Pass and Hurricane Pass. The discharge of the organic-rich water reduces water clarity and salinity in the northern part of Estero Bay.

Research reveals that the altered flow pattern impacts the Caloosahatchee River estuary and Estero Bay. The U.S. Geological Survey has undertaken a study to examine hydrology and salinity patterns in Estero Bay. Continuous salinity and flow measurements are being taken at

Mullock Creek, Estero River, Imperial River, Matanzas Pass, Big Carlos Pass, and Big Hickory Pass (fig. 1). Surface-water salinity and temperature data also are being collected near the mouth of the Caloosahatchee River; at points in Matlacha Pass, Pine Island Sound, and Sanibel Island; and as far south as Wiggins Pass. These data, collected on a monthly basis, will be used to generate salinity maps. The salinity, flow and temperature data and additional discharge measurements may be collectively used to quantify the volume of water from the Caloosahatchee River that enters Estero Bay.

The Caloosahatchee River receives water from Lake Okeechobee (to the northeast) and from numerous tributaries. The tributaries north and south of the river drain a large basin consisting mainly of agricultural fields. The South Florida Water management District (SFWMD) regulates releases from Lake Okeechobee to the Caloosahatchee River. Flow on the Caloosahatchee River is controlled by a series of gated structures, operated by the U.S. Army Corps of Engineers (USACE). South Florida Water Management District permits discharge into the river in regulated pulses. The low-level pulse release is designed to limit negative impacts to the estuary. However, the river must also be maintained for navigation, water supply, and flood control. The USACE controls the locks on the river to meet these water demands. During summer 2002, the flow-way gates of the westernmost lock (Franklin Lock, S-79) were open almost continuously. Consequently, the Caloosahatchee River release occurred all summer, with highest flows during the period of discharge from Lake Okeechobee.

Water from the Caloosahatchee River was detected in the near-shore waters of the Gulf of Mexico as far south as Wiggins Pass, which is about 20 miles south of the mouth of the river. Salinity in the Gulf of Mexico substantially decreased during periods of large water releases from the river and was significantly lower off of the northern barrier islands than farther south where Caloosahatchee discharges had less effect. Freshwater entering the Gulf of Mexico from the Caloosahatchee tends to color the oceanic water brown or black. Further research will be required to understand the full extent of the freshwater discharge from the Caloosahatchee River.

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Monitoring and Mapping Salinity Patterns in Estero Bay, Southwestern Florida

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Estero Bay is a very long and shallow estuary located about 3 miles south of the Caloosahatchee River along the southwestern coast of Florida. Abundant and diverse flora and fauna exist within the bay and its watershed including threatened and endangered species. Historically, sheet flow from several sloughs drained into Estero Bay. Most flow now is concentrated at several inflow points as a result of rapid development within the watershed. The principal inflows come from Hendry Creek, Mullock Creek, Estero River, Spring Creek, and Imperial River (fig. 1).

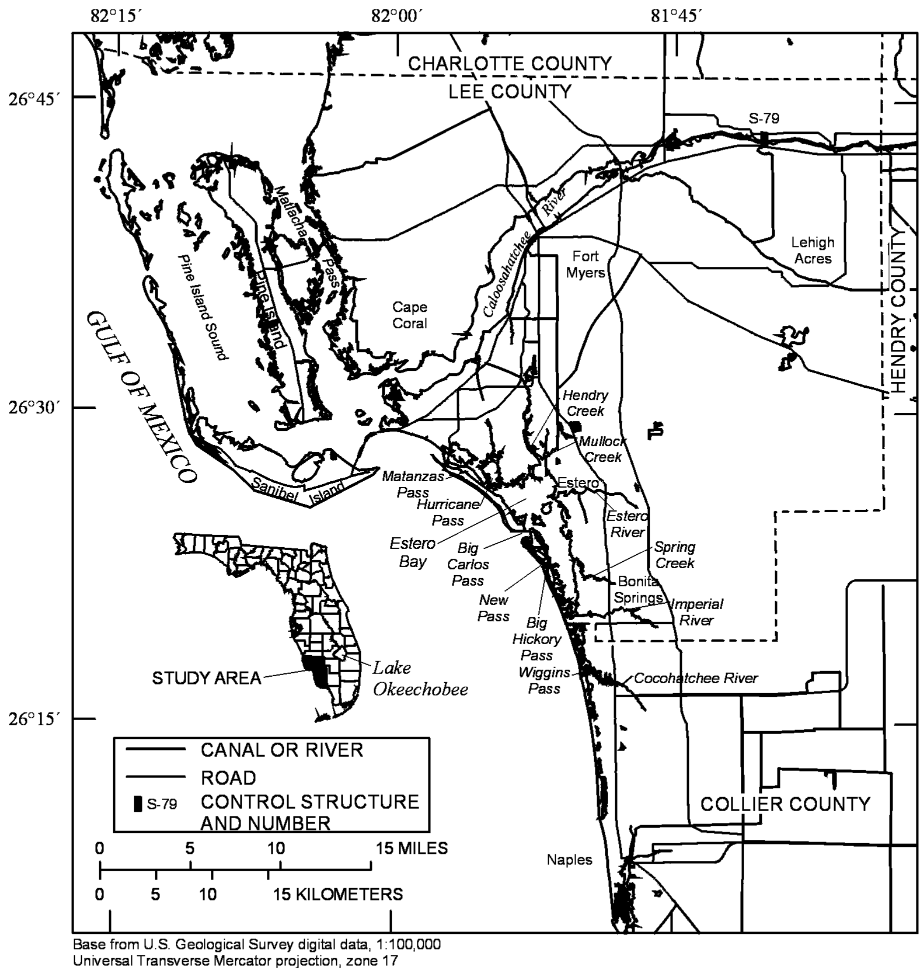

Figure 1. The Estero Bay watershed.

Water exchange with the Gulf of Mexico is restricted by a series of barrier islands, with most exchange through four passes; Matanzas Pass, Big Carlos Pass, New Pass, and Big Hickory Pass. Monitoring and mapping salinity in Estero Bay will help determine the effects that altered flows have had on the aquatic health of the bay.

Baseline data for Estero Bay and its tributaries are needed to provide regional resource managers information to manage future development around the bay and its watershed. The U.S.

Geological Survey has undertaken a study to map salinity patterns and determine freshwater residence times in Estero Bay. Salinity is the chemical tracer that will be used to map water movement through Estero Bay and the information generated from this project will be used in the development of hydrodynamic models and statistical analysis of salinity variance the bay.

The study began in April 2001 and will end in September 2004. Monthly surface-water salinity and temperature data are presently being collected throughout Estero Bay. The methods of data collection involve attaching a water-quality sensor to the stern of a boat just beneath the water surface and logging the precise location of data points using a global positioning system (GPS) receiver. Two boats are used to collect about 6,000 individual data points are in the estuary over an 8-hour period. These data are used to generate the surface-water salinity maps and for statistical analysis of salinity variability due to stormwater releases through the Caloosahatchee River.

Salinity results reveal a large volume of water from the Caloosahatchee River moves a short distance through the Gulf of Mexico and then enters Estero Bay through Matanzas Pass. This organic-rich water may reduce light penetration and salinity and increase sedimentation in the northwestern part of the bay. Water entering the northeastern part of the bay travels south and mixes with water from the Estero River before flowing through Big Carlos Pass. In the south-central bay, hydrologic exchange is limited and salinities increase. Salinity data in southern Estero Bay suggest the Imperial River discharges to the south and north in similar volumes. The Imperial River discharge leaves Estero Bay through Big Hickory Pass and New Pass.

The salinity maps can be used to assess trends in saltwater movement within the estuary and improve an understanding of manatee and fish migration. The information from these maps also can be used for hydrodynamic model verification and to help map seagrass beds.

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Functional Response of Three Wading Bird Species to Prey Density

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Declining wading bird populations in the last century have been considered one of the most prominent signs of the degradation of the Everglades ecosystem. Consequently, recovery of these populations will be a key indicator of successful restoration efforts. It has been hypothesized that the specific mechanism by which Everglades degradation has led to declining bird populations is related to changes in hydropatterns. These changes have most likely altered the availability of prey to wading birds.

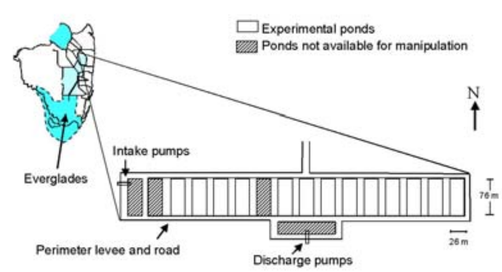
Prey availability is determined by both the abundance of prey and the vulnerability of prey to capture. Prey abundance is affected by factors such as nutrient levels and hydroperiod whereas vulnerability to capture is affected by such things as behavior of the prey species, water depth, vegetation density, and body size.

Each component of prey availability is affected differently under various water management scenarios. For example, management for long periods without severe drydowns changes the species composition of the fish community. Different species of fishes exhibit different behavioral response to predators, thus changing their availability to capture. Moreover, these behavioral differences of the prey may be dependent on water depths. When the water column is deep, social species like the golden shiner (*Notemigonus crysoleucas*) may occur in schools and present wading birds with a very different capture probability than more solitary fishes like the bluegill (*Lepomis macrochirus*). However, as the water level recedes, capture probabilities of the two species may converge.

Ongoing modeling efforts in south Florida, such as the USGS Across Trophic Level System Simulation (ATLSS) program, integrate information on hydrology and wading bird food availability to provide predictive power for future water management decisions. Currently, the biggest information gap limiting the wading bird component of ATLSS is foraging success as a function of prey availability and water depths. We conducted a series of experiments aimed at determining the effects of water management (manifested through changes in prey availability) on the use of foraging sites by wading birds. Here we present the preliminary analysis and results of the experiment addressing the effect of fish species, fish density and water depth on wading bird foraging behavior.

The study was conducted in the Everglades Nutrient Removal Project adjacent to the northwest boarder of A.R.M. Loxahatchee National Wildlife Refuge, Palm Beach County, Florida (fig. 1). The experiment was initiated on 10 March 1997 when ponds were stocked with golden shiners (*Notemigonus crysoleucas*) and bluegill (*Lepomis macrochirus*), and was completed on 15 March 1997 when bird use nearly ceased.

Figure 1. Location and arrangement of experimental ponds.



Treatments were assigned randomly among 12 ponds using a 2x2x2 (water depth 10 cm, 28 cm; fish density low and high; fish species golden shiner and bluegill) factorial arrangement with two replicates.

Foraging flocks were monitored with a video camera. Following the video monitoring, time-activity budgets of focal birds were constructed from videotapes. Three bird species were observed during this experiment: Great Egret (*Ardea alba*; visual feeder), White Ibis (*Eudocimus albus*; tactile feeder) and Wood Stork (*Mycteria americana*; tactile feeder). Two measures of prey consumption were calculated, mean prey capture per minute and the mean time interval between prey captures. The relationship between these two measure of prey consumption and predicted fish density (fish/m^2) was investigated. We wanted to determine if capture rates were affected by low versus high fish density treatments.

Capture rate (fish/min) and the mean time interval between prey captures were plotted against predicted fish density for visual (figs. 2, 3) and tactile (figs. 4, 5) feeding wading birds. After visually inspecting the data, it appeared that prey density did not influence capture rates for visually feeding birds. In other words, wading birds had similar capture rates at low and high predicted fish densities. Sample sizes were too small to draw conclusions about the tactile feeding species.

Figure 2. Predicted fish density vs. capture rate for **visual** feeding wading birds at 10 and 28 cm water depths.

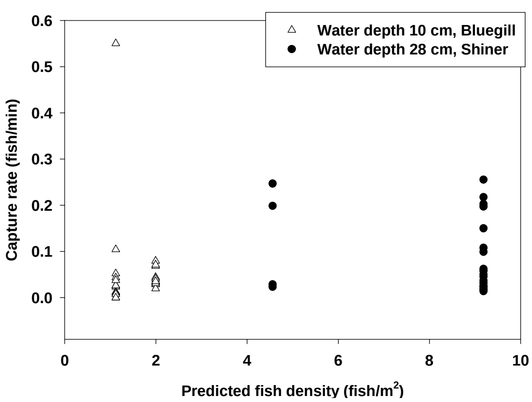


Figure 3. Predicted fish density vs. mean interval between captures for **visual** feeding wading birds at 10 and 28 cm water depths.

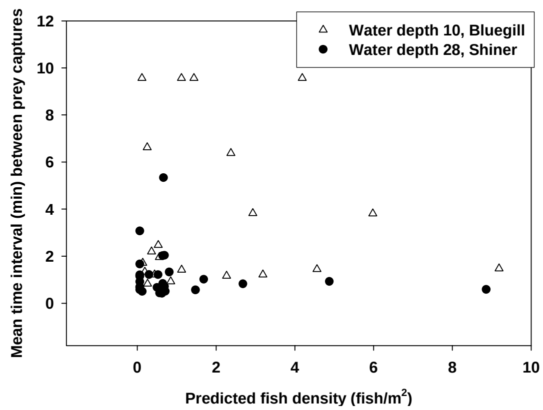


Figure 4. Predicted fish density vs. capture rate for **tactile** feeding wading birds at 10 and 28 cm water depths.

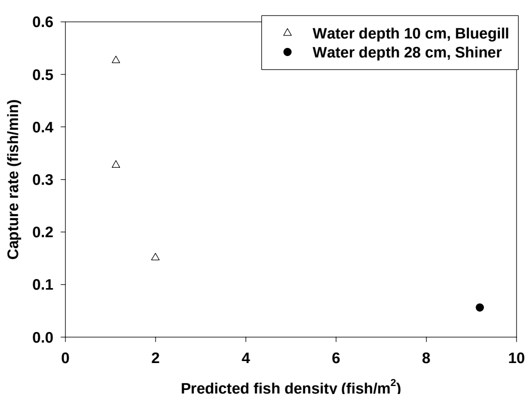
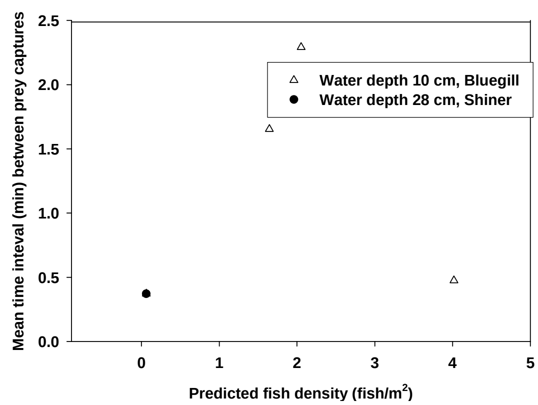


Figure 5. Predicted fish density vs. mean inteval between captures for **tactile** feeding wading birds at 10 and 28 cm water depths.



Several of our experiments showed a strong numerical response to prey density by wading birds, in contrast to the apparent lack of functional response shown here. In other words, once these birds were at the ponds, capture rates were similar. One possible explanation for constant capture rates is that wading birds will leave a patch before intake rates decrease substantially. As a result, no decreasing intake rates can be detected. The fish density at which an individual wading bird will leave a pond in search of a new foraging locale is termed the giving up density (GUD). Further investigation of the relationship between prey density and wading bird foraging behavior will be conducted. The GUD will be calculated for this experiment and offer useful insight into the linkage among drydowns, fish populations and wading birds.

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Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project: Integration of Bioeroding Sponge (Genus *Cliona*) Survey

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McMaster University, Hamilton, Ont., Canada

In 2001, the EPA Science Advisory Panel recommended that the Coral Reef Monitoring Project (CRMP) integrate monitoring of bioeroding sponges into the existing CRMP sampling protocol. Bioerosion is an important but often over-looked aspect of reef health. A healthy reef must maintain the appropriate balance of reef accretion and destruction. Boring sponges can account for as much as 90% of total boring, among them the genus *Cliona* is especially destructive. For this survey three species (*Cliona delitrix*, *C. lampa*, and *C. caribboea)* were selected as the major bioeroders. Earlier work by Rose and Risk had linked abundance of *C. delitrix* to fecal bacteria levels in seawater. Based on this, Dr. Risk was asked by CRMP to develop a survey methodology that could easily be incorporated into ongoing surveys.

At the onset of sponge infestation, a small discreet tube-like opening or papillae is visible on the surface of the coral colony. As the sponge matures, it becomes more exposed and expands across the colony's surface. The growth rate of *Cliona delitrix* is not known; however, colonies have been observed to expand over live coral at a linear extension rate of 10-20 cm/yr. Bioeroding sponges use a combination of chemical etching and other physical methods to remove the host's calcium carbonate. As the sponge bores through the coral colony, tiny fragments of coral are excavated and expunged through excurrent canals (osculae). Over time the coral colony is riddled with a series of connecting tunnels and cavities. This dramatically alters the structure and integrity of the coral colony, leaving it more susceptible to destruction by physical disturbances such as wave action.

Cliona delitrix is bright orange, with large excurrent openings. *Cliona lampa* is less common than *C. delitrix*, darker orange in color, with slightly smaller excurrent openings. *Cliona carribboea* is brown to olive in color, with many small excurrent openings upon close observation. *C. carribboea* often looks like and feels like a velvety scum growing over corals. To the touch these sponges feel like a thin soft layer over a hard base. This is because they only remove about 50% of the coral tissue.

To facilitate incorporation of the clionid sponge census into the existing CRMP sampling scheme, a method had to be developed based on existing project station layout (Figure 1.). One meter-wide belt transects provide the maximum spatial coverage available. Only the following equipment is needed for the survey: 30-meter underwater survey tape, meter stick marked in 10cm increments, underwater slate and data sheets, and the appropriate dive equipment. An underwater survey tape marks a center of reference for the belt transect. The meter stick is held perpendicular to the survey tape is used to create the 1-meter wide belt transect. Only the portions of clionid colonies within the 1-meter wide belt transect are recorded. The data collector begins by swimming from the offshore stake stopping at the first Clionid colony in the 1-meter belt. For each clionid colony, the location (as distance in meters from the offshore stake), area (in m^2) and stony coral species affected are recorded. Area is measured within a 40cm by 40cm quadrat frame divided into 5cm by 5cm grids. The number of grids occupied by the clionid colony is recorded to the nearest half grid by observing the colony in a map or planar view. Data are only collected from above, not into overhangs or in holes. Once the transect is completed, the survey tape is recovered, and redeployed on the subsequent transect. The observer must keep pace with the video data collection to ensure the videographer is not interrupted or delayed while filming. Roughly 5-7 minutes is available for each 22-meter long transect. The collected data is then entered into a Microsoft access database and original data sheets filed and stored at the Florida Marine Research Institute.

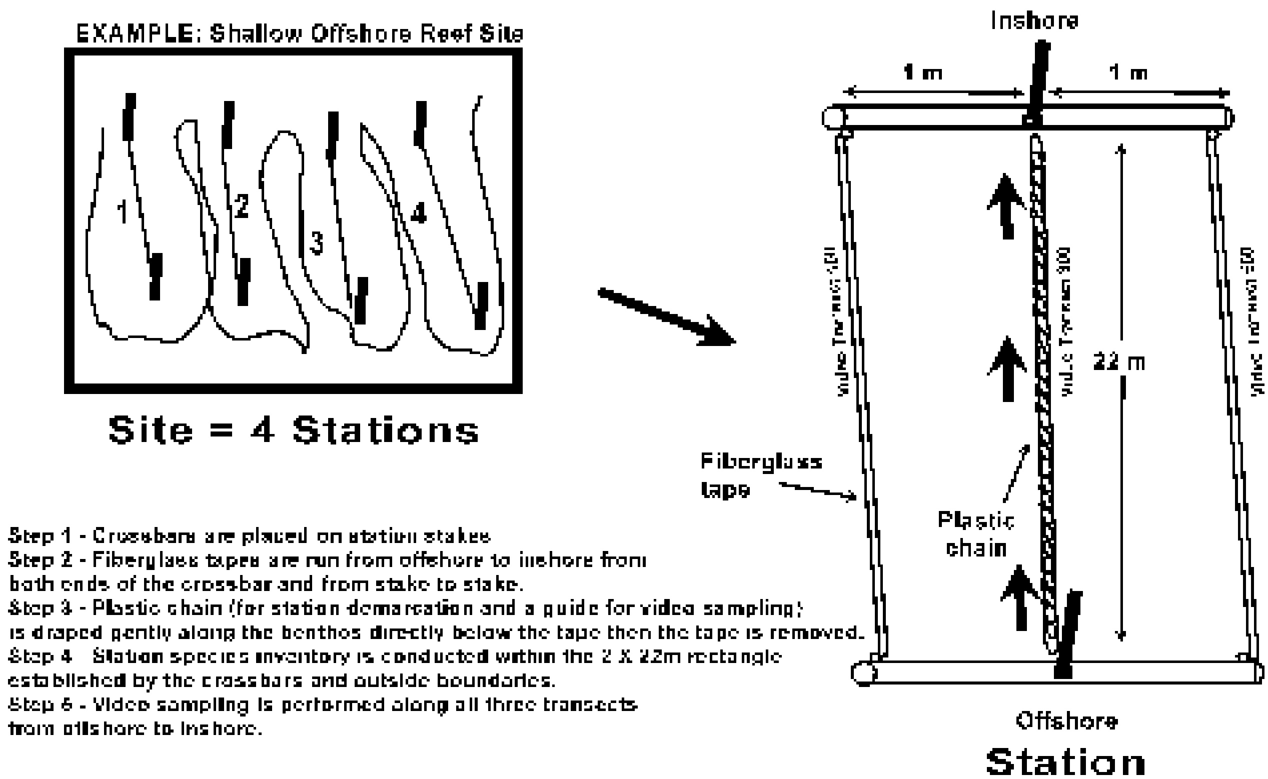

Figure 1. CRMP site and station layout.

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Linking Development to the Status of Benthic Communities: Challenges and Lessons from the Florida Keys

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What is the connection between development and benthic communities in the Florida Keys? Can we predict the effect of further development on benthic communities? These questions are central to the establishment of management policies in the Florida Keys. As part of the Florida Keys Carrying Capacity Study (FKCCS) we addressed these two questions based on existing data. Our efforts focused on direct human impacts (e.g., prop scars, groundings and anchoring damage, snorkeling and diving impacts), as well as indirect impacts of development (e.g., pollutant loads).

Water Quality and Benthic Communities in the Florida Keys National Marine Sanctuary.

Based on four years of monitoring data, Boyer and Jones (2002) concluded that, at a Keys-wide scale, the Florida Keys National Marine Sanctuary (FKNMS) exhibited “very good” water quality. The Upper Keys generally have lower nutrient concentrations than the Middle or Lower Keys. Concentration of TN generally decreased from inshore to offshore; the same occurred for TP, with the exception of the Upper Keys, where TP increased offshore, oceanside. A median TN:TP ratio of 62.10 suggests a P-limited environment.

Keller and Itkin (2002) reported statistically significant differences in TN and TP between Upper and Middle Keys in samples from canals and other nearshore locations. TN was lower in sampling stations near developed areas (41.3 µm) than in natural shorelines (52.3 µm). Annual mean was not statistically different between stations with regard to region (Upper, Middle, Lower Keys), shoreline type (developed, undeveloped), island side (bayside, oceanside), or season. A significant correlation between TP and Chl *a* suggested that P-limitation occurs.

Kruczynski and McManus (2002) provide an extensive discussion of water quality issues in the Florida Keys. They reviewed TN and TP data for three canals, and show values between 19.8 and 40.5 µm for TN and between 0.21 and 1.04 for TP; both higher than those observed in open waters. Lapointe et al. (1994) also measured elevated TN and TP levels (>35 µm and >0.45 µm, respectively) at sampling stations that received direct nutrient inputs, including a canal in Big Pine Key.

As part of the FKCCS, Fourqurean and Miller-Rutten (2002) investigated nearshore (<1 km from shore) benthic communities in the Florida Keys. They attempted to determine if temporal or spatial variation in benthic communities was associated with land use activity in the Florida Keys. Both nearshore benthic communities and their associated nutrient regimes exhibited spatial variation throughout the Florida Keys. Nearshore benthic communities exhibited very little variation over the past 40 years, even in the face of tremendous land development in the Florida Keys. The results provided little evidence to support the hypothesis that there is a significant relationship between land use and spatial or temporal variation of nearshore benthic communities and their associated nutrient regimes throughout the Florida Keys. Results indicate that substrate, not land use, is the most important factor associated with benthic community distribution and composition.

Also as part of the FKCCS, URS Corporation developed stormwater and wastewater pollutant loading models for the Florida Keys. Model runs suggest that pollutant loads would be greatly reduced with the implementation of wastewater and stormwater master plans already adopted. However, the link between pollutant loads, water quality and the status of benthic communities in the FKNMS remains elusive.

Direct Human Impacts. No comprehensive boat traffic study exists for the Florida Keys (Leeworthy 1998, Stolpe 1998, Matthews and Donovan 1992, FKNMS 1996; Kruer 1993). Existing studies and monitoring efforts are insufficient to establish a connection between population and the number of boats utilizing the FKNMS or to predict the effect of changing numbers of boats.

The Florida Marine Research Institute (FMRI) developed a map of scarred seagrass areas (Sargent et al. 1995). We performed multiple regression analyses, which showed no significant correlation between the distribution of scarred areas and a series of development surrogates, including development status of the nearest shore, location of marinas and boat ramps, location of navigational aids, and location of channels. The distribution of scarred seagrass areas was only correlated with distance from shore (independently of shoreline type) and water depth. Similarly, an examination of the FMRI boat groundings database shows that boat groundings occur mainly near reef areas, in popular, shallow destinations.

In a Florida study, Tagle (1990) showed divers touched coral heads an average of seven times during a 30-minute interval, while five percent of divers have more than 20 incidents per 30-minute dive. No other quantitative assessment of snorkeling or diving impacts was available. Rouphael and Inglis (1995) claimed that diver damage to corals is unlikely to have major consequences for local coral populations, but may be substantive enough to affect the aesthetic appeal of the sites.

Conclusions and Recommendations. Development may directly and indirectly affect benthic communities, as evidenced by prop scars, coral damage, and high pollutant concentrations in canals and other confined waters in the Florida Keys. However, despite the existence of an extensive and growing body of literature on the ecological resources and water quality characteristics of the FKNMS (reviewed in Porter and Porter 2002, Sullivan et. al 1996), the available data are insufficient to establish a clear connection between development, nutrient regimes, and nutrient effects on benthic communities in the FKNMS. Available data are also insufficient to establish predictive relationships between land development activities and the impacts listed above.

While the relationship between development and benthic communities is of paramount interest to scientists, resource managers, and other stakeholders in the Florida Keys, existing data and research programs address the issue only from limited perspectives. If resource managers are to be able to assess the effect of future development on the benthic communities of the Florida Keys, research must focus on establishing predictive relationships between development and the ecology of benthic communities. A centralized research coordination program, which brings together and provides overall focus to disparate efforts, may be necessary to effectively tackle this important scientific and management issue.

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Contaminant Status and Trends in National Estuarine Research Reserves

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Inputs of toxic chemicals provide one of the major types of anthropogenic stress threatening our Nation's coastal and estuarine waters. To assess this threat, the National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends (NS&T) Program Mussel Watch Project monitors the concentrations of more than 70 toxic chemicals in sediments and on the whole soft-parts of mussels and oysters at over 300 sites around the U.S. Twenty of the 25 designated areas that comprise NOAA's National Estuarine Research Reserve System (NERRS) have one or more Mussel Watch monitoring sites. Trace elements and organic contaminants were quantified including As, Ag, Cd, Cu, Hg, Ni, Pb, Zn, total PCBs, total PAHs, DDT and its metabolites, and butyltins. Generally the Reserves have trace element and organic contaminant concentrations that are at or below the median concentrations determined for all NS&T Mussel Watch monitoring data. For bivalve tissues, arsenic concentrations were 'high' along the U.S. Southeast coast, and as a result, within those Reserves. These high concentrations were most likely from natural phenomena, not pollution. They are not a health concern because of the chemical form in which arsenic is found. Trends were derived using the Spearman-rank correlation coefficient. It was possible to determine if trends exist for sites at which six or more years of data are available. Generally no trends were found for trace elements but when trends were found they were usually decreasing. The same general conclusion holds for organic contaminants but more decreasing trends were found than for trace elements. The greatest number of decreasing trends were found for tributyltin and its metabolites. With a few exceptions, the National Estuarine Research Reserves represent some of the least contaminated estuaries in the US. There are three National Estuarine Research Reserves in Florida: Apalachicola Bay, Rookery Bay, and Guana Tolomato Matanzas (GTM). There are a total of six NS&T monitoring sites found in or close to these NERRs. None of these reserves are categorized as being in the high category for organic contaminants vis a vis the other NS&T sites, and only a few of the trace elements quantified by the project are seen to be high in these reserves. Likewise few contaminant trends either increasing or decreasing were found for these Florida estuaries.

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Update of the Coastal and Estuarine Data Archaeology and Rescue Program for South Florida

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There is a significant number of documents and data related to the marine environment that have never been published, and are thus not used by scientific community and academia. These documents and data are important because they can help define the state of the coastal environment in the past, and thus are essential when evaluating the current state of degradation and setting restoration goals. The Coastal and Estuarine Data/Document Archeology and Rescue (CEDAR) was established to collect unpublished data and documents on the coastal and estuarine ecosystem; convert and restore information judged valuable to the South Florida restoration effort into electronic and printed form, and distribute it electronically to the scientific community, academia and the public. "Data Archaeology" is used to describe the process of seeking out, restoring, evaluating, correcting, and interpreting historical data sets. "Data Rescue" refers to the effort to save data at risk of being lost to the science community. CEDAR differs from simple document scanning in that review and editing of the final product is necessary to insure clarity and completeness. To date, more than 100 publications have been made available in electronic and/or CD form. PDF files of the documents can be downloaded here <http://www.aoml.noaa.gov/general/lib/cedardoc.html>. The most extensive works rescued to date are the early 1970s biodiversity study of southern Biscayne Bay; the 1979 fish assessment of Florida Bay; a 1970s assessment of fish deformities in Biscayne Bay; the 1983 assessment of Looe Key National Marine Sanctuary; and the 1983 assessment of the Key Largo National Marine Sanctuary. The field diaries of Dr. Charles M. Breder related to South Florida and the Caribbean continue to be published.

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A Summary of Baseline Vegetation Data for Phase I of the Kissimmee River Restoration Project and Expectations for Wetland Vegetation Recovery in the Restored System

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The historic Kissimmee River floodplain was covered by approximately 15,769 ha of wetland vegetation communities, including about 11,000 ha in the area designated for ecological restoration. Broadleaf marsh, wet prairie, and wetland shrub were the dominant historic vegetation community types. Due to channelization of the river system and maintenance of stable water levels, most of the wetland vegetation communities that once occurred on the floodplain were drained and converted to unimproved and improved pasture or covered with spoil material from dredging of the C-38 canal. Restoration is expected to reestablish the species composition, density, and physiognomic characteristics of vegetation communities that were present on the historic floodplain. The Kissimmee River Restoration Evaluation Program includes a vegetation mapping component to measure and document vegetation trends during baseline (pre-restoration) conditions and at various stages of recovery. Vegetation mapping on a landscape scale by photointerpretation of aerial photography is an integral component of the evaluation of restoration responses in the Kissimmee River and floodplain. Reference conditions based on historic records and maps produced from pre-channelization photography were used to predict how and where vegetation communities in the restored system would redevelop. Vegetation community coverage derived from mapping of baseline and post-restoration vegetation coverage will be compared to these reference conditions. Photointerpretation data for the area affected by Phase I of the restoration project indicate that remnant wetland vegetation communities covered 1657.07 hectares (32.7%) prior to restoration. Based on reference condition data, wetland vegetation communities are expected to reestablish and eventually comprise approximately 3923 hectares on this restored section of floodplain.

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Vocal Surveys of Anuran Population in the Everglades Agricultural Area

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Implementation of flood control projects, begun more than a century ago, has decreased the size of Everglades wetlands (Light and Dineen 1994). The Central and South Florida Flood Control Project established more than 600,000 acres of muck wetlands southeast of Lake Okeechobee as the Everglades Agricultural Area (EAA). Currently, several different companies manage the EAA, each with their own management practice. This study focuses on the management practices in and around sugar cane fields and how these practices affect the local anuran populations. In order to determine the anuran species present in the EAA we conducted 10-minute vocalization surveys at approximately 30 points in 6 different sites. Each site is surveyed once a month. The five sites in the EAA are located at the perimeter of sugar cane fields maintained by four companies, Wedgeworth Farms, Sugar Cane Growers Cooperative, US Sugar Corporation and two sites maintained by Okeelanta Corporation. The last site is along several impoundments in Loxahatchee National Wildlife Refuge. Each point in the survey is located near a canal and/or ditch. The sites surveyed are maintained in different ways, especially along the canals and ditches, and we want to determine if this has an effect on the anuran populations. We began surveying in October 2002 and have identified eleven species in the EAA using vocalization surveys. There are two introduced species: *Bufo marinus*, and *Eleutherodactylus planirostris planirostris*, both heard in low numbers. The native species heard are *Bufo terrestris*, *Acris gryllus gryllus*, *Psuedacris nigrita verrucosa*, *P. ocularis*, *Rana heckscheri*, *R. utricularia*, *R. grylio*, *Bufo quercicus*, and *Hyla squirella*. According to preliminary data, more species have been heard at the US Sugar site than at any of the others (Table 1). This site is a mixture of sugar cane, wooded areas and a few small man-made shallow ponds. Surveying will continue at least through November 2003. The overall study design includes visual encounter surveys and tadpole surveys as well.

Table 1: Species detected through vocalization surveys at each study site.

	Wedgeworth	COOP	Okeelanta East	Okeelanta West	US Sugar	Lox
Bufo terrestris	**X**	**X**	**X**	**X**	**X**	**X**
Acris gryllus dorsalis	**X**	**X**	**X**	**X**	**X**	**X**
Psuedacris nigrita verrucosa	**X**	**X**	**X**			
Rana utricularia	**X**		**X**	**X****	**X**	**X**
Psuedacris ocularis	**X**	**X**	**X**	**X**	**X**	**X**
*Rana heckscheri **					**X**	
*Bufo marinus **		**X**			**X**	
Eleutherodactylus planirostris planirostris			**X**		**X**	
Rana grylio					**X**	
Bufo quercicus					**X**	
Hyla squirella	**X**					

* Introduced to South Florida
** Visual encounter in addition to vocalization

Reference:

Light, S.S., and J.W. Dineen. 1994. Water control in the Everglades: a historical perspective. pp. 47-84 in: Everglades: The Ecosystem and its Restoration. S.M. Davis and J.C. Ogden, eds. St. Lucie Press, Delray Beach, FL.

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Southwest Florida Amphibian Monitoring Network

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Amphibians, especially "calling" frogs and toads have been documented in various contexts as good indicators of hydrologic change and ecosystem health. The vast majority of anurans in Southwest Florida are dependent on water or very wet habitats for successful reproduction. Many wetland communities have been either eliminated or are being impacted by various types of land development in the region. In addition, recent changes in federal permitting of wetlands under the jurisdiction of the Clean Water Act have put less emphasis on isolated wetlands that are important to anuran survival.

In 2000, the Southwest Florida Amphibian Monitoring Network (SFAMN) was established to begin monitoring "calling" anurans in Charlotte, Lee and Collier Counties. The network was established with citizen volunteers trained and supervised by professional biologists to identify the calls of male frogs and toads in the area. Currently 17 listening routes are monitored throughout the three county region, utilizing protocols very similar to those proposed by the North American Amphibian Monitoring Program. Volunteers monitor one night each month from June through September. Route locations represent diverse habitat types including urban, agricultural and various natural wetland and upland communities. Three seasons (2000-2002) have now been completed.

Eighteen species of anurans have been detected in the area. Detections of the Bull Frog (*Rana catesbeiana*) and Cope's Gray Treefrog (*Hyla chrysoscelis*) represent potentially new distribution records for these species in Florida. Inter-year shifts in frequency of occurrence for several species were significant and may have been related to an extended drought period occurring during the first three years of the project. Species considered as indicators of relatively unaltered wetland systems such as the Barking Treefrog (*Hyla gratiosa*) were detected in association with such systems in northern Lee and southern Charlotte Counties and may serve as useful indicators of changing hydrologic conditions over time. Furthermore, the documented presence of certain anuran species may be useful in prioritizing certain geographic areas and associated habitats for restoration purposes.

Several non-indigenous anurans were detected including the Cuban Treefrog (*Hyla septentrionalis*), Greenhouse Frog (*Eleutherodactylus planirostris*) and Giant Toad (*Bufo marinus*). These non-indigenous species represented ten percent of all detection events in 2000. The Cuban Treefrog and Greenhouse Frog are commonly heard calling at most of the routes monitored. Trends in frequency of occurrence for certain species regarding their proximity to various habitat types is yet unclear and may be complicated by extreme drought conditions prevailing in recent years. GIS analysis is being applied to determine potential correlations between the presence and relative abundance of anuran species detected and associated habitat types. Continued monitoring of calling anurans for subsequent years will be necessary to further elucidate trends in frequency of occurrence related to various factors such as habitat type, hydrology and changes in land cover over time.

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Freshwater Fishes as Indicators of Wetland Hydrology and Function in South Florida

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Freshwater fishes are important components of marsh systems, filling niches in the aquatic food web from primary consumers of vegetation and detritus through intermediate levels as predators on aquatic insects, crustaceans and other fish. Fishes, in turn, are prey for a myriad of predators and scavengers. Recent surveys conducted for the *Isolated Wetland Monitoring Program* of the South Florida Water Management District (SFWMD) indicate that surveying fish community structure is also a cost effective method of identifying wetland hydrologic condition. An initial survey was conducted in 1997 at 20 isolated wetlands across south Florida, including shallow marsh, wet prairie, and cypress dome habitats. Based on those results, and an extensive literature review in the SFWMD, three functional feeding groups (and habitats of wetland fishes) were identified: (1) small omnivorous fishes – shallow, ephemeral wetlands, (2) small predatory fishes - wetlands with deepwater refugia, and (3) large predators and open-water fishes -semi-permanent, deepwater wetlands.

Functional feeding groups (1) and (2) include fish that have adapted to the relatively harsh extremes found in natural wetlands of south Florida. When these natural extremes are amplified by anthropogenic disturbances, we can expect to see shifts in fish community structure and possibly the loss of certain species. The loss of small fish and aquatic invertebrates from isolated wetlands can disrupt food chains and affect wading bird populations by reducing forage habitat. A follow-up study investigated the freshwater fish communities in three isolated, shallow-water, hydric flatwood wetlands connected to cypress domes in the Flint Pen Strand in Lee Co., Florida using clear plastic fish traps and other non-destructive sampling techniques. The study objectives were to determine fish community structure and evaluate the potential for using wetland fish communities and individual species as indicators of hydrologic alteration and water-level drawdown. Sampling was conducted during February, April, and September-October 1998 to assess seasonal fluctuations in water levels and fish populations and community structure. A total of six fish families, including nine genera, and at least 12 species (11 native fish species and one exotic cichlid) were collected using Breder Traps. The highest fish diversity (H'=1.542 and 1.414) was found in the slash-pine dominated canopy that included scattered cypress. Predictive models using stepwise (interactive) multiple linear regressions indicated that water depth, habitat type, and sediment type were closely associated with number of species, individual abundance, and species diversity. Several potential indicator species and assemblages were identified that may be useful in monitoring of wetlands for hydrologic disturbance (e.g., water-level drawdown). Study results indicate that hydric pine flatwoods are associated with the overall production and diversity of small forage fish species in Southwest Florida's forested wetlands. Additional research is needed to fully understand: 1) the life history requirements of freshwater, wetland fish species, 2) responses wetland associated fishes make to water level manipulations, and 3) the tolerance that these have to acute and chronic anthropogenic disturbances.

Current research for the U.S. Fish and Wildlife Service is being conducted in the Picayune and Fakahatchee Strands in Collier County, FL. The purpose of this study is to identify characteristics of aquatic refugia for macroinvertebrates, fish, amphibians, reptiles and wading birds during periods of drought (or dry season) and also identifying pathways for dispersal of aquatic fauna from refugia to shallow or ephemeral wetlands during wet periods. Preliminary results are presented from the first year of this three-year study.

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The Caloosahatchee Estuary: Applied Research to Determine Freshwater Inflow Limits

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Anthropologic modification of water flows is a leading cause of environmental problems that extends throughout South Florida. The physical evidence of this is perhaps best exemplified by the multitude of canals that have proliferated from the primary system established as part of the Central and South Florida Project. This web of artificial waterways has enabled the alteration of predevelopment watershed hydrology and increased diversion away from historical ecosystems in order to serve and protect human related activities. Modification of river discharge to coastal areas by diversion, water withdraws, channelization, and damming has dramatically changed the timing and magnitude of the freshwater supply to South Florida estuaries. The impacts from these changes include decreased bio-diversity, alteration and loss of livable habitat, excessive stratification, hypoxia, eutrophication, and possibly fish disease. As the human need for water increases, the amount of freshwater required to ecologically sustain estuaries has become an increasingly important issue for resource managers. The current and future challenge to managers and restoration efforts is how to allow human manipulation of freshwater, while at the same time satisfying the needs of the estuarine environment. A first step in meeting this challenge is to estimate estuarine requirements for freshwater. In this report, we present the scientific approach employed by the South Florida Water Management District to address the issue of proper water allocation from the Caloosahatchee River to the downstream estuary.

Like most of south Florida's estuarine watershed, the Caloosahatchee system has been greatly altered. The river has been channelized (C-43) and 20% more water flows to the estuary on the average because of a connection made to Lake Okeechobee for flood control protection. The river also has been deepened and three water control structures were added to better convey water movement from the watershed and the Lake. The last structure, Franklin Lock and Dam (S-79), was completed in 1966 and prevents saltwater encroachment upriver, effectively truncating the upstream extent of the estuary and its associated oligohaline zone. The public operation and private use of this water control infrastructure can result in both diversion of water away form the estuary during dry conditions and to the estuary from the watershed and Lake during wet periods. Long term records for S-79 indicate huge fluctuations in water flows can occur. These discharges can range from 0 to well above 12,000 ft^3 per second. Enough water annually passes through S-79 to fill the volume of the estuary (3.6 billion ft^3) over 8 to 9 times.

In 1985, the District began an estuary research program to determine the optimum quantity of water needed by the Caloosahatchee Estuary to protect key biota. These species, or Valued Ecosystem Components (VECs), helps sustain the ecological structure and function of the estuary by providing food, living space, and foraging sites for other naturally occurring estuarine species. Oysters and submerged aquatic vegetation (SAV) are VEC examples. Therefore, limits of water quantity and related water quality that protect these species should lead to a healthy and diverse estuarine ecosystem. Adoption of this resource-based strategy requires specific information, which includes identifying key biota, their location, and their response to changes in water quantity and quality. The more comprehensive and scientifically based this information, then the more reliable and defendable are the resulting recommended inflows.

For the Caloosahatchee, as the research program evolved, a semi-tiered approach for data acquisition developed. A more detailed description of the research results and program linkage will be provided in the presentation. However, in summary:

1) A literature and information review lead to selecting SAV as the original VEC and also confirmed the importance of flow from S-79 as a major influence on estuarine biota throughout the estuary, from S-79 to the Gulf of Mexico.

2) Based on historical information, a sampling program was designed that initially included seagrass, as well as other biota. Seven sampling areas were selected that extended along the longitudinal and salinity axis of the estuary (approximately 75 km), from near the structure to southern Pine Island Sound. All sampling was conducted monthly, beginning in 1986, with plans to continue until a predetermined range of flows was adequately represented. Therefore, having daily measured inflows at S-79, the major source of freshwater, is paramount for both understanding the influence of flow on biota and water quality, as well as ensuring a range of flows is adequately sampled that fully represents the conditions encountered by the estuary. This is the link that made the science applied and applicable to our research goals. This critical link is often lacking in other estuaries that now are trying to develop flow recommendations as part of the Everglades Restoration effort and Southwest Florida Feasibility Study (SWFFS).

As expected, analysis of water quality information confirmed that salinity is highly variable due to the large fluctuation in freshwater delivery. This variability at the head and mouth of the estuary often exceeds the salinity tolerance of oligohaline and marine species, implicating salinity as a major stressor that is clearly linked to freshwater inflow volume. Sampling of SAV along the longitudinal axis of the estuary, which overlaps with the fluctuating salinity patterns caused by changing flows, helped determine a preferred salinity envelope for the entire estuary. The results from sampling the other biotic groups indicate that diversity, distribution, and abundance increases at all stations, from the inner estuary out to San Carlos Bay, when salinity zones are equitable in size and salinity is supportive of all the SAV species along the longitudinal axis.

3) Field and lab experiments were conducted on Caloosahatchee SAV to assess salinity tolerances under controlled conditions. The majority of these experiments isolated salinity as the single treatment factor. The experiments analyzed to date support the results from the field survey, confirming the importance and strong influence of salinity on SAV. Field and laboratory research was begun under contract in 1999 to assess oysters as an additional VEC.

4) Recognizing the importance of salinity in the Caloosahatchee and its correlation to flow lead to the installation of continuous salinity sensors in 1992 along the longitudinal axis of the estuary. A steady state salinity model was developed in 1996 that predicted salinity based on flows and allowed the development of the current recommendations. Work is underway to develop a fully hydrodynamic model that eventually includes non-conservative water quality constituents. This will allow the evaluation of potential water quality changes within the recommended flow limits and help address concerns related to eutrophication and the possible need to reduce nutrient loading to the estuary.

5) Simply promoting the presence and good health of SAV may not fully provide the desirable results. Therefore, it is important to understand how salinity and flow affect the morphological characteristics of SAV beds and their use by associated biota. Contractual efforts are underway to help address these issues. Similar contractual work is being conducted for oysters.

6) Finally, institution of a management strategy is weakened without subsequent evaluation or monitoring. In the Caloosahatchee, long term monitoring includes hydroacoustic sampling of SAV. In addition, aerial surveys have been completed and routine updates planned. The salinity sensors will continue to provide instantaneous information that can be compared with continuous flow data from S-79 and data from an ongoing water quality monitoring program. Additional monitoring efforts are being considered as part of the SWFFS, based on conceptual model development that link stressors and species of special concern.

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Southwest Florida Feasibility Study Development of Hydrologic Targets for the Caloosahatchee Estuary

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The Southwest Florida Feasibility Study (SWFFS) seeks to identify water resource problems and solutions that protect aquatic ecosystems, wildlife, biological diversity, and natural habitat by assessing feasible alternatives and opportunities that will provide environmentally sensitive water flows and water quality, while fulfilling the water supply and flood protection demands of both the environment and human population.

To help accomplish this goal, *coastal indicator regions* have been identified throughout the study area. These *indicator regions* were selected because of their valuable ecosystem resources and associated water management problems. The hydrologic condition and requirements of each *coastal indicator region* will be given special consideration as part of the SWFFS alternative assessment process, which will help ensure that environmentally sensitive water allocations are provided locally and for the entire study area. The Caloosahatchee Estuary was selected as one of the *coastal indicator regions.*

Water level and timing, along with water flows to tide are the two *performance measures* that are applicable to the *coastal indicator regions*. Within each *indicator region*, Valued Ecosystem Components (VEC) are identified when possible. VEC are defined as key biological features or organisms that provide habitat for a multitude of other species and can serve as an indicator of ecosystem health. Appropriate *ecological targets* and environmental conditions are then identified that link VEC health with the *performance measures* (flow and/or water level). *Hydrologic targets* are the actual *performance measure* values assigned to specific water control structures or gages that have a strong correlation with the *ecological targets* associated with the VEC within an *indicator region*.

This resource-based strategy for determining *hydrologic targets* depends on having information regarding: (1) the presence and location of VEC, such as submerged aquatic vegetation, black mangroves, or oysters; (2) VEC ecological requirements and limits; (3) how the ecological requirements (*targets*) vary over a range of flow and/or water levels at VEC locations; and (4) a good correlation between VEC *ecological targets* and measured flow or stage at historic structures and gages. For example, if freshwater inflow to an estuary is defined as the *performance measures*, then the *hydrologic targets* could be defined as the appropriate volume, distribution and timing of flows from an influential water control structure that would achieve the preferred salinity and seagrass density (*ecological targets*) at appropriate locations within the *indicator region*. All four of these requirements are available for the Caloosahatchee Estuary.

This paper will present the purposed *hydrologic targets* for the Caloosahatchee Estuary that are under consideration by the Southwest Florida Feasibility Study Team. These targets are based on the results of a long term, multifaceted research program. They offer a good example of applied research that can be used to help evaluate water resource management alternatives and the specific requirements of the SWFFS.

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Experimental Manipulation of Iron and Phosphorus Availability in Everglades Sawgrass Marshes

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To examine the interaction between soil nutrient dynamics and sawgrass production, we have added reactive iron oxides to triplicate, $1m^2$ vegetation plots in the Taylor Slough and C-111 drainage basins (FCE LTER stations TS/Ph 1 and 4, respectively). Unamended plots serve as controls in this long-term experiment designed to run for 3-5 years. For the first year of study, we have documented similar levels of 1N HCl extractable iron in surface soils from control plots (~ 10 mM). Total phosphorus, however, is significantly higher (~5 vs 2 mM) and extractable sulfur is significantly lower (~2 vs 5 mM) in soils from control plots in Taylor Slough basin. To date, iron addition to the experimental plots in the Taylor Slough basin has not changed the total phosphorus or extractable sulfur in surface soils, relative to controls. In contrast, both total phosphorus and extractable sulfur have increased in surface soils with iron amendment in the C-111 basin. Sawgrass production in the first year of study is lower from experimental plots at both locations, and we suspect this effect is due to the physical inhibition of shoot emergence caused by the iron oxide application. Soil organic content, however, is not different between treatment groups or basins.

In a prior seagrass study in Florida Bay, we showed that iron additions promoted soil phosphorus retention and decreased root exposure to dissolved sulfides. We expect the results of our long-term study will reveal some of the interactions among soil nutrients and plant production in sawgrass marshes of the Everglades.

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Status and Conservation of the American Crocodile in Florida: Recovering an Endangered Species While Restoring an Endangered Ecosystem

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The American crocodile (*Crocodylus acutus*) is primarily a coastal crocodilian that is at the northern end of its range in South Florida. In Florida, habitat loss due to the expansion of a rapidly growing human population along coastal areas of Palm Beach, Broward, Dade, and Monroe counties has been the primary factor endangering the US crocodile population. This loss of habitat principally affected the nesting range of crocodiles, restricting nesting to a small area of northeastern Florida Bay and northern Key Largo by the early 1970's. When crocodiles were listed as endangered in 1975, scant data were available for making informed management decisions. Field and laboratory data suggested that low nest success, combined with high hatchling mortality, provided a dim prognosis for survival. Results of monitoring programs conducted over the last 30 years by the National Park Service, US Fish and Wildlife Service, Florida Game and Fresh Water Fish Commission (now Fish and Wildlife Conservation Commission), and Florida Power and Light Company focused on nesting ecology and growth and survival of crocodiles. These programs enabled managers towards better conservation efforts, to which crocodiles have responded positively, resulting in a more optimistic outlook for crocodiles in South Florida.

Data on captures, nests, and models relevant to the American crocodile in Florida were collected from the individuals and agencies responsible for conducting research and monitoring on crocodiles since they were listed as endangered in 1975. Most of this work has centered on the main nesting colonies in Everglades National Park, Crocodile Lake National Wildlife Refuge, and Florida Power and Light Company's Turkey Point Power Plant site. Only recently have surveys systematically extended beyond these core areas. In addition, the collection of data on crocodile mortalities, unusual locations, and relocations has been ongoing. The compilation of these data will allow for comparisons between the three nesting colonies, affording us the opportunity to make determinations of long term trends in population parameters, such as nesting (Figure 1), and monitor exchange and movements of individuals between and within study areas.

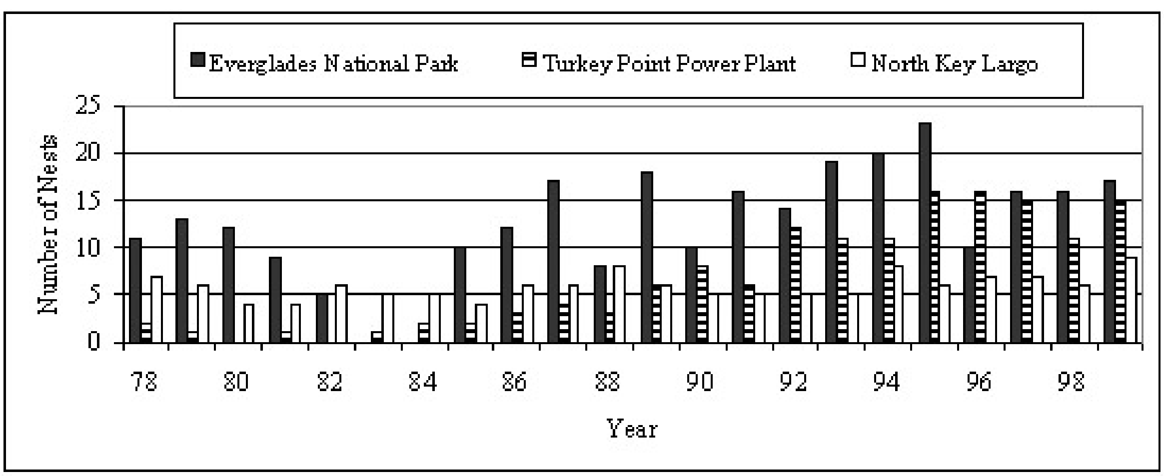

Figure 1. Summary of the total number of crocodile nests for the three nesting colonies in South Florida.

Currently, crocodiles face new issues--Florida and Biscayne Bays have undergone a number of changes that have caused a great deal of concern for the ecological health of these ecosystems and associated crocodile habitat. Efforts have been made, and continue to be made, to improve Florida Bay and Biscayne Bay. Monitoring and research studies have continued on crocodiles with the dual purposes of assessing the status of the population while evaluating ecosystem restoration efforts. As with other species of wildlife in South Florida, the survival of crocodiles has been linked to regional hydrological conditions, especially rainfall, water level, and salinity. Alternatives for improving water delivery into South Florida estuaries may change salinities, water levels, and availability of nesting habitat in the receiving bodies of water. Research and monitoring will be essential to ensure the continued survival of an endangered species in this changing environment.

There are more crocodiles in more places today than there were in 1975 when crocodiles were declared endangered. Crocodiles now occur in most of the habitat that remains for them in southern Florida. Most of the remaining habitat is currently protected in public ownership or engaged in energy production. In these areas, destruction of habitat has not been an issue. However, questions of potential modification of habitat through continued alteration of freshwater flow due to upstream development and potential curtailment of the range of crocodiles need to be addressed.

The American crocodile has been identified in the South Florida Water Management District Conceptual Model as having the potential to provide a quantifiable measure of restoration success. Determination of trends and year-to-year variations in population parameters are a critical part of an expanded monitoring program to support the development of ecological indicators and success criteria for the restoration effort. The relevant biological factors of this endangered species are well understood and existing databases afford good records of past and present population parameters. This provides us the unique opportunity to integrate endangered species recovery and conservation with ecosystem restoration and management in South Florida.

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Relating Water Flow to Wetland Processes and Everglades Restoration: Getting the Water REALLY Right in the River of Grass

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Historical analyses suggest that advective movement of water and sediments through the Everglades maintained the "corrugated" topography of the Everglades landscape. Drainage and compartmentalization of this landscape during the last century have reduced or eliminated water flow. In many areas, this has been accompanied by topographic homogenization and loss of plant community heterogeneity. We hypothesize that the advective transport of flocculent organic material (floc) links water flow, landscape maintenance, and vegetative pattern heterogeneity. Floc production is relatively slow, but appears to be greater that its decomposition rate. Without water flow, floc accumulates in deeper water habitats, reducing topographic relief and flow capacity. We are testing the hypothesis that increased water flow increases floc transport downstream, maintains deeper flow pathways (sloughs), and enhances landscape/topographic heterogeneity. Additionally, because the phosphorus content of floc is high **(**370-560 µgP gdw^{-1}**),** we hypothesize that restored downstream floc transport will restore an important energy subsidy to oligotrophic estuaries. We present long-term (1998 – 2001) Cladium productivity data from the southern Everglades to demonstrate ecological responses to relatively rapid increases in hydroperiod, such as would be expected if increased flow scours out old marsh sloughs. Cladium annual production (AP) is quite low across the oligotrophic southern Everglades landscape (100 – 500 gdw m^{-2} y^{-1}). Furthermore, we found significant negative relationships between annual Cladium production and a) mean annual water level and b) mean Eleocharis stem density. Fifty percent of the interannual variation in *Eleocharis* stem density in these marshes was explained by mean annual water depth (positive relationship) and Cladium culm density (negative relationship). These data suggest that, if a restoration of flow to Everglades wetlands scours old sloughs and "re-corrugates" the landscape, ecological responses to these changes will be rapid, predictable, and non-disruptive. This coupling of physical and ecological studies of water flow may help shape Everglades Restoration efforts.

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Northern Everglades Canals: Alligator Population Sources or Sinks?

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The Comprehensive Everglades Restoration Plan (CERP) includes the proposed removal of canals that fragment the Everglades wetland landscape. Dense populations of American alligators (*Alligator mississippiensis*) exist in canals throughout the system. Clutch and hatchling survival in canal and interior habitats at A.R.M. Loxahatchee National Wildlife Refuge (LNWR) were calculated during 2000 and 2001 to investigate the effects of canal habitats on alligator production. Data were collected from 112 nests and 779 hatchling alligators. Individuals from 57 hatchling pods were recaptured during this study.

No sampled clutches in the interior experienced flooding during 2000 and 2001 (fig. 1). However, most clutches in canal habitats were flooded or partially flooded (fig. 1). Nests were depredated by raccoons (*Procyon lotor*) at a higher rate during 2001 than 2000 (fig. 2). The number of clutches successfully producing at least one hatchling was greater during 2000 than 2001, and greater in interior than canal habitats (fig. 3). Survival probability estimates for 2000-cohort hatchlings for the first 6 and 13 months of life were 44% and 20%, respectively. Mean production per nest after 13 months was 2.4 $\pm$ 0.5 in interior and 0.8 $\pm$ 0.8 in canal habitats.

Compared to nests in interior habitats, canal nests were subjected to a larger range of water levels during clutch incubation and were more susceptible to flooding. Flooding was found to be the greatest risk to canal nests at LNWR. The majority of nests in LNWR interior habitats were on tree islands. High clutch mortality, small pod size, and overall low mean hatchling survival at LNWR, resulted in negligible production in canal habitats during 2000 and 2001. Comparatively high adult densities in canals at LNWR, and likely other areas of the Everglades, are sustained by immigration and high adult survival rates. Everglades canals appear to be population sinks for alligators and canal removal will probably not affect the overall population.

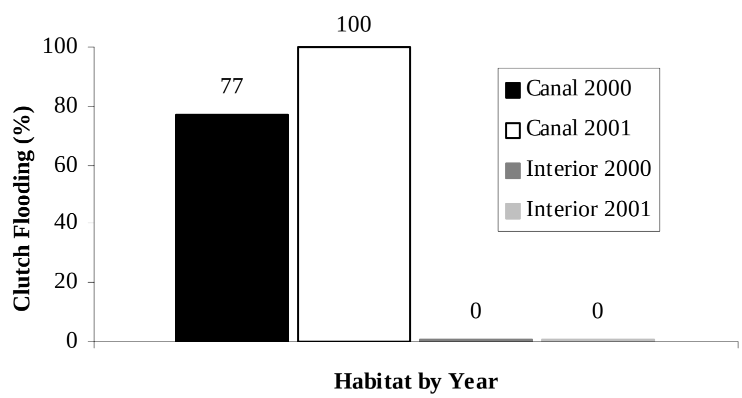

Figure 1. Percentage of American alligator clutches that experienced flooding during incubation in canal (*n* = 13 and 30) and interior (*n* = 35 and 24) habitats at A.R.M. Loxahatchee National Wildlife Refuge during 2000 and 2001, respectively.

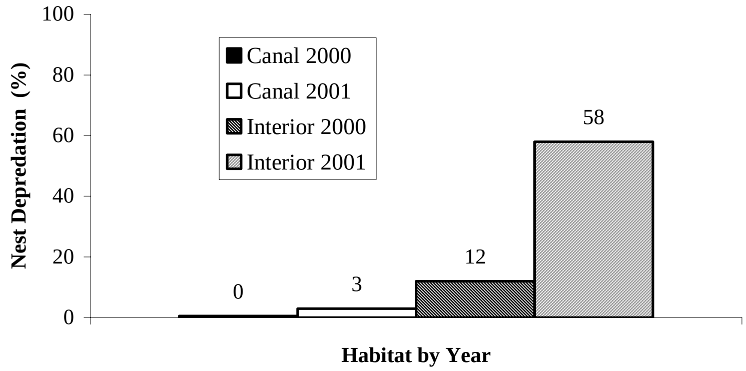

Figure 2. Percentage of American alligator nests that experienced depredation during incubation in canal (n = 13 and 29) and interior (n = 33 and 24) habitats at A.R.M. Loxahatchee National Wildlife Refuge during 2000 and 2001, respectively.

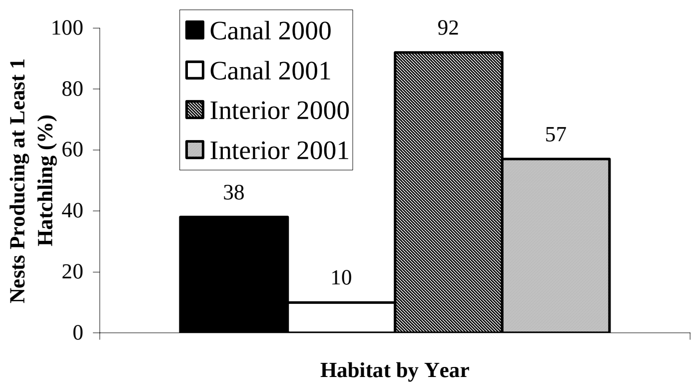

Figure 3. Percentage of American alligator nests that successfully produced at least one hatchling during the hatch event in canal (n = 13 and 30) and interior (n = 36 and 35) habitats at A.R.M. Loxahatchee National Wildlife Refuge during 2000 and 2001, respectively.

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Variation of Soil Topography and Soil Forming Factors Between Ridge and Slough Communities

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Soil accretion and oxidation are arguably the most significant autochthonous feedback mechanism influencing larger scale allochthonous forcing functions in wetlands. Soil accretion/oxidation over time can change the relative elevation of a site and thereby alter inundation hydroperiod, water flow, nutrient availability and depth to bedrock among other variables. In the Everglades there are two principal sources of sediment accretion; one is the result of net organic matter deposition, and the second, calcite formation that is mediated by changes in pH due to photosynthesis within periphyton communities. Sources of oxidation include those that are microbially mediated and those that result from heat catalyzed oxidation in the case of fire. Both of these oxidation mechanisms being significantly increased as a result of reduced hydroperiod.

In Shark River Slough, the vegetative mosaic often described as “Ridge and Slough” is in part the result of differences in topographic relief often running in a north/south direction parallel to flow. Since the mid 1930’s, however, differences in elevation between higher ridges and lower sloughs have decreased allowing colonization of slough communities by less inundation tolerant wet prairie species and encroachment by *Cladium jamaicense*. Some evidence suggests that this historic elevation differences was on the order of 30-60 cm. As part of this study, a survey of 10 sites (8 within Everglades National Park and 2 within Water Conservation Area 3A) indicate that this difference in elevation between ridge and slough has decreased to 30 cm or less. Findings also identified an often discrete demarcation between taller stands of *C. jamaicense* > 200cm in height (possibly demarcating the historic ridge) and shorter stands < 200cm in height (possibly demarcating recently colonized slough areas). This change in elevation and vegetative morphology suggests a fundamental change in the historic rates of biotically mediated sediment accretion mechanisms associated with ridge and slough development.

To address this question, a two year monitoring study has begun to evaluate carbon accretion rates in the ridge and slough community, evaluate liter quality of dominant biomass producers and measure rates of organic matter decomposition. These parameters will be used to develop a model of soil accretion characteristics in these vegetative communities. Early findings indicate significant differences in litter quality between ridge and slough species, with ridge species having more recalcitrant litter both in terms of C/N ratio as well as LCI indices. In addition, wet prairie species, often found colonizing previous deeper water habitat, tend to have C/N and LCI indices intermediate between *C. jamaicense* (ridge dominant species) and *Nymphaea odorata* (slough dominant species). These differences in litter quality suggest a greater potential for soil accretion in ridge communities versus slough communities, and between wet prairie species and slough species. In ridge communities, however, historic soil accumulation is now likely offset by shorter hydroperiods in ridge communities resulting in increased decomposition rates. Litter bag studies initiated in Fall 2002, and CO_2 and CH_4 evolution rate studies will not yield conclusive evidence of carbon loss dynamics for another 6-12 months.

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Development of an Invasion Index and Remote Identification Technique for Assessing *Lygodium microphyllum* on Tree Islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge

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Fred H. Sklar
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The ecosystem of the tree islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge is undergoing significant changes due to the invasion of *Lygodium microphyllum*. Monitoring these changes is of critical concern to Refuge Managers and researchers who study the application of remotely sensed data for vegetation mapping. This research investigates the utility of four-meter multispectral Ikonos satellite imagery captured in March, 2002, versus color infrared aerial photographs, taken around the same time, for recognizing and quantifying *Lygodium microphyllum* on the Refuge. A statistical relationship will also be established between selected soil properties and the spatial distribution of *Lygodium microphyllum* on tree islands invaded. Earth Resources Data Analysis System (ERDAS), version 8.5, image processing software was used to perform an unsupervised classification of the Ikonos data and to select random points for accuracy assessment. Thirty two random points were verified during ground reference and the findings will be used to compute the overall accuracy percentage of the classification.

Preliminary results have indicated that there are approximately 677 ha (1671 acres) of tree island vegetation that have been invaded by *Lygodium microphyllum*, and the invasion is mainly in the north-central and north western regions of the Refuge. A traditional air photo interpretation approach and accuracy assessment technique will be used for the color infrared aerial photographs. The method that yields the higher percentage accuracy value will be utilized to create a Lygodium invasion index. In order to establish the statistical relationship with soil properties and the spatial distribution of *Lygodium microphyllum*, twenty four soil cores were extracted from six tree islands in the northern and southern regions of the Refuge, between October 29 and November 25, 2002. In both regions, one island without *Lygodium microphyllum*, and two invaded islands were sampled. All cores were extracted according to the protocol established by the Everglades Division at the South Florida Water Management District. Soil cores will be analyzed for ash content, bulk density, moisture content, pH, total nitrogen, and total phosphorus. Analysis for nitrogen will be conducted with the U.S. Environmental Protection Agency's method 351.2 and 365.1. Method 365.4 will be used for phosphorus. Ash content will be determined by using the U.S. Environmental Protection Agency/Army Corps of Engineers method 3-59. A statistical relationship will be established using the Statistical Analytical System (SAS), version 8.0. Mean values of the concentration of the soil properties analyzed on the islands without *Lygodium microphyllum* will be compared to those for invaded islands, between the northern and southern islands, using ANOVA analysis.

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Impact of Photooxidation and Cometabolism on Petroleum Degradation by Bacteria from Pristine and Oil-contaminated Sites

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Some petroleum components are biologically refractory. These compounds are potentially harmful to marine species especially if they are exposed to luxurious concentrations. The biological fate of these compounds in aquatic ecosystems is influenced by the physical and chemical factors, an understanding that forms the basis of this study. A series of laboratory experiments were conducted using bacteria from a Tampa Bay (TB), an oil-contaminated site and from Turkey Point (TP), a pristine site to study the biodegradation of marine petroleum. Crude oil exposed to ultraviolet radiation (UVR) in artificial seawater for 10 h and 16 h respectively, was incubated with or without ground pinfish powder as the labile cometabolite and marine bacteria in 60 mL serum bottles. Parallel series of incubations was carried out using unphotooxidized petroleum. CO_2 respiration was used as the indicator of biodegradation. Gas chromatography was used to determine CO_2 concentrations while an isotope ratio mass spectrometer was used to determine the source of the CO_2 in the cometabolism experiments by analyzing stable carbon isotope ratio.

The results show that at 10 h of exposure to sunlight, photooxidized petroleum is more biolabile than unphotooxidized PHCs despite an initial inhibition of bacterial respiration. As indicated by CO_2 evolution, TB bacteria were found to be better petroleum degraders than the TP bacteria. However, TP bacteria degrade more pinfish than TB bacteria. When TP bacteria were augmented with TB bacteria, petroleum degradation equaled that of TB bacteria alone. Mass Spectrometric analysis reveals that the presence of pinfish enhances bacterial degradation of unphotooxidized petroleum by TB bacteria by more than 40%, while there was no significant increase by the TP bacteria. Petroleum that was exposed to sunlight for 16 h was totally inhibitory to bacteria from both TB and TP sites even in the presence of labile pinfish. Cumulatively, photooxidation and cometabolism increase petroleum degradation by TB bacteria but not by TP bacteria. However, increased exposure to sunlight enhances petroleum toxicity to bacteria from both sites, which limits its biological fate in the aquatic system.

Since cometabolism increases degradation of petroleum by bacteria at TB site, this approach can be applied in bioremediation of oil spills in similar environments. However, this approach is not applicable at pristine sites since the bacteria are poor petroleum degraders.

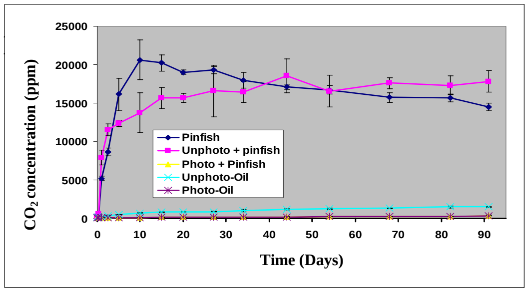

Figure 1. Degradation of pinfish and petroleum by Turkey Point Bacteria. Cometabolism did not influence degradation of petroleum. Petroleum that was exposed to UVR for 16 hrs was inhibitory to bacteria respiration even in the presence of labilepinfish substrate. Unphotooxidized petroleum were only degraded to a limited degree compared to pinfish.

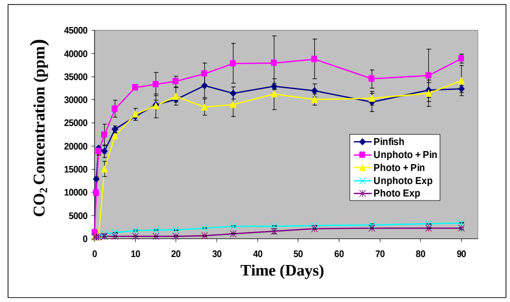

Figure 2. Degradation of pinfish and petroleum by Turkey Point bacteria. Petroleum that was exposed to UVR for 10 hrs was degraded to a lesser degree than unphotooxidized petroleum probably due to phototoxicity. Pinfish was more degradable than photooxidized and unphotooxidized petroleum.

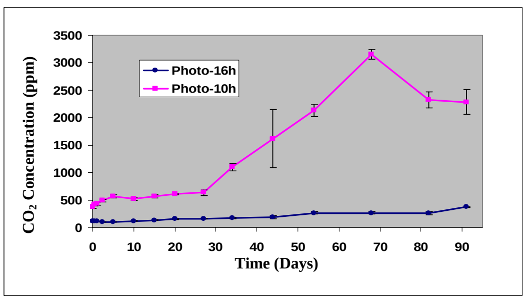

Figure 3. The effects of length of UVR exposure on petroleum degradation by Turkey Point Bacteria. Petroleum that was exposed to sunlight for 10 hrs was degraded to a significantly higher degree than petroleum that was exposed for 16 hrs. This indicates an increase in petroleum toxicity with increased UVR exposure.

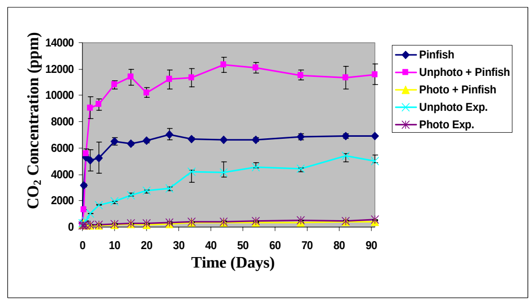

Figure 4. Degradation of pinfish and petroleum by Tampa Bay Bacteria. Cometabolism increases degradation of petroleum. Petroleum that was exposed to UVR for 16 hrs was inhibitory to bacteria respiration even in the presence of labile pinfish substrate. Unphotooxidized petroleum was degraded significantly relative to photooxidized petroleum, however, there was an initial lag phase. Degradation of pinfish was significantly higher than that of unphotooxidized petroleum due to higher lability.

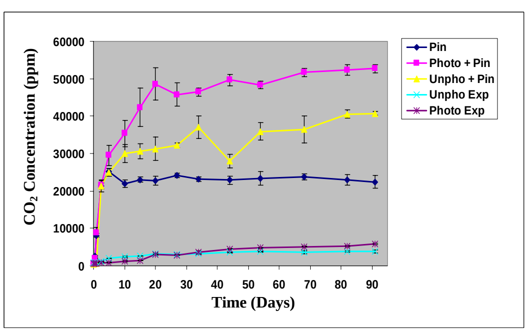

Figure 5. Degradation of pinfish and petroleum by Tampa Bay Bacteria. Petroleum that was exposed to UVR for 10 hrs was more biodegradable than unphotooxidized petroleum. There was an initial lag phase in degradation of photooxidized petroleum, which is attributed to petroleum phototoxicity. Pinfish was more degradable than photooxidized and unphotooxidizedpetroleums.

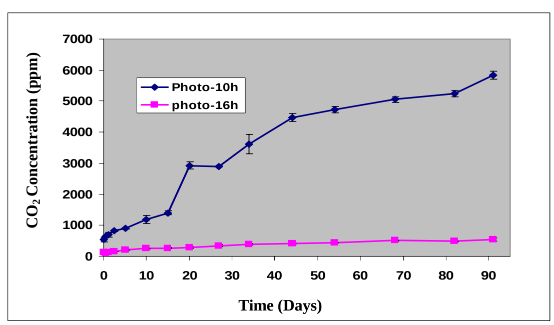

Figure 6. The effects of length of UVR exposure on petroleum degradation by Tampa Bay Bacteria. Petroleum that was exposed to sunlight for 10 hrs was degraded to a significantly higher degree than petroleum that was exposed for 16 hrs. This indicates an increase in petroleum toxicity with increased UVR exposure. UVR exposure increases labilty of petroelum but increased exposure may cause toxicity by concentration.

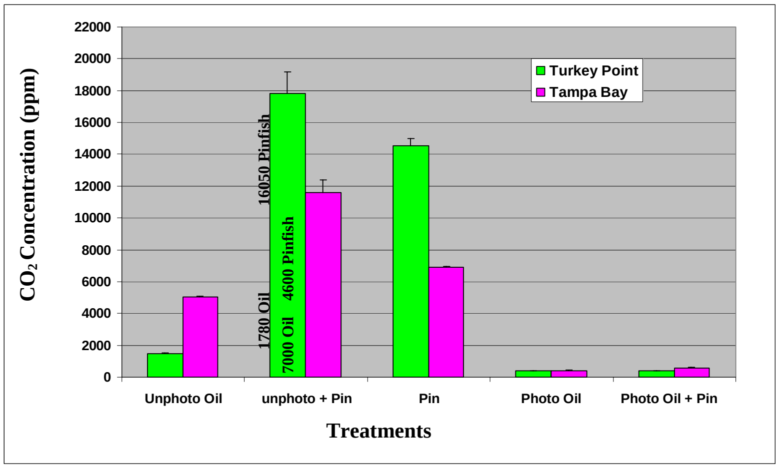

Figure 7. Comparison of substrates biodegradation by marine bacteria from Turkey Point and Tampa Bay after 90 days. $\delta^{13}C$ data indicated that for Tampa Bay bacteria 60% (7000 ppm) of the CO_2 respired in the cometabolism is due to the utilization of petroelum while 40% (4600 ppm) is due to the utilization of pinfish, where as for Turkey Point it is 10% (1780 ppm) and 90% (16050 ppm) respectively. Cometabolism increases petroleum degradation by Tampa Bay bacteria by 40% while no increase was observed with Turkey Point bacteria. Turkey Point Bacteria degrade more pinfish than Tampa Bay bacteria.

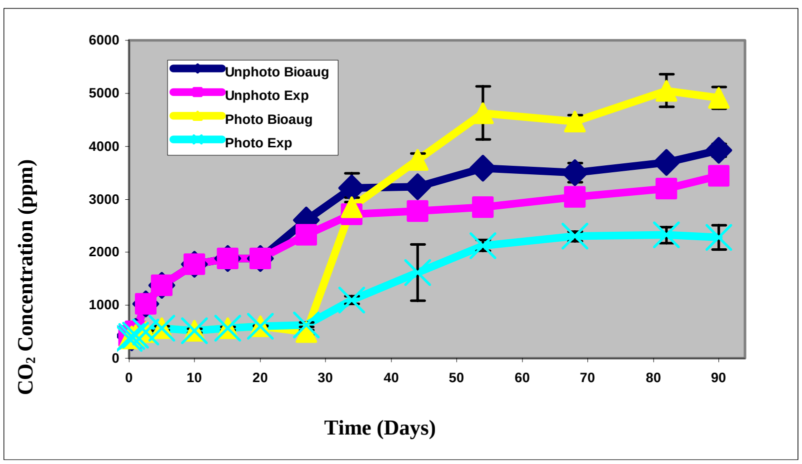

Figure 8. Degradation of petroleum by Turkey Point Bacteria augmented with Tampa Bay Bacteria. Augmentation of Turkey point bacteria with Tampa Bay bacteria increases degradation of both photooxidized and unphotooxidized petroleum when compared to unaugmented groups. The photooxidized augmented group shows greater degradation than the unphotooxidized augmented group.

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High-Resolution, Small-Footprint, Waveform-Resolving Lidar: EAARL Applications in the Florida Keys Reef Tract

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The term 'lidar' (derived from '*li*ght *d*etection *a*nd *r*anging') refers to active optical techniques that use a pulse of laser light to make range-resolved remote measurements. Distance between the lidar sensor and reflecting target(s) is calculated as a function of time elapsed between transmission of a well-characterized laser pulse and its return to the detector (i.e., the two-way travel time), and the speed of light in the medium of transmission. Such techniques are finding wide application in the fields of topographic and hydrographic surveying, forestry, and the geological and atmospheric sciences.

A number of South Florida lidar coastal applications are now being explored with the NASA Experimental Advanced Airborne Research Lidar (EAARL), a relatively lightweight, low-power sensor designed for deployment on light aircraft. The system is presently capable of synchronized collection of precision navigation data, georectified digital aerial photography, and temporally resolved lidar waveform data. Coupled hyperspectral imaging capabilities are to be added early in 2003. Designed for cross-environment (subaerial and subaqueous) applications, the lidar component of EAARL utilizes a green (532-nm) laser for maximum water penetration. Under typical surveying conditions (300-m operating altitude, two-pass coverage), EAARL covers approximately 43 km^2/hr, with a swath width of ~240 m, a spot size ("footprint") of ~15 cm and horizontal sample spacing of ~ 1 x 1 m. Each returned laser waveform is sampled every 1 ns, which is equivalent to, vertically, every 15 cm in air and 11 cm in water.

Because of the unique nature of the system, off-the-shelf software is not available for EAARL data processing, feature extraction, and image display. The development of new software has necessarily accompanied the design, construction and deployment of the hardware components. The processing code is written in Yorick, a high-level programming language designed for scientific applications, while the integration platform and graphical user interface (GUI) capabilities have been built using the Tcl/Tk language and toolkit. The raw EAARL waveform data are processed to return derived data in the form of first-return elevation (e.g., top of vegetation in subaerial vegetated areas), bald-earth elevation, water-surface elevation, submerged topography, and water depth. For the purposes of data exploration and display, the software package includes the capability to display and query linked aerial photographs, individual returned waveforms, composite rasters, and maps. A second custom software package utilizes the aircraft navigation data and camera parameters to generate georectified photomosaics of the digital aerial photography collected during each lidar survey.

EAARL capabilities and their potential applications are presently being explored in a variety of environments, including the optically transmissive waters of the Florida Keys reef tract. EAARL laser returns in these waters are retrieved typically from $\leq$ 15 m water depth. Including engineering test flights, three surveys have been conducted in South Florida (July 2001, September 2001, and August 2002), covering portions of Biscayne and Dry Tortugas National Parks, as well as the northernmost reaches of the Florida Keys National Marine Sanctuary.

In all, approximately 160 GB of laser sounding data and 200,000 accompanying digital aerial photographs have been collected over the Florida reef tract. The lidar data are now being processed at the U.S. Geological Survey, with the aim being the routine production of easily extractable data subsets as well as GIS-ready point data, grids, and maps. After post-processing of the associated GPS data, the EAARL lidar data are parsed into 2 x 2 km tiles for ease of management. Present geographic coverage over the Keys includes 360 of these tiles, grouped into 40 larger (24 x 24 km) index tiles. Each tile and index tile is named according to the easting and northing values of its northwestern corner, as are any features that are extracted during subsequent analysis (e.g., individual patch reefs). Each flightday's data is first processed tile-by-tile for initial checks on data quality and internal consistency. Subsequently, all data for a given tile are merged and used to create final map products and provide input data for subsequent analyses.

Initial EAARL surveys have been targeted to satisfy not only basic research needs, but also high-priority areas identified by those with stewardship responsibilities for the reefs. One direct outcome from the EAARL surveys is the production of high-resolution topographic/bathymetric maps. Such maps are of obvious utility for field researchers, resource managers, and recreational users.

A particular advantage of this type of digital data is the potential for automated feature extraction. Biscayne National Park, for example, contains thousands of small patch reefs inshore of the bank-edge barrier reefs. While, due to their sheer numbers, characterizing or even identifying each one manually would be a Herculean task, the EAARL data lends itself well to this type of problem.

Another potential application of this high-resolution topographic (subaerial and submerged) data is the provision of boundary conditions for numerical models of circulation, sediment transport, wave run-up, and tsunami and hurricane inundation. Earlier data sets for many areas of South Florida and the Caribbean are inadequate for such applications.

One novel application takes advantage of the unique capabilities afforded by the small footprint and high-resolution sample spacing of EAARL. Preliminary analyses indicate that EAARL-derived "optical rugosity" of the patch and barrier reefs of the northern Keys may provide a meaningful landscape measure related to habitat complexity.

Other research topics and applications currently being explored with EAARL data collected in the South Florida region include ongoing algorithm development and refinement, as well as pilot inquiries into lidar characterization of water-column and subaerial vegetation/canopy vertical structure.

Future work will be aimed at expanding both the geographic coverage and site diversity of the EAARL coral reef data set. If adequate funding partnerships can be established, additional EAARL surveys will be flown to cover the Middle and Lower Keys as well as selected sites in the Caribbean. Surveying the remainder of the Keys reef tract could lead to a seamless series of high-resolution, GIS-ready map products. Surveying sites outside the Keys region would provide the expanded range of site diversity that is required to more thoroughly explore EAARL capabilities in terms of substrate characterization.

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Creation of a Geodatabase of the Digital Aerial Photography Archives for the Greater Everglades of South Florida and the Southern Inland and Coastal System

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The project to create a digital archive of historical aerial photographs for the Greater Everglades is an important first step in the development of an understanding of the pre-drainage vegetation in the south Florida landscape. This knowledge is essential in the development of "endpoints, restoration goals and performance measures to gauge restoration success" (Smith and Foster, 2002). Work on the digital archive has progressed with the creation of two open file reports publishing maps from 1927 – 1935 and imagery from 1940 (Smith *et al* 2002; Smith *et al* in press). In addition to these two sets, scanning of photographs dating from 1952 and 1987 has progressed, with an open file report of the 1987 set due to be published in the near future.

Concurrent with the development of the digital archive, information about the photography was recorded in a relational database using Microsoft Access. The data recorded included information on the flight, the photography, the scanning process and detailed information on each individual photograph.

After scanning of the photography, georeferenced mosaics of the flight lines were constructed indicating the general locations of the photography. From these mosaics, approximate center points of each photograph were recorded in the database, thereby providing general locations to which the photographic metadata could be linked (Figure 1). The utility of linking the metadata with physical locations became readily apparent. It would be even more useful if the metadata about the photograph could be linked to each georeferenced raster image in the archive.

It has always been the intention of the digital archives project to create georeferenced imagery of the south Florida photography. However, in order for the imagery to be useful as a tool, it must be integrated into a geographic information system (GIS). This presents a challenge to users since, as individual files, the raster images are very large thus limiting their use to small study areas, and effectively restricting their use in landscape-scale analyses. The challenge of incorporating raster images with large file sizes (e.g., 160 MB) into a geographic information system is resolved in the ArcGIS geodatabase system using ArcSDE and Oracle database management software.

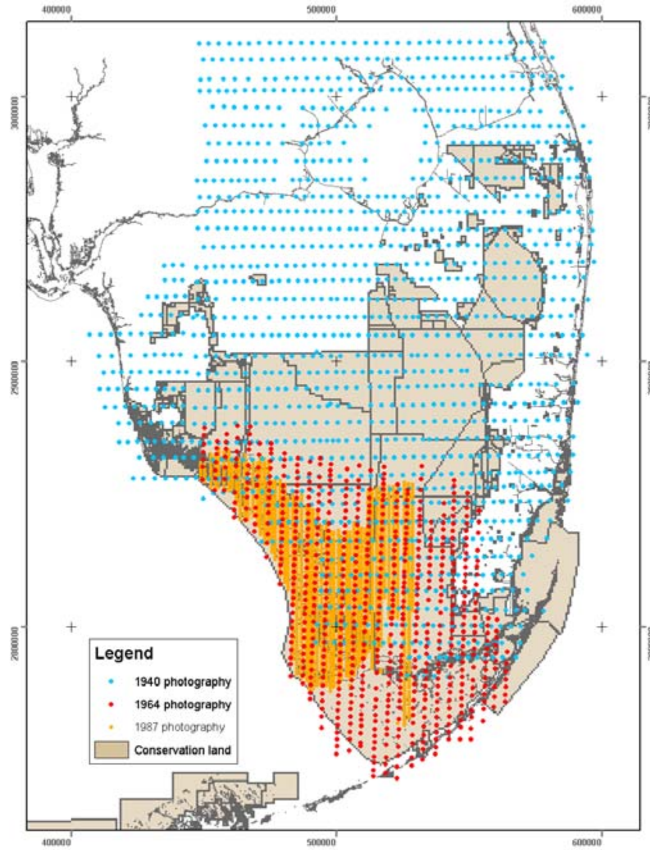

Figure 1. Map showing approximate center points of photography in the Digital Aerial Photography Archives for the Greater Everglades.

To test the geodatabase system as it applies to the Digital Aerial Photography Archives for the Greater Everglades of South Florida, a limited area was selected as a pilot project. The project consists of a geodatabase that includes georeferenced raster imagery from 1940, 1964 and 1987 incorporated with tables of detailed information about the photographs. It also includes vector files and raster imagery of the T-sheets that are based on a 1927 aerial photographic survey (Smith *et al* 2002). The selected area corresponds to the Southern Inland and Coastal System (Area 6) of the Everglades. The geodatabase is part of the South Florida Information Access (SOFIA) clearinghouse and can be searched and used free of charge by accessing the SOFIA web address (http://sofia.usgs.gov/exchange/).

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Dissolved Oxygen in the Kissimmee River: Baseline Condition and Initial Response to Restoration

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Channelization of the Kissimmee River transformed the flowing river into a central drainage canal (C-38) with a series of reservoir-like pools. Flows through remnant river channels were eliminated allowing aquatic vegetation to encroach upon open water areas and oxygen-depleting organic sediments to accumulate over the river's sandy substrate. The 9-m deep canal also drained the adjacent floodplain, thereby reducing the ratio of surface area to volume of water and limiting the ability of the system to be re-aerated through wind and flow-induced mixing. Dissolved oxygen (DO) has been identified as an important component for evaluating success of the Kissimmee River Restoration project because it is essential to the metabolism of most aquatic organisms and it is easily measured.

Pre-restoration DO data were collected at stations within the river channel between March 1996 - June 1999. Mean DO concentrations were consistently low (< 4 mg/L) at all stations during this baseline period; however, dry season concentrations were slightly higher than wet season concentrations. A clinograde oxygen profile and thermal stratification during the wet season also were observed.

Restoration of continuous, variable flow through reconnected river channels is expected to flush flocculent organic sediments and increase DO concentrations by reducing biochemical and sediment oxygen demand and increasing atmospheric aeration. Continuous flow should restrict/preclude mid-channel growth of aquatic macrophytes and reduce the potential for deposition of organic matter over mid-channel substrates. Initial post-construction (February 2001 - present) response of DO will be presented. Changes in river channel water column community metabolism due to restoration also will be discussed.

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Applying the Success of the Stormwater Treatment Areas to the Greater South Florida Restoration Effort of the Comprehensive Everglades Restoration Plan.

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The Everglades is an internationally recognized oligotrophic ecosystem, and acknowledging that more than half of the original 1.17 million hectares (ha) has been lost to drainage and development, it is still the largest subtropical wetland in the United States (Davis & Ogden, 1997). Historically these areas were part of a rainfall driven landscape that periodically received flow from Lake Okeechobee and was comprised of five major ecosystems: 1) sloughs, 2) deep channels, 3) periodically dry sawgrass ridges, 4) elongated tree islands, and 5) circular tree islands (Sklar et al., 2000). In 1949, Congress approved the Central and South Florida (C&SF) Flood Control project, which created a system of canals and levees, designed to promote agricultural and urban growth in south Florida, and in the 1960s six Water Conservation Areas (WCAs) were created to provide flood protection, water supply and wildlife habitat. The WCAs along with the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), and the Everglades National Park comprise the remnant Everglades ecosystem. These areas are being negatively impacted by hydrologic changes and nutrient-rich runoff generated from these increasing urban and agricultural sources (Light and Dineen, 1994; Chimney and Goforth, 2000).

In 1994, the State of Florida enacted the Everglades Forever Act (EFA) [Section 373.4592, Florida Statutes] that mandates both hydrologic modifications, improved water supply and improved water quality in order to protect the remaining Everglades. Additionally, in December 2000, the Water Resource Development Act (WRDA) of 2000 was signed into law approving the Comprehensive Everglades Restoration Plan (CERP). While the EFA requires the South Florida Water Management District (SFWMD) and the Florida Department of Environmental Protection (FDEP) to carry out the Everglades Program, designed primarily to achieve Everglades ecosystem restoration through the improvement of water quality and management goals, CERP authorizes the implementation of hydrologic and other environmental improvements. CERP is comprised of over 60 components, which are grouped into more than 40 projects. CERP is designed to restore, protect and preserve the water resources of central and south Florida, including the Everglades over the next 30 years [WRDA 2000, S.2796-100(A)] (www.evergladesplan.org).

As part of the EFA directive, SFWMD and FDEP initiated construction, research and monitoring of several large treatment wetlands (ca. 17,000 ha) called Stormwater Treatment Areas (STAs), designed to reduce nutrient levels in runoff to a design target of 50 µg-P/L (ppb) before it reaches the Everglades (Chimney & Moustafa, 1999).

To date, most of these STAs have been constructed on previously farmed agricultural land, and are positioned in the southern region of the Everglades Agricultural Area (EAA). Collectively these STAs have removed over 200 mt tons of phosphorus that would have otherwise been transported into the WCAs. In general, the STAs are in permit compliance and with the exception of STA-5, are discharging mean TP values of less than 50 ppb.

The projects in CERP were selected based on their synergistic effect to the overall plan to restore, protect and preserve the water resources of the region. Each project must be formulated to achieve local and system-wide goals and objectives as defined by CERP. Specifically, CERP identifies the system-wide benefit of retaining water supply for the natural areas and identified the Acme Basin B Discharge project to provide water to the natural system. With the EFA mandate, current discharges to the Refuge from Acme Basin B within the Village of Wellington, Palm Beach County, may be diverted from the natural system. The CERP process will identify ways to continue the water deliveries to the natural system. In order to provide ecological enhancement of the Refuge, the quality of the water supplied to the natural system is important; therefore, the STAs design and research will be considered in the formulation of CERP projects.

The incorporation of new technologies into the formulation of all CERP projects will help ensure success in the restoration, protection and preservation of the water resources of central and south Florida. Therefore, the Project Implementation Report (PIR) for the Acme Basin B Discharge project will incorporate all previous research concerning STAs when developing potential alternatives for the project. In this presentation we will identify some of the key findings of the STAs and how they may be incorporated into the Acme Basin B Discharge PIR.

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Molecular Forensics of Introduced Swamp Eels (Synbranchidae)

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Synbranchid eels within the Asian genus *Monopterus* have been found in several regions of the southeastern United States and in Hawaii. These same forms are sold live in fish markets and the pet trade in some U. S. cities. Established populations have been identified from near Atlanta, Georgia as well as near Tampa and North Miami, Florida. The most recent population to be discovered is in close proximity to Everglades National Park in Homestead, Florida. Swamp eels are predators capable of dispersal over land and therefore have the potential to disrupt already threatened ecosystems. We carried out phylogenetic analyses of the known populations from the U.S., as well market samples and samples from the native ranges of these species. We gathered nucleotide sequence data from the mitochondrial 12S and 16S rRNA genes, and two nuclear genes to determine the pattern/level of genetic variation in introduced and native swamp eel populations in order to (1) identify distinct lineages and species (2) look for evidence of hybridization among lineages (3) identify introduction pathways**.**

Our results to date indicate that the swamp eels in the U.S. represent at least four genetically distinct lineages that trace to different native source populations. Some Florida populations are more closely related to Chinese samples, while others are most closely related to populations and fish market samples from Vietnam, Indonesia, and Malaysia. The Georgia and Hawaiian populations are related to Japanese and Korean populations. These lineages differ in traits that are relevant to their dispersal, control and management, and potential effects on ecosystems where they have been introduced.

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ATLSS PanTrack Telemetry Visualization Tool

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ATLSS PanTrack is a visualization tool designed to display and analyze spatial movement data of panthers over georeferenced landscape maps. It has been customized for the display of radiotelemetry observations collected for the Florida panther endangered species recovery project. PanTrack was developed to help define panther behavior rules for the spatially explicit, individual-based ATLSS Deer/Panther model. The effectiveness of individual-based models depends upon the availability of detailed observations about individuals on the landscape, and on the ability to find patterns in these observations that provide insight into key animal behaviors. The availability of PanTrack, a programmable tool customized for the Florida panther data set, has facilitated the evaluation of telemetry data, and has also proved invaluable in facilitating interaction and exchange of information between the modeler and field biologists, allowing on-the-spot confirmation of field observations in the context of the full set of monitoring data and rapid visual identification of patterns in landscape/panther associations. Having a readily customizable display and analysis tool has also enabled researchers to study published panther analyses closely, evaluating whether trends reported in spatial and temporal subsets of panther data are reflected in the entire data set.

South Florida is home to the last remaining population of endangered Florida panthers (*Puma concolor coryi*). Panther survival is threatened by habitat loss and degradation, geographical isolation, disease, and problems associated with small population size, including inbreeding and sensitivity to stochastic events. The current verified population size is 80 adult and subadult panthers. Because the few remaining panthers have been intensively studied, a fairly detailed database is available for individuals in the population. Monitoring of Florida panthers by radiotelemetry, initiated in 1981 with the radio-collaring of two individuals, has now expanded to include 39 panthers. Over 60,000 telemetry locations are available over the monitoring period. Four Global Positioning System (GPS) collars were deployed for the first time in 2002, providing as many as 8 locations around the clock compared to the current collection schedule of 3 daytime locations per week.

Recent demographic trends in the panther population are in sharp contrast to earlier observations, necessitating a thorough reevaluation of rules and parameters in light of changes in the population. A genetic restoration project was initiated in 1995 because of low genetic variation and health and reproductive problems likely caused by inbreeding. Eight reproductive females from a closely related subspecies of *Puma concolor* were translocated from Texas and introduced into the South Florida population. Five of those females have mated with Florida panthers, producing a total of 17 F1 offspring over a 7-year period. F1 panthers and their offspring have been vigorous and healthy thus far, showing none of the heart and reproductive problems seen in Florida panthers. The success of genetic restoration in increasing genetic variation and producing healthy intercrossed panthers has changed the course of panther recovery, and has confounded published theories and opinions about panther ecology in South Florida.

The panther population has more than doubled since 1995, including a 5-fold increase in formerly sparsely populated areas of BCNP and ENP, thought by some researchers to be unsuitable habitat for panthers. Earlier observations and theories about habitat use, home range establishment, dispersal patterns, and rates of reproduction and kitten survival must now be reevaluated in light of new data. Pre-introgression panther habitat selection studies that focused narrowly on forest were based on the unsupported assumption that habitats associated with daytime telemetry locations are representative of total habitat use. Panther distribution patterns previously attributed to habitat suitability now appear to have resulted from dynamics associated with limited dispersal potential in a small, inbred population with low reproductive rates living in a barrier-rich environment.

Panther recovery and Everglades restoration efforts, and the modeling projects that support and guide them, depend on accurate characterizations of panther habitat use and requirements, based on all available information. With these changes in mind, the set of panther location observations (1981-1995) on which preliminary panther behavior rules for the ATLSS Deer/Panther model were originally based has been expanded to include post-introgression observations so that recent trends can be reflected in revised rules for behavior and habitat use. The PanTrack Tool is being used to display and analyze the full set of available panther telemetry data for the purpose of redefining behavior rules. The predictive capabilities of an individual-based model are closely tied to the realism of the decision rules that determine how individual animals move across the landscape, interact with one another and respond to their environment. The definition of these rules is in turn tied to the availability and interpretation of empirical observations about these behaviors and movement patterns. In this context, PanTrack has been used to study abundance and distribution; movement and dispersal patterns; seasonal effects; home range characteristics; patterns of reproduction, recruitment, and mortality; effects of gender, age, and genetic group, and patterns of habitat use.

ATLSS panther researchers have reported results of their analyses in an extensive article in the online journal *Conservation Ecology*. Using programming extensions to PanTrack, innovative telemetry mapping and fractal analysis techniques were used to explore panther habitat use and home range characteristics. Wildlife biologists contributed field observations indicating that habitat selection is considerably broader during active nighttime hours than during daytime. The paper provides a critical evaluation of the assumptions and limitations of the dominant forest-centered view of panther ecology, concluding that percent forest cover is a poor predictor of home range size and that forest cannot be considered a surrogate for useful panther habitat. Factors other than habitat have contributed substantially to habitat suitability, population density, and distribution.

The authors conclude that *Puma concolor* in Florida, as elsewhere in their range, are habitat generalists, exploiting the broad spectrum of available habitats for hunting, resting, mating, travel, denning, and dispersal. While panthers readily utilize forested habitat with understory and prey, we found no support for the view that only forested land within a habitat mosaic is potential panther habitat, or for the contention that only forested habitats are used by panthers within existing home ranges. This work suggests a more ecologically-consistent management and recovery paradigm based on maintaining the integrity of the system of overlapping home ranges that characterizes panther social structure and satisfies breeding requirements. Such a paradigm focuses on the requirements for reproductive success of a small population in a changing environment.

PanTrack currently operates on Sun workstations or on PC's with a LINUX operating system installed. Installation of PV-WAVE Version 7.50 (Visual Data Analysis Software by Visual Numerics) is required. PanTrack data and program installation require 15MB of disk space. The run-time PanTrack screen consists of a Landscape Map Window and a menu board user-interface. Zoom and animation windows may be created and dismissed during the session. Data may be subset for display by time period (day, month, year) and/or by group (e.g., individuals, age, gender, genetic lineage, cause of death).

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Effect of Hydropattern Changes on Ecological and Biological Properties of Forested Wetlands Located in the Central Everglades: A Tree Island Monitoring Program.

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Flood control and water management implemented by the Central and Southern Florida Project in the late 40's altered historic water patterns in the Everglades National Park and the Water Conservation Areas (WCAs). One of the most sensitive indicators caused by past water management practices has been the change in the physical, ecological and biological properties of tree islands. For instance, in the early 1960s, the number of tree islands in portions of WCA-2A and WCA-3A significantly decreased due to prolonged high water levels that caused the death of tree species on these islands. In contrast, prolonged low water levels in the northern section of WCA-3A resulted in tree island destruction because peat fires removed the top 25 cm of their peat, resulting in water depths too great for tree species colonization.

Since tree islands are ecologically important and given their potential use as indicators of appropriate water management, the South Florida Water Management District has implemented a comprehensive research program to monitor this crucial component of the Everglades Landscape. By monitoring the health of tree islands, it is feasible to adjust the hydropattern in marsh areas of the Everglades through adaptive management and thus to ensure tree island persistence and restoration. The monitoring program includes monthly sampling of litterfall, bi-monthly measurements of tree growth and annual vegetation surveys on nine tree islands located on WCA-3A and 3B. Based on hydroperiod patterns, these nine islands were grouped into two island types: wet (inundated less than 6 months and 10 cm of water level) and flooded (inundated more 6 months and 30 cm of water level) islands. The main objectives of this monitoring program are a) to characterize spatial and temporal long-term patterns of litterfall production, tree growth, and species composition, and b) determine the effects of water level fluctuations on below and aboveground primary production on tree islands.

Preliminary results have shown that flooded tree islands have lower litterfall production rates relative to wet tree islands. Over the study period, litterfall production for the two island types has been 0.90 $g/m^2/day$, and 1.65 $g/m^2/day$ for flooded and wet islands, respectively. *Salix caroliniana*, *Annona glabra*, and *Magnolia virginiana* contributed 65% of the total litterfall production in flooded tree islands. In contrast, *Persea borbonia*, *Myrica cerifera*, and *Chrysoblanus icaco* contributed 70 % of the total litterfall production in wet tree islands. The leaf fall production pattern for these six tree species was related to their abundance and distribution on each island type. Nonetheless, these results suggest that tree islands subjected to shorter hydroperiod have higher litterfall production than tree islands subjected to longer hydroperiod.

Tagged trees were grouped into two water level fluctuations, low and high. Patterns of tree growth showed that *Myrica cerifera*, *Annona glabra*, *Persea borbonia*, and *Salix caroliniana* had higher growth rates than *Chrysoblanus icaco*, and *Magnolia virginiana*. Similarly, *S. caroliniana* showed a strong seasonal growth, being higher during the dry season and lower during the rainy season. In contrast, *M. cerifera*, *P. borbonia*, and *A. glabra* showed higher growth during the rainy season relative to the dry season. On the other hand, *C. icaco* and *M. virginiana* did not show any strong seasonal growth. Water level fluctuations significantly affected the growth patterns of only *S. caroliniana* which had higher growth rates on tree islands subjected to short hydroperiod, growth rates of other tree species were not significantly affected by water level fluctuations. The relationship between hydrologic patterns and aboveground primary production processes suggests that a single, simple hydrologic restoration target is further complicated by how different environments are best suited for these six different tree species.

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Using Multivariate Statistics to Identify Sensitive Biogeochemical Indicators in the Northern Everglades

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The extent of vegetation displacement in the Northern Everglades and resulting changes in environmental conditions (loss of slough habitat, substrate quality for e.g.) has resulted in a need for a sensitive set of indicator(s) that prelude changes in the vegetative communities in response to nutrient enrichment. Microbial communities play a critical role in nutrient cycling, mediating and responding to nutrient levels. Consequently, multiple microbial parameters have been shown to individually respond to nutrient enrichment. However, in this complex array of indicator forms, which is the most sensitive response? Certain data analysis techniques are capable of screening multivariate data arrays in order to select the best *"explanatory"* variables, i.e. those variables that best distinguish grades of ecological disturbance.

In this study, we used the extensive data base collected by researchers at the Wetland Biogeochemistry Laboratory for the past 12 years (Table 1). These biogeochemical data were collected along the eutrophic gradient in the Water Conservation Area 2A (WCA 2A) of the Everglades.

We found that when complete set of variables describing chemical composition of soils were used, observations clustered naturally in multivariate groups that, with some misclassification, fell in line with the sites. No misclassification for the samples obtained from the impacted area; slight misclassification for the intermediate and unimpacted site. This precluded the necessity of an a priori classification of the data.

Table 1 Description of the soil chemical and biological parameters used in the data analysis

Chemical Parameters		**Biological Parameters**	
TP	Total Phosphorus (mg/kg)	**MBP**	Microbial Biomass Phosphorus (mg/kg)
TPi	Total Inorganic Phosphorus (mg/kg)	**PMP**	Potential Mineralizable Phosphorus (mg/kg/d)
Lab. Pi	Labile Inorganic Phosphorus (mg/kg)	**PMN**	Potential Mineralizable Nitrogen (mg/kg/d)
In Pi	Inorganic Phosphorus (mg/kg)	**MBN**	Microbial Biomass Nitrogen (mg/kg)
FAP	Fulvic Associated P (mg/kg)	**MBC**	Microbial Biomass Carbon (mg/kg)
HAP	Humic Associated P (mg/kg)	**APA**	Alkaline Phosphatase Activity (ug/g/h)
ResidueP	Residue Organic Phosphorus (mg/kg)	**Beta**	B-glucosidase activity (ug /g /h)
Lab. Po	Labile Organic Phosphorus (mg/kg)	**Dehyd**	Dehydrogenases activity (ug /g /h)
TN	Total Nitrogen (g/kg)	**Peptidase**	Peptidase activity (ug /g /h)
TON	Total Organic Nitrogen (mg/kg)	**Anaer. C02**	Anaerobic Microbial Respiration (ug/g/d)
TKN	Total Kjedhal Nitrogen (mg/kg)		
NH4-N	Ammonia Nitrogen (mg/kg)		
TC	Total Carbon (g/kg)		
TOC	Total organic carbon (mg/kg)		
LOI	Loss on Ignition (%)		
Ca	Calcium (mg/kg)		
Mg	Magnesium (mg/kg)		
Fe	Iron (mg/kg)		
Al	Aluminum (mg/kg)		

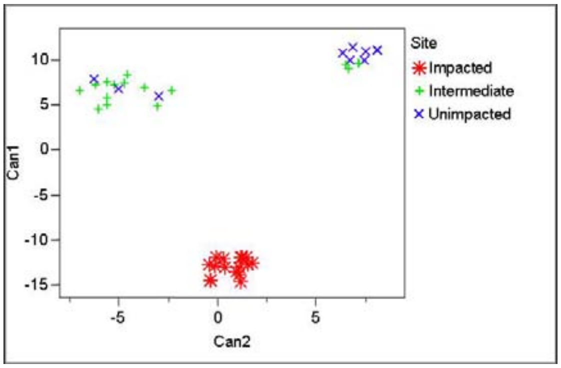

Figure 1 Stepwise Canonical Discriminant Analysis of chemical data set on clusters derived from the chemical characterization data. Biplot of the first two canonical variables (Can1 and Can2 or υ1 and υ2).

Stepwise discrimination of the chemical soil characteristics resulted in two Discriminant functions that best described group membership. A plot of the first two functions (υ1 and υ2 resulting in Can1 and Can2 respectively) is presented in Fig. 1, which illustrates the potential of the canonical Discriminant functions.

The set of parameters that compromise Can1 are powerful at distinguishing between the impacted areas and the transitional/unimpacted areas. Likewise the set of parameters that compromise Can2 are capable at separating the intermediates site from the unimpacted site.

The first two raw canonical variables employed in the discrimination are:

$$\upsilon 1 = 0.0001 * Ca + 0.26 * TN - 0.026 * TPi - 0.03 * Al - 0.106 * Lab.\ Po - 0.025 * HAP - 0.001 * Mg$$
$$\upsilon 2 = 0.00004 * Ca - 0.47 * TN - 0.011 * TPi + 0.01 * Al + 0.015 * HAP + 0.001 * TOC - 0.01 * FAP$$

These functions are a subset of chemical variables that are the best predictors of group membership, i.e. site. In comparing the standardized coefficients, Can1 consists of a contrast of extractable Ca and total N content to the total inorganic P, extractable Al, labile organic P, humic acid associated P, and extractable Mg (Canr^2=.833) and Can2 consists of a contrast of mainly Ca, Al and fulvic associated P with total N and total inorganic P (Canr^2=.167).

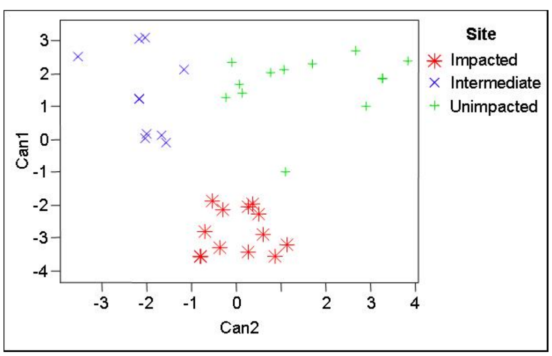

Figure 2 Stepwise Canonical Discriminant Analysis of biological data set on clusters derived from the chemical characterization data. Biplot of the first two canonical variables (Can1 and Can2 or υ1 and υ2).

We then projected the microbiological soil characteristics of the observations on the groups established by the chemical soil characteristics. The biological response variables were extraordinarily successful (no misclassification) at predicting group membership of the observations. Discriminatory data analysis indicated that mainly the microbiological measures associated with the phosphorus cycle were determinant in predicting group (site) membership.

The first two raw canonical variables employed in the discrimination are:

$$\upsilon 1 = 0.0089 * MBP - 0.14 * PMP + 0.020 * PMN + 0.00023 * APA$$
$$\upsilon 2 = 0.013 * MBP + 0.026 * PMP - 0.023 * PMN - 0.00041 * APA$$

In comparing the standardized coefficients, Can 1 consists of a contrast microbial biomass P and alkaline phosphatase with potential mineralizable P (Canr^2=.694), Can 2 contrasts microbial biomass P with potential mineralizable N (Canr^2=.306). Of the entourage of biogeochemical indicators of ecological disturbance, microbiological measures were more adept at distinguishing a nutrient enriched site, a reference site and an intermediate site. We therefore show that biological responses variables are valid tripwire indicators in case of nutrient impacts, resulting in a selection of Everglades specific sensitive biogeochemical indicators.

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Soil Productivity Relationships and Organic Matter Turnover in Dry Tropical Forests of the Florida Keys

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Soil productivity and nutrient cycling were examined in five upland dry tropical forest types in the Florida Keys. These forests have developed on thin soils, predominantly organic, over limestone. Forest aboveground productivity was inversely related to electrical conductivity of soil extract. Production also increased with increasing soil nutrients. Mean litter production in the hammocks of the Keys was 6.3 Mg/ha/yr, which is within the range reported for 34 dry tropical forests. In light of the small storage capacity of the soils, the relatively high rates of production suggest that trees in these forests are obtaining some of their water and nutrient supplies from the aquifer.

Although turnover time is rapid, organic matter production exceeds decomposition in Florida Keys upland forests, permitting the development of organic soils. Thirty to 62% of newly senesced material was decomposed during the first two years after exposure to field conditions. Radiocarbon dating indicated turnover times ranged from 29 to 100 years in the high-productivity hammocks. Efficient nutrient cycling is necessary to sustain the high production rates we observed.

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Snakehead Fishes and Florida Waters

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Two, perhaps three individuals of the northern snakehead, *Channa argus*, were released into a 1.8 ha retention pond in Crofton, Anne Arundel County, Maryland, during 1999 or 2000 by a local resident. This airbreathing species is native from the Yangtze River basin, China, western Korea, northward to the Amur River along the Chinese-Siberian border. Up to 90% of its diet consists of fishes. This is the most prolific snakehead species with large females capable of releasing 155,000 oöcytes per year in two to 5 spawning events. Maximum size is reported to almost 1.5 m total length. Temperature tolerance is 0-30º C. This fish was introduced and became established in Japan (1920s), Czechoslovakia (1956-1960), and Kazakhstan, Turkmenistan, and Uzbekistan (1961-1964). Attempts to establish the species in Russia (Moscow Province, 1949-1953) failed.

Presence of this species in the heavily vegetated Maryland pond was discovered in May 2002 when an angler caught and subsequently released a 41 cm individual after photographing the fish. Maryland Department of Natural Resources (MDDNR) personnel sent a digital image of the specimen to the U.S. Geological Survey (USGS) Center for Aquatic Resources Studies in Gainesville, Florida, in June where it was identified as a northern snakehead.

On 30 June 2002, another angler caught a 67 cm northern snakehead from the same pond. A week later, the same angler and his daughter captured several juvenile snakeheads using dipnets, confirming reproduction. MDDNR biologists subsequently captured approximately 100 juveniles with electrofishing. The pond in which this species existed was approximately 68 m from the Little Patuxent River, a pathway, along with the possibility for transfer to novel waters by anglers, heightened potential for wider dispersal.

The good news is that, thanks to early tests on captured juveniles by MDDNR and University of Maryland biologists that proved the northern snakehead susceptible to eradication by rotenone, the population of snakeheads (over 13,000 fish) was eliminated from the Crofton pond in early September 2002. A question remains if this species escaped earlier into the Little Patuxent River. MDDNR, U.S. Fish and Wildlife Service, and USGS biologists cooperated throughout this endeavor in what has been termed a "rapid response" effort.

The bad news for Florida is that the same species has been captured from the St. Johns River near Lake Harney, Seminole and Volusia counties, on two occasions in 2000. Reproduction and establishment have not been verified to date, but are likely. More bad news is that another snakehead species, *Channa marulius*, the bullseye snakehead, was discovered established by Florida Fish and Wildlife Conservation Commission biologists in 2001 in lakes and canals in Tamarac, Broward County. This species is reported to reach lengths of 1 meter or more and is a subtropical to warm temperate species. The really bad news is that neither species is confined to a body of water from which it could be eradicated. The worst news is that both species have potential to become established in the Kissimmee drainage and southward. All snakeheads are predators, mostly feeding on other fishes, with many behaving as "thrust predators", darting from rest or hidden locales to engulf prey which, for several species, can be up to 1/3 the body length of the predator.

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Do Marine Reserves in Florida Keys National Marine Sanctuary Protect Spiny Lobsters?

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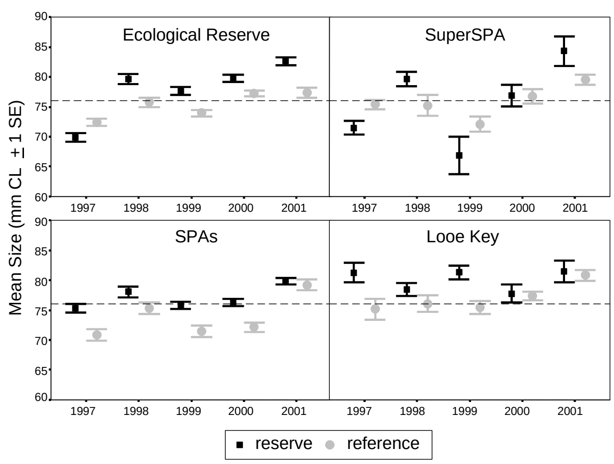
If marine reserves in the Florida Keys National Marine Sanctuary are effective in protecting spiny lobsters, *Panulirus argus*, from harvest, we expect that lobsters will become larger and more abundant inside the reserves compared to exploited areas. To determine reserve effectiveness, we monitored spiny lobsters in thirteen pairs of reserves and exploited reference areas twice a year from 1997-2001. Samples were taken during July (the end of the closed fishing season) and during September/October after several months of the fishing season. Reserves were comprised of 11 (0 = 82 ha) Sanctuary Preservation Areas and Research Reserves (SPAs), one large (515 ha) SuperSPA, and one 3,000 ha Ecological Reserve (ER). Sampling was stratified by habitat type (forereef, backreef, offshore patch reef, nearshore patch reef) in the ER and three subsamples were taken on each habitat; three subsamples were taken on the forereef at the SuperSPA, and one sample was taken at the other eleven SPAs. Sampling consisted of a 60-minute search during which we counted and attempted to catch and measure all lobsters observed. Data from SPAs, the SuperSPA, and the ER were analyzed separately and compared with data from their respective exploited reference areas. Additionally, Looe Key SPA and its reference area were treated separately because Looe Key has been a marine reserve since 1981.

In 1997, mean lobster size was below the legal limit in both reserves (excluding Looe Key) and references. Since protection, mean lobster size in reserves has generally been larger than legal size, whereas it remained at or below the legal limit in exploited areas (Fig. 1). In all years, mean size of legal lobsters was larger in reserves than in references. Additionally, abundance of very large lobsters (≥ 100 mm CL) increased in the ER relative to its reference area.
Lobster abundance varied among years with a high in1999 and a low in 1998. Lobsters were much more abundant in Western Sambo ER and its reference than elsewhere. There were always fewer lobsters in Carysfort SuperSPA than in its reference. In most years, abundance declined in both reserves and references during the open season, but the decline was less precipitous in reserves (Fig. 2). The decline in lobster abundance inside reserves during the fishing season indicates that overall, the reserves are too small to totally protect lobsters from harvest. However, viewed separately, several of the reserves, including the ER, appear to provide at least a temporary refuge for spiny lobsters, while others do not appear to function as lobster reserves at all. Effectiveness appears to be a function of reserve size, location, and habitat protected.

Figure 1. Size of lobsters in Florida Keys National Marine Sanctuary, 1997-2001.



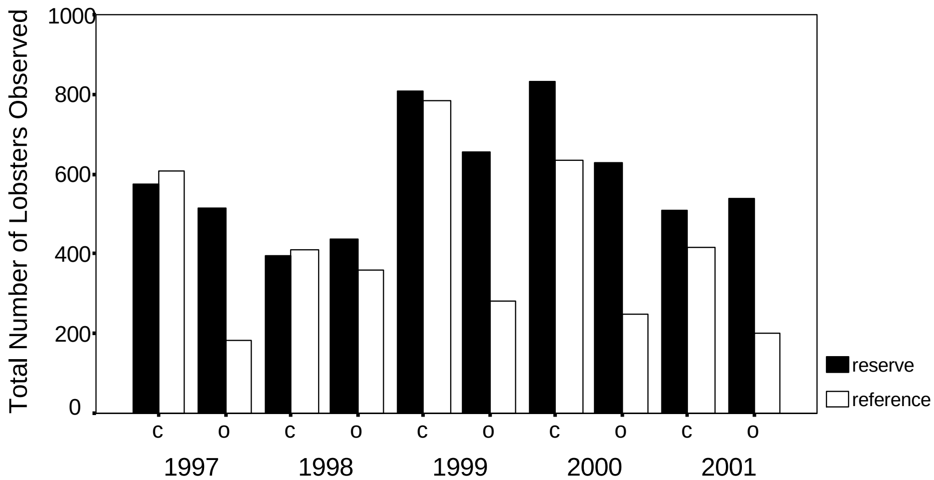


Figure 2. Total number of lobsters observed in FKNMS reserves and reference areas during closed (c) and open (o) fishing seasons, 1997-2001.

In 2002, we focused on the Western Sambo ER, because it has shown signs of effectiveness. We discontinued sampling at all other reserves except Looe Key SPA because it has been a lobster reserve for more than 20 years, and Eastern Sambo Research Reserve because it is close to the ER and lobsters have been very abundant there. A relative abundance index (RAI) of legal-sized lobsters during the closed season was calculated to account for natural yearly variation in lobster abundance. RAI was calculated as the mean abundance of legal lobsters in the reserve minus mean abundance legal lobsters in the corresponding exploited area each year (Fig. 3).

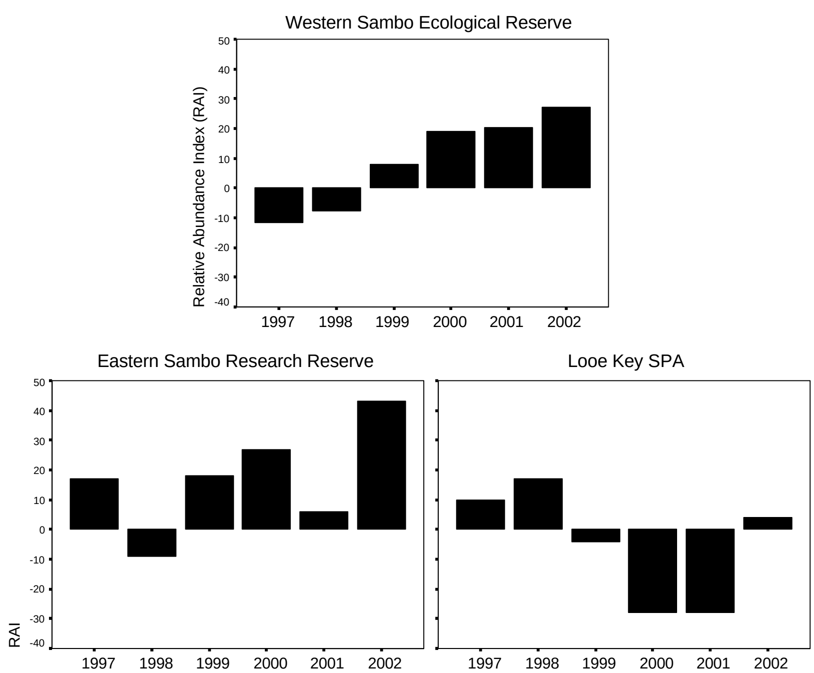


Figure 3. Relative abundance index of legal-sized lobsters on forereef habitat during the closed fishing season, 1997-2002.

Abundance of legal-sized lobsters on the forereef at Western Sambo ER during the closed fishing season relative to that in the exploited area has been increasing each year since the reserve was created. The same cannot be said of lobster abundance at Looe Key SPA. The probability of a lobster wandering outside of a small protected area during its daily life is high. Additionally, the smaller protected areas encompass only a single habitat type. Our data indicate that a residential population of spiny lobsters is becoming established within Western Sambo Ecological Reserve. The expansion of lobster size-frequency in the ER suggests that some of the lobsters remain in the reserve for an extended period of time. Habitat for all lifestages of spiny lobsters is protected within the reserve. Once adults establish residence, the ecological reserve is sufficiently large to protect a portion of the population as they travel to foraging grounds and between winter dens and spring spawning habitat.

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Role of Flow-Related Processes in Maintaining the Ridge and Slough Landscape

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A quantitative picture of pre-drainage Ridge and Slough landscape features was developed from a synthesis of diverse historical sources including maps, photographs, quantitative U.S. General Land Office surveys, narrative descriptions from cross-Everglades expeditions, and historical aerial photos. Specific pre-drainage parameters identified include characteristic vegetation of ridges and sloughs; shapes, typical dimensions, and orientations of the landforms; and elevation differences between ridges and sloughs. In combination with narrative descriptions, these parameters provided a template representative of the pre-drainage landscape condition.

This template was then used to evaluate the current condition and types of changes found in the remaining areas of this landscape. The comparison focussed on three defining characteristics: (1) vegetation, (2) vertical dimensions (microtopography), and (3) spatial patterns. Areas known to have been altered by elevated P levels were excluded (NE Water Conservation Area 2A). Based on these characteristics and the assumed pre-drainage template, no presently remaining areas could be classified as “pristine.” The western portion of Water Conservation Area 3A most closely resembled the template, with a good match in spatial pattern. However, the degree of vertical relief appears to be less than one third of the original (“flattened microtopography”), and the sloughs have been invaded by emergent wet prairie species. Water Conservation Area 3B was the most severely altered, being affected in all three characteristics. Other areas were intermediate between these extremes. Overall, comparison with the historic template suggested extensive and significant degradation of the remaining Ridge and Slough landscape.

Significantly, an apparent endpoint for degradation of the Ridge and Slough landscape is conversion to a flat landscape in which the original elevation differences between ridges and sloughs completely disappear, and the landscape comes to form a uniform stand of sawgrass. Areas that appear to be at or close to this endpoint were found in northwest WCA 2A, northern WCA 3A, and WCA 3B.

In the second part of the investigation, we evaluated a number of recently proposed hypotheses concerning Ridge and Slough landscape maintenance for their ability to explain observed characteristics of the pre- and post-drainage systems. No single hypothesis appeared capable of explaining all the observed phenomena. However, a combination of water depths and water flows (and the post-drainage alterations in both) appeared to be most able to explain the full set of observations.

Because field research in this area is still in its infancy, we did not specify an exact flow-related mechanism in the above exercise; instead, we simply required that the mechanism be related to some aspect of water and material transport. As such the mechanism would have a directional component. Further research is required to distinguish between mechanisms related to transport of dissolved substances (e.g., organic carbon or nutrients), versus those related to transport of particulates (e.g., organic flocculent material). Research is also required to weigh the relative importance of average versus extreme transport events.

Full mechanistic understanding is likely to require a number of years of field and theoretical work. The degradation of substantial areas of Ridge and Slough landscape that has already occurred emphasizes the importance of restoration and prevention of further degradation. Ideally, restoration decisions would be based on a fully mechanistic understanding of this landscape's geomorphology. Unfortunately, the ecological risks of further degradation will likely require decisions much sooner. Wherever possible, such decisions should make full use of the empirical information found in the landscape. So far, the landscape points toward the necessity of restoring both pre-drainage water depths and unimpeded, pre-drainage patterns of flow.

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The Effects of the Cuban Treefrog (*Osteopilus septentrionalis*) on Native Treefrog Populations within Everglades National Park

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Native amphibian fauna throughout South Florida is currently threatened by the presence of an exotic competitor, the Cuban treefrog (*Osteopilus septentrionalis*) (fig. 1). First reported in the Florida Keys (Barbour, 1931), Cuban treefrogs expanded their range and were present in Everglades National Park as early as the 1950's (Meshaka 2001). Cuban treefrogs compete with native treefrogs for breeding space and food sources.

Figure 1: Cuban Treefrog (*Osteopilus septentrionalis*) in Everglades National Park

In addition, Cuban treefrogs and their tadpoles are carnivorous and prey upon other frog species (Meshaka 2001; Babbitt and Meshaka 2000). Despite anecdotal evidence, no study has shown the extent to which Cuban treefrogs reduce populations of native hylids in natural areas. The goal of this study is to examine the direct effect Cuban treefrogs have on native treefrog populations within Everglades National Park. Native treefrogs studied included the Green (*Hyla cinerea*; Hci), and Squirrel (*Hyla squirella*; Hsq).

Population estimates for treefrogs were obtained through a mark-recapture study using PVC refugia. Five study plots were selected within Everglades National Park (2 mangrove and 3 pine rockland sites). Two of these sites are near disturbed areas, while all others are fairly remote. After initial population estimates were obtained, Cuban treefrogs were removed from sites to examine the recovery of native populations. Additionally, predation of hylids by Cuban treefrogs was quantified through stomach content analysis of removed animals.

To date, approximately 2,200 individual frogs have been included in this study. Preliminary results indicate Cuban treefrogs are more numerous in plots 501 and 101, which are located near disturbed areas, while remote sites contained larger populations of native species (fig. 2). Initial results indicate that native populations significantly increase as Cuban treefrogs are removed. The largest population increases occurred at sites where Cuban treefrogs were originally most dense (table 1). Preliminary analysis of stomach contents suggest that predation on hylid treefrogs is higher in mangrove than pine rockland sites.

To adequately monitor the effects of Cuban treefrogs on native populations, this study will continue until Fall 2003. After completion, the results of this study may be used to identify factors that facilitate or obstruct dispersal of Cuban treefrogs into natural areas. In addition, this information will be incorporated into an ArcInfo model of the potential spread and impact of Cuban treefrogs on native species in protected areas. Data will be available to cooperating agencies and the public.

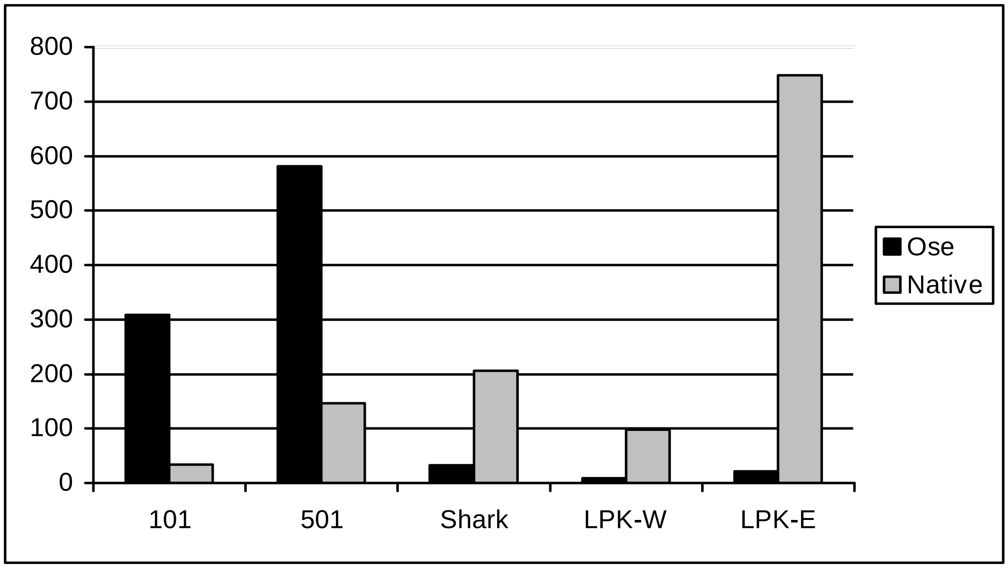

Figure 2: Total captures of Cuban (Ose) and native treefrogs in study plots within Everglades National Park from November 2000 to November 2002

Table 1: Mean number of captures per visit of Cuban (Ose), Green (Hci) and Squirrel (Hsq) treefrogs before and after removal of Cuban treefrogs in sites 101 and 501 (* statistically significant)

SITE AND SPECIES	N (NUMBER VISITS) PRE-REMOVAL	N (NUMBER VISITS) POST-REMOVAL	MEAN CAPTURES PRE-REMOVAL	MEAN CAPTURES POST-REMOVAL
501-Ose	30	8	28.100 (± 5.497)	30.375 (± 5.928)
501-Hci *	30	8	1.533 (±0.328)*	19.500 (± 6.743)*
501-Hsq *	30	8	0.267 (± 0.117)*	1.500 (±0.886)*
101-Ose	29	7	15.414 (±3.260)	13.714 (±2.476)
101-Hci	29	7	1.517 (±0.411)	0.143 (±0.143)
101-Hsq *	29	7	0.379 (±0.104)*	3.571 (±1.343)*

References:

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Barbour, T. 1931. Another introduced frog in North America. Copeia 1931(3): 140.

Meshaka, W.E. 2001. The Cuban Treefrog in Florida – Life History of a Successful Colonizing Species. University Press of Florida.

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Avian Response to Nutrient Enrichment in the Northern Everglades

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Abstract.- Years of nutrient enrichment from urban and agricultural runoff have led to eutrophication of the northern Everglades. To examine the influence of nutrient enrichment on the avian community, we surveyed birds along a nutrient gradient in Water Conservation Area 2A (WCA 2A). Bird species were generally more abundant in the nutrient enriched sites than unenriched sites. However, differences in species composition were observed between enriched and unenriched sites. In the naturally nutrient limited Everglades, nutrient enrichment fundamentally changes the structure of the Everglades and is therefore incompatible with ecosystem restoration.

Introduction.- The Everglades was originally an oligotrophic, phosphorus-limited wetland with nutrient inputs restricted primarily to rainfall (Davis 1994). Currently, phosphorus additions to the northern Everglades are about 10-20-fold higher than historical levels (McCormick and O'Dell 1996, McCormick et al. 1999). Little is known about the effects of nutrient enrichment on birds in the Everglades, and this is a particularly important issue in the face of the current Everglades restoration efforts. We hypothesized that abundance of the non-wading birds would be higher in nutrient-enriched areas as the result of increased productivity leading to increased food resources. We hypothesized that the abundance of wading birds would be lower in nutrient-enriched areas as a result of minimal slough habitat available for foraging due to cattail encroachment.

Methods.- The study was conducted in WCA 2A in the northern Everglades. Nutrient enriched water flows from north to south in WCA 2A creating a nutrient gradient extending approximately 8 km into the interior of the marsh (Payne et al. 2001). To gather information on the non-wading-bird community across this nutrient gradient, we surveyed birds with point counts at 10 sampling sites in 1996 and 1997. A repeated measures ANOVA was used to examine differences in bird abundance and species richness across the nutrient gradient. To gather information on wading birds, aerial systematic reconnaissance flights (Bancroft and Sawicki 1995) were flown in 1991 and 1995 to obtained bird abundance data in 4-km^2 cells across WCA 2A. An ANCOVA with water depth as a covariate was used to compare wading-bird abundance in enriched and unenriched cells.

Results.- There were more individuals (all species combined) in enriched sites compared to transitional and unenriched along the nutrient gradient ($P = 0.05$; Fig. 1). There was not a significant effect of nutrient enrichment on species richness. Of the four dominant species in the study, Boat-tailed Grackles and Common Moorhens were more abundant in enriched sites ($P \leq 0.02$) while Common Yellowthroats were more abundant in unenriched sites ($P < 0.01$). Red-winged Blackbirds showed no effect. Examining species compositional differences, the bird community in enriched areas tended to have more species that prefer densely vegetated areas (i.e., rails, bitterns) whereas unenriched areas had more species that utilize open areas (i.e., shorebirds). In the wading bird community, Wood Storks and Great Egrets were more abundant ($P < 0.01$) in the enriched compared to unenriched 4-km^2 cells in a dry year (Fig. 2). Great Egrets and all wading bird species combined had significantly more individuals ($P < 0.01$) in the enriched compared to the unenriched cells in a wet year. For White Ibises and Wood Storks, the models did not converge in the wet year, however, there tended to be more individuals in enriched compared to unenriched cells.

Discussion.- The results of this study suggest that some members of the bird community tend to increase in abundance with nutrient enrichment. Changes in habitat (i.e., increased amount of substrate for nesting or foraging) or changes in the food web that increased food resources were presumably the cause. Overall, water depth was the main factor affecting wading bird foraging. After accounting for water depth, wading bird abundance generally increased in nutrient-enriched areas even though cattail invasion left few open-water sloughs for foraging. We suspect this was because the few open-water areas available to wading birds had a higher availability of prey. However, the majority of open-water sites in enriched areas in our study had been artificially created by airboat traffic. We hypothesize that in dry years the abundance of wading birds is primarily driven by decreasing water levels concentrating prey, but in wet years wading bird abundance is also driven by habitat characteristics, such as nutrient enrichment, that may make prey more available. Although bird abundance may generally increase in nutrient-enriched areas of the Everglades, this is undesirable when indicative of an unhealthy ecosystem. Nutrient enrichment fundamentally changes the Everglades by changing the species composition and productivity of different components of the system.

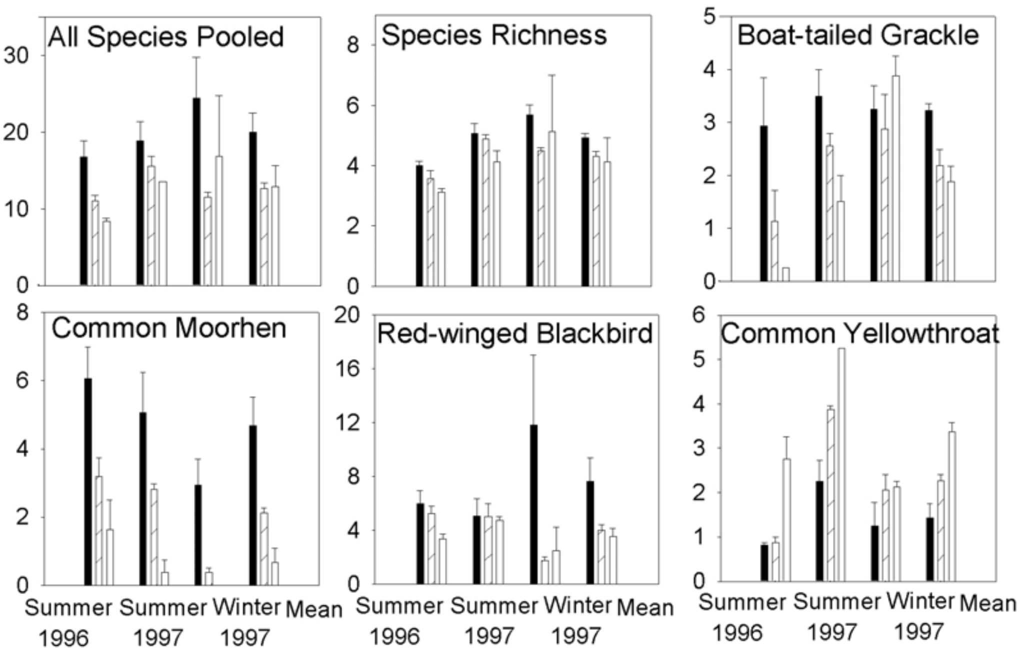

Fig. 1. The mean ± SE number of birds per site in enriched (*n* = 4; solid black), transitional (*n* = 4; striped white), and unenriched (*n* = 2; solid white) areas.

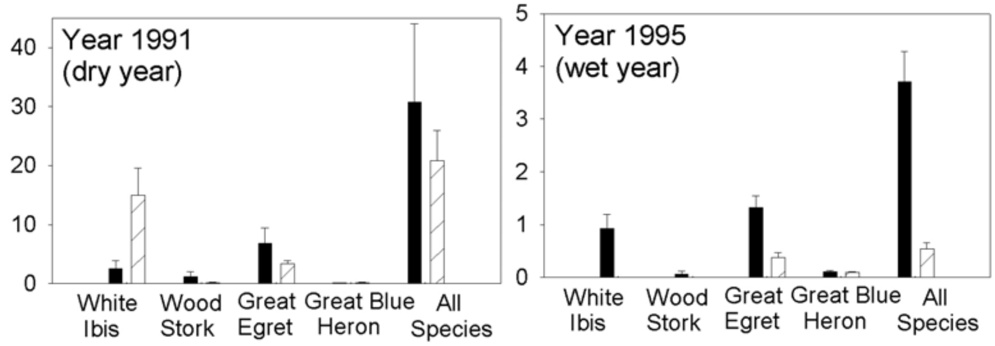

Fig. 2. The mean ± SE number of four common wading bird species and all wading species combined in enriched (*n* = 22 in 1991, *n* = 108 in 1995; solid black) and unenriched (*n* = 128 in 1991, *n* = 342 in 1995; striped white) cells.

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Lower West Coast Aquifer Delineation for Hydrologic Model Development

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The South Florida Water Management District (SFWMD) is preparing a regional hydrologic analyses of the lower west coast (LWC) planning area of Florida of the SFWMD. The LWC area includes all of Lee, Collier, Hendry, and Glades Counties, and parts of Charlotte and Monroe Counties. Hydrologic models will be used to evaluate options for hydrologic restoration of the area. An important part of this study is a regional hydrogeologic characterization. Previous studies have been conducted on a county basis and are difficult to compile for a regional study. This created a need for a regional hydrogeologic study of the LWC.

This poster presents the results of this comprehensive study of the hydrogeology of the surficial and intermediate aquifer systems. The aquifers studied included the water-table and Lower Tamiami aquifers of the surficial aquifer system, and the Sandstone and Mid Hawthorn aquifers of the intermediate aquifer system. In general, this is the hydrostratigraphic section from land surface to an average depth of about 550 feet. A series of nine regional cross-sections, four databases, and 28 maps were prepared. The databases include information on more than 2000 wells. This information includes well construction data; formation, aquifer, and aquaclude tops and thicknesses; and potentiometric water level data for the wet and dry seasons of the year 2001. Aquifer properties are being extracted from previous studies and summarized in tabular form.

The hydrogeologic investigation delineated the extent of each aquifer. The confinement which separates the water-table from the limestones of the Lower Tamiami aquifer has a limited areal extent and, where that confinement is not present, the limestones of the Pliocene-age Tamiami formation form the basal part of the water-table aquifer. The sandstones of the Upper Miocene-age Lehigh Acres member of the Peace River formation, which comprises the Sandstone aquifer, are of variable thickness. Distribution patterns indicate deposition in a deltaic environment. The numerous limestone units of the Middle Miocene-age Arcadia formation, which comprise the Mid Hawthorn aquifer, have variable thicknesses and areal extents, reflecting shifting eustatic sea levels and possible tectonic influences during this period.

For the three deeper aquifers, the western, coastal portion of the study area shows the influence of paleotopographic position, along the axis of the Florida Platform, on aquifer thickness and lithologic composition. In general, a higher carbonate to clastic ratio is present in those aquifers in that area. To the east, the overall thickness of the formations is greater and carbonate to clastic ratios are lower. Subsidence in this eastern area, around and south of Lake Okeechobee, and including the Everglades, may have been accompanied by some tectonism. This tectonism appears to have occurred primarily in the Middle to Late Miocene, was a more plastic rather than brittle reaction to stress, and generally takes the form of broad folding. The greater accomodation space available in this eastern is exhibited in the much greater thicknesses of sandstone units in the Sandtone aquifer. The water-table aquifer is also much thicker in this area.

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Effects of the Exotic Old World Climbing Fern on the Ant Diversity of Tree Islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge

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Biological invasions have become a worldwide epidemic that often result in severe alterations of habitats and wildlife communities. Invasions by exotic plant species can disrupt normal habitat processes including geomorphic processes, biogeochemical cycling, hydrological cycles, fire regimes, the recruitment of native species, and the dependent wildlife communities (Macdonald et al. 1989, Clouse 1999). Exotic plant species host fewer insect species than adjacent native plants or than individuals of the same species in the plant's native habitat (Southwood 1982, Clouse 1999, Memmott 2000).

Mild climates and accelerated international trade make certain areas especially susceptible to biological invasions. Such is the case in South Florida where one third of the plant species are exotic (Pernas 2002). Recently, the exotic Old World climbing fern, *Lygodium microphyllum,* has surpassed other exotic species to become the most important threat to the greater Everglades ecosystem (Ferriter et al. 2001). Recent surveys of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Loxahatchee NWR) show that *L. microphyllum* occupies 9,175 hectares, or about 16 percent of the total area (Bailey and Thomas, Jr. 2000). The majority of the area infested by *L. microphyllum* is tree island habitat. *L. microphyllum* poses a significant threat to the native plant and animal communities by decreasing the amount of native vegetation present (Brandt and Black 2000), which leads to the creation of more homogenous tree islands and overtime may alter the related wildlife communities.

Because most insects are directly dependent upon plants for food and shelter, they are often used as indicators of the health of the vegetation community. There are many attributes that make ants, in particular, useful for biodiversity studies. Many species of ants are present in the world and in most habitats. Ants make up a large amount of the biomass in almost every habitat, they have stationary nesting habitats, which allow them to be resampled over time, and ants exhibit sensitivity to environmental changes (Alonso and Agosti 2000).

We have developed a study that investigates how the ant communities on tree islands are affected by *L. microphyllum.* The objectives of this study are: to compare the ant species richness, evenness, and diversity indices on tree islands with and with out *L. microphyllum;* to explore the correlation between ant diversity and habitat characteristics (plant species diversity, plant structural diversity, litter characteristics); and to compare ant species dominance on tree islands with and without *L. microphyllum.*

We have established 15 study islands representing three types of islands. Five islands have little to no *L. microphyllum* and have been used little if at all by people; 5 islands have a large amount of *L. microphyllum* infestation and have been used little if at all by people; and 5 islands have little to no *L. microphyllum* and have been used extensively as study sites for tree island research. We sample these islands for ants using four methods: litter collection/Berlese funnel, baiting, beating, and visual collection. Results from sampling will be used to determine ant abundance, diversity, and dominance. We also sample the vegetation of these islands and the resulting data will be used to determine species and structural diversity.

Sampling for ants began in August 2001. As of January 2003 all 15 of the islands have been surveyed. A total of 35 species have been observed using all sampling methods. The number of ant species per island ranges from 9 to 18 and thus far we have found no significant difference between island groups. There are 5 species of ants that occur on the largest number of islands (N=13). These 5 ants include 2 exotic species and the presence of these exotic species does not significantly affect the species richness of other islands. Sampling of the 15 islands will continue through January 2003 until each island has been sampled using all four methods. New species continue to be identified. Data collected on ant species will be compared to data collected from vegetation sampling to identify any correlation between ant communities and vegetation structure and diversity.

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The Effect of Plant Community Structure on Apple Snail Abundance in the Everglades

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As the exclusive food of the endangered snail kite and prey to a variety of other wetland fauna, apple snails are generally recognized as a critical resource warranting monitoring in the context of the Greater Everglades ecosystem restoration. Snail kite abandonment of wetlands in dry down conditions have led to unsubstantiated conclusions that drying events (presumably of any timing and duration) devastate snail populations, thus forcing kites to leave. Researchers and natural resource managers have subsequently recommended nearly continuous inundation of wetlands deemed critical habitat to kites. However, suppressing drying events would be contrary to critical aspects of snail autecology that have been documented: 1) longer hydroperiods decrease the abundance of emergent wet prairie macrophytes needed for snail oviposition and aerial respiration and 2) snails do tolerate dry down conditions (the majority surviving up to 4 months once they reach a threshold size) and that this species has a life history well adapted to periodic dry downs. Not only are snails adapted to dry downs, we believe that drying events are essential to supporting suitable snail habitat. Elucidating the relationship between apple snail abundance and habitat structure also relates directly to habitat management for snail kites. As visual hunters, snail kites cannot forage in densely vegetated habitats such as sawgrass and cattail, but selection among more structurally 'open' habitats (slough or prairie) have not been documented. If they have a preference, it could be because some habitats support more snails than others, or because the structure of some habitats may render snails more available to foraging kites. This study tests the hypothesis that snail abundance is greater in prairie versus slough habitats, and contributes to an understanding of habitat selection by foraging kites.

Two concurrently funded projects were initiated in Spring 2002 in two different Everglades wetland units: WCA-1 (funded by US Fish and Wildlife Service) and WCA-3A (funded by US Geological Survey), which taken together will function as a single more comprehensive study. A total of 6 sites were selected to test hypotheses about snail abundance and habitat structure. Each site consisted of prairie habitat (dominated by emergent species of *Eleocharis, Rhynchospora* or *Panicum*) juxtaposed and/or interspersed with slough habitat (dominated by *Nymphaea odorata*). In most sites, the prairie (especially) or slough was not contiguous; i.e., the prairie habitat sampled within a site may have been partitioned into 3 or more patches. Patches of habitat judged as transitional or intermediate between prairie and slough (i.e., patches with both *Nymphaea* and emergent macrophytes) were avoided.

Snail density was determined using 1-m^2 throw traps (n≈50-70 throw traps in a 50 x 50 m area) extracted with a dip net, with explicit estimation of capture probabilities to assess sampling efficiency across different habitat types. The 1-m^2 throw trap method has also proven effective in estimating crayfish (*Procambarus alleni*) and freshwater prawn (*Palaemonetes paludosus*) densities; therefore, we recorded numbers of these important prey items found during our snail sampling effort. Throw trap sampling was conducted from approximately February through early May in order to avoid the annual post-reproductive die-off. Egg cluster production was monitored in transects established in each sampling site in order to document that throw trapping was completed prior to the die-off.

At this point we have not completed our analyses; thus, any conclusions should be considered preliminary. Data were analyzed within a generalized linear modeling framework. Preliminary results indicate consistently higher snail densities in the prairie habitat relative to the *Nymphaea*-dominated slough. A similar trend was found for crayfish. Habitat effect on freshwater prawn density varied among sites, but no overall habitat effect was indicated. The data appear to support the hypothesis that snail abundance in prairie exceeds that in slough habitats.

Qualitative assessment of the data thus far suggests that within the wet prairie communities, there may be specific associations among snails and some plant species. Such associations will be a primary focus of this study over the next two years, and we expect to refine the hypothesis regarding apple snail-plant community- snail kite interactions accordingly. Given the inextricable link between hydrology, vegetation and apple snails, this research effort will support the development of ecologically significant performance measures that respond to the Greater Everglades restoration activity.

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The Effects of Cattle Grazing on Flora and Fauna in the Kissimmee River Valley, Florida

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The impacts of cattle grazing on plant communities, small mammals, and herpetofauna were studied on a section of drained Kissimmee River floodplain. Six approximately 1.5 ha fenced exclosures were constructed in semi-improved pasture for replicate treatment of 3 grazed and 3 control (ungrazed) sample sites. Small mammals and herpetofauna were sampled from October 1996 through July 2001 using Sherman live traps and drift fences accompanied by funnel traps. Plant species occurrence, percent cover, herbaceous height and shrub height were recorded on random 1 m quadrats for two baseline and four post-treatment samples. One hundred plant species were recorded during the study period, including 25 exotic species. Bahia grass (*Paspalum notatum*) occurred most frequently in over 76% of the plots with a mean coverage of 52%. Comparisons of baseline and post-treatment data showed that cattle grazing had a significant effect on vegetation height ($P > 0.001$) and shrub coverage ($P > 0.01$), and shrub height ($P > 0.01$). Repeated measurements were used to determine the possible effect of grazing on plant species over time. Percent coverage of the native *Andropogon virginicus* declined significantly ($P > 0.0001$) between baseline and treatment while percent cover was significantly higher ($P > .01$) in the control plots compared to the grazed plots. Percent occurrence and cover of the exotic Bahia grass was significantly lower ($P > 0.0001$) in the control plots than in the grazed plots. Results for other exotic and native plant species varied. Chi-square contingency tables (2 X 2) showed that proportions of cotton rats (*Sigmodon hispidus*) and harvest mouse (*Reithrodotomys humulis*) were significantly lower ($P > 0.001$) in grazed exclosures. However, least shrew (*Cryptotis parva*) and those herpetofauna captured in large enough numbers for analysis, appeared to be unaffected by grazing. Analysis of covariance using small mammal trap rates over time also indicated greater declines ($P > 0.0001$) of cotton rats in the grazed plots as compared to the control plots. Harvest mouse trapping rates showed similar declines although no significant differences were detected. Decline of important food species for cotton rats such as *Andropogon virginicus* might help explain the effects of grazing. The reduction in shrub and herb percent cover might also explain the proportional differences in numbers of harvest mouse; a species that prefers advanced old field succession. On heavily grazed pastures, reduction of plant food and cover may have resulted in fewer small mammals while most herpetofauna species and the insectivorous least shrew appeared to be unaffected by grazing.

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Hyperspectral Monitoring of Kissimmee River and Stormwater Treatment Areas (STAs)

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Recent projects have investigated the effectiveness of hyperspectral remote sensing for characterizing ecosystem restoration project areas, including mapping and monitoring exposed and submerged aquatic vegetation (SAV). The results of these projects to-date show that automated vegetation mapping from hyperspectral remote sensing is a promising tool that could significantly lower costs and expedite evaluation of the restoration process.

A Kissimmee River Restoration (KRR) Hyperspectral Remote Sensing Pilot Study, sponsored by the Jacksonville District of the U.S. Army Corps of Engineers, is now being completed by Lowe Engineers, LLC, and Science Applications International Corporation (SAIC). The project's objective is to assess the effectiveness of HSI for characterization of an ecosystem restoration project area. The project also considers the potential framework for an ecosystem-wide remote sensing monitoring program for large projects such as the Comprehensive Everglades Restoration Program (CERP) and assesses the potential to develop systems to measure the results of restoration projects economically, efficiently and accurately, while limiting time-consuming and expensive field sampling on the ground.

Originally developed for NASA and military missions, HSI measures the spectra of vegetation and materials observed in a scene. The resulting data contains an unprecedented amount of information. For example, hyperspectral imagery can be used to monitor hydrologic patterns, as well as the spatial distribution and health of various terrestrial and wetlands-dependent vegetation. Of particular interest is detecting and tracking changes in the density and spatial extent of exotic and native plant species often used as indicators of restoration success. Given the wide variability of Everglades ecosystems, the number of species of interest, and potential land access limitations, hyperspectral remote sensing bypasses many of the constraints of traditional ground-monitoring campaigns and offers an affordable approach to environmental change detection.

Airborne HSI data was collected over a section of the Kissimmee River restoration area. In parallel, an extensive ground-truth campaign used on-foot surveys and airboats to ground-truth data and assess vegetative cover and conditions. The data has been used to create two vegetation maps: one map classifying 68 vegetation communities and a second map distinguishing 12 habitat types. SAIC's Abacus® tool was used to perform semi-automated spectral mixture analysis and produce layers mapping abundance of vegetation and other surface materials (endmembers). These abundance layers provided sufficient information and diversity to separate over one hundred spectrally unique classes via unsupervised methods. Supervised classification was then applied to map the extent of specific classes of interest, defined as combinations of endmembers. Over 300 ground truth points were used for HSI accuracy assessment.

The Kissimmee River results also demonstrate the capabilities of HSI to detect and map submerged aquatic vegetation (SAV) and confirm earlier results indicating hyperspectral imaging is a promising tool for mapping SAV species and abundance throughout South Florida. These earlier results were the product of a hyperspectral data feasibility study completed for Cell 5 of Stormwater Treatment Area 1-W (STA 1-W). The research was performed by SAIC and sponsored by the Ecological Technologies Division of the South Florida Water Management District (SFWMD). The study revealed many positive indications of the feasibility of using HSI for classifying SAV.

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Ecosystem Response as a Dynamic Guide to the Design and Operation of CERP: Major Considerations and Challenges for the RECOVER Monitoring and Assessment Plan

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The success of CERP in achieving its restoration objectives requires a focused and fully integrated monitoring and assessment plan. The RECOVER Monitoring and Assessment Plan (MAP) must not only track system responses to the implementation of CERP, it must also provide understanding of why restoration goals have or have not been achieved, and provide an interpretation of the ecological surprises that inevitably will arise. This paper provides an overview of some of the major considerations in developing a MAP that will effectively guide the future design and operation of CERP. The monitoring of wetland food chains supporting the restoration of wading bird nesting will provide an example of how MAP design is based on these considerations.

<u>System-wide Hypotheses and CERP Premises</u>. The rationale for choosing monitoring components and supporting research for the MAP is based on system-wide hypotheses and CERP premises, which are derived from the ecological conceptual models.

- System-wide Hypotheses: System-wide hypotheses describe our current, broad understanding of the causal factors that have led to a loss of the ecological characteristics of the greater Everglades system as a result of drainage and development.
- CERP Premises: Each system-wide hypothesis links to CERP premises, which state assumptions of how CERP will restore the ecological characteristics that have been lost. The CERP premises are the bases for the monitoring components and supporting research in each module of the MAP.
- Adaptive Management Questions: The monitoring components and supporting research are designed to answer adaptive management questions. Will the natural system respond to the implementation of CERP as the premises indicate it should? If not, how can the design and/or operation of CERP be modified to achieve desired ecosystem responses?

<u>Integration of Monitoring Components and Supporting Research</u>. Monitoring components and supporting research of the MAP are integrated and coordinated within six modules that represent a combination of major ecosystem sub-units and functional groupings.

- Greater Everglades Wetlands
- Southern Estuaries
- Northern Estuaries
- Lake Okeechobee
- South Florida Hydrology Monitoring Network
- South Florida Mercury Bioaccumulation

The integrated monitoring components and supporting research proposed for each module are designed to provide a more complete understanding of the interrelationships and underlying processes that will be responsible for the changes detected by the monitoring plan. The modules are also designed to support one another, in the recognition that ecosystem sub-units and functional groupings are interconnected. For example, the Regional Hydrology Monitoring Network will be optimized to support all the other modules, and freshwater flows from the tidal creeks of the Greater Everglades Wetlands Module will support the interpretation and modeling of salinity and nutrient patterns in the Southern Estuaries Module.

Parsimony. A prerequisite for the success of the MAP is its financial sustainability over multiple decades. This requires identifying a minimum set of monitoring components and supporting research that are necessary to track and understand the success, and lack of success, of CERP in achieving its major restoration objectives. The focus of the MAP on system-wide hypotheses and CERP premises, on adaptive management questions, and on the key parameters and processes within the integrated modules has identified an initial set of monitoring components and supporting research that are considered to be necessary.

Interpretation, Learning, and Understanding the Unexpected. In order to learn from and to interpret the monitoring results, the underlying processes responsible for the changes detected by the monitoring plan must be understood and the monitoring plan itself must provide that understanding. The MAP is designed to provide the necessary understanding for interpretation and learning in four ways:

- Develop monitoring components to track the key parameters pertaining to each CERP premise.
- Develop an integrated and coordinated sampling program to monitor the interrelated performance measures and processes within each module.
- Create a spatial, temporal and statistical design for each module to address key uncertainties and to detect unexpected consequences.
- Embed into each monitoring module the research and modeling support that is necessary to answer the key questions that cannot be answered by monitoring design alone.

Lessons Yet to be Learned. Both CERP and the MAP are at scales and levels of complexity unparalleled in the histories of ecosystem restoration and adaptive management. Monitoring plans in support of adaptive management at smaller scales and lesser levels of complexity have generally failed. Failures have resulted in part to the inability to learn from and to interpret ecosystem responses, and in part the reluctance to limit monitoring to a minimum set of key parameters that are financially sustainable over an adequate duration of time. The strategies proposed here to overcome these obstacles are experimental in themselves, and as such they are likely to require substantial refinement over the course of CERP, as understanding is gained not only about ecosystem response, but also about how to effectively detect and interpret it.

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Application of a Finite Element Two-Dimensional Variable Saturation Flow Model to Simulate Evapotranspiration from Shallow Water Table Environments

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At present a relatively small body of knowledge exists on shallow groundwater evapotranspiration (ET) in humid environments having a mix of natural vegetation cover. We will present research details conducted using HYDRUS-2D, a finite element two-dimensional variable saturation flow model, to investigate ETfrom a natural vegetative cover. In south and central Florida, ET varies in space due to a heterogeneous vegetative cover and in time in response to the fluctuation of the water table and the atmospheric conditions. Water table fluctuations are monitored along two flow-transects covering two types of vegetative landscapes in Lithia, west central Florida. Observation wells, rainfall gauges and a total weather station are maintained at the site. Detailed soil analysis was carried to estimate the soil hydraulic properties at this site and to fit the van Genuchten model of soil properties. Optimization algorithms provided in HYDRUS-2D are adopted to fine-tune the soil hydraulic parameters till the observed and simulated ground water levels agree to the desired accuracy. To avoid the hydrostatic pressure assumption, water levels are specified at the bottom of the observation wells. Dry period having zero precipitation are utilized to minimize the error due to air encapsulation, which causes large and rapid fluctuation in water tables during heavy storms. Different root depths are assigned to different segments of the transect to represent the mix vegetation which consisted of a riparian zone with relatively deep roots, and a pasture-land zone with shallow roots. Evaluation of calibration and verification results quantitatively and qualitatively confirmed the reliability of HYDRUS-2D to satisfactorily model the spatial and temporal variability of ET for this complex vegetative cover.

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Overview of the Across Trophic Level System Simulation (ATLSS) Program: Model Development, Field Study Support, Validation, Documentation, and Application

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An overview of the ATLSS Program is presented. The program has produced a set of models of spatially explicit species index, population demography, and ecosystem process models that are available for applications. In addition, the program has supported field studies designed to produce data for model construction and validation. This report describes the following aspects of the program.

The Spatially Explicit Species Index (SESI) models quantify relative effects of hydrologic conditions on the habitat suitability of species. There are several currently available ATLSS SESI models:

- Cape sable seaside sparrow breeding potential index (Version 1.1)
- Snail kite breeding potential index (Version 1.1)
- Long-legged wading bird foraging condition index (Version 1.1)
- Short-legged wading bird foraging condition index (Version 1.1)
- Empirically-based fish biomass index (Version 1.1)
- White-tailed deer breeding potential index (Version 1.1)
- American alligator breeding potential index (Version 1.1)
- Everglades and slough crayfish (Version 1.1)
- Apple snail SESI model (Version 1.1)

The ATLSS SESI models accomplish the following. They produce values for habitat suitability ranging from 0.0 to 1.0 for all 111,000 cells of the 500 x 500 m array. These can be calculated for every individual year in the multi-year sequence (1965-1995 for the Restudy scenarios), or averages can be taken over any set of years (e.g., wet years, dry years, all 31 years). The SESI models are intended to be used to make relative comparisons between scenarios, not to produce absolute evaluations of habitat quality. The output can be viewed using the ATLSS Data Viewer, which allows viewing at any scale and performing of statistics. The ATLSS Data Viewer is available to all agencies that are interested. Training sessions can be scheduled when requested.

There are currently three available ATLSS Demographic Models. The ATLSS demographic models are spatially explicit individual-based (SEIB) models of the dynamics of the populations:

- Cape sable seaside sparrow demographic model (SIMSPAR - Version 1.3)
- Snail kite demographic model (EVERKITE - Version 3.1)
- American alligator (Version 1.1)

The ATLSS Structured Functional Group models simulate the size-structured and biomass dynamics of the population. There is currently one available ATLSS Structured Functional Group model:

- Freshwater fish dynamics (ALFISH - Version 3.1.17)

There are background models that provide landscape information for other ATLSS models:

- High Resolution Topography (HRT - Version 1.4.8)
- Vegetation productivity (HTDAM -Version 1.1)
- High Resolution Hydrology (HRH - Version 1.4.8)

ATLSS model runs for scenario evaluations can be made in the following ways for particular models. The Snail kite demographic model (EVERKITE) is available in PC form for use (can be downloaded from Web) and user support for those wanting to use this model. Alternatively, this model will be run at the University of Miami and results posted. Currently, the remaining ATLSS models can be run at the University of Tennessee, which is funded to carry out several such runs. Results will be posted. Also, these models can be installed at agencies with Unix workstations. A NSF-funded project at the University of Tennessee is currently underway to allow dispersed resource managers to access remotely the capabilities of the SInRG (Scalable Intracampus Research Grid) at the University of Tennessee. This will allow users at resource agencies in South Florida, with relatively little computer expertise, to initiate ATLSS simulations on the computers at the University of Tennessee.

Technical documentation of ATLSS models is available on the ATLSS web site (ATLSS.ORG) and listed in ATLSS Program Publications (available) - and will be further improved. Open literature publications exist for the available ATLSS models. Nearly all models have appeared in open-literature, peer-reviewed papers (see ATLSS Publications). An internal USGS panel reviewed the ATLSS Program in May 2002. Additional review by the Model Refinement Team of CERP is planned.

Validation of models is an important issue. Some degree of model validation has been performed on some models (SIMSPAR, ALFISH). Model validation on other models depends on the availability of data sets. Now data sets are becoming available for several species, and new data for others. A "validation tool", which can be applied along with the ATLSS Data Viewer, allows empirical data (e.g., nest success rate, fish biomass) to be compared spatially with SESI index values at any spatial scale. Statistical testing can be done via Excel spreadsheets. Validation is being done, or will be done soon on Cape Sable seaside sparrow, snail kite, and American alligator SESI models.

User interfaces for running models and analyses have been developed. For running SESI models - only a UNIX platform currently available, but extension to PC is planned. The snail kite model (EVERKITE) runs on a PC.
Output of the SESI models can be displayed on the ATLSS Data Viewer. This will be extended to the demographic models.

ATLSS models nearly completed or under development include:

- Vegetation succession model
- Alligator structured population model
- Apple snail structured population model
- Crayfish structured population model
- Roseate spoonbill SESI model
- Estuarine fish dynamics

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Capabilities and Limitations of Stormwater Treatment Areas for Reducing Phosphorus Loads to the Water Conservation Areas: A Biogeochemical Perspective

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Alterations in natural drainage patterns in south Florida during the past century have resulted in pronounced adverse impacts to the Everglades ecosystem. These hydrologic perturbations have been exacerbated by phosphorus (P) loadings from agricultural and urban runoff. To attenuate P loadings in runoff from the agricultural areas located in the northern portion of the watershed, the State of Florida has undertaken a program to build six, large (920– 6670 ha) treatment wetlands, termed Stormwater Treatment Area (STAs).

The four STAs currently in operation are removing a substantial load of P that otherwise would have entered the Water Conservation Areas (WCAs). Research dedicated towards further improving the performance of STAs has revealed several key biogeochemical factors that influence P removal. Three of the most important factors identified to date include water column P speciation, vegetation type, and sediment P stability.

Water column P speciation, or the partitioning of P between particulate, dissolved organic and dissolved inorganic fractions, is particularly important with respect to P sequestration and transport in the watershed. During 1998-1999, a period during which the western flow path of STA-1W provided an outflow total P concentration of 14 ug/L, the sequential wetlands (Cells 2-4) within this flow path removed 95% of the inflow soluble reactive P (SRP), 90% of the inflow particulate P (PP), but only 50% of the inflow dissolved organic P (DOP). The presence of DOP, which is not readily available to biota and is readily transported through the conveyance system, probably places a lower limit on STA outflow concentrations.

Improved understanding of P biogeochemistry in south Florida wetlands recently has led to management practices that likely will enhance STA performance. Submerged aquatic vegetation (SAV) communities are now recognized to be particularly effective at enhancing STA P removal. Submerged macrophyte photosynthesis promotes precipitation of $CaCO_3$ in the moderately “hard” agricultural drainage waters (ADWs) that enter the STAs. Phosphorus removal is enhanced under such conditions due to the adsorption or co-precipitation of P with $CaCO_3$. It is unclear, however, whether STA performance will be comparable during periods when treating Lake Okeechobee waters, due to their typical two-fold lower calcium concentrations than the ADWs.

Sediments are the ultimate P sink for the STAs. Because of water column precipitation of $CaCO_3$, some SAV-dominated wetlands (e.g., STA-1W Cell 4) have removed 250 – 400 grams calcium for every gram of P removed from the water column. Phosphorus fractionations of sediments have revealed that much of the sediment P is associated with calcium, which contributes in part to the stability of the sediment P.

The inflow, highly loaded regions of the STAs contain high concentrations of P in sediment porewaters, which may contribute to a substantial internal loading of P to the water column under certain environmental conditions. Such a reflux of sediment P also is likely to occur in the impacted areas of the WCAs once they receive STA discharges, rather than direct discharges of

ADWs. Sediment porewater P concentrations in outflow regions of STA wetlands are substantially lower than inflow concentrations. Whereas the “highly loaded” regions of an STA at times may export sediment P, the flux of P from sediment porewaters in the outflow region of STA-1W Cell 4 was found to be negligible, which probably has contributed to the low total P outflow concentrations provided by this wetland.

Continued research towards understanding these key biogeochemical aspects (i.e., water column P speciation, aquatic plant ecology/processes, and sediment P stability) will lead to improved design and operational strategies for the STAs.

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Miami-Dade Agriculture as an Ecosystem Buffer: Will it Survive Economics, Urban Development Pressure and Pestilence?

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Miami-Dade County is home to what has been called the "crown jewel" of Florida agriculture. The subtropical climate, abundant water, and curious and innovative entrepreneurs from all over the world have created one of the most diverse agricultural communities on the planet. Early settlers in the late 1800s were taken with the climate, and traditional vegetable production was the main agricultural activity. Miami-Dade County quickly became a major supplier of traditional vegetables and citrus in the winter months when most of the U. S. was in the grips of cold weather.

Today, Miami-Dade County remains the second largest producer of agricultural products in the state, generating more than $1.0 billion annually in economic activity for the local economy. Major crop categories include traditional winter vegetables, tropical fruits and vegetables, ornamental horticulture and aquaculture. A recent study by the Institute of Food and Agricultural Sciences (IFAS) identified 25 traditional and tropical vegetables of commercial importance to the county and 23 tropical fruits that are produced commercially, hundreds of species of ornamental plants produced by commercial nurseries, and limited aquaculture production of freshwater ornamental fish, prawns and tilapia.

Despite the large and diverse agricultural sector in Miami-Dade County, all is not well. The agricultural production area, which is located in the southern part of the county, is currently experiencing detrimental pressures from many fronts. Fruit and vegetable producers are facing serious economic pressures from foreign competitors; land prices have been soaring due to the rapidly growing population, and restrictive pesticide and other environmental regulations continue to increase production costs. The environmental issues are likely to be exacerbated as the Everglades Restoration effort progresses. Further, introduction of exotic pests pose an ever-increasing threat.

In 2002, the Institute of Food and Agricultural Sciences (IFAS) was asked by the Florida Department of Agriculture and Consumer Services (FDACS) to conduct a comprehensive study to determine ways to improve the economic returns to agricultural producers and agribusinesses in Miami-Dade County. The underlying purpose of the study was to identify ways to retain land in agricultural production in the face of unrelenting urban development, increasingly stringent environmental regulations, economic pressures from escalating levels of international competition, production challenges resulting from invasions of exotic pests, and impacts of technological change.

An IFAS research and extension team comprised of 29 faculty and professional staff conducted an in-depth two-year study of virtually every aspect of agriculture in Miami-Dade County, examining economic, social, and technological issues and trends that are impacting the long-term survivability of the agricultural sector. The IFAS team included economists with specialization in marketing, production economics, regional and land economics, and international trade; other areas of expertise included horticulturists, soil scientists, entomologists, plant pathologists, geographic information systems (GIS) specialists, and plant physiologists. This paper provides an overview of the exhaustive IFAS study, with emphasis on economic trends and the major factors that threaten the long-term survivability of Miami-Dade County's agricultural sector and its role as a buffer between intensive urban development, the Everglades National Park, Biscayne National Park, and Florida Bay.

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Measuring and Mapping the Topography of the Florida Everglades for Ecosystem Restoration

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One of the major issues facing ecosystem restoration and management of the Greater Everglades is the availability and distribution of clean, fresh water. The South Florida ecosystem encompasses an area of approximately 28,000 square kilometers and supports a human population that exceeds 5 million and is continuing to grow. The natural systems of the Kissimmee-Okeechobee-Everglades watershed compete for water resources primarily with the region's human population and urbanization, and with the agricultural and tourism industries. Therefore, surface water flow modeling and ecological modeling studies are important means of providing scientific information needed for ecosystem restoration planning and modeling. Hydrologic and ecological models provide much-needed predictive capabilities for evaluating management options for parks, refuges, and land acquisition and for understanding the impacts of land management practices in surrounding areas. These models require various input data, including elevation data that very accurately define the topography of the Florida Everglades.

Surface water levels and sheet flow in the Everglades are very sensitive to any differences in topography because of the region's expansive and extremely flat terrain. Therefore, hydrologic models require very accurate elevation data to simulate and predict water flow direction, depth, velocity, and hydroperiod. Water resources, ecosystem restoration, and other land management decisions will rely in part on the results of these models, so it is imperative to use the best elevation data available to achieve meaningful simulation results. Elevation data points are being collected every 400 meters in a grid pattern to meet the requirements of various hydrologic models. The vertical accuracy specification for these elevation data is ±15 centimeters (6 inches) as referenced to the North American Vertical Datum of 1988 (NAVD88).

Because traditional methods for collecting elevation data for the Everglades are impractical or too costly, the U.S. Geological Survey (USGS) conducted a feasibility study to determine if state-of-the-art techniques using the Global Positioning System (GPS) could meet the strict vertical accuracy specifications of the elevation data. The feasibility study successfully demonstrated that differential GPS techniques, using airboats to navigate transects, could in fact meet the vertical accuracy requirement. Also, the land surface being surveyed in the Everglades is typically under water and obscured by vegetation. This precludes the use of other methods for collecting very accurate elevation data, such as photogrammetry, Light Detection And Ranging (lidar), Interferometric Synthetic Aperture Radar (ifsar), or other alternative remote sensing technologies. Therefore, topographic surveys over such a large area of the Everglades with such a stringent accuracy specification can only be accomplished efficiently by using GPS technology. This is especially the case in a harsh and inaccessible wilderness environment with unique landscape characteristics.

Because the Everglades is so expansive and remote and includes environmentally sensitive areas, impenetrable vegetation, or other areas unapproachable by airboat, access to many places is possible only by helicopter. To solve this accessibility problem, the USGS developed a helicopter-based instrument, known as the Airborne Height Finder (AHF), which is able to measure the terrain surface elevation in a noninvasive, nondestructive manner. Using an airborne GPS platform and a high-tech version of the surveyor's plumb bob, the AHF system distinguishes itself from remote sensing technologies in its ability to physically penetrate vegetation and murky water, providing reliable measurement of the underlying topographic surface.

Accuracy tests have shown that the AHF system can consistently measure elevation points at the subdecimeter level. An accuracy test of the AHF was conducted in May 2000 when 17 National Geodetic Survey (NGS) first-order benchmarks were measured at two different helicopter hover heights. The average difference between the AHF measured elevations and the NGS published data sheet values was 3.3 cm. The largest difference was 8.6 cm, and the smallest difference was 0.2 cm. The root mean square error was 4.1 cm. These accuracy test results provide confidence that the elevation dataset being produced meets the ±15 cm vertical accuracy specification.

Elevation data collected with the AHF have been applied in the USGS-developed Southern Inland and Coastal System (SICS) numerical simulation model, which requires very accurate data for its hydrodynamic surface-water computations. The SICS model was originally constructed with topographic estimates based on pre-existing contour maps. Although these contour maps meet national map accuracy standards, the derived elevation data are not adequate for hydrologic modeling purposes for the Florida Everglades. However, the distribution of surface-water flows simulated by the SICS model was greatly improved when the AHF elevation data replaced the previously estimated topography in the model. Flow and inundation estimates north of the West Lake area (southwest portion of the SICS model domain) are most significantly affected by this elevation difference.

To date, tens of thousands of elevation data points covering significant parts of the Florida Everglades have been collected and processed using differential GPS methods with airboats and the helicopter-based AHF system. These data are organized by USGS 7.5-minute quadrangle maps and are available from the South Florida Information Access Web Site at http://sofia.usgs.gov.

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Data in the Key of ZZZ: Development of a Network to Establish Vertical Reference Datum for Research Stations in the Southwest Coastal Everglades

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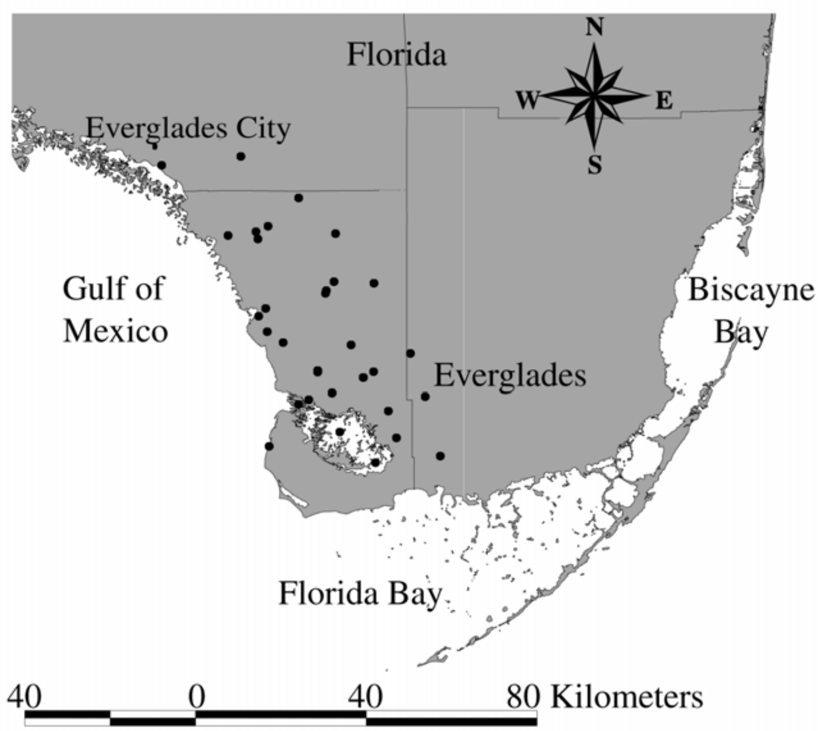
Some of the most remote locations in all of the National Park Service system in the lower 48 states are located in the southwestern, coastal areas of Everglades National Park. Highland Point lies on the coast between the mouths of the Lostmans and Broad Rivers and is more than 40km from the nearest trail-head. This mangrove and marsh dominated coastal wilderness is at the southern end of the Everglades, where the "River of Grass" meets the Gulf of Mexico. It encompasses over a third of the Park's total acreage.

As the Comprehensive Everglades Restoration Plan (CERP) is implemented, questions have arisen related to monitoring restoration success in this region. Since 1996 the USGS/BRD has established and maintained a network of study sites for sampling hydrology, sediments and vegetation. Benchmarks were established and set to a relative datum at a total of 13 hydrological stations. This network of benchmarks has been used as a starting point to develop a broader survey of vertical elevation. Thirteen of the benchmarks have been installed by driving a pipe to refusal, capping it, and setting the mark with cement to maintain a stationary point of occupation that is separate from the wooden platforms constructed for fieldwork measurements. Ten other control locations are temporary locations consisting of a PK nail hammered into the top of a hydrologic station platform with the assumption that the platform remains stable through time.

The elevation factor Z is the critical variable for much of the work in the Everglades as well as Florida Bay and the Florida Keys Reef Tract. An accurate reliable key of Z is needed to convert field measurements into metrics that are cross-comparable. It also serves to satisfy the vertical variable in flow models. Essentially, an accurate elevation will become an established pivot point for data comparison among the scientific studies of various disciplines such as biology, water, remote sensing, and geology that are underway within the Everglades.

An accurate elevation for the Everglades portion currently exists for only one site of this network. To begin to bridge this gap, annual surveys have begun starting in June 2000 with long-term, repetitive occupation time from 8 hours to 24 hours upon selected benchmarks. These surveys are tied to the closest National Geodetic Survey (NGS) sites available having the best vertical control published. These sites include FLGPS Thompson, FLGPS GEB, and Tidal 8724948EH7. The surveys will begin to establish a strong reliable network for the original 13 stations. High precision Ashtech GPS receivers and antennas are the instruments used for receiving the L1 and L2 signals from the satellite constellation which are then post processed to obtain the horizontal and vertical (XYZ) information for each benchmark. Thirty-four stations in total have been occupied in the last two years three of, which are NGS control points that will be the tie to the National Geodetic Survey's network.

Because technology is rapidly improving and this elevation survey is relatively young, the post processing method has been carried out using three different methods. The first method uses PNAV post processing software. This software calculates vectors between locations and based upon the repetition of vectors and their quality, it calculates coordinates for the location. The second method is Automated Gipsy by the Jet Propulsion Lab. This method can be applied when a location cannot be tied into an established network like an NGS location. Submission of long occupation times to Automated Gipsy will produce a location in an ITRF## format which can be transformed into NAVD88. The third method utilizes OPUS (Online Positioning User Service) located on the NGS website. This method requires submittal of a GPS file and OPUS determines the three best CORS stations (Continuously Operating Reference Station) for processing the location of the submitted file. Both OPUS and Automated Gipsy are automated and require minimal file preparation, whereas, PNAV is controlled solely by the user allowing choice selections of vector inclusion and exclusion to maintain accurate results.



Graphic of South Florida displaying site locations in elevation survey that have been occupied to date.

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Contribution of Internal Phosphorus Loads in Water Conservation Area Canal Sediments

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Phosphorus (P) has been identified as a major limiting nutrient to productivity in south Florida freshwater ecosystems. As a result, significant efforts have focused on reducing P loading to sensitive wetland areas of South Florida such as the Everglades National Park, and the Water Conservation Areas (WCA). Part of this effort has included the creation of wetland Stormwater Treatment Areas (STA's) to intercept water coming from Agricultural and Urban Landscapes and to remove P prior to discharge into WCA canals. The south Florida canal network is then used to convey this water to discharge points to the south and east. However, sedimentation and historic P loading to these canals may have resulted in a significant amount of P stored in the sediment. Because of this potential P load within the canals, questions have been raised regarding the release of the internal P load to the water column and elevation of P concentrations as water moves from the STA's to discharge points. This investigation was initiated to characterize and evaluate the forms of sediment P present in WCA canal sediments and to evaluate the potential flux rate of P from sediments within the canals to overlying "low P concentration" floodwaters.

The canals investigated were L7, L39, L40, L6, L5, L38, and Miami. We determined the current bathymetry of the canals, conducted inventory of the sediment in the canals, assessed the labile and non-labile pools of inorganic P and organic P in canal sediments from 20 different locations to the south and east of existing and proposed STA's. We also estimated the potential P flux from canal sediments to the overlying water column at these same sites. Characterization of sediment P and potential P flux determined in this study will provide a better assessment of the short and long term potential contribution of internal sediment P loads to the water column of those canals surveyed.

Sediment properties including sediment depth, bulk density, organic matter content, and P content varied considerably from canal to canal. For example, the Miami canal north had the lowest organic matter content (14.9%), while L7 North had the highest organic matter content at 48%. Canal midpoint sediment depths varied from zero at several transects in L-38 that were bare of sediment to over 10 feet at the far north end of L-7, where stagnate water conditions prevail. The higher the organic matter content of the sediments, the lower is the bulk density. Sediments with the highest total P concentrations were found adjacent to L-40 (STA-1E), and Miami Canal (STA's 5 and 6). Phosphorus fractionation in the sediments showed an interesting break down of relatively available P with geography. L40S (STA 1E) sediment has 35% relatively available P, L7/L39 (STA 1W) sediment has 19%, L6/ L38/ L5 (STAs 2, 3, and 4) sediment has 18% while the Miami canal sediment (STAs 5 & 6) has 12%. The Miami canal had the lowest organic matter content and an average total P concentration of 1110 ± 374 mg/kg, however, most of the P being Ca and Mg bound and not readily available for release. The L-40 canal had an average P concentration of 1142 ± 141 mg/ kg, a higher portion of the P is bound to Fe and Al and in organic forms. The top-12-cm layer P mass in all the canals reaches downstream of the STAs is estimated to be in excess of 175 000 kg.

To estimate P release from sediments, intact sediment cores were incubated in the dark at room temperature. Four floodwater exchanges were conducted on cores collected in 2001. There is a wide spatial variability in internal P release potential within these canals. Site aggregation indicates that the highest maximum and average flux rates of dissolved reactive phosphorus (DRP) occurred in the L-40 canal adjacent to STA-1E (5.73 $\pm$ 2.62 and 8.43 $\pm$ 9.64 mg P m^2 day^{-1} for the 1st and 2nd floodwater exchanges). Rates of DRP flux were lowest in canal sites adjacent to STA's 2-4. Cumulative P release from sediments, representing the total amount of P that was released from the sediment to the water column during the four-floodwater exchanges, was lowest at canal sites adjacent to STA's 2, 3 and 4. The greatest maximum P release was similar at two sites L40-C24 (80.00 $\pm$ 30.38 mg m^{-2}) and L39-C25 (80.43 $\pm$ 17.07 mg m^{-2}). The smallest average P release at any canal site was from canal L6 sites C7 (4.58 + 0.82 mg m^{-2}).

Based on correlations between P flux and physico-chemical parameters measured, mineralization of organic bound P and release from Fe and Al-bound fractions are likely significant storage pools influencing release of P to the overlying water column in canals. Sediment P at sites in the L-40 canal are more labile due to elevated Al and Fe-bound fractions making it more susceptible to changes in redox state, and a high organic bound fraction resulting in long-term slow release through mineralization. In contrast, aggregated sites within the Miami Canal had similar total P concentrations, but average and maximum P flux rates were generally lower as the distribution of P was greatest in the Ca and Mg bound pool.

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Relationships Between Hydraulic Efficiency and Phosphorus Removal in a Submersed Aquatic Vegetation-Dominated Treatment Wetland

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A dye tracer study (rhodamine-WT) was performed on a 147-ha submersed aquatic vegetation (SAV)-dominated wetland in Stormwater Treatment Area – 1 West (STA-1W). STA-1W is one of the constructed free water surface wetlands in south Florida intercepting agricultural runoff for phosphorus removal prior to flowing into the Everglades.

Two dimensional, time series plots of the dye concentrations revealed that a disproportionate amount of tracer flowed along the eastern and western levees of the cell. The tracer response curve developed from the outflow data indicated a prominent short circuit, which resulted in 44% of the volumetric flow bypassing the SAV community and exiting the wetland with only partial treatment for P removal.

The volumetric efficiency of the wetland was high (~100%), but the hydraulic efficiency was low, as described by a low tanks-in-series number (N=1.3). The dispersion number for the wetland was high (D=1.25), indicating that transport is dominated by diffusion and dispersion rather than convection (bulk flow).

Total phosphorus (TP) loadings to the SAV wetland were relatively constant during the tracer testing period. This resulted in “steady-state” TP concentrations among the internal and outfall stations during the study. Based on longitudinal P concentration gradients, faster flowing short-circuit channels that contained little SAV were not as effective in reducing TP concentrations (k=0.24 day^{-1}) as the more densely SAV-occupied areas (k=0.50 day^{-1}) that characterized most of the wetland. This was because the channel provided both a shorter detention time and conditions less conducive to removal and retention of P relative to the more quiescent, shallower SAV zones.

Our results suggest that tracer evaluations, coupled with internal P concentration gradient measurements, are a useful approach for determining hydraulic efficiency of a wetland and its effect on P removal. These types of investigations also provide a sound basis for STA modeling, optimization, and design studies.

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Past Stony Coral Growth (Extension) Rates on Reefs of Broward County, Florida: Possible Relationships with Everglades Drainage

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Introduction

Scleractinian reef building corals can be long-lived (hundreds of years) and produce massive calcareous skeletons. These skeletons preserve a skeletal record of both time and growth. Alternating bands of high and low-density skeletal material are present and are visible through X-radiography, where each pair of bands represents approximately one year's annual extension of the coral. The presence of time-dependent banding within coral skeletons can provide a useful tool for reconstructing environmental variables that affect growth (and also the chemical composition) of coral skeleton. Skeletal growth includes: physical lengthening of the coral skeleton (extension), material distribution within the skeleton (density), and mass accretion of the skeleton over time (calcification), all of which may be quantified over time. The chemical characteristics of the coral skeleton coupled with the inherent chronological record of the growth bands also can provide environmental information. The carbon and oxygen stable isotopic composition of the skeleton is valuable for reconstruction of temperature, salinity, and light level characteristics. The chemical composition of the skeleton can mimic the chemical composition of the seawater in which the coral grew. The fluorescence characteristics of the skeleton can show the influence of terrestrial water input. Trace element composition of the skeleton can show water temperature (Sr/Ca), upwelling (Ba/Ca), radioactivity (e.g., U/Ca), and hydrocarbon pollution (e.g., V/Ca).

Reef corals growing on coral reefs of Southeast Florida (Broward County) are at the extreme northern end of their range, increasing their sensitivity to environmental limiting factors. Because Everglades restoration will significantly affect canal discharge and hence possible ocean salinity variations, one purpose of this investigation was to determine if salinity and canal discharge had impact on coral growth.

Methods

In this study we have analyzed the skeletal growth (annual skeletal extension) of over 154 corals collected from reefs of Broward County, Florida. Specimens consisting of two coral species (star corals (*Montastrea annularis (M.a.)* complex and brain corals *Diploria labyrinthiformis (D.l)*) were collected at 4 sites at two depths (9m and 18m) along an approximately 30 mile north south latitudinal gradient. Once collected, coral skeletons were sectioned using a large diamond bit masonry saw into slabs approximately 0.5-cm thick. Slabs were oriented normal to growth band surfaces. Multiple slabs were cut from each coral for replication and comparison of banding patterns. Each slab was X-radiographed onto Kodak AA Industrex film to reveal density banding. X-ray negatives were printed into positives for the entire length of the coral growth record. Annual extension (from top of one high density –HD- band portion to the next lower HD top) for each band was measured by caliper along two separate transects, normal to growth band boundaries.

Normalized coral chronologies were constructed by dividing the mean of each growth measurement transect into each annual extension value. Each normalized or index transect was then averaged into a whole index coral master chronology. Normalized annual linear skeletal extension rates of the corals were examined over 16 common years (1985-1970). Individual normalized coral chronologies were ensemble averaged into site, depth, and combined site depth master chronologies for each of the two species.

Individual site masters (by species and depth) were compared to environmental variables. Environmental data included water temperature and density (salinity) from Miami Beach, rainfall (Lower East Coast) as tabulated by SFWMD, and canal discharge (North New River canal USGS) data. Man-induced perturbations (i.e. beach renourishment projects) were also compared.

Results

Site averages of absolute coral growth indicated that southern 9m deep specimens (.49 cm/yr for *M.a*., .51 cm/yr for *D.l*) had higher rates of growth than northern counterparts .34 cm/yr for *M.a*., .45 cm/yr for *D.l*. In the southern collection sites, 9 m deep growth of both species tended to be greater than 18m deep growth (.33 cm/yr *M.a.*, .42 cm/yr *D.l.*).

Correlation analysis indicated that the time pattern of coral extension was similar among sites, species, and depths. This was exemplified by the obvious agreement of site master chronologies. (Average master chronology correlation over the period 1985-1970 ranged from r=.4-.8, n=45) Comparisons of chronologies to recorded environmental variables (water temperature, salinity, and canal discharge) revealed a positive correlation of coral extension with density (salinity), and negative correlations with rain and discharge.

While a gradient of decreasing intensity of correlation away from canals was not well defined, for Rain: deep *M. annularis* and deep *D. labyrinthiformis* were more highly negatively correlated with rain than corresponding mid depth series. This may be a light effect associated with light limitation at depth in more rainy/cloudy years. For discharge: mid *M. annularis and* mid depth *D. labyrinthiformis* were more highly correlated negatively with discharge than corresponding deep series.

This study indicates that freshwater sources, including those emanating from the Everglades Drainage canals may adversely affect offshore coral growth. Further investigations are needed to gauge the extent of past effects and the predict future impacts related to Everglades restoration.

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Establishing Minimum and Maximum Freshwater Inflows to the Caloosahatchee Estuary, FL

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Anthropogenic modification of the Caloosahatchee River and its watershed has altered the delivery of freshwater to the downstream Caloosahatchee Estuary. The resulting fluctuations in salinity frequently exceed salinity tolerances of estuarine biota. As a first step in reducing this variability, the South Florida Water Management District has been using a resource-based approach to establish minimum and maximum estimates of freshwater inflows. The approach is a combination of the Valued Ecosystem Component (VEC) approach, developed by the US Environmental Protection Agency (USEPA, 1987), and the habitat overlap concept, developed by Browder and Moore 1981.

The VEC approach has been modified to focus on critical estuarine habitat. In some cases that habitat might be physical, such as an open water oligohaline zone. In other cases the habitat is biological and typified by one or more prominent species (e.g. an oyster bar, mangrove prop roots, grass beds). It is important to note that these habitats are distributed along the estuarine salinity gradient with different habitat forming species occupying different portions of the salinity gradient. The success of these habitat forming species is critical to the success of the many other species that utilize the habitats and the salinity zones in which they occur. A major assumption of this approach is that conditions that are suitable for habitat forming VEC will also be suitable for the species that utilize them. For the Caloosahatchee, beds of submerged aquatic angiosperm grasses have been identified as a VEC.

The overlap concept of Browder and Moore (1981) forms the basis for relating freshwater discharge to VEC or other estuarine resources. In the present application, freshwater inflow produces a temporal and spatial overlap between grass beds and physiologically tolerable salinities.

Salinity tolerances of submerged aquatic vegetation were used to make estimates of inflow limits. Downstream, the marine grass, *Halodule wrightii*, was used to estimate maximum inflows, while upstream, a salt-tolerant freshwater species, *Vallisneria americana*, was used to estimate minimum flows. Salinity tolerances, determined from laboratory experiments and field observations combined with results of relationships between discharge from the Caloosahatchee River and salinity in the estuary indicated: (1) mean monthly inflows of 300 cfs provided tolerable salinities for upstream SAV, and (2) maximum mean monthly flows of 2800 cfs or less would avoid mortality of downstream marine SAV. Analysis of field survey data indicated that this flow range was not detrimental to other biotic components of the system including zooplankton, ichthyoplankton and benthic macrofauna.

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Inventory and Monitoring of the Amphibians and Reptiles of Biscayne National Park

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Declines in amphibian populations have been recognized worldwide over many regions and habitat types (Alford and Richards 1999). No single cause for declines has been found, although acid precipitation, environmental contaminants, the introduction of exotic predators, disease agents, parasites, and the effects of ultraviolet radiation have been suggested. In fact, several factors may interact in such a manner as to threaten populations (Carey and Bryant 1995). A major factor in the loss of amphibian and reptile populations has been and continues to be the loss of habitat.

In response to concerns about the lack of basic knowledge of the amphibians and reptiles inhabiting Department of Interior (DOI) lands, inventory programs are being instituted nationwide. The Center for Water and Restoration Studies of the U.S. Geological Survey is conducting a reptile and amphibian inventory of Biscayne National Park (BISC) in cooperation with the Florida Cooperative Fish and Wildlife Research Unit. BISC is primarily an aquatic park with small islands and spans over 173,000 acres.

We have established 16 permanent inventory sites that are sampled on a monthly basis in BISC. During each sampling occasion, a 20m radius circular plot is searched using standard visual encounter survey (VES) techniques, and a 10-minute vocalization survey is conducted to detect calling anurans (frogs and toads). The locations of these sites were chosen randomly within habitat strata. Four of these sites (two in scrub habitat and two in mangrove habitat) are on the mainland portion of the park. Eight monthly sampled sites (three in scrub habitat, two in prairie habitat, and three in mangrove habitat) are on Elliott Key, the largest island in BISC. Two monthly sites (one in mangrove habitat and one in hammock) exist on both Sands Key and Boca Chita Key. In addition to the 16 monthly sites, we also have conducted surveys at six other random sites. These have all been in scrub and mangrove habitat sites on the mainland and on Elliott Key. Our goal is to continue to add random sites until all habitats on islands and the mainland have been surveyed.

Sampling for amphibians and reptiles in (BISC) began on May 2, 2002. As of November 30, 2002 a total of 22 sites have been surveyed during 76 sampling occasions. A total of 65 individuals of 12 species during VES surveys (table 1) and 7 species of anurans by vocalizations (table 2) have been observed.

Nine amphibian species have been detected in BISC, all anurans. Three of the nine amphibian species are introduced in South Florida: the greenhouse frog (*Eleutherodactylus planirostris*), the Cuban treefrog (*Osteopilus septentrionalis*), and the marine toad (*Bufo marinus*). These species have been detected on the islands and mainland of BISC. Five of the native amphibian species detected, the green treefrog (*Hyla cinerea*), the squirrel treefrog (*Hyla squirrella*), the leopard frog (*Rana sphenocephala*), the Florida cricket frog (*Acris* gryllus), and the pig frog (*Rana grylio*) have only been detected in mainland parts of the park. The narrowmouth toad (*Gastrophryne carolinensis*) is the only native frog detected on the islands to date.

Six species of reptiles, four lizards and two snakes have been detected. Of the lizards, the brown anole (*Anolis sagrei*) and the tropical house gecko (*Hemidactylus mabouia*), are both introduced in South Florida. Tropical house geckoes are especially abundant on the buildings of Elliot Key. The green anole (*Anolis carolinensis*) and the Florida reef gecko (*Sphaerodactylus notatus*) are native to South Florida. The two snakes, the ringneck snake (*Diadophis punctatus*) and the Florida water snake (*Nerodia fasciata pictiventris*) are both native. Each of these has only been observed once.

Monthly sampling of the 16 permanent plots will continue through July 2003. In addition, random points throughout the park will be sampled. Each of these will be sampled at least twice during the study. We expect the number of species encountered to increase as this study continues, especially the number of reptiles.

Although the final inventory may include many species not encountered to date, the substantial constituency of exotic amphibian and reptiles inventoried in BISC during this study calls for some concern.

Table 1: Number of reptiles and amphibians counted during visual encounter surveys in Biscayne national Park during 2002.

	Mainland	Elliott Key	Sands Key	Boca Chita Key
Hyla cinerea	3	0	0	0
*Osteopilus septentrionalis**	5	4	0	0
Rana sphenocephala	1	0	0	0
*Anolis sagrei**	2	25	2	5
Anolis carolinensis	0	0	1	0
Diadophis punctatus	1	0	0	0
*Bufo marinus**	0	0	0	0
*Eleutherodactylus planirostris**	0	9	2	1
Gastrophryne carolinensis	0	1	0	0
*Hemidactylus mabouia**	0	2	0	0
Nerodia fasciata pictiventris	0	1	0	0
Sphaerodactylus notatus	0	0	1	0

*These species have been introduced to BISC.

Table 2: Locations of anuran species detected during vocalization surveys in Biscayne National Park during 2002.

	Mainland	Elliott Key	Sands Key	Boca Chita Key
Acris gryllus	X			
*Bufo marinus**	X		X	
*Eleutherodactylus planirostris**	X	X	X	X
Hyla cinerea	X			
Hyla squirrella	X			
*Osteopilus septentrionalis**	X	X		
Rana grylio	X			

*These species have been introduced to BISC.

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Effects of Water Management on the Growth and Survival of Red Mangrove Recruits

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Many coastal parks and refuges are impounded or drained to control mosquito outbreaks or to foster wildlife use with nominal concern for the health and resiliency of native plant populations. Mangrove trees predominate the subtropical coastlines of Florida though little is known about how managed or restored hydrology might effect species success. Neotropical tree species, *Avicennia germinans, Laguncularia racemosa, and Rhizophora mangle* persist in a rather broad spectrum of salinity and hydrologic regimes, though data are lacking on specific growth and survival habits with changing hydrology. An innovative field experiment was devised to monitor mangrove growth response to changing water level patterns in a coastal refuge of southwest Florida utilizing controlled impoundments. Red mangrove, *Rhizophora mangle*, propagules of select size and genotypic groupings were outplanted in fixed and floating nursery structures designed to mimic tidal and static water level datums related to land/soil elevation. Two remeasurements were conducted in the first 6 months of study of shoot growth and survival based on leaf sets and seedling height production. Results show dramatic growth stimulation with tidal fluctuation affected by management protocol compared with static water levels. Plant survival was not significantly affected by treatment, though susceptibility to insect attack and dieback was greater with higher soil elevation above mean water level. There were no significant differences between genotypes or with initial propagule size on growth start and success. Study findings suggest that hydroperiod plays a much more important role in controlling mangrove growth and success than previously documented. This empirical evidence will be used to upgrade mangrove forest simulation models and to predict how large-scale water management and restoration alternatives may affect habitat quality and distribution of coastal plant communities.

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SELVA-MANGRO: Integrated Landscape and Stand-level Model of Mangrove Forest Response to Sea-level Rise and Hydrologic Restoration of the Everglades

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

Mangroves are halophytes and can, therefore, tolerate the added stress of waterlogging and salinity conditions that prevail in low-lying coastal environments influenced by tides. Global warming has been projected to increase sea water temperatures and expansion that may accelerate sea level rise and further compound ecosystem stress in mangrove dominated systems. While early researchers attributed zonation patterns to salinity gradients, more recent field and experimental studies indicate that mangroves have wide tolerances to salinity and other soil factors and may be influenced to a greater degree by local hydrology and episodic disturbance events. Increases in relative sea level will eventually raise saturation and salinity conditions at ecotonal boundaries where mangroves are likely to advance or encroach upslope into freshwater marsh/swamp habitats. Changes in freshwater runoff as a result of climatic variability and water management controls may alter the health and migration of mangrove communities in conjunction with potential sea-level rise.

A landscape simulation model, SELVA-MANGRO, was developed for mangrove forests of south Florida to investigate the potential impacts of climate change and freshwater flow on the quality and distribution of future mangrove habitat. The SELVA-MANGRO model represents a hierarchically integrated landscape model that manages the exchange of system parameters up, down, and across scale between linked simulation models SELVA and MANGRO. SELVA is a Spatially Explicit Landscape Vegetation Analysis model that tracks predicted changes in the biotic and abiotic conditions of each land unit (1 sq ha) on an annual basis for the entire simulated landscape. The SELVA model administrates the spatial articulation of the landscape composed of land units composed of habitat classifications (forest, marsh, aquatic) and any forcing functions that predict changes in hydrology and disturbance. Intertidal forest units are then simulated with the MANGRO model based on unique sets of environmental factors and forest history. MANGRO is a spatially explicit stand simulation model constructed for mangrove forests of the neotropics. MANGRO is an individual-based model composed of a set of species-based functions predicting the growth, establishment, and death of individual trees. MANGRO predicts the tree and gap replacement process of natural forest succession as influenced by stand structure and environmental conditions.

Model applications were conducted to forecast mangrove migration under projected climate change scenarios of sea-level rise and saltwater intrusion for the Everglades coastal margin without hydrologic restoration. A high resolution model of surface topography was needed to predict the rate and fate of coastal inundation from sea-level rise over the next century. Tidal inundation and circulation are key factors controlling mangrove distribution in this coastal environment. The ability to predict landward transgression of mangrove caused by sea-level rise depends on the relationship between landward slope and elevation in relation to tide range and extent plus an understanding of relative sea-level rise. A historic topographic and drainage map circa 1940-50 with 1 ft contour intervals across the south Florida Everglades was rectified and digitized into a geographic information systems application. Boundary zones of major habitat classes were also digitized from the natural vegetation map of Florida produced by Davis (1943) to delineate the lower and upper elevations of the intertidal zone as defined by mangrove extent. The coastline was assigned an elevation of mean sea level while the upper transition zone of mangrove extent was approximated at mean high water for available tide datums along the southwest coast of Florida. These combined data sources and proxy contours served as baseline elevation values for constructing a detailed digital elevation model of south Florida for SELVA-MANGRO application.

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

Modeling upgrades are under development for the SELVA-MANGRO model to assess the impact of increased freshwater runoff under various Everglades restoration alternatives. Empirical data of riverine and basin mangrove forests show that precipitation and runoff events effect short-term hydrology and salinity conditions that are relatively minor in relation to coastal influences of daily and seasonal tidal forcing. Everglades restoration alternatives will increase runoff conditions above current normal patterns and may abate any influence of sea-level rise in the near future. Model trials indicate that proposed freshwater flow rates may need to exceed current engineering design to affect stage and salinity at the coastal margin to affect potential mangrove migration and expansion into freshwater habitats.

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Biological Control of Invasive Plants in Everglades Ecosystems

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The USDA, ARS Invasive Plant Research Lab develops sustainable biological control methods to manage invasive weeds that threaten aquatic, wetland, and upland ecosystems including Florida's prized Everglades. This involves exploratory foreign surveys to find biological control agents, risk analysis of those agents, establishing field populations, evaluating their efficacy, and assessing non-target impacts, as well as developing strategies to enhance their efficacy. A multi-disciplinary team investigates plant and insect demographics, the ecological genetics of plants and insects, plant and insect reproductive biology, insect eco-physiology and nutritional ecology, plant tissue biochemistry, insect-plant interactions, and both intraspecific and interspecific plant competition. Weed species under investigation include the aquatic weeds waterhyacinth (*Eichhornia crassipes*), waterlettuce (*Pistia stratiotes*), giant salvinia (*Salvinia molesta*), and hydrilla (*Hydrilla verticillata*), wetland invaders melaleuca (*Melaleuca quinquenervia*) and Old world climbing fern (*Lygodium microphyllum*), and upland invaders Brazilian peppertree (*Schinus terebenthifolius*) and skunk-vine (*Paederia odorata*). Construction of a new biological control quarantine facility is nearly complete. This facility will greatly expand the capability of the lab, allowing us to conduct simultaneous risk assessments of multiple insects on each of several target weeds.

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Variation Among *Melaleuca quinquenervia* (Myrtaceae) Populations in Florida and Its Influence on Performance of the Biological Control Agent *Oxyops vitiosa* (Coleoptera: Curculionidae)

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Melaleuca quinquenervia (Cav.) Blake (Mytaceae) was imported into Florida over a century ago as a landscape plant. A favorable climate and periodic wildfires helped *M. quinquenervia* thrive; it now occupies about 200,000 hectares in southern Florida. Careful scrutiny of early horticultural catalogs and USDA plant introduction records suggests at least six distinct introduction events. Allozyme analyses indicate that the pattern of these introductions, and the subsequent redistribution of progeny, have resulted in geographic structuring of the populations in southern Florida. For example, trees on Florida's Gulf Coast have a greater effective number of alleles and exhibit greater heterozygosity than trees on the Atlantic Coast. Essential oil yields from *M. quinquenervia* leaves follow a similar trend; Gulf Coast trees yield nearly twice as much oil as Atlantic Coast trees when both are grown in a common garden. These differences are partially explained by the predominance of a chemical phenotype (chemotype) very rich in the sesquiterpene *trans*-nerolidol in *M. quinquenervia* trees along the Gulf Coast, but rich in a mixture of the monoterpene 1,8-cineole and the sesquiterpene viridiflorol in trees along the Atlantic Coast. Performance of the imported biological control agent *Oxyops vitiosa* differed dramatically in laboratory studies depending on which chemotype they were fed. Larval survivorship was fourfold greater on the *trans*-nerolidol chemotype. Growth was also greater, with adult *O. vitiosa* gaining nearly 50% more biomass on the *trans*-nerolidol plants than on the second chemotype. We are currently investigating whether these differences can be detected in the field.

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Assuring the Role of Fire in the 2050 Greater Everglades Ecosystem

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The purpose of the Fire in the 2050 Greater Everglades subcommittee of the South Florida Interagency Fire Management Council is to develop an approach for assuring that fire is a part of the South Florida restoration effort over the next 50 years. The Comprehensive Everglades Restoration Plan (CERP) has the goal of restoring the hydrology of South Florida to benefit both human and natural elements of the landscape. A monitoring plan is currently being developed as part of CERP to evaluate the success of this restoration in terms of hydrology, water quality, and the plant and animal communities that are expected to exist in South Florida in 2050. The monitoring program is meant to be an adaptive assessment process by which changes in the ecosystem can be measured, and evaluated to make certain that restoration is happening as planned. If it is not, information from the monitoring program and other research efforts can be utilized to assess what adjustments need to be made in the plan to correct problems as they are detected.

While the work being done as part of CERP is absolutely necessary to the restoration of South Florida, we were concerned that hydrology is not the only environmental factor that will determine the success of the restoration effort, particularly in terms of the natural environment. Fire and control of exotics are two other major factors that will play a major role in determining what South Florida natural environments will look like in 2050. While there are at least some systematic efforts to deal with invasive native and exotic plants in South Florida, until now there has not been a systematic approach designed to assure that fire will be able to contribute to the restoration and maintenance of the natural South Florida environment over the next 50 years.

The 2050 Fire subcommittee is a team of individuals from government agencies and other constituencies in South Florida who are interested in the development of a plan that would assure the appropriate application of fire in South Florida over the long term. We would like to synthesize information on where fire is appropriate both in terms of habitats and specific locations within the region, timing and frequency of fires, available and needed resources to accomplish prescribed burns at each specific site and throughout the region as whole, constraints on accomplishing our objectives and how best to deal with them, as well as any other topics the team feels should be part of a viable plan. The ultimate goal would be to see that good long-term fire planning has the opportunity to influence CERP in ways that will help CERP attain its own objectives for restoration in South Florida.

Most of the subcommittee's efforts to date have focused on developing a consensus on the role of fire in natural South Florida plant communities. To accomplish this we first needed to agree on a plant community classification that was meaningful in terms of land management, particularly as influenced by natural landscape processes. We adapted an earlier conceptual model, which illustrated how Big Cypress plant communities were distributed in terms of hydroperiod and frequency of severe fires, to include all non-tidal South Florida plant communities. We also developed a summary table designed to contrast each of these communities in terms of topographic setting and soils, dominant vegetation, hydrology, and fire.

Our current efforts have been to show how major nuisance and exotic pest plant species are distributed in terms of our conceptual model. This is providing a synthesis of information on how these species relate to fire and hydrology, and the plant communities maintained by these processes. The next step in this effort will be to synthesize this same information for listed species.

We view the 2050 Fire subcommittee's efforts as being a long term process designed to initially develop general principles on how fire relates to both natural and developed South Florida ecosystems and their resources, and then works to apply these principles to the realities of managing individual sites.

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Development of a Southwest Florida Pre-Development Plant Community Map

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A map showing pre-development plant communities has been derived for southwest Florida. Fifteen major types of communities were classified, based on their relation to the hydrology of the area. The information will be used to support modeling efforts of the Natural Systems Group for the Southwest Florida Feasibility Study. Pre-development is defined as the condition of the landscape prior to the arrival of Europeans in southwest Florida, when hydrology and fire regimes were the primary determinants of plant community distributions. Two primary sources of digital data were combined and refined using supplementary material and professional knowledge of the study area.

A Natural-Soils-Landscape-Positions (NSLP) map had recently been created by the South Florida Water Management District by aggregating soil-survey units according to their landscape positions (depressions, flats, knolls, ridges, etc.) and, to some extent, to their hydrologic regimes. In its initial form, the classification was inadequate to sort out the individual plant communities or to provide the hydrologic parameters required by the model. Furthermore, the data did not cover the entire study area. However, no better source of data was available in digital format, so the group modified and expanded this classification of the soil-survey units for a five-county area into a set of 15 plant-community types.

The Big Cypress National Preserve (BCNP) and the adjacent Everglades National Park (ENP) lands were not included in the NSLP coverage. However, a recent plant-community classification and vegetation map was available for these areas. The group reclassified that database into the same fifteen plant-community types. Only small portions of BCNP have been altered from their pre-development condition.

Additional adjustments were made to ensure consistency. All "disturbed" areas on the original maps were reclassified to our best estimate of the pre-disturbance communities, based on supplementary information such as older soil surveys, aerial photographs, permitting records, and the knowledge of individuals with long-term experience in southwest Florida. The soils-based and vegetation-based maps were joined and adjusted in an effort to create a seamless database. Additional areas (notably in western Broward County) were adapted from older soil surveys. The resulting product represents the best information that could be developed within the time constraints for the project.

We have classified the pre-development plant communities in southwest Florida into fifteen major types, based on their hydrologic characteristics. The highest level of classification is whether a community is tidal or non-tidal. The second level separates various hydrologic regimes according to hydroperiod, average wet-season water depth, and minimum dry-season water depth during an average year and during a 10-year drought. Lastly, we divided them according to their successional stage -- early successional (herbaceous wetland or pine flatwoods community) or later successional (community dominated by cypress and/or hardwoods).

The map attempts to reconstruct "pre-development" vegetation. One should not assume that all differences from existing vegetation/landcover result from agricultural or urban development. Differences also may reflect changes in hydrologic and/or fire regimes, as well as the presence of invasive exotic plants. The map provides a basis for reconstructing hydrology in pre-development southwest Florida, and is designed to support a hydrologic model having a mesh (cell size) of about 20 acres.

Major participating agencies on this project include the Collier County Planning Department, Florida Fish and Wildlife Conservation Commission, South Florida Water Management District, USDA Natural Resources Conservation Service, USDI Fish and Wildlife Service, and USDI National Park Service.

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Evaluation of Hydrology and Plant Community Changes Resulting from Alternative Restoration Scenarios in the Southern Golden Gate Estates of Southwest Florida

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The South Golden Gate Estates (SGGE) was originally dominated by wetland communities, particularly cypress forest and to a lesser extent, herbaceous wet prairies. Even those sites normally designated as uplands, particularly islands of pine flatwoods, often had water at or above the ground surface for at least short periods during wetter portions of the year. Subsequent to drainage, upland pines, cabbage palms, and hardwoods have invaded many of the cypress forests. In addition, severe and frequent fires have eliminated many of the pine and cypress trees, furthering the conversion of these lands to earlier shrubby successional stages of upland or shallow wetland plant communities. The character of the original SGGE has also changed as a result of the invasion of exotic plant species, particularly Brazilian pepper, onto drained and disturbed sites.

The long-term goal of the proposed restoration is to return the hydrology of as much as is possible of the SGGE to a condition comparable to that which existed prior to drainage. The combination of a restored hydrologic regime, a restored fire regime, and an appropriate exotic vegetation control program can be expected to return most of SGGE to its pre-drainage character, including the plant communities and wildlife that it supported at that time.

Methods

There were two sets of plant community maps used in our analysis of SGGE restoration. The first was two plant community maps provided by the Natural Resources Conservation Service (NRCS). These were detailed maps of the distribution of major plant community types in SGGE in 1940 and 1995. The other set of maps was based on hydrology calculated by the MIKE SHE model for Pre-Development and 2050-Without-Project conditions, and for the restoration alternatives. Plant community distributions were predicted based on the hydrologic characteristics of each major community type and on model output of average wet season water depths (July 1 through October 1).

One problem with making comparisons between the MIKE SHE and NRCS maps is that they had different boundaries, particularly along the coast. The MIKE SHE hydrology model was not designed to deal with tidal influences. The use of a constant mean high tide boundary at its southern periphery was required by the characteristics of the model. Regardless, the lack of data on topography and water circulation patterns would have greatly limited the usefulness of any existing model in this area. Thus, the model minimizes the amount of area influenced by tides by leaving out most the estuarine habitat located south of Tamiami Trail, which were included in the NRCS maps. In addition, the MIKE SHE model had extended coverage to the west of SGGE to try to minimize problems with model boundary conditions and increase the accuracy of the model within the area of interest. This boundary on the NRCS map, however, is somewhat closer to the Miller Canal. These differences become significant when we try to compare plant community acreages and percentages between Pre-Development, Existing, and restored conditions between the two sets of maps.

Another difference is the quarter mile cell size of the model, which does not allow for the inclusion of small features or features with a lot of edge, both of which can be more precisely shown on the NRCS map. In the model, the former are usually incorporated into larger features, and the latter tend to be erratically distributed because of the necessity to produce average values for each cell.

The NRCS plant community maps provided excellent documentation about where changes had occurred from Pre-Development to current conditions. They also represented a valuable baseline with which to compare future change following restoration, particularly where a return to Pre-Development conditions is the restoration target. However, while the NRCS maps provided good estimates of plant community acreages for Pre-Development and Existing conditions, they are not able to provide an estimate of restored condition acreages. The only acreage estimates for restoration conditions are those that can be calculated based on the hydrology model. Thus, since these two sets of maps cover somewhat different areas, the only fair comparison of plant community acreages for the three conditions would be one based on the hydrology model, which is the approach we took on this project.

Modeled Changes In Plant Communities

It is important to be aware that the greatest value of the MIKE SHE model used in this study is its ability to quantitatively estimate future conditions when certain features of a system are altered in specific ways. Real ecosystems are far too complex to represent accurately in a model. However, the ability of a model to synthesize our current understanding of the major features and processes operating within an ecosystem allows us to manipulate the model so that we can then evaluate the implications of those specific manipulations much more precisely than would otherwise be possible.

The MIKE SHE model has permitted us to compare water levels, and by extension the major plant communities associated with Pre-Development, 2050-Without-Project, and a number of restoration alternatives.

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ATLSS Vegetation Succession Model Project

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The USGS's Across Trophic Level System Simulation (ATLSS) models in their current form all assume that vegetation will remain unchanged over the period of the model simulations. This is not likely to be true, as changes in hydrology are almost certain to result in changes in vegetation patterns in many parts of the Everglades over periods of decades. There is already some evidence of changes in vegetation types in some areas of the Everglades over the last ten years.

The development of a set of succession models for the major vegetative types in the Everglades region is generally regarded as being essential, if scientists and managers are to be able to project the possible effects of changes in the hydrology of the region. Vegetation response is also sensitive to changes in nutrient concentrations and fire. Furthermore, important animal species, such as wading birds, the snail kite, and the Cape Sable seaside sparrow, have specific habitat needs that are tied to particular types of vegetation. The basic goal of this ATLSS project is to develop succession models that estimate future patterns of vegetation for targeted habitats and to describe how these habitats are affected by changes in hydrology, available nutrients, fires and the interaction of these processes. Three basic community types, "pine/scrub/flatwood", "cypress forest", and "herbaceous plant communities" will be included in the modeling. Within these types, a more detailed structure using Florida GAP vegetation alliances has been developed, allowing for explicit alliance responses to patterns of hydrology, nutrients, and fire.

The vegetation succession model will cover ~48% of the total area in South Florida (urban, agricultural, and mining areas excluded), uses all 22 of the Florida GAP alliances present in the ATLSS study area and will provide yearly estimates of vegetation alliance distribution at a 100x100 meter resolution. Model parameters have been determined from an intensive literature review followed by an extensive compilation and synthesis of the available data (available in two documents: Plant Community Parameter Estimates and Documentation for the Across Trophic Level System Simulation (ATLSS), and Nutrient and Fire Disturbance and Model Evaluation Documentation for the Across Trophic Level System Simulation (ATLSS)). The information from the literature review was structured around the Florida GAP vegetation alliances, which provided a basis for the model parameters and succession models of the three basic community types.

Review of the data suggests that, at the spatial scale of the ATLSS succession model, the effects of hydrology, phosphorous, and fire are very important, while the effects of nitrogen enrichment are of lesser importance and will not substantially affect model dynamics. Two different fire types will be included in the model: those that damage the soil, commonly referred to as muck fires, and surface fires that destroy vegetation but do not burn the soil. Making a distinction between muck and non-muck fires is important for succession modeling because burning soil changes local topography, which in turn changes the hydrology of local habitats. The interactions between fire and hydrology, and fire and nutrients have also been estimated in the succession documentation, based upon the limited available information on interaction effects for the vegetation alliances in South Florida.

The model uses a two-part approach to simulating the process of succession. First, a static look up table was constructed for each basic community type. Each look up table describes the potential future states of a plant community as a function of the history of hydrology, fire, nutrients and the interaction between these processes. The table also provides parameters for the expected time for a change to take place for each of the different processes affecting succession. The look up table is based on the literature review and synthesis.

Secondly, once local environmental changes indicate that succession to a new vegetation alliance is possible, the succession pathway is treated as a Markovian stochastic process. The change to the new vegetative state is random with the probability distribution for the various new states and the expected time for transformation given by the look up table.

Presenting the output of the vegetation succession model will follow the relative assessment approach using three panel maps applied in the analysis of other ATLSS models. This synthesis will present two maps representing the distribution of FGAP vegetation alliances produced by two different hydrology scenarios with the third map indicating locations and type of differences between the two distributions. The classification of differences is still an open question and depends largely on what information is most useful to the various scientific, managerial and policy making entities operating in South Florida.

ATLSS model evaluation will begin in the earliest stages of model development. The evaluation effort is necessary to determine the usefulness and accuracy of plant community succession in ATLSS. Peer review, Turing tests, gradient response and extreme condition tests, and tracing the behavior of specific variables or vegetation types through a model run are all possible model evaluation procedures suitable for the plant community succession module of ATLSS.

There are several goals for the succession model: it will provide an estimate of relative changes in vegetation distribution in response to changes in the abiotic environment and it will provide additional information about the potential effects of restoration. Model results will also be useful as input to other ATLSS and non-ATLSS models, including SIMSPAR and the ATLSS SESI models, that simulate processes sensitive to changes in the distribution of vegetation in South Florida.

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Modeling the Spread and Control of *Lygodium microphyllum* in A.R.M. Loxahatchee NWR

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Lygodium microphyllum is an invasive fern in South Florida that has a significant negative impact on the flora and fauna of the region. It is of particular concern in the A.R.M. Loxahatchee NWR where it currently affects 36% of the refuge. The fern forms dense colonies on tree islands where it overgrows native plants, including trees. Tree islands infected with *L. microphyllum* have decreased plant diversity and may become unsuitable habitat for many animal species.

Controlling *L. microphyllum* requires both detecting and treating infected tree islands. However, when both detection and treatment must be funded from a common fixed budget, trade-offs must be made between the two. Modeling is a useful tool for clarifying the relationship between these two components of management and aiding the control of *L. microphyllum* infections. We have constructed a simple mathematical model, utilizing a standard epidemiological structure in which islands are classified as "Susceptible, Infected, or Recovered" to analyze the spread, detection and control of *L. microphyllum* in the A.R.M Loxahatchee NWR.

The model incorporates the dynamics of tree island infection, the detection of infected islands, the application of treatment where infestations are detected and the recovery or reinfection of tree islands after treatment. Detection of infected tree islands is based on a number of factors, including the level of infestation (% cover), the level of effort put into detection programs and the mode of sampling. We combine these into a single parameter that represents detection efficiency, the rate at which previously undetected infections are detected. Since infections can only be treated once they are detected, increasing detection rates should improve overall management of *L. microphyllum*. Treatment is divided into two types: one that allows for rapid recovery of a tree island and one that requires a long recovery time. The simplicity of this model means there are relatively few parameters that need to be estimated. In addition, numerical solutions are also easily obtained for any given combination of detection and treatment. This allows us to explore a large number of different scenarios involving different levels of detection and treatment, to provide rankings of alternative control strategies. The primary focus of this model is the trade-off between detection and treatment needed to best manage *L. microphyllum*.

An alternative approach we are investigating uses GIS map layers to explicitly model the location of tree islands and the distribution of infection. In this model, as in the previous one, tree islands are in one of three states: susceptible, infected or recovering. However, the process of infection is now potentially more complex. Infection can depend on the proximity of infected tree islands and the mode of dispersal of *L. microphyllum* between tree islands. Control of *L. microphyllum* is also more complex since there are a large number of potential ways in which treatment can be applied. For example, is treatment applied randomly across infected tree islands or is it applied to all islands within a corridor? How should treatment corridors be arranged? The effects of the spatial distribution of tree islands on *L. microphyllum* infections and treatment are the focus of this type of model.

The GIS model suggests an important question: can current methods used to detect *L. microphyllum* infection also be appropriately applied to monitor the effects of treatment, or are additional field monitoring methods needed? The current method for detecting the presence of invasive species describes the level of cover for large (102 acre or 1 km2) quadrats, with one, two or three cover classes. Our modeling approach could be used to estimate how sensitive current methods are at detecting changes in *L. microphyllum* infection resulting from control efforts.

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Progress and Future Direction in Topographic Modeling for ATLSS Models

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Topographic variation in South Florida, though generally small, is very important for the flora and fauna of the region. Recently the US Geological Survey (USGS) started the High Accuracy Elevation Data (HAED) collection project with the goal of obtaining an estimate of topography in South Florida at a high spatial resolution (nominally 400x400 meters) with high vertical accuracy (vertical estimates are accurate to within about 3 cm). The project has now collected, processed and made available topographic data for a large portion of the natural areas in South Florida, including most of the Everglades National Park (ENP), portions of Big Cypress National Preserve (BCNP) and Water Conservation Area 3.

Prior to the existence of the HAED project there were no topographic maps of South Florida with both the spatial resolution and spatial extent needed to model the ecology of fauna and flora in South Florida. To fill this void, the Across Trophic Level System Simulation (ATLSS) project developed the High Resolution Topography (HRT) model. This model estimates elevation for 30x30 meter grid cells across the natural regions of South Florida. The estimation is based on the types of vegetation and the patterns of hydrology at each location. The founding assumption of the HRT model is that plants tend to be in places where local topography and hydrology combine to create a suitable habitat. Knowledge of the vegetation and hydrology at a location can be used to estimate elevation by choosing an elevation that results in hydrologic conditions suitable for local vegetation.

Three data sets form the basic inputs into the HRT model: a map of the distribution of vegetation in South Florida, a map of the history of hydroperiod distributions, and a table of hydroperiod preferences for each of the vegetation types in the vegetation map. The hydroperiod preferences are derived from a review of available literature. The vegetation distribution map used is the Florida GAP (FGAP) map (version 2.1) created by Leonard Pearlstine at the University of Florida. The FGAP map assigns one of 43 vegetation types to each 30x30 meter cell over most of South Florida.

The hydroperiod data for the HRT model is created from the Calibration/Verification run of the South Florida Water Management Model (SFWMM). The SFWMM is managed by the South Florida Water Management District (SFWMD) and is the standard hydrologic model for South Florida. The Calibration/Verification run of this model is considered to be the one that most accurately reflects the historical pattern of hydrology in South Florida from 1979 to 1995. The SFWMM partitions South Florida into a grid, where each grid cell is 2x2 miles. The model estimates water depth in each 2x2 mile cell on a daily time step from January 1, 1979 to December 31, 1995.

Over the past two years there have been a number of advances in the ATLSS High Resolution Topography (HRT) modeling project. An extensive literature review, Plant Community Parameter Estimates and Documentation for the Across Trophic Level System Simulation (ATLSS) by Paul Wetzel has been completed and peer-reviewed. This document describes the hydroperiod preferences of the natural vegetation types used in the 6.1 version of the Florida GAP (FGAP) map.

The second major advance is the development of a new HRT map. This new version is based on FGAP 6.1, hydrology data from the South Florida Water Management Model (SFWMM) version 3.7 and the hydroperiod estimates that appear in Wetzel's report. We are currently waiting for a more current version of the SFWMM Calibration/Verification output before completing a final version of the new HRT map.

Finally, we have begun an analysis that looks at the relationship between HAED elevations, distribution of vegetation as provided in the FGAP map and hydrologic parameters as predicted by the SFWMM. This analysis uses a multiple regression model with vegetation type and a number of yearly average hydrologic variables as predictors and elevation estimates from the HAED collection project as the response variable. There are two major purposes in performing this analysis. The first is to test an assumption made by the HRT model that there is a relationship between the elevation of a location and the vegetation associated with that location by FGAP. The second is to determine if a multiple regression model can be used to predict HAED elevation based on vegetation and hydrology. Both of these results provide a basis for evaluating the output of the HRT model.

This analysis has been completed for the Big Boy Lake HAED sampling unit. The regression coefficients for several of the vegetation types in this region are significantly non-zero. This indicates that vegetation provides some information about variation in topography. However, the r^2 and PRESS values for the regression model are not sensitive to the presence of vegetation as a descriptor variable. This indicates that in the Big Boy Lake region the overall contribution of vegetation to explaining variation in elevation is small. The conclusion we draw from this result is that for the Big Boy Lake HAED region we do not expect the HRT to perform well when compared to the HAED data since the inputs to the HRT model have very little relationship to the HAED elevation data. The limited scope of this analysis leaves a number of unanswered questions. The relationship between vegetation and HAED elevation in other regions and at other spatial scales has not yet been explored. While working with the HAED data we have noticed that elevations were not sampled in some tree islands. According to Greg Desmond, HAED project leader at USGS, the methods used to collect elevation data for HAED result in the systematic omission of tree islands. The effect of the sampling bias that arises from this omission is to compress the variance in measured elevations relative to the actual variance.

The HAED data will become the primary basis for topography used by ATLSS models. However, the availability of the HAED topography does not completely eliminate the need for the HRT model. In the short term there is still a need to use HRT estimates of topography for regions not yet covered by the HAED project. In the long term, the methodologies used in the HRT model may be needed to augment the topography generated by the HAED. We propose using the HRT map and the HRT methodologies to augment the HAED topography in areas where HAED has omitted vegetation structures, or has compressed variation. Work has begun on identifying regions where the HRT model can be useful for augmenting the HAED topography and the methods needed to incorporate HRT output into a HAED-based topography.

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Non-Indigenous Fishes in Restored and Natural Wetlands on the Big Cypress Seminole Indian Reservation

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Establishment of non-native fishes in South Florida has been shown to adversely affect native fish communities, and an important goal of Everglades restoration is to minimize such impacts. Most studies on non-native fishes have taken place in Everglades National Park and the coastal canal system, while the effects of non-native fishes in the aquatic ecosystems of greater South Florida have been largely unexplored. In particular, the Big Cypress portion of the Greater Everglades Ecosystem has been poorly studied. Since fish are the primary basis of the food web that supports the bulk of the wading bird populations throughout southern Florida, as well as various mammalian and reptilian predators, this information is particularly important to successful restoration. In this study on the Big Cypress Seminole Indian Reservation (Figure 1) we are examining the development of new fish assemblages within a newly restored wetland and comparing these to nearby, less-impacted wetlands.

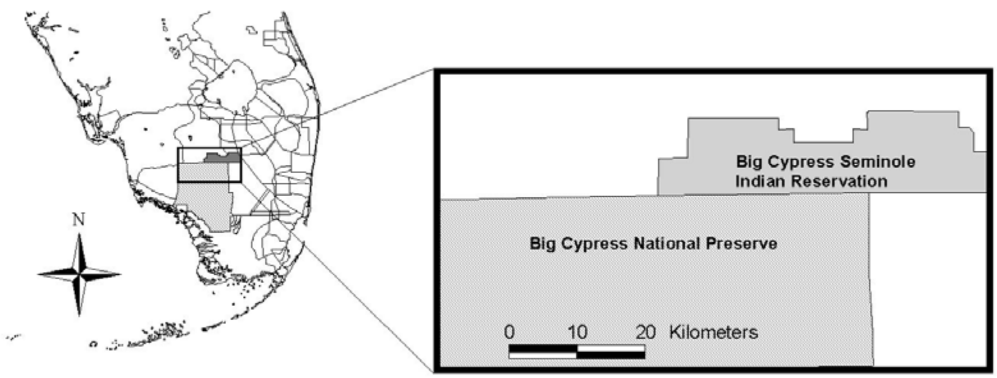

Figure 1. Location of the Big Cypress Seminole Indian Reservation in South Florida.

The Seminole Tribe of Florida has undertaken several wetland restoration projects on the Big Cypress Reservation. These include wetlands being restored in association with the USDA-NRCS as part of the Wetland Reserve Program (WRP) as well as wetland impoundments being created in the context of the Water Conservation Plan, a designated Critical Project of the Comprehensive Everglades Restoration Plan. In all these restoration projects, rehydration of the impoundments will be accomplished by pumping water in from adjacent canals. We have been comparing native and non-native fish community patterns in a WRP site, which is dominated by a formerly desiccated mixed forested wetland and pasture matrix, with historically similar but less impacted habitats. Our objective was to determine the response of both native and non-native fish populations to wetland restoration.

Data collection for this study began in May of 2001 and will continue through March, 2003. Sampling is being conducted in three habitat types; wet prairies, cypress swamps and canals using a variety of sampling methods. These methods include minnow traps, throw traps, gill nets, seines and boat electroshockers. We are also sampling in borrow ponds created during the construction of the WRP site because they are the main dry season refugia for fish and other aquatic organisms within the WRP. One concern with the WRP rehydration method is that non-native fish living in the canals may be introduced into the WRP impoundments. To partially address this, a net has been placed over the outflow of the WRP pump to attempt to block non-native fish introductions into the WRP. The net is regularly sampled to assess the effectiveness of this method in preventing fishes from entering.

A large number of fish species have been identified in both the restored wetland and in the less impacted natural habitat (Table 1). In the restored wetland, preliminary results collected through December 2002 show that both native and non-native fish species richness were highest in the adjacent canal and secondarily in the wet prairies/former pastures areas. The cypress swamps had the lowest overall native and non-native species richness. Sampling data for the same period collected in the natural area show that the canal had the highest overall species richness, but surprisingly, non-native species richness was highest in the cypress swamps. Data from the first wet season shows that native species diversity was higher in the natural area compared to the restored WRP site. However, non-native species diversities were not significantly different between the two sites. Interestingly, two non-native fish species not previously known to be present in the Big Cypress region were also documented, the brown hoplo (*Hoplosternum littorale)* and the pike killifish (*Belonesox belizanus*).

This study is establishing baseline data for fish communities in the Big Cypress region and is documenting the patterns of colonization and abundance of non-native fishes in a restored wetland in comparison with more natural habitats. We are also testing the effectiveness of blocking inflows for reducing colonization of a restored habitat by non-native fishes. These results may be useful to both land managers and scientists trying to limit non-native species introductions in wetland restoration sites.

Table 1. Native and non-native fish occurrence in habitats within the restored wetland and the Native Area from March 2001 through December 2002.

Wetland	**Restored**			**Native Area**		
Family / ***Species***	**Wet Prairies**	**Cypress Swamps**	**Canal**	**Wet Prairies**	**Cypress Swamps**	**Canal**
Lepisosteidae						
Lepisosteus platyrhincus	+		+		+	+
Cyprinidae						
Notemigonus crysoleucas	+		+			+
Catostomidae						
Erimyzon sucetta						+
Ictaluridae						
Ameiurus natalis	+	+	+			
Ameiurus nebulosus			+			
Clariidae						
*Clarias batrachus**	+		+			
Callichthyiidae						
*Hoplosterum littorale**			+		+	
Cyprinodontidae						
Fundulus chrysotus	+	+	+	+	+	+
Fundulus confluentus	+			+		
Jordanella floridae	+	+	+	+	+	+
Lucania goodie	+	+	+	+	+	+
Poeciliidae						
*Belonesox belizanus**				+		
Gambusia holbrooki	+	+	+	+	+	+
Heterandria formosa	+	+	+	+	+	+
Poecilia latipinna	+	+	+	+		+
Atherinidae						
Labidesthes sicculus						+
Centrarchidae						
Elassoma evergladei					+	
Enneacanthus gloriosus				+	+	
Chaenobryttus gulosus	+		+	+	+	+
Lepomis macrochirus	+		+	+	+	+
Lepomis marginatus	+			+	+	+
Lepomis microlophus	+		+	+		+
Lepomis punctatus			+		+	+
Micropterus salmoides			+	+		+
Percidae						
Etheostoma fusiforme			+	+	+	+
Cichlidae						
*Astronotus ocellatus**					+	
*Cichlasoma bimaculatum**	+	+	+	+	+	+
*Cichlasoma uropthalmus**	+		+	+	+	+
*Oreochromis aureus**	+		+		+	+
*Tilapia mariae**	+		+		+	+

* Non-native fish species

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Using Stable Isotope Analysis Techniques to Characterize the Food Web of the Kissimmee River, Florida.

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The Kissimmee River, which flows just south of Orlando to Lake Okeechobee in central Florida, has been severely altered by channelization and levees. Planning for ecological restoration of this damaged ecosystem began in the 1980's. Implementation of the restoration project began in 1999, and will eventually restore 43 miles of meandering river along with 27,000 acres of wetland. Although restoration construction is complete in parts of the river, the project has not begun in other areas. An important part of this project involves evaluating the success of Kissimmee River restoration. It is extremely important to know if fish habitat has been restored to pre-channelization conditions. The goal of my research in the Kissimmee River is to characterize the food web of the now-restored portion of the river and compare this reach to the remaining channelized portions. This research will aid in restoration evaluation by providing information on changes in the fish food web in the restored portion of the river. I am using stable isotope analyses to accomplish my research goals. The most commonly used isotopes in ecological studies are carbon and nitrogen. Carbon isotopes are often used to determine the source of carbon to an organism. Nitrogen isotopes can be used to determine the trophic structure of food webs. Therefore, carbon and nitrogen isotopes can be used to characterize the trophic structure and sources of organic matter in food webs.

My main research question is whether the food web of the fishes of the Kissimmee River in the restored portion of the river has changed compared to that of the remaining channelized reaches. Benthic invertebrates are extremely limited in abundance in the channelized Kissimmee River due to habitat reduction and limited oxygen availability. Benthic invertebrates should increase in abundance in restored portions of the river, providing valuable food to fishes. I hypothesize that these benthic invertebrates will become important in the diets of fishes in the restored portions of the Kissimmee River. Further, I hypothesize that floodplain vegetation, which was largely eliminated by channelization, will become a major carbon source to the Kissimmee River food web. Many native fishes were drastically reduced in abundance by channelization, and I hypothesize that the trophic structure of the restored river will shift from lentic food sources to lotic food sources after restoration.

To date, dominant fish from the channelized and restored portions of the river have been collected and analyzed for their stable isotope composition. We have also collected and analyzed the stable isotope composition of many components of the current food web. These samples include invertebrates, plants, and fishes. In addition, inorganic carbon sources to the Kissimmee River food web (CO_2, dissolved inorganic carbon) have been collected from Kissimmee River water in both the channelized and restored portions of the river. We are using isotopic analyses of these materials to develop a detailed picture of the food webs of the restored and channelized portions of the Kissimmee River. Initial results of this study of the Kissimmee River food web will be presented.

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Water Quality and Physical Features of Goliath Grouper Nursery Habitat in the Ten Thousand Islands

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The objectives of this project were to characterize the essential habitat for juvenile goliath grouper in their historical center of abundance, the Ten Thousand Islands of southwest Florida. All harvest of goliath grouper has been prohibited in U.S. waters since 1990, and the species is a candidate for the U.S. Endangered and Threatened Species List.

We compared the abundance of juvenile goliath grouper from 1999-2000 in natural tidal passes, or rivers, to their abundance in channelized canals (Figure 1). These rivers and canals link the upstream freshwater system of the Big Cypress Basin to the system of bays that empty into the Gulf of Mexico through a series of channels around mangrove islands. Most of the area is completely undeveloped and protected, yet it is downstream from areas in the Big Cypress Basin that have been subjected to massive changes in water delivery over the years. This area will be affected by the activities of the Southern Golden Gates Estates restoration project (SGGE).

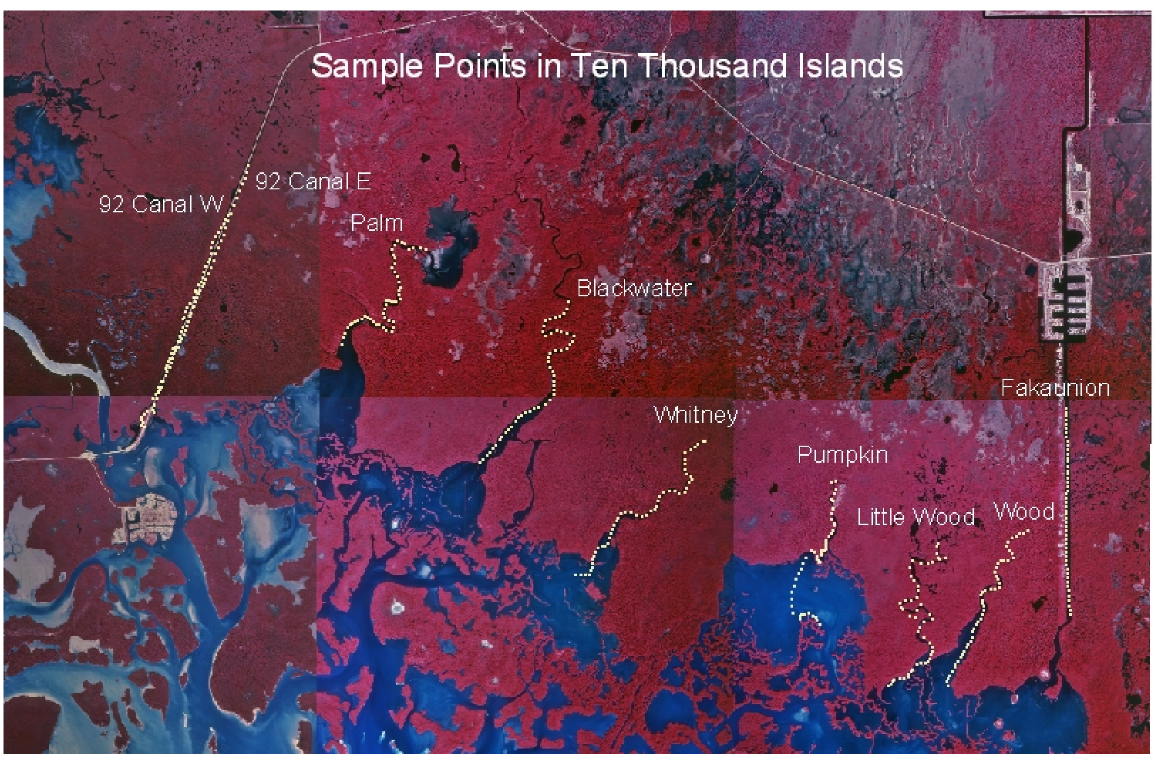

Figure 1. Six natural, tidally influenced rivers and three canals in the Ten Thousand Islands of southwest Florida, U.S.A. Canals on either side of U.S. Highway 92 are labeled 92 Canal West and 92 Canal East. The dots on the river and canal transects designate locations where fish traps and crab traps were placed to catch juvenile goliath grouper, *Epinephelus itajara*, from 1999-2000.

The natural rivers should provide optimal microhabitat for the juvenile goliath grouper, including mangrove overhangs along eroded shorelines and rocky depressions in tidal passes. Canals, on the other hand, tend to have straightened shorelines with little to no eroded banks and mangrove overhangs. Since they are dredged, canals are also of relatively uniform bathymetry, lacking the natural depressions that rivers contain. We hypothesized that the physical features of the two habitat types would differ and that the goliath grouper would be more abundant in the natural rivers.

In each river/canal, we used 40 crab traps and 10 fish traps, with each trap placed 0.05 nautical miles (nmi) apart. Beginning in 2000, we deployed YSI datasondes to continuously measure temperature, salinity, dissolved oxygen and depth during the time that the traps were soaking. The amount of eroded (vs. depositional or straight) shoreline was measured by taking GPS waypoints at the beginning and end of each section of eroded shoreline and measuring the distance between the two points using GIS ArcView software. The heterogeneity of the bottom (i.e. the presence/absence of rocky holes and other obstructions) was estimated by taking a depth reading every 0.1 nmi along each side of the river/canal. The change in depth from each reading was then calculated and averaged for the entire river/canal.

A total of 687 juvenile goliath grouper were caught in the nine rivers and canals that were sampled from 1999-2000. There was a lot of variability of catch among the rivers, making comparisons of rivers and canals more difficult that we had initially thought. Goliath grouper CPUE and total catch were highest in Little Wood River, Palm River, and Blackwater River. Very few goliath grouper were caught in the Wood, Pumpkin and Whitney Rivers, however, due to anoxic conditions in these rivers. While two of the canals, Faka Union and 92 West Canal, had lower CPUE and total catch of goliath grouper than in several rivers, 92 East Canal had higher CPUE and total catch than many of the natural rivers.

Our hypothesis that natural rivers would provide better and more habitat than canals would for juvenile goliath grouper was based on the assumption that the shorelines and bathymetry would be vastly different between rivers and canals. Rocky holes and mangrove undercuts should provide optimal habitat for goliath grouper in the form of shelter from current and an ideal location for ambush predator activities. Our visual assessment of Faka Union Canal bore out that hypothesis, since the canal is completely straight with no eroded shorelines and a uniform bathymetry. The two other canals, however, are not completely straight and the slight meanders have resulted in some shoreline erosion, providing undercut habitat for goliath grouper and other fish. In fact, the 92 East Canal had more eroded shoreline than all of the natural rivers, except the Little Wood River. However, none of the canals had heterogeneous bathymetry, as expected.

Optimal conditions for juvenile goliath grouper appear to be a combination of the presence of eroded shorelines and depressions along the bottom, high tidal amplitude and tidal currents, salinity variation within an acceptable range (so that the area does not become totally fresh or hypersaline) and no extended periods of anoxia. The Little Wood and Palm Rivers had the best combination of all of these features, and consequently yielded consistently higher numbers of goliath grouper. What may be more important to determine, however, is why some of the rivers in the Ten Thousand Islands provide more of the optimal habitat and conditions than the other rivers, particularly since the rivers are adjacent to one another and are all downstream from the same Big Cypress Basin.

The SGGE may have direct impacts on the habitat of juvenile goliath grouper in the Ten Thousand Islands. Precious little is known concerning the animals in the natural rivers and canals in the area, with the bulk of the research activities taking place in upland and freshwater areas. However, the restoration activities will surely affect areas downstream. The Wood River, for instance, may be starved of upstream water flow, due to the presence of the Faka Union Canal. The SGGE project includes plugging the vast network of canals that lead to Faka Union in order to restore a more natural sheet flow. Undoubtedly, the Faka Union Canal and the adjacent riverine systems will be altered by these changes.

The Whitney River has enough eroded shoreline and bathymetric complexity to be considered a river with optimal physical habitat for goliath grouper. The lack of water flow and periods of anoxia, however, led to high mortality of organisms found in our traps and a very low catch rate of fish. Should the sheet-flow be restored throughout much of Big Cypress Basin, areas like the Whitney River may be restored for goliath grouper and possibly other species of fish to have more optimal habitat in which to reside and grow.

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The Geographical Signature of Tidal Rivers in Southwest Florida as Ecological Guiding Views for Restoring the Caloosahatchee River

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The direction tidal river restoration takes depends upon how well its authentic condition is known. Rivers altered for decades or more have scant scientific data so their restoration depends on prescriptive targets based on regulatory criteria, ecological performance standards, or other management end-points. I examined features of tidal rivers in southwest Florida for geographic signatures useful as benchmarks or registration points in river restoration. Most, but rarely all, rivers in this region exhibit common sets of geographical features within which the spatial order of particular features is consistent. Geographic sets are identified for geological, hydrological, chemical, and biological features and the relative order of features within sets is characterized. Data gaps prevent a thorough assessment but the observed patterns may be useful to river managers by providing templates for the design of restoration programs, as illustrated and evaluated in a case study of the Caloosahatchee River and estuary (CRE). The CRE's restoration will be limited by significant historical constraints, but an ecological guiding view of river restoration could be developed by mapping geographic signatures of other rivers into a spatially explicit river model. Attainability of the geographic model would have to be evaluated with physical, water quality, and ecological models. Such models could also test the extent to which signatures between geographic sets are intrinsically associated. This work was supported by Mote Scientific Foundation and South Florida Water Management District.

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Distribution and Occurrence of Inorganic and Organic Contaminants in Sediments from Everglades and Biscayne National Parks

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Abstract

South Florida is in the process of undergoing the largest environmental restoration project in the history of the United States, namely, the restoration of the Everglades. One important component needed for the restoration effort is the environmental assessment and ecotoxicological evaluation of trace pollutants in the Everglades ecosystem. Pollutants such as trace metals, PCBs, organochlorine pesticides, PAHs and others, reach these aquatic environments mainly through atmospheric transport, agricultural, and other human-related activities. This study presents preliminary data on eleven major and trace metals, PCBs, organochlorine pesticides and PAHs in sediments from Everglades, and Biscayne National Parks, and discusses their environmental significance.

Sampling

For Everglades National Park, samples were collected from 5 distinctive areas. The first transect follows an east-west direction across the northern boundary of the park which receives water from the Water Conservation Areas to the north of the Park and lies just south of Tamiami Trail, the major highway in this area. The second transect follows a north-south direction across the eastern boundary of the park, this transect lies closest to the Homestead Agricultural Area (HAA). The third transect is located in the drainage basin of the C-111 canal which flows through most of the HAA. The last two transects follow the Shark Slough and Taylor Slough which flow in a south, south-west direction from the north and east boundaries, respectively.
For Biscayne National Park, samples were collected from areas near land along the channel from Black Point Marina, off the channel from Turkey Point, near the outflows of major canals, as well as from sites near Elliot Key, a barrier island approximately 10 km offshore.

Results and Discussion

A total of 11 elements (Be, V, Cr, Co, Ni, Cu, Zn, As, Cd, Pb, and Al) were chosen for analysis. Concentrations of the elements analyzed were ranked by concentration and plotted in reference to Sediment Quality Assessment Guidelines (SQAGs) for which Probable Effects Level (PEL) and Threshold Effects Level (TEL) are available (MacDonald, 1994). A few elements, including Lead, Nickel, Arsenic, Copper, and Chromium exceeded the TEL criteria for several stations located in the east boundary of the park while Lead was the only element exceeding the PEL criteria in the one of the Chekika stations. Also worth noticing is the fact that arsenic concentrations In several samples fall within the range of significantly toxic sediments based on amphipod and Microtox™ bioluminescence tests as reported by NOAA for Tampa Bay sediments (1994). Comparison of the aluminum normalized trace metal showed potential enrichment for several elements, in particular Lead. None of the organic pollutants detected in

Everglades National Park soils/sediments exceeded the PEL criteria. However, DDT and some of its metabolites (mainly DDE) were above the established TEL criteria in one station along Tamiami Trail and one along the east boundary. Other chlorinated compounds such as endosulfan and hexachlorobenzene were detected in the samples but concentrations rarely exceeded 1 ppb. In Biscayne National Park, only total PCB concentrations exceeded TEL criteria at BBBP1, the sampling station located inside Black Point Marina. Concentrations of chlorinated pesticides and PCBs detected in this study are consistent with those reported by Pfeuffer (2000) for areas located outside the park's boundaries.
Total PAH concentrations detected for both Everglades National Park and Biscayne National Park fall below the TEL criteria and below the ranges reported by NOAA as significantly toxic for other highly scrutinized areas such as Tampa Bay and Biscayne Bay.

Conclusion

In general, this study concludes that there is no significant widespread anthropogenic contamination in areas surveyed within Everglades and Biscayne National Parks. However it is worth noting that the mean concentrations observed in the North transect, East Transect, and Shark slough are greater than those observed in the Taylor slough and C-111 transects for some contaminants. Compounds of particular concern, based on the observed concentrations, include several metals such as lead, arsenic, copper and chromium and organics such as DDT and its metabolites. Other compounds like endosulfan however, may represent a potential risk based on their frequency of occurrence rather than their concentration levels. Ongoing efforts are now focused on these problem areas of the park to determine trends in transport and distribution as well as to determine the presence of these contaminants in organisms with potential for bioaccumulation.

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Estimating Water Quality Along the Southwest Florida Coast for Hydrologic Models Using Helicopter Electromagnetic Surveys

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Modern, three-dimensional hydrologic models are valuable tools for understanding and managing ground-water resources. They are also beasts that need to be fed great quantities of data in the form of hydrologic properties. Throw solute transport in the model and you have a beast on steroids requiring thousands of estimates of water quality. Traditional approaches relying upon water quality measured in wells and then interpolated or extrapolated across the model can be woefully inadequate, especially when well data are sparse. Combining well information with the results of helicopter electromagnetic (HEM) surveys keeps the hungry beast satisfied and produces a better hydrologic model.

HEM surveys measure the electrical conductivity of the ground at multiple frequencies using an instrument pod slung beneath a helicopter. A measurement is made about every 5-10 meters along flight lines. Flight-line spacing is typically 400 meters. The depth of exploration varies from 20 to 50 meters depending upon the formation resistivity. (Electrical resistivity is the reciprocal of electrical conductivity.) In more conductive zones, such as those saturated with seawater, the exploration depth is diminished, while in freshwater saturated zones deeper exploration is possible. The HEM data are used to estimate a layered-earth electrical resistivity model at every measurement point. The data can then be used to create a three-dimensional grid of electrical properties.

Electrical resistivity of geologic materials is controlled by the amount of pore space, the electrical resistivity of the pore fluid, the degree of saturation, and the presence of clay minerals. The relationship between specific conductance (SC) of the pore water and the formation resistivity can be determined by correlation of data from wells. Using this correlation, the HEM determined electrical resistivity model can be turned into estimated water quality.

This approach was used with a previous HEM survey (see Fig. 1) in Everglades National Park (Fitterman and Deszcz-Pan, 2001, 2002). We are using the same approach with a survey flown in October 2001 over parts of Big Cypress National Preserve (BCNP) and Everglades National Park (ENP). The survey has 2692 line-km of flight lines covering an area of approximately 1020 sq-km (see Fig. 1).

The primary products of this survey are apparent resistivity maps, one for each of the five measurement frequencies. Lowering the frequency probes deeper into the subsurface. The data are converted into resistivity-depth functions which are then used to produce formation-resistivity, depth-slice maps. The depth-slice maps are used to create a formation resistivity volume that can be interactively displayed. The cell size of this volume is 200 m horizontally and 5-10 meters vertically, dimensions that are commensurate with the Tides and Inflows in the Mangrove Ecotone (TIME) hydrologic model being developed by Schaffranek et al., 2003.

The depth-slice maps show a general decrease in formation resistivity (0.5-10 ohm-m) moving towards the coast with resistivities inland that are in the range of 20-100 ohm-m. (Images of the depth slices can been seen at the South Florida Information Exchange web site: http://sofia.usgs.gov/projects/geophys_map/.) The transition between the conductive and resistive zones deepens in the landward direction starting near the surface and reaching a depth of 50 meters over a distance of 2 to 5 km. This feature is interpreted as being the freshwater/saltwater interface. There do not appear to be any influences on this transition that can be related to natural drainages or manmade features as are seen in ENP (Fitterman and Deszcz-Pan, 2001).

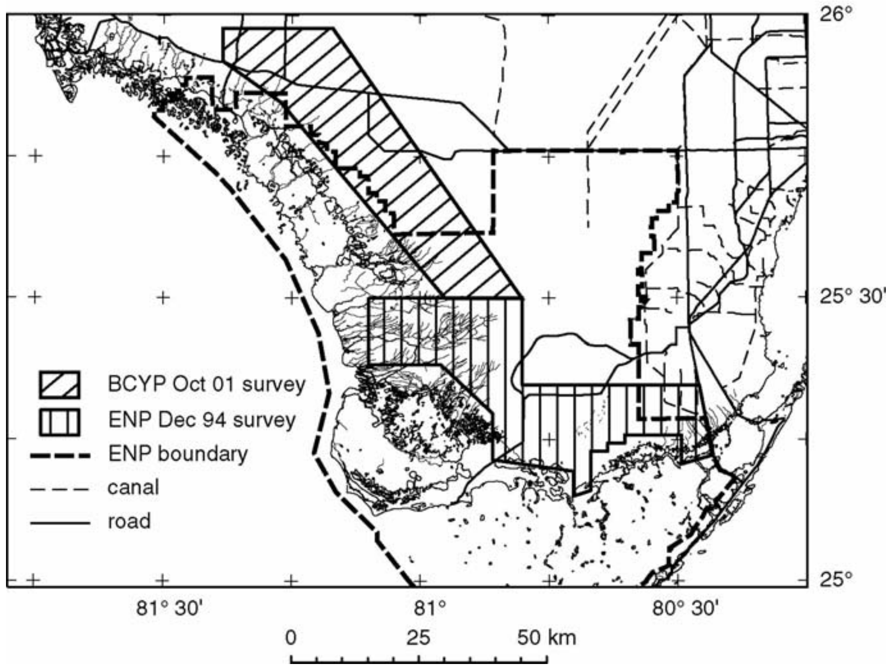

Figure 1 Location of south Florida HEM surveys.

Weedman et al. (1997, 1999) developed relationships between the formation water SC and the bulk formation resistivity in the northern part of the BCYP survey that we use in creating a three-dimensional water quality estimate. In turn this information is used in the TIME model as data to compare against the calculated salinity variations (Schaffranek et al., 2003).

The use of HEM data combined with water quality information from selected wells is a new approach for meeting the data demands of three-dimensional hydrologic models. The relatively flat lying geology in south Florida justifies the use of one-dimensional interpretation of the HEM data. The sparsity of clay minerals in the aquifer makes establishing the relationship between water quality and formation resistivity relatively straight forward. The combined use of well and HEM data could be used to sate the bestial data requirements of modern hydrologic models in other study areas.

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Everglades Landscape Model: Advances in Integrated Ecological Assessment

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The Everglades Landscape Model (ELM) is a spatially distributed simulator of ecosystem responses to altered water and nutrient management in the greater Everglades. In its quantitative description of regional landscape dynamics, the ELM integrates the direct and indirect interactions among hydrology, phosphorus cycling, soil/detrital decomposition, macrophyte & periphyton dynamics, and habitat succession. The version that is available for application to water management scenarios has been well-calibrated for stage heights and water column phosphorus concentrations in >50 locations throughout the greater Everglades region. This version 2.1a is thoroughly documented on our website (http://www.sfwmd.gov/org/wrp/elm), including detailed responses to a recent inter-agency review.

The focus of ongoing model refinement is an update to the calibration-validation period of record from 1979-1995 to 1979-2000. This is a critical update, as some of the most thorough synoptic and experimental Everglades research programs were initiated after 1995. The updated ELM v.3.x will make use of enhanced system understanding and increased spatial and temporal monitoring of more ecological variables and process-rates in order to refine or validate the ELM performance.

The following are the Performance Measures that are available from regional ELM simulations, in gradient/Indicator Regions and regional maps:

Surface Water Quality (v.2.1a)

- Total Phosphorus concentration
- Total Phosphorus net load (accumulation)
- Tracer (concentration and accumulation) of water flows that have bypassed STA treatment

Soils (v.3.x)

- Total Phosphorus concentration
- Accretion

Periphyton (v.3.x)

- Phosphorus:Carbon ratio in tissue
- Carbon biomass
- Community type

Macrophytes (v.3.x)

- Phosphorus:Carbon ratio in tissue
- Carbon biomass
- Community type

These ELM Performance Measures were discussed and accepted for use by the Water Quality Team of the Comprehensive Everglades Restoration Plan's REstoration COordination and VERification group, and aspects of these were proposed as part of the RECOVER Monitoring and Assessment Plan.

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Lake Trafford Restoration

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Lake Trafford is the only freshwater lake in southwest Florida. It is the headwaters to the Corkscrew marsh and at high water level during the wet season it drains south through Fakahatchee strand to Southern Golden Gate Estates Critical project area. Lake Trafford has suffered from several fish kills in recent years that have been linked to hypereutrophic conditions in the lake. The lake water exhibits high phosphorus, nitrogen and algae concentrations. The lake has a thick layer of silty sediment that contains high concentrations of nitrogen and phosphorus. The silty sediment consists of a layer of flocculent organic sediment that is up to 1.5 m thick and a layer of soft marl up to 1.2 m thick. The high nutrient concentrations in the sediment maintain high nutrient concentrations in the lake water. The silty sediments also limit the fish spawning and macroinvertebrate food sources for the fish.

Analysis of the sediment indicates that the organic sediment is separated from the marl by a distinct layer of shells and sand that appears to be the original lake bed. Organic C^{14} dating indicates that the organic sediment is up to 1000 years old while the shell layer is 5000 years old and the marl is 7000 years old.

The Big Cypress Basin of the South Florida Water Management District and the US Army Corps of Engineers have developed a restoration project for the lake that will remove the silty sediment from the lake. This will improve the water quality in the lake by reducing the availability of plant available phosphorus in the sediment and the lake water. Removal of the flocculent sediment will improve habitat for fish.

A watershed management plan is being developed for the Lake Trafford watershed to control nutrient loads in the future. The watershed management plan includes a stormwater management plan for the Immokalee urban area that drains to Lake Trafford. Immokalee currently has a minimal stormwater drainage system and limited water quality treatment facilities. The watershed management plan will be designed to reduce nutrient loads to the lake in the future.

Water quality in the lake has been sampled monthly for the last six years. The nutrient levels indicate the lake is hypereutrophic. However, the dissolved oxygen level remains high and the fishery has been very productive in the last couple of years.

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Water Storage in Agricultural Impoundments

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Availability of water to meet the needs of agriculture and the environment is limited in the Caloosahatchee Watershed. It is necessary to construct regional water storage facilities to capture and store runoff from the watershed. It may be possible to use agricultural impoundments to increase the water storage capacity. There are 14,000 acres of stormwater detention impoundments in the Caloosahatchee watershed. Many impoundments could be modified for water storage. The modified impoundments could increase water storage for agriculture and provide some flexibility for the growers in local water management. However, there is a concern that seepage and evapotranspiration would reduce the effectiveness of the impoundments.

Four agricultural impoundments were selected in the Caloosahatchee Watershed for evaluation of water storage capability. The impoundments were selected based on the soil and site characteristics that affect water storage potential. Surface water inflows and outflows and impoundment water levels and weather parameters were monitored on a 15-minute measurement interval. Inflows included pumped drainage from the citrus grove, rainfall and seepage inflow. The outflows included evapotranspiration, surface water discharge and seepage. A water budget was developed for each impoundment and groundwater seepage was estimated from the water budget.

The results of the water budget analysis indicate that primary inflow to the impoundments is pumped drainage from the citrus groves. Pumped inflow ranges among the impoundments from 50 percent of inflow during the dry season to 90 percent of inflow during the wet season. The primary outflow from the impoundments was seepage to surface water. Seepage accounted for 35 to 60 percent of the water loss from the impoundments. Evapotranspiration accounted for 5 to 33 percent of the water loss. The remaining outflow was stormwater discharge downstream. A large percent of the seepage loss was recovered from the grove ditches and pumped back into the impoundment. Pumped inflows to the impoundments included shallow groundwater from adjacent parcels. At one site water was effectively stored until the middle of the dry season by effective seepage collection.

Although most impoundments are constructed to the minimum standards for stormwater detention they can be retrofit with improvements to reduce seepage and improve water storage. These improvements include increasing width, height and compaction of embankment and improving seepage collection. With good seepage collection it is possible to retain water for freeze protection or short-term irrigation requirements.

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UF/IFAS Roles in the Lake Okeechobee Protection Program Highlighting Demonstration of Water Quality Best Management Practices for Beef Cattle Ranching in the Lake Okeechobee Basin

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Since the 1970s, the health of Lake Okeechobee has been threatened by increasing phosphorus loads, harmful high and low water levels, and the spread of exotic species. To address these issues, the Florida Legislature established the Lake Okeechobee Protection Program in 2000. It identifies major remediation activities to be jointly addressed by the Florida Department of Agriculture and Consumer Services (FDACS), Florida Department of Environmental Protection (FDEP) and the South Florida Water Management District (SFWMD). Due to the location of Lake Okeechobee within the South Florida Ecosystem, projects conducted under the Lake Okeechobee Protection Program will influence future activities of the Greater Everglades Ecosystem Restoration.

Working with state agencies identified in the Lake Okeechobee Protection Program legislation are teams from United States Army Corps of Engineers (COE), Florida Natural Resources Conservation Service (NRCS) and University of Florida/IFAS.

In mid-July 2000, UF/IFAS was invited to participate in the Lake Okeechobee Protection Program. By September of 2000, Vice President Mike Martin formed a UF/IFAS Task Force and in October 2000, Drs. Wendy Graham and Mitch Flinchum were named as the UF/IFAS co-project directors for research and extension, respectively. In December 2000 an interagency workshop was held in Gainesville to coordinate and define UF's involvement and to broaden UF/IFAS faculty participation. The outcome of that workshop identified gaps in current research knowledge and extension programs potentially important to the success of the Lake Okeechobee Protection Program.

The Lake Okeechobee Protection Program can logically be divided into 5 major categories with four of the categories being under the leadership of SFWMD. These are: (1) Lake Okeechobee Construction Program; (2) Exotic Species Program; (3) Internal Phosphorus Control Program; and (4) Research and Water Quality Program. The 5th major component is the Watershed Phosphorus Control Program is jointly lead by FDACS, FDEP and SFWMD with NRCS and UF/IFAS assisting. This major component addresses Agricultural and Non-Agricultural Non-Point Source Phosphorus Control through Best Management Practices (BMP) Development, Technical Assistance/Cost Sharing for BMP Implementation, and finally BMP Monitoring and Evaluation. Also included under this major component is a Wastewater Treatment and Residuals Program lead by FDEP.

<u>The University of Florida/IFAS roles include the following</u>:

1. Development of a Reflectance Spectroscopic P-Sensor for Terrestrial and Aquatic Ecosystems in the Lake Okeechobee Drainage Basin, funded by FDACS ($399,300)

2. Nutrient Management Planning Education for Florida, funded by FDACS ($586,005)

3. Implementation and Growers Evaluation of a WEB-based Nutrient Management Plan Support System (NUMAPS) for Florida Crops, funded by FDEP and FDACS ($456,297)

4. Phosphorus Retention and Storage by Isolated and Constructed Wetlands in the Lake Okeechobee Basin, funded by FDEP, FDACS, and SFWMD ($1.9 million)

5. Demonstration of Water Quality Best Management Practices for Beef Cattle Ranching in the Lake Okeechobee Basin, funded by FDEP, FDACS, SFWMD ($1.2 million)

6. Crop Phytoremediation of Phosphorus-Enriched Soils in the Lake Okeechobee Region, funded by FDACS ($320,880)

7. Okeechobee County Extension Office is working with team from SFWMD and FDEP on Educational Programs for Non-Ag BMPs with Existing Resources.

This presentation emphasizes the "Demonstration of Water Quality Best Management Practices for Beef Cattle Ranching in the Lake Okeechobee Basin." The length of this project is three years allowing for sufficient pre- and post BMP hydrologic monitoring. The objectives are: (1) to implement on-ranch BMP demonstrations that appear most promising for ranches in the Lake Okeechobee basin, and to evaluate the change in phosphorus load to surface and ground water from implementing these practices, (2) to communicate these BMPs/results to beef cattle ranchers through extension publications and other appropriate mechanisms, and (3) to evaluate the ability of the Beef Cattle Management Decision Support System (BRADDS) and/or the Watershed Assessment Model (EAAMOD-WAM) to simulate the water quality effects of the demonstrated BMPs.

Cow-Calf Best Management Practices to be demonstrated/evaluated include:

1. Improved nutrient management according to an approved nutrient management plan including soil forage analysis, fertilizing based on IFAS recommendations, not fertilizing in or near (within 20 feet) of water bodies, ditches, and canals.

2. Improved pasture management including rotational grazing, stocking densities based on water quality and forage availability, relocating feeding/watering area away from drainage ditches, fencing cattle out of waterways and maintaining vegetative cover on grazed pastures.

3. Improved water management including raising water level (risers) to hold water and slowly release it after rains.

4. Use of soil amendments to increase phosphorus retention and reduce edge of field losses of P "hot-spots" in cow-calf pastures.

Sites where SFWMD had two or more years of water concentration monitoring data with higher than desired concentrations were selected. Appropriate flumes/weirs will be installed at sub-watersheds to measure surface out-flow of phosphorus loads from each BMP site. Groundwater monitoring systems will be installed to assess potential changes in groundwater quality. Each site will be measured for a one-year baseline period before BMPs are implemented.

The soil amendment BMP demonstration involves chemically characterizing, laboratory testing and screening a variety of potential amendments, including Ca-, Fe-, and Al-based water treatment residuals, silicate slag materials, lime and gypsum for effects on P leaching and movement. Two amendments exhibiting the most positive environmental and economic benefits will be demonstrated.

Costs/benefits will be evaluated for BMPs implemented on this project. Each BMP will be assessed as to its effectiveness for phosphorus removal, measured against background levels represented by pre-BMP conditions. Economic analyses and results including local scale analyses of costs and benefits will be conducted, and an estimate of the total/unit cost of phosphorus removal for the various BMPs both independently (where possible) and jointly, over time, will be reported.

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Shifts in the Position of the Marsh/Mangrove Ecotone in the Western Florida Everglades

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The Everglades of southern and central Florida are a unique system that has been recognized as a valuable global resource. Up until the 1940's it had remained relatively undisturbed, with only minor incursions along the coastal fringe. This results in a situation in which to study the impacts of both global climate change and land use change on coastal ecosystems. In 1900 a broad freshwater system stretched from Lake Okeechobee southward for more than 160 km before draining into the estuaries along the southern tip of the Florida mainland. Today, over 600,000 ha of marsh has been converted to the Everglades Agricultural Area for production of sugarcane, sod and winter vegetables.

It has been hypothesized that shifts in the position of the mangrove / marsh ecotone are pulsed events, possibly initiated by large-scale disturbance and/or influenced by sea level rise. As the flow of freshwater to the estuaries decreases, this results in an emulation in the rise in sea level. This reduction in freshwater flow, in conjunction with events such as hurricanes, fire, sea-level rise, and decreased precipitation may be influential in the migration of the mangrove forest into the freshwater marsh.

Select areas along the western coast of Everglades National Park (Figure 1) are examined using a time series of aerial photographs from the park archives (Briere et al, this volume; Coffin et al, this volume).

In some of the areas we examined, the decreases in the freshwater marsh occur closest to the coastline. In these areas the marsh has persisted further inland and has even shown signs of returning along the edges of some rivers and bays (Figure 2). Historical aerial photos have shown in some areas that the migration of the mangrove forest into the freshwater marsh is evident. In other regions no change is apparent. Determining which factor or combination of factors contributes to this migration remains to be answered. However, it would appear given the diversity of patterns we see along the marsh/mangrove ecotone, it is a complex process.

Figure 1: Western coast of Everglades National Park. The area in the vicinity of the Lopez River is enclosed in a box in the upper left corner.

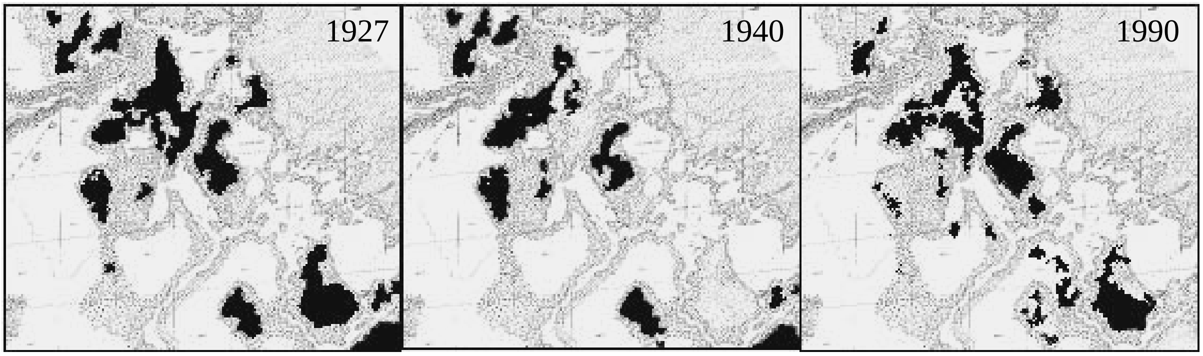

Figure 2: Location of the marsh in the vicinity of the Lopez River in 1927, 1940, and 1990. The shaded areas indicate the extent of the marsh for a specific year.

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Seagrass Monitoring in the Florida Keys National Marine Sanctuary: Seasonal Pattern and Long-Term Trends at Permanent Monitoring Sites

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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. In order to meet these objectives, we have developed these goals for the project:

1. Define the present distribution of seagrasses within the FKNMS
2. Provide high-quality, quantitative data on the status of the seagrasses within the FKNMS
3. Quantify the importance of seagrass primary production in the FKNMS
4. Define the baseline conditions for the seagrass communities
5. Determine relationships between water quality and seagrass status
6. Detect trends in the distribution and status of the seagrass communities

To reach these goals, 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*); and 4) seagrass nutrient availability using tissue concentration assays and stable isotope analyses.

Despite the subtropical climate, seagrass beds are highly seasonal in the FKNMS. The seasonal maxima of standing crop was about 32 % higher than the yearly mean. Productivity of *T. testudinum* was both temporally and spatially variable. Yearly mean areal productivity averaged 0.70 g $m^{-2}d^{-1}$, with a range of 0.05 g m^{-2} d^{-1} to 3.29 g m^{-2} d^{-1}. Specific productivity ranged between 3.2 and 34.2 mg $g^{-1}d^{-1}$, with a mean of 18.3 mg $g^{-1}d^{-1}$. Annual peaks in specific productivity occurred in August, and minima in February. Integrating the standing crop for the study area gives an estimate of 1.4×10^{11} g of *T. testudinum* and 3.6×10^{10} g of *S. filiforme*, which translate to yearly production of 9.4×10^{11} g of *T. testudinum* leaves and 2.4×10^{11}g of *S. filiforme* leaves.

Elemental and isotopic content of seagrasses were also seasonal, and there was a spatial pattern in the relative availability of N and P across the 30 seasonal monitoring stations in the Florida Keys National Marine Sanctuary, with generally lower mean N:P offshore of the Florida Keys on the Atlantic Ocean side of the island chain, and higher N:P close to shore and on the Gulf of Mexico side of the island chain. The N:P of seagrass leaves was significantly correlated with the median ratio of total N to total P of the overlying water column, suggesting that the same processes control the relative availability of N:P in both the water column and the benthos in south Florida. In general, C:N and C:P were low in winter months and high in summer months. The amplitude of the seasonal variation in elemental content at a station varied as a function of the mean annual nutrient content. Sites with low mean C:N or C:P had low amplitude, while sites with high ratios had high amplitudes. Seagrass growth rates at these sites have also been shown to follow the sine model. Within sites, there were strong relationships between seagrass growth rate and elemental content: as growth rate increased, so did the C:N and C:P (see example site, Figure 7). Across all sites, there were significant relationships between growth rate and N and P content of *Thalassia testudinum*.

The average δ^{13}C and δ^{15}N of *Thalassia testudinum* leaves at the seasonal monitoring sites were not significantly correlated ($r = -0.07$, $p = 0.72$), but the average isotopic values were related to the elemental content. Sites with relatively low N:P had light δ^{13}C signatures, while sites with high N:P had heavy signatures (Figure 10). While linear fits were significant, the data were more closely described by a hyperbola with an asymptote at about -8 ‰. Average δ^{15}N increased as the mean C:N at a site increased (Figure 10).

There was a marked seasonal variation in both δ^{13}C and δ^{15}N of *Thalassia testudinum* at the seasonal monitoring stations. In general, values for both δ^{13}C and δ^{15}N were heavier in summer months and lighter in winter months. Average annual variation in δ^{13}C was 1.90 ± 0.11 ‰ for all sites, with minimum of 1.14 ‰ and a maximum of 3.58 ‰. Average annual variation in δ^{15}N was 1.7 ± 0.1 ‰, with a minimum of 0.8 ‰ and a maximum 3.4 ‰. Seagrass growth rate, C:N and C:P ratios, and C and N stable isotope ratios all showed peaks during the summer months. Across sites, there was a significant relationship between the seagrass growth rate at a site and δ^{13}C: δ^{13}C increased by 0.30 ± 0.09 ‰ for every 1 g $m^{-2}d^{-1}$ of productivity increase (ANCOVA, $F = 10.7$, $p = 0.001$). However, there was no significant relationship between growth rate and δ^{15}N across all sites (slope of relationship in ANCOVA not significantly different from 0). There was a significant relationship between δ^{15}N and C:N, with an increase in δ^{15}N by 0.03 ± 0.01 ‰ for each unit increase in C:N (ANCOVA, $F = 4.8$, $p=0.03$).

There were two types of long-term trends in the monitoring data: rapid changes caused by the disturbance from hurricanes, and longer-term, more gradual changes. The passage of Hurricane George on September 25, 1998 caused an immediate loss of 3% of the density of *Thalassia testudinum*, compared to 19% of the *S. filiforme* and 24% of the Calcareous green algae. The seagrass beds at three stations were completely obliterated by the storm. Stations that had little-to-moderate sediment deposition recovered from the storm within one year, while the station buried by 50 cm of sediment and the two stations that experienced substantial erosion had recovered very little during the three years after the storm. Early colonizers to these severely disturbed sites were calcareous green algae. Hurricanes may increase benthic macrophyte diversity by creating disturbed patches with the landscape, but moderate storm disturbance may actually reduce macrophyte diversity by removing the early successional species from mixed-species seagrass beds.

More troubling for the long-term management of the nearshore marine ecosystems in the Florida Keys were the long-tern trends in relative abundance of primary producers and nutrient content of seagrasses that were consistent with models of eutrophication of tropical seagrass beds. Such trends have now been observed at 5 of our monitoring sites in the middle Florida Keys.

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The Rise and Fall of Mercury Contamination in Everglades Biota, 1890 – 2003: A Retrospective Study of Wading Bird Museum Specimens

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Surveys of wetland predatory animal tissues during the late 1980’s and 1990’s showed that the Everglades ecosystem was highly contaminated with mercury (Hg), resulting in health advisories for human fishers and increased mortality in many predatory animals. Ciconiiform birds have very high bioaccumulation factors for this contaminant, and their feathers have been shown to be reliable indicators of Hg dynamics in the wetland food web. Although several potential sources of Hg contamination have been identified, the timing and track of contamination is largely unknown in biota prior to the late 1980’s. To help identify the source, and to search for “precontamination” background levels, we compared methylmercury (MeHg) content in feathers of museum specimens (Great Blue Herons, White Ibises and Great Egrets) going back to 1900 with those from more recent collections (1985 – 2003). Over 99% of mercury in feathers was in the methylated form, suggesting that there had been little contamination of museum specimens with mercuric preservatives, Mean MeHg concentrations in feathers during the recent period ranged between 7.46 mg/kg (dry weight) for White Ibises and 21.03 mg/kg for Great Blue Herons. During the period 1900 – 1980, mean Hg concentrations ranged between 1.04 mg/kg (White Ibises) and 3.38 mg/kg (Great Blue Herons), and were significantly lower than the recent period for all species (Figure 1). The approximate onset of contamination in the feather dataset (between 1975 and 1980, see Figure 2) and the enormous recent reduction in mercury contamination during the late 1990’s (>75%) is consistent with trends in Hg emissions from local municipal sources. We also believe that because dietary mercury in wading bird prey can be derived quantitatively from feather tissue levels, the historical measurements may be useful for establishing target regulatory goals for background mercury in Everglades fishes. The pattern of mercury emissions and contamination during the 1990’s suggests a significant lag (4 – 7 yr) between changes in mercury inputs from local sources and responses in wading bird tissues.

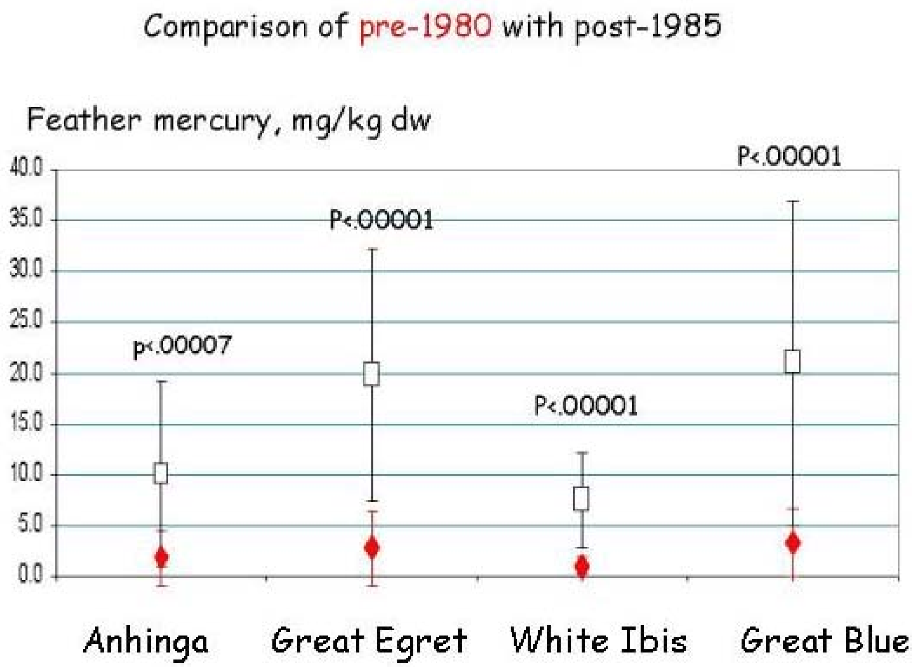

Figure 1. Comparison of mean methylmercury concentrations in feathers of piscivorous birds from the Everglades between 1900 –1980 (red) and 1985 – 2000.

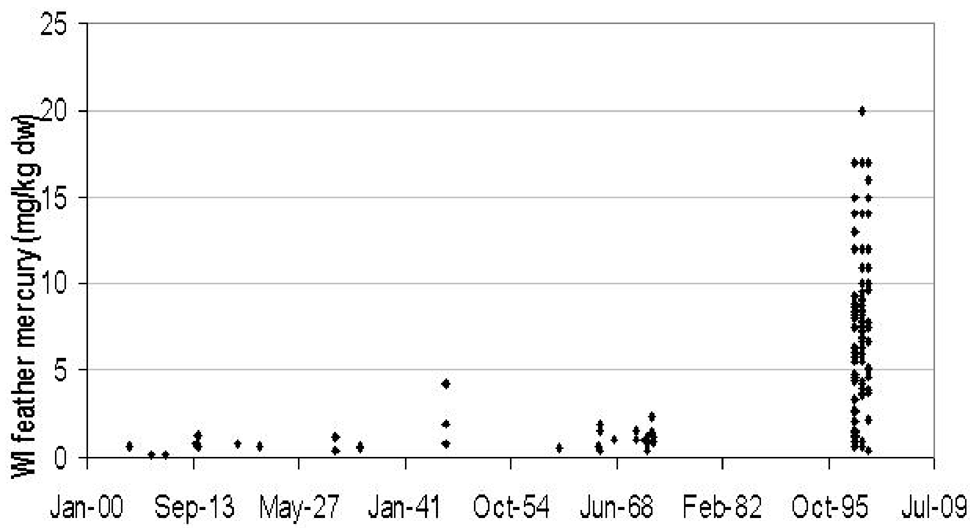

Figure 2. Methylmercury concentrations in feathers of White Ibises between 1900 and 2000. Numbers on X-axis are years (eg, Jan 41 is 1941).

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Experimental Phosphorus Enrichment in Everglades National Park: I. Approach and Methods

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This presentation describes the approach and methods of phosphorus (P) dosing research at the experimental flume facilities established by in Everglades National Park by the Southeast Environmental Research Center at Florida International Univerisity. This research was originally designed to provide critical baseline information needed to establish Class III water quality standards for the Everglades Protection Area. Research began in 1998 when we completed the installation of three, four-channel 100-m long flumes in previously unimpacted wet prairie marsh of Shark River Slough in Everglades National Park. Low-level P-addition treatments of 0, 5, 15 and 30 ppb above ambient concentrations are imposed at the upstream end of the channels and delivered downstream by natural flow and spiraling through biota. This study differs from other P enrichment experiments by delivering measured concentrations of P continuously into water flowing into long (100 m), replicated, experimental channels established in natural marsh; this mimics the way P enters the natural system from canal inputs. Responses in all relevant abiotic and biotic parameters have been measured downstream from inputs for a period of 4 years.

The central hypotheses guiding our dosing research are that:

1) Low-level additions of P to the water column will induce an ecosystem state change in the Everglades that will eventually lead to the types of disturbed ecosystems that occur in enriched areas elsewhere in the system.
2) Responses measured first in microbial components will cascade through the food web to induce imbalances throughout other components of the ecosystem.
3) Ecosystem state change will occur more rapidly when the concentration of experimentally added P is greater, but the endpoint of this ecosystem state change will not be affected by the concentration of experimentally added P (*i.e*., there is no P threshold; time, not P concentration, is the independent variable of importance).
4) During ecosystem state change, the system may become N limited and may actually be a source of P to downstream wetlands.

These hypotheses are illustrated in Figure 1.

Briefly, our experimental design consists of three, four-channel 100-m long flumes that were established in pristine *Eleocharis* "wet prairie" marshes. Each flume has a control channel and 3 experimental channels representing a range of P concentrations bracketing currently proposed water quality standards: a low dose, treated with P to increase ambient total P (TP) concentrations to 5 $\mu g\ l^{-1}$ (5 ppb, or ≈0.17 µM), medium dose, treated with P to increase ambient total P (TP) concentrations to 15 $\mu g\ l^{-1}$ (15 ppb, or ≈0.5 µM), and high dose, treated with P to increase ambient total P (TP) concentrations to 30 $\mu g\ l^{-1}$ (30 ppb, or ≈1.0 µM) above ambient. Reference plots have been designated in an untreated area of marsh adjacent to each flume to facilitate the detection of “edge” effects in the flumes. We attempted to minimize “edge” effects in the experimental design by restricting our sampling to the center of broad (3-m wide) channels and by using floating docks with plastic retaining walls, rather than elevated platforms, which are known to produce shading effects.

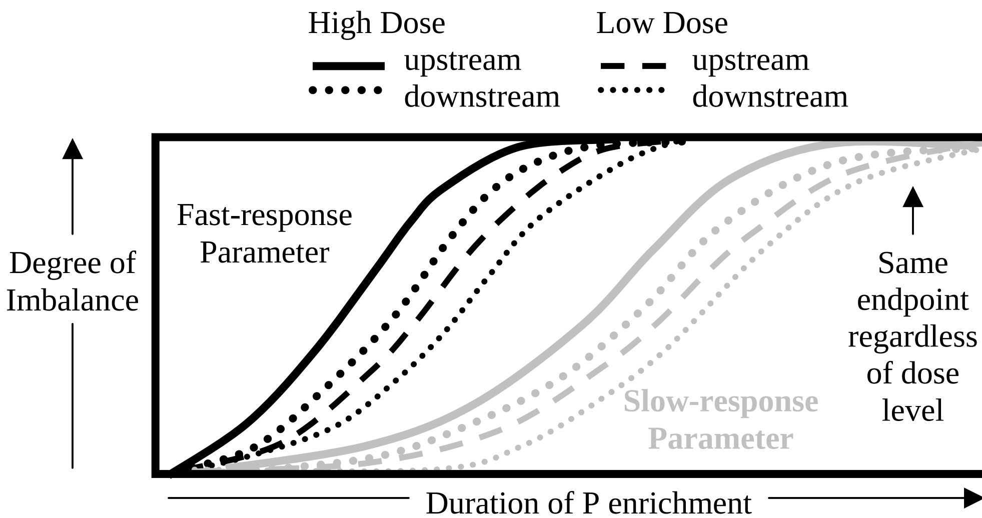

Figure 1. Schematic representation of the hypotheses driving experimental dosing research at FIU.

Phosphorus additions to our flume channels are electronically controlled and based on instantaneous water volume to maintain consistent experimental concentrations. The first 10 m of each flume channel is the nutrient mixing area and the zone where we measure water flux. This mixing area is devoid of vegetation and has a solid fiberglass "floor" fixed to the soil surface. Highly sensitive acoustic Doppler flow sensors, which measure flow rates down to 1-2 mm sec^{-1} and integrate flow across the width and depth of the channel, are set up in these mixing areas. They transmit channel-specific flow rates in real time to an on-site computer that also receives real-time water level data from a pressure transducer. The computer calculates channel-specific flux and determines the rate at which P must be pumped into that channel, based on its programmed treatment level. Phosphorus is added from a reservoir filled with NaH_2PO_4 + Na_2HPO_4 (to make a pH of 7.0). We are thus adding P as soluble reactive P (SRP) which is quickly taken up into particulate fractions (measured as TP) in the mixing areas. The on-site computers are interfaced to cellular communications, allowing us to access water flux data, met station data, pump status, and system diagnostics at any time. All on-site electronics are powered by solar panels and a bank of deep-cycle batteries.

Our research team has been sorted by discipline into 8 Key Element Groups, including: environmental monitoring, biogeochemistry, microbial ecology, soils, periphyton, macrophytes, fauna, and data integration. All key parameters are sampled on a regular schedule when water is flowing and P is being added.

To analyze ecological response to P dosing in our experimental flumes, we acknowledged that flow rates into the channels differed among the 3 sites. As in the natural system, low-dose, low-flow channels received a lower load of P than high-flow channels receiving the same P concentration. Therefore, we first determined the cumulative load of P received at the head of each channel throughout the 4 year dosing period. We then related each response parameter to cumulative load at the head of the channel, with distance from that load entered as a covariate.

The following series of presentations will address results pertaining to the 4 hypotheses, the application of these results to interpreting large-scale enrichment patters in Everglades marshes, and the implications of our design in setting water quality compliance standards.

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Experimental Phosphorus Enrichment in Everglades National Park: III. Application to Large-Scale Pattern of Enrichment in Everglades Marshes

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To determine the relevance of results of experimental P enhancement studies to enrichment patterns in the larger Everglades ecosystem, we assessed the distribution of the same abiotic and biotic parameters along transects that parallel P gradients in 5 Everglades marshes. The experimental P-dosing study, described in detail in other GEER presentations in this same session, added P at 0, 5, 15 and 30 ppb above ambient concentrations to the upstream end of 4 channels in 3, 100-m long flow-through flumes. Responses in the water, microbial community, periphyton, flocculent detritus, soils, macrophytes and fauna were measured at select stations downstream from inputs for a period of 4 years. Our hypothesis was that low -level additions of P to the water column would induce an ecosystem state change in the Everglades that would eventually lead to the types of disturbed ecosystems that occur in enriched areas elsewhere in the system. We therefore measured the same variables along transects that extend from canal-water inputs to the unimpacted interior of WCA-1, WCA-2A, WCA-3A, Shark River Slough and Taylor Slough. Transects were sampled in both the wet and dry seasons.

In the P-addition experiment, we detected a cascade of responses consistent with our hypothesis that microbial parameters would be the first to respond, followed by the floc, soils and finally the plant and animal communities. Biotic alterations were first detected at upstream stations and progressed downstream at load-dependent rates. These changes, while related to upstream dose concentration, preceded P enhancements in the surrounding water column, indicating rapid biotic uptake and downstream spiraling. Extending these findings to the marsh transects, we expected to find little correlation of water column P with biotic structure and function except in areas with a long history of enhancement that are now saturated in P. In addition, we expected to find a sequence of alterations downstream of canal inputs, with disruptions in periphyton assemblages indicated significantly downstream of enhanced P inputs, enriched soils, or altered plant communities.

In all basins we found a significant negative correlation of periphyton tissue P content with distance from inflow, and this relationship was always stronger than similar distance-water column TP concentration relationships. Periphyton biomass was depressed and assemblage composition altered at sites adjacent to canals. Using data from the experimental control channels in ENP as a model for an unenriched marsh, we detected departures from ambient conditions further downstream from canal sources for attributes of the periphyton community (TP content, biomass, composition) than for soil nutrient content or plant composition. In comparisons to similar data from these basins collected in 1989, we found P-related impacts to be migrating downstream in WCA-2A and WCA-1. The within-marsh patterns of change are related to changes in P concentration in canal-water inputs.

In summary, our P-enrichment experiments and transect surveys indicate that the microbial community responds quickly to changes in P-input and can provide an indication of impending ecosystem change. Changes in periphyton attributes were followed temporally and spatially by changes in the soil parameters and the plant and animal communities in a predictable manner in both experimental and natural settings. That these changes are correlated with alterations in upstream nutrient loading but not necessarily the water column P concentration at a given site suggests that biotic data, rather than water quality, be used to monitor and predict the degree of current or pending ecosystem alteration.

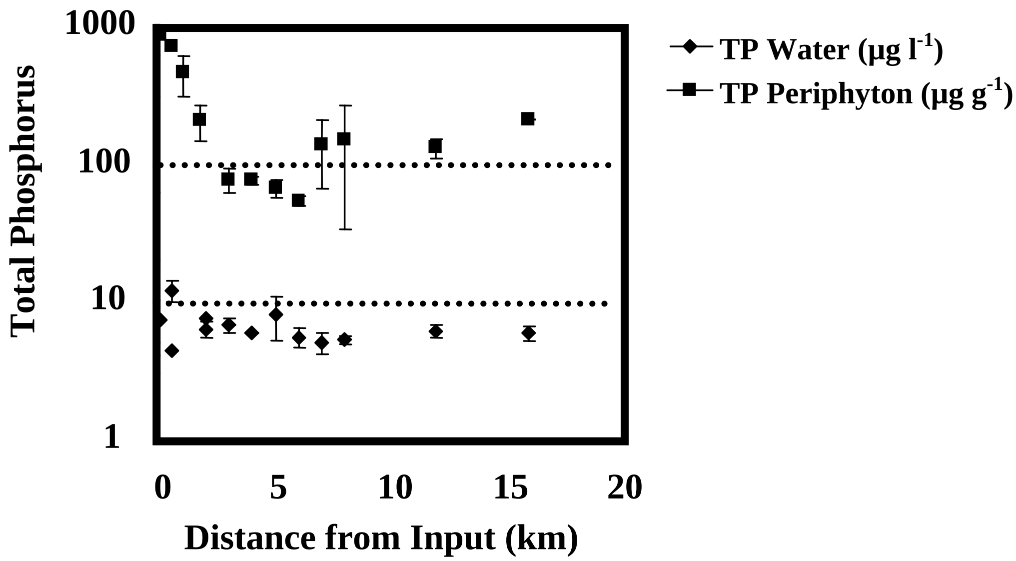

Figure 1. TP concentration in water and periphyton tissue across a 17 km transect from S-12C inflow structure to the interior of Shark River Slough, Everglades National Park, showing a significant decline in periphyton TP away from the canal without a significant change in water TP.

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Nutrient Cycling, Litter Accumulation, and Decomposition in Bayhead Tree Islands of the Southern Everglades

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Freshwater flow is the subject of great interest concerning Everglades restoration. Restoring freshwater flow to the system will not only increase flow, but may also increase nutrient inputs to downstream communities. The southern Everglades is one of the first regions to undergo hydrologic restoration, and is thus a good test for predicting the effect of large-scale Everglades restoration. In this study, part of an ongoing, long-term experiment, we characterized pool sizes and fluxes of phosphorus, nitrogen, and the primary organic matter cycles through southern Everglades tree islands. Our goal is to utilize this base ecosystem model to quantify the effects of increased freshwater flow through hydrologic restoration of the southern Everglades. In bayhead tree islands, leaf litterfall contributes the greatest proportion of organic matter, and approximately 60% is accumulated on the forest floor. Our modeling effort shows that P and N are also largely retained within the tree island system, with limited remineralization to soil porewater. However, preliminary decomposition estimates show that 40% of cocoplum leaf litter undergoes decomposition within 18 months. Large accumulation and low remineralization would suggest that decomposition rates must be influenced by surface water flowing through tree islands seasonally. We estimated that a relatively large proportion of tree island litterfall is available for marsh ecosystem processes through decomposition, and will likely have a greater influence if loading of available nutrients increases with increasing freshwater flow through the southern Everglades.

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Determination of Caffeine, a Specific Marker for Wastewater Contamination, in Coastal Environments from the Florida Keys

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Recently, there has been a growing interest in the presence of pharmaceuticals in the aquatic environment. Pharmaceuticals are developed with the intention to perform a biological effect so there is no reason to believe that they will be "environmentally harmless". Generally, drugs are absorbed by the organism and subject to metabolic reactions. However, a significant amount could leave the organism unchanged via urine or feces and enter sewage or manure. In addition, recent studies show that elimination of pharmaceuticals in municipal sewage treatment plants (STP) is often incomplete. The Florida Keys have approximately 85,000 permanent residents and 2.5 million tourists each year. Most of the Keys do not have modern sewage-treatment plants and its population is mainly served by septic tanks, underground injection wells and as much as 10,000 illegal cesspits. This fact, combined to the existence of waterfront properties sitting on a porous limestone foundation creates a good opportunity for water quality degradation via wastewater intrusion. To assess the infiltration of human derived waste and to check for the presence of pharmaceuticals coastal waters, caffeine was selected as a probe mainly because of its anthropogenic nature, the uniqueness of its origin, its environmental fate, and its elevated consumption. An average person consumes and discards large amounts of caffeine daily. Depending on its origin, freshly brewed coffee contains between 10 to 400 mg/L (parts per million) of caffeine while caffeinated sodas have between 100 and 130 mg/L consequently a single person can generate hundreds to thousands of mg of caffeine per day. The liver extensively metabolizes caffeine and only about 3% leaves the body unmetabolized. Thus, the major source of caffeine in domestic wastewater comes from unconsumed coffee, tea, soft drinks, or medication moving through ineffective on-site wastewater treatment systems (septic tanks). Crowded areas of septic systems present a high risk of microbial fecal contamination to groundwater and general degradation of water quality. Studies in the Florida Keys have already shown widespread bacterial and viral contamination of surface waters often associated with septic systems. Our study area concentrates in the Florida Keys, mainly the Little Venice area (Marathon Key) but also includes several other canal systems from Key Largo to Key West serviced by both septic tanks and wastewater treatment plants.

Caffeine was either extracted by LLE or SPE. In liquid-liquid extraction, a one-liter surface water sample is fortified with 50 µl of 1.000 ng/ml of atrazine-d5, used as the internal standard. Then, 20 g of NaCl are added to increase the ionic strength of the solution followed by 1.00 ml of 1M K_2PO_4 buffer to bring the water to pH~8.1. After each extraction with 50 ml of $MeCl_2$ the organic layers are passed through anhydrous sodium sulfate and concentrated in a water bath to about 1 ml. After taking the sample to dryness using a flow of clean nitrogen, the samples are reconstituted with 500µl 50:50 MeOH:H_2O and analyzed using LC-APCI$^+$-MS.

In the solid-phase extraction method, a 500 mg Oasis® HLB plus cartridge was used. The cartridge was conditioned with 5ml MeOH followed by 5ml H2O. A 1 L water sample containing 20 g of NaCl at pH~8.1 and 100 µl of internal standard was filtered and passed through the cartridge using a multichannel peristaltic pump at a rate of 10 ml/minute. Elution of caffeine and atrazine-d5 from the cartridge was achieved with 2 ml of a solution of 1% Acetic acid in 80:20 MeOH:H_2O followed by 2 ml of methanol. The combined eluents were then evaporated to 500 µl and analyzed using a Finnigan navigator aQa LC-MS operating under positive ion atmospheric pressure chemical ionization (APCI+) in selected ion monitoring (SIM) for the $[M+H]^+$ pseudo-molecular ions. The corona pin voltage was set at 4.5kv, the fragmentation cone voltage at 15V, and the source temperature at 350°C. For the HPLC separation, a Luna C-18 reverse phase column (150 x 4.6 mm, 5µ) was used with a linear gradient from 30:70 MeOH/H2O to 100% MeOH for 10 min. The flow rate was set at 1.0 ml/min. The ions analyzed in the SIM mode for caffeine were 195 and 196 and for Atrazine-d5 were 221 and 223Caffeine was detected in a large number of the samples collected ranging from the Miami River to Key West Municipal Marina. Concentrations of caffeine in open waters are generally low and near the method detection limit (<4 ng/L) while areas affected by water quality problems had concentrations of caffeine between 30 to 200 ng/L respectively. Specifically for Little Venice, occurrence of caffeine was widespread and more frequent in canals and enclosed waterways (LV01 to 09) than in open bay waters (LV-10). No significant differences in concentrations were observed between the mouth and head of the canals but the station located at the end of the 112th street canal (LV-03) was consistently higher than other stations in the survey. Although correlations with other water quality parameters such as nutrients (nitrates, nitrites, total phosphorous, reactive phosphorous, TOC, chlorophyll, etc.) and bacterial counts (FC and EC) were generally poor ($r^2 < 0.2$) station LV-03 still had the highest levels for most of these parameters during the period sampled. No trends were also apparent between the caffeine concentrations and average rainfall. These results point out the complexity of water circulation in the canal systems where a large tidal exchange between Florida Bay and the Atlantic Ocean waters tend to dominate the saltwater circulation. Preliminary data on water stratification indicates that caffeine concentrations are elevated in well-mixed systems when compared with stratified ones. To validate this observation, collection of both surface and bottom waters is already underway.

The relevance of these findings both simple and profound; if caffeine is present in the water, many other “biologically active” pharmaceuticals and personal care products could be present as well. Future research is needed to establish not only the occurrence but also the extent of this wastewater contamination and the potential effects to near coastal ecosystems at risk.

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Occurrence and Transport of IRGAROL 1051, a New Antifouling Herbicide, and Its Major Metabolite in Coastal Waters from Biscayne Bay and the Florida Keys

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IRGAROL 1051 is a relatively new triazine based herbicide used as an antifouling booster in copper oxide based bottom paints. IRGAROL is relatively non-toxic to aquatic animals, but is a potent inhibitor of photosystem II in marine and fresh water algae. IRGAROL water concentrations have been extensively reported world wide with values ranging from 1 to up to 4000 ng/L (1). However, data for US coastal waters is scarce and often limited in its spatial coverage (2, 3). Since recent reports have shown that IRGAROL could inhibit photosynthesis in corals at concentrations as low as 100 ng/L (2), the scope of this research was two fold. First to conduct a detailed survey of IRGAROL occurrence in marinas and waterways along South Florida coastline from Biscayne Bay to Key West and secondly to assess the spatial extent of IRGAROL dissipation from known point sources with respect to potentially sensitive benthic habitats.

IRGAROL, M1, and Atrazine were analyzed in 2-L seawater samples by LLE followed by GC/MS-SIM determination on a 30m x 0.32 mm x 0.25u DB-5MS capillary column. Concentrations of the herbicide were detected in 95% of the samples collected (102/107) at or near marinas and major waterways. Concentrations of the herbicide ranged from <1 to 362 ng/g with a 90 % of the samples having concentrations below 62 ng/L. The major metabolite of IRGAROL, M1, was detected in most of the samples at concentrations that ranged from 3 ng/L to 62 ng/L while the concentrations of Atrazine where generally low and near the method detection limit (1 to 3 ng/L). In contrast, sampling conducted at a major reefs (Looe Key, Molasses Reef, and Conch Reef) showed only background levels of IRAGROL (<1 to 1.92 ppt) in only 17% of the samples collected (5/29). Concentrations of IRGAROL rapidly declined from the marinas and where at or below the detection limit within 1701 m of the most concentrated point source. GIS data show that most of the coral reef habitats present in the Florida Keys are located at least 5000-8000 m from the nearest inland marinas so the potential for IRGAROL concentrations to reach 100 ng/L in these areas is relatively small. Additional work is already underway to assess the potential impacts of the herbicide to small near-shore assemblages of corals and other aquatic vegetation.

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The Loxahatchee Impoundment Landscape Assessment (LILA) Facility: A Macrocosm Approach to Experiments with Microtopography, Water Depth, and Flow Rate

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The restoration of the Everglades relies on an adaptive assessment framework that evaluates progress based on performance measures with quantitative targets. The Loxahatchee Impoundment Landscape Assessment (LILA) facility is a tool to interpret the complex patterns that come from monitoring biological performance measures in the natural system. LILA supplements ecological monitoring by making the monitoring results more certain and more cost effective.

LILA involves sculpting key physical features of the Everglades landscape into existing marshes and then manipulating water depths and flow rates to induce a response by **(1) wildlife, (2) tree island, and (3) ridge and slough communities** (Table 1). By linking hydrology with these three Comprehensive Everglades Restoration Plan (CERP) high priority features of the greater Everglades ecosystem, LILA will serve as a pilot study for hydrologic regimes proposed under CERP but yet to be implemented on a broad scale. From a scientific perspective, LILA acts as a bridge between the results of small-scale microcosm experiments and large-scale ecosystem monitoring. From a restoration and management perspective, the strength of LILA is that the certainty of data interpretation is high because hydrology and other critical processes are controlled and replicated.

LILA is being built in the A.R.M. Loxahatchee Wildlife Refuge headquarters area at Boynton Beach, Florida. Four small impoundments (7 ha in size) called "macrocosms" will be constructed from the two existing impoundments. In each macrocosm, a shallow and a deep slough will be sculpted from the existing marsh surface. Ridges, the tops of which will be at existing ground surface elevation, will separate sloughs. Constrictions in the sloughs will produce areas of higher flow velocities within each macrocosm. LILA is capable of producing water velocities of up to 2 cm/sec, which is in the range of flow rates thought to occur in the Everglades historically. Each slough will contain a shallow and deep hole 6-m in diameter designed to simulate alligator holes and provide deep-water refuges for fishes. Access to the refuges by aquatic animals will be controlled with plastic mesh fencing. Deep sloughs will contain two tree islands 14 m x 49 m in size and 0.91 m higher than the slough bottom. One tree island in each macrocosm will be built entirely from peat and one tree island will be built from peat that sits upon a limestone rubble core. LILA provides flowing water to each impoundment with a re-circulating water system controlled by an electric pump, gravity flow, and gated structures.

Besides being scientifically advantageous, LILA provides an ideal opportunity to educate the public about CERP and its goals. LILA provides the public easy access to a site where construction work that is so much a part of CERP is visibly producing restored tree islands, restored ridge and slough habitats, increased wildlife use, and an obvious example of the integration of science into the restoration process. An information kiosk will be constructed during the earthmoving phase so visitors will understand the purpose of the construction activity and see the link between short-term disturbances and long-term restoration.

Wading Bird Studies: One of the leading explanations for population declines of wading birds in the Everglades is that the way food becomes available to birds has changed because of changes in hydrologic patterns. Prey availability is linked to the seasonal drydown in water levels, but there is very little understanding of the specific conditions that produce patches of highly available prey. The objective of the wading bird component of LILA is to determine the effect of fish community composition, physical features of the Everglades and hydrologic factors on prey availability during the seasonal drydown. Three sets of studies focusing on (1) wading bird foraging success, (2) fish concentration events, and (3) fish community composition will be conducted to quantify those effects (Table 1). Both components of prey availability (i.e., prey density and vulnerability to capture) will be manipulated. Fish studies will measure fish density and movement patterns in relation to microtopography and deep-water refuges.

Tree Island Studies: More than half of the tree island habitat in WCA3 has been lost since 1940. Tree island losses have been attributed to abnormally high or low water levels and changes in tree island size and shape have been attributed to reduced flow rates. The restoration of the Everglades may require not only preventing additional tree island losses, but also restoring tree islands where they have been lost. A pilot project to assess tree island restoration techniques is an essential first step in that process. Assessment of tree island restoration techniques consists of four types of studies: (1) effects of water flow on tree island development, (2) significance of limestone cores for tree island health and development, (3) flooding tolerances of trees, and (4) seed dispersal of dominant trees (Table 1).

Ridge and Slough Studies: In much of the Everglades, the clear pattern of ridges and sloughs has partially or completely disappeared. This landscape feature has been lost to invasion by cattail, sawgrass and possibly by sedimentation. It is hypothesized that this loss of spatial pattern reflects a “flattening” of the landscape, that is, a diminishing of the difference in elevation between ridges and sloughs. A key question is what hydrologic conditions are needed to maintain a ridge and slough landscape under moderately enriched conditions? What processes keep sloughs open? LILA will test some of the mechanisms thought to maintain a ridge and slough landscape: sediment transport, differential primary production, and differential decomposition rate. Testing these mechanisms is an essential step for understanding and modeling this defining feature of the Everglades. Many of the same approaches being proposed for the study of tree island origin and development will be used to study ridge and slough formation and persistence. Sedimentation and erosion and plant community responses will be examined in four studies: (1) water velocity profiles, (2) sedimentation and elevation change, (3) vegetation density, composition, and succession, and (4) peat accumulation rates (Table 1).

Table 1. Primary components of the LILA project. The first three components are assessment studies and the last is the public outreach portion.

Project component	Questions	Response Variables
Wildlife Studies		
Wading Bird Foraging Success	How does prey density, water depth, and vegetation structure affect the foraging success of wading birds during drydown?	Wading bird habitat use Wading bird feeding success
Fish Concentration Events	How does microtopography and deep-water refugia affect the concentration of fish during drydown?	Fish density on ridges and in sloughs Fish movement patterns
Fish Community Composition	How does the presence of piscivorous fish affect the habitat use and movement of small fish during drydown?	Fish density on ridges, in sloughs, and in refugia Fish movement patterns
Tree Island Studies		
Tree Island Restoration Techniques	Is a limestone core needed to support tree island vegetation?	Aerial mapping of island morphology Vegetation growth Root penetration and biomass
Water Velocity and Tree Island Development	Are directional, moving waters needed to maintain tree islands?	Soil accretion Vegetation community coverage
Flooding Tolerances	What are the hydrologic water tolerances for the major woody species needed for tree island restoration?	Plant growth parameters Canopy density Transpiration Survivorship
Seed Dispersal Enhancement	Which perch types are most effective at enhancing seed dispersal and seedling establishment?	Number, size, and species of seedlings and bird use of perches
Ridges and Slough Studies		
Ridge and Slough Sustainability	Is the threshold velocity for sedimentation and erosion different for ridges and sloughs	Organic matter deposition in ridges and sloughs. Total suspended solids in sloughs. Peat subsidence/accretion
Ridge and Slough Restoration	What are the hydrologic conditions needed to maintain a ridge and slough landscape in moderately enriched conditions?	Above- and below-ground productivity Veg. density/composition Seed dispersal Decomposition
Public Outreach		
LILA as a CERP Demonstration Project for Everglades Restoration	How is CERP going to restore the Everglades and benefit wildlife and tree islands?	N/A

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A Test of the Prey Size Hypothesis as an Explanation for Decreased Wading Bird Nesting in the Southern Everglades

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One hypothesis of why wading bird nesting in the southern Everglades has declined is that shortened hydroperiods due to drainage have reduced the size structure of the fish community. If wading birds need large fish for profitable foraging, then any reduction in the availability of that size class would decrease wading bird body condition and the ability of birds to successfully produce young. This hypothesis was first proposed for Wood Storks but has since been extended to wading birds in general. This hypothesis is attractive because it posits a solid link between wading bird populations and more fresh water reaching the southern Everglades estuaries (i.e., increased hydroperiod), a major restoration goal. The implications of increased size structure of the fish community are currently unknown for wading bird species other than the Wood Stork. Such information is critical if we are to restore and sustain the entire suite of species that comprise North America's most diverse wading bird community.

Previous studies have documented the importance of water depth in determining foraging site quality for wading birds. Therefore, any test of fish size also should account for water depth. In this study I tested the effects of fish size and water depth on the numerical response of free-ranging wading birds. For each bird species, the null hypothesis was that neither water depth nor fish size had an effect on site selection. Treatments were fish size (golden shiners 5 cm or 9 cm in total length) and water depth (19 cm, 28 cm, or 37 cm). Initial fish density in all ponds was about 5 fish/m^2, which would be about average for density of prey-sized fish in the Everglades. Data were analyzed in a mixed-model framework with the response variable transformed as $\ln(y + 0.5)$.

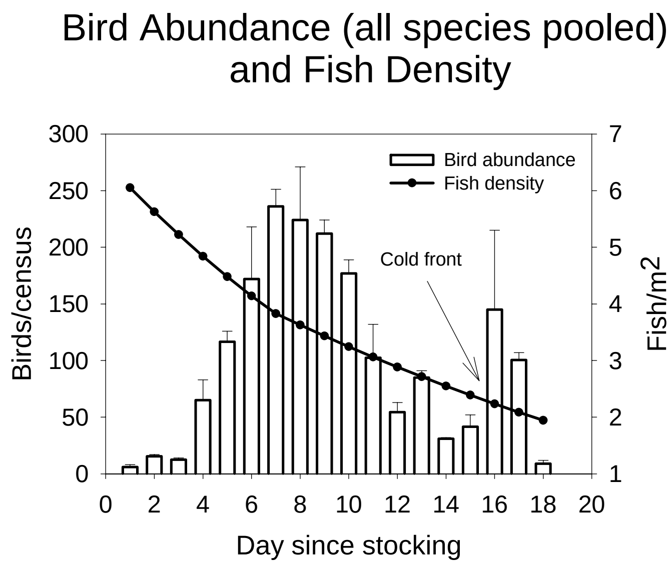
The experiment was conducted from 24 Jan - 11 Feb 1997 in 12 0.2-ha ponds adjacent to the northern Everglades of Florida. The ponds were built within a 1545-ha constructed wetland. This experiment was one of a series of experiments that examined foraging site quality for wading birds.

Bird abundance (all species pooled) at the site increased from day zero, when ponds were initially stocked with fish, until day seven, when abundance peaked at about 240 birds (Fig. 1). Thereafter bird abundance decreased to about 30 birds at day 15, and then increased abruptly for two days. This spike in abundance was probably due to an influx of migrants following the passage of a cold front, something that is assumed to occur in South Florida but has rarely been documented. The general pattern of bird use prior to the cold front was very similar to an experiment with fish density in 1996.

Also, similar to the previous experiment were the relative abundance of species and the timing of their peak densities. The Great Egret was the most abundant species overall but it didn't reach maximum density until the abundance of White Ibis and Snowy Egret had started to decline. This suggests that Great Egrets found the site attractive even after White Ibis and Snowy Egrets were abandoning the site because of reduced prey availability.

Analysis of the treatments showed that increased water depth reduced the density of Great Egrets, Little Blue Herons, Snowy Egrets, Tricolored Herons, Glossy Ibises, White Ibises, (P < 0.05, all tests) and Wood Storks (P = 0.07), although the relationship was weak for Wood Storks. Fish size was strongly (P = 0.003) and positively related only to density of Great Egrets. The relationship was weakly (P = 0.06) positive for Wood Storks and weakly (P = 0.07) negative for Glossy Ibises. The latter species experienced high rates of kleptoparasitism by Boat-tailed Grackles when handling large prey. Neither treatment variable affected the density of Great Blue Herons (P > 0.16, both tests).

Fig. 1



This study supports the notion that Great Egrets and Wood Storks prefer foraging sites with larger fish than what are commonly found in the Everglades today. The stronger response to prey size by the larger bird species is consistent with the greater energetic requirements of these birds. The smaller bird species showed no preference for larger fish, and Glossy Ibis, the smallest species, actually avoided sites with large fish. Although two of the three largest wading bird species preferred foraging sites with large fish, these birds have very different population trends, suggesting that fish size is not likely to be a mechanism controlling populations of both species. Wood Storks would be most likely to be affected by a reduction in fish size because they prefer sites with larger fish and previous experiments showed that these birds are more constrained in their choice of foraging sites than are other Everglades wading birds. There is no evidence that a reduction in the size structure of Everglades fishes would have had an impact on foraging site quality of the other species examined here.

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Evapotranspiration Rates from Two Different Sawgrass Communities in South Florida During Drought Conditions

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Evaporation and plant transpiration (ET) are significant components of the water budget in South Florida. Water loss through ET can exceed rainfall during dry years. Recent advances in instrumentation and measurement techniques have made it possible to develop a better understanding of ET processes and to quantify ET rates. ET rates at two sites vegetated primarily by sawgrass, one in Blue Cypress Marsh near Vero Beach in the St. Johns River floodplain and the other in the southern Everglades of Everglades National Park (fig. 1), yield significantly different ET rates during drought conditions that occurred in January through June of 2000.

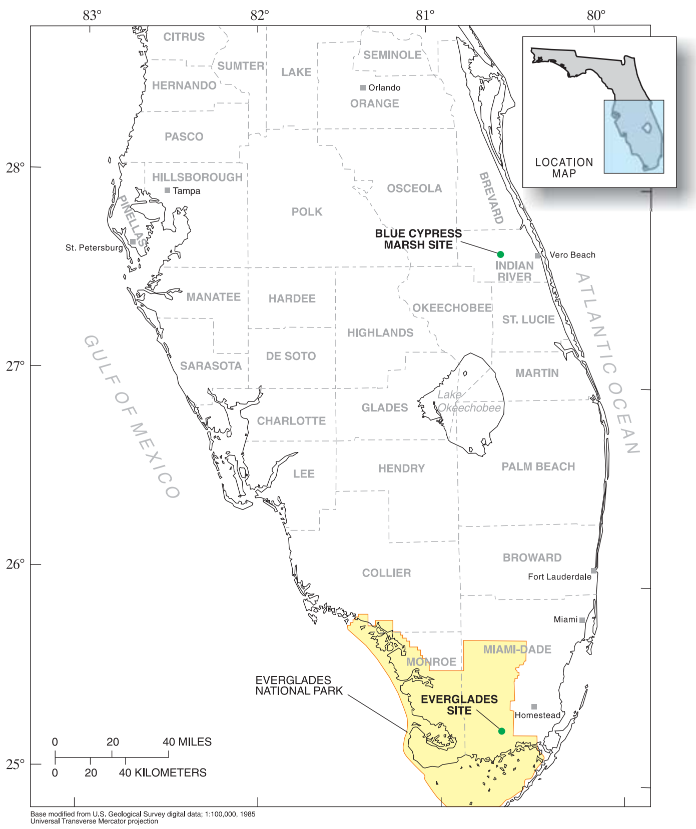

Figure 1. Location of Blue Cypress Marsh site and Everglades site

The Blue Cypress Marsh site (BCM) has dense sawgrass in a thick peat soil. At this site, the ET fraction (EF), which is the ratio of latent heat (the energy equivalent of ET) to the sum of latent heat and sensible heat (convective heat transport), was affected little by the change in water level even when nearly 3 feet below land surface. The Everglades National Park site (ENP) has a relatively sparse rush/sawgrass community in a thin marl soil. At this site, the EF decreased markedly as the water level dropped to about 2 feet below land surface.

The monthly total ET was greater at BCM than at ENP for each month except January (fig. 2). The largest differences in monthly ET rates (greater than 1 inch) occurred from March through July, when water levels were below land surface at one or both sites. Annually, the total ET was

55.7 inches at BCM and 43.5 inches at ENP. This difference in annual total ET is not explainable by differences in available energy (138 watts/m^2 at BCM and 132 watts/m^2 at ENP for 2000), and is the result of the differences in EF between the two sites.

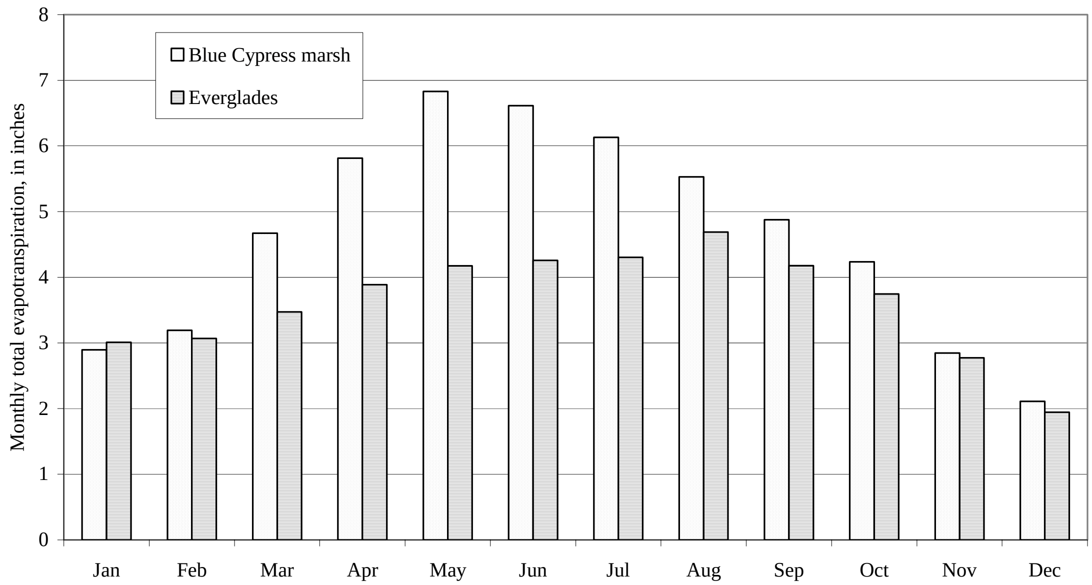

Figure 2. Monthly total evapotranspiration, January 2000 through December 2000.

The EF (and hence ET) apparently are related to water level at the ENP site but not at the BCM site. The reason for this difference in behavior of EF is not understood, but probably is related to the differences in plant cover and soil type between the two sites. The thick sawgrass cover at BCM apparently is able to transpire at maximum efficiency even when the water level is more than 2.5 feet below land surface. The thick peat soil layer may play a role in this high EF even during low-water conditions by providing a reservoir of soil moisture from which the sawgrass can draw. Additionally, the sawgrass coverage at BCM is relatively uniform and thick, and the incident solar radiation only penetrates the top of the sawgrass. At ENP the vegetative cover is thinner and less extensive. Heating of the sawgrass probably is less than heating of the land surface in exposed locations, so that the utilization of available energy for sensible heat transport likely is less at the BCM site than at the ENP. Less sensible heat transport relative to latent heat transport would cause a relatively high EF.

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Self-assembly of Slough-Ridge-Tree Island Landscapes in the Central Everglades: A Model for the Integration of Hydrological and Ecological Processes

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We propose that spatially coupled, positive and negative feedbacks among vegetation, peat accumulation, and hydrology have driven the self-assembly of the slough-sawgrass ridge-tree island patterning of Shark River Slough in Everglades National Park and adjacent Water Conservation Areas. A detailed understanding of these feedbacks is fundamental to any attempt to predict the ecological effects of proposed hydrological changes in the central Everglades – shifts in water levels and flows will not simply move vegetation zones up and down existing microtopographic gradients, but alter those gradients as well, possibly quite rapidly.

Our model is based on the following ideas:

1. As peatland ecologists have long recognized, on a gently sloping mineral substrate inundated much of the time, peat should accumulate to form a *roughly* level surface, reflecting low rates of decomposition of fallen plant material below the roughly horizontal water table, and the higher rates of decomposition and/or ignition above the waterline.

2. Random initial rises in elevation above the general level of this wet, gently sloping peatland should increase the rates of net peat accretion, as a consequence of slightly better aeration allowing more rapid rates of plant growth and peat deposition, with only slight increases in the rate of peat decomposition. Initial “bumps” in substrate height would thus tend to be amplified, growing into sawgrass ridges and ultimately, tree islands. The greater height of the resulting vegetation on wooded rises would attract egrets, herons, turtles, and alligators; these predators would funnel nutrients (especially P) to the resulting tree islands and accelerate plant growth even more. Ultimately, negative feedbacks of peat accumulation on peat height – via increased decomposition or likelihood of combustion during fires – could limit the height and extent of tree islands and (by implication) the area of intervening sloughs.

3. Increases in the area of ridges and islands would channel flow into increasingly narrow sloughs, with a disproportionate portion and duration of flow in the lowest portions of the sloughs. The presence of high water in sloughs would tend to maintain them and prevent them from occupying too small a proportion of the landscape, by restricting plant production and hence peat deposition. The low density of sedge/waterlily peat may also allow more groundwater flow through the sloughs. Flow is essential for this set of feedbacks to operate and maintain the sloughs: on a level substrate, one might expect all sites to become “bumps” and generate a level landscape overall. Flow could maintain a slough-ridge-tree island microtopography in the absence of any erosive processes.

4. As a consequence of the spatially coupled feedbacks operating on sloughs vs. ridges and tree islands, we expect that peat accretion rate (ΔH) should rise, then fall with peat height (H) relative to mean water-table height. This non-linear relationship of peat growth rate to peat height should

reflect differing, non-linear relationships of the rates of plant production and peat decomposition along the slough-tree island gradient; it would tend to amplify incipient ridges and deepen incipient sloughs, and lead to self-assembly of a patterned peatland. Drainage would tend to produce parallel sloughs running straight downslope; groundwater transport of nutrients accumulating on ridges and islands should tend to elongate them downslope as well, producing tails. The streamlining of tree islands can arise not from erosion, but simply as a self-organizing pattern that minimizes mixing across boundaries between areas with different nutrient supply rates that set, in part, different peat accretion rates.

5. We propose that specific, previously overlooked differences between cation-poor boreal peatlands and the cation-rich, P-poor Everglades are responsible for the striking differences in horizontal patterning that these ecosystems display. It is simply not possible to account for patterning parallel to flow in the Everglades based on the mechanisms that produce patterning perpendicular to flow (e.g., strings, flarks) in boreal peatlands.

6. Other feedbacks might modulate the expected relationship of ΔH vs. H. Fires spreading through sawgrass may be less likely to spread into (and perhaps burn the substrate of) tree islands, in which shading by tall woody plants eliminates most of the highly flammable graminoids from the understory. Waterlilies may also create an important additional feedback enlarging or maintaining the sloughs. Such plants are favored by deeper water and may themselves creater deeper water – they have internal winds in their petiolar aerenchyma that literally blow oxygen to their roots and rhizomes, some of which diffuses into the surrounding substrate and should thus increase the local rate of peat decomposition.

We and our colleagues have now begun to test several aspects of this model, using stratigraphic data and measurements of present-day production and decomposition along gradients of microtopography, soil depth, and flow speeds in different portions of the central Everglades that have had radically different flow regimes and water-control policies over the past several decades. Our aim is to integrate our findings with data on the present-day distributions of different vegetational bands and a model for landscape-sacle sheetflow to ask how proposed changes in water-control policy might affect the resulting mosaic of vegetation, landforms, and hydroregimes. In the longer term, we would like to determine whether ΔH vs. H feedback varies as we expect along the length of the Everglades.

Spatially coupled, positive and negative feedbacks may be the most important determinants of hydrology, substrate, and vegetation in the central Everglades. Models that assume substrate elevations and permeabilities as given – rather than as part of a dynamic peatland ecosystem in which hydrology, substrate, and vegetation all have strong feedbacks on each other – are ecologically simplistic. Adopting a more dynamic view may help explain why the Everglades are so flat despite substantial variation in the height of the underlying bedrock; why the vegetated landscape is streamlined into sloughs and ridges, and dependent on water flow; why tree islands can have little connection to fluctuations in depth to the rocky substrate; why there may be substantial dynamism in the horizontal position of sloughs and ridges; and why there may be striking regularities in the spacing of islands and ridges.

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Floating Peat Islands and Patch Formation in the Northeastern Everglades

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Floating islands are common in the waterlily-rich northeastern Everglades where they appear important in the formation of vegetational patches in the marshes, including the predominant type of tree-island. Floating islands of various sorts are an interesting phenomenon found worldwide including in other peat marshes such as the waterlily-rich "prairies" of Okefenokee Swamp, Georgia. Waterlilys facilitate the formation of floating peat mats. These initiate by detachment of buoyant uppermost peat and rootmat from the marsh bottom. Gas-filled arenchyma tissue, especially in the large rhizomes, provides buoyancy that adds to that from bubbles of decompositional gasses in the peat. Few or no floating peat islands were observed to originate except from waterlily vegetation. Possibly some physical characteristic of waterlily peat also accommodate, e.g., perhaps they more easily separate along planes to allow formation of the mats. The floating mats immediately create emerged sites, which soon are colonized by plants requiring shallower water than is available in the surrounding waterlily-rich marshes (the deeper marshes) or colonized by plants that tolerate no flooding at all at least at younger stages. Many floating islands drift slightly (mainly by wind) and leave behind an exposed shallow depression. The eventual resunk relicts of island mats and the depressions at their formation sites both are lingering topographical influences on the marsh vegetation. These are involved in both the formation and enlargement of vegetational patches, or rarely instead their obliteration (a floating island was once observed to encompass and eliminate one of the many small tiny patches of waterlily marsh found in the broader sawgrass marshes). The small mounds (low peat plateaus) are strongly implicated in the origin of the extremely numerous small bayhead tree-islands that occupy larger peat mounds in the same region of the Everglades (mainly the A.P. Marshall Loxahatchee National Wildlife Refuge). At least one fully established such island has been seen seemingly to expand by means of a floating island forming in the slough along its edge.

The northeastern Everglades now in CA1 and northern CA2A are (or were) waterlily dominated or codominated, but also host numerous sawgrass strands (elongated stands) and, more importantly here, vast numbers of smaller irregular sawgrass patches and patches of other emergent marsh plants as well as thousands of bayhead tree-islands. Most of the tree-islands occupy small peat mounds. Floating peat islands are common and were noted before impoundment (J.H. Davis, pers. comm.). The waterlily root mat here helps facilitate flotation and occasionally little more than the rootmat layer floats, though more often with a layer of peat accompanying (total 15+ cm thick). Mats are both strong and buoyant enough to support a standing person.

Many floating islands move laterally, sometimes just a few meters offside the emergence depression, sometimes tens of meters (distinctive size and shape of island and emergence hole are the evidence). Wind is the main mechanism, at least for more distant movement, with taller vegetation (e.g., sawgrass, bushes, small trees) likely acting as "sails." Movement means that a low peat "plateau" forms even upon resinking or reattachment after dry season stranding, which is promoted by drifting into shallows toward the edge of the waterlily sloughs.

New floating peat islands, with bare peat surfaces, and other recently formed ones, with an adjacent unvegetated emergence site, were initially examined and the flora listed, re-examined over the next year or so, examined several years later, and a few observed again about 25 years after initially. Colonization by marsh vegetation that differs from that immediately adjacent in the surrounding slough is very rapid (within a year) and mostly is by seed. Where tree-islands are common within tens or hundreds of meters, colonization by tree-seedlings is sometime rapid also. Bushy vegetation and fruiting specimens of dahoon holly and red bay were observed on islands still fully afloat. Tree-species colonization is faster than that reported for Okefenokee Swamp.

After a quarter century there still was not found (in the several sites re-examined) an example of the many small attached patches of bushes or small trees that are seen in these same marshes and assumed to be main stages in the development of the small peat-mound tree-islands. However, peat stratigraphy from fully established tree-islands suggests that many went through prolonged stages as patches of shallower marsh (sawgrass or arrowhead) within the waterlily marshes. Many small distinct patches of sawgrass, or of other marsh plants such as pickerelweed or arrowhead, are presently found in the waterlily sloughs and waterlily-rich mixed wet-prairies. These plants typify shallower water than waterlilys. One patch specifically examined lay upon a low (roughly 10-15 cm) but steep-sided peat "plateau" that likely formed by reattachment of a floating peat island (for what other mechanism exists?). Many of the innumerable other small patches of shallower marsh are suspected to have the same origin.

A unique condition (for the Everglades) of hydrologic stability occurs atop a peat island while afloat, a condition that may last for years in deeper sloughs. The surface is always damp but never inundated. Sag areas found in some mats are very shallowly inundated but at stable depth. This unusual stability in habitat may in large part explain the presence of some rarer marsh species and probably explains the almost singular occurrence of sundew (*Drosera*) in the Everglades (CA1). Unfortunately, the recent re-examination of floating islands shows that they also can facilitate growth of the troublesome weed tree, *Melaleuca*.

The depressions formed by the emergence of those floating islands that eventually drift away (even slightly) are likely important in maintaining patches of the deepest marsh. A conspicuously dense stand of white-waterlily pads (leaves) often marks them after a few years.

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It's the End of the World As We Know it - *Lygodium microphyllum* Is Strangling the Everglades Restoration Project

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Lygodium microphyllum is a climbing fern native to wet tropical and subtropical regions of the Old World. First detected as naturalized in Martin County, FL in 1965, it has become a serious weed in the state. Hundreds of Everglades tree islands in the Loxahatchee National Wildlife Refuge and thousands of acres of remote wilderness areas of Everglades National Park, Big Cypress National Preserve and Jonathan Dickinson State Park and are ravaged by this aggressive exotic species. *L. microphyllum* is also expanding its range northward, becoming increasingly common in the Kissimmee River Valley and the bay swamps of the Lake Placid area. The species has recently been noted along the Peace River and along Hillsborough County’s Little Manatee River.

Previous experience with other highly invasive plants (such as *Melaleuca quinquenervia*) has shown that plant populations tend to reach a “critical mass” of coverage and then begin an exponential rate of expansion, often spreading faster than management efforts can be effectively instituted. *L. microphyllum* has reached such a critical mass in South Florida, and threatens to jeopardize the Everglades Restoration Project. Current control methods are inadequate and biological controls need to be quickly developed and applied to attempt to bring this invasive species under control. The exponential spread of Lygodium has immense potential impact on Everglades ecology including future wading bird populations that depend on tree islands for nesting.

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Herpetofaunal Distribution and Occurrence on the Kissimmee River Floodplain Prior to Restoration

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Channelization of the Kissimmee River resulted in the loss of approximately 14,000 ha of floodplain wetlands and substantially altered hydrologic characteristics of remaining wetland habitats. Amphibians and reptiles were identified as critical biological components for assessing restoration of the Kissimmee River ecosystem due to their role in food web dynamics, complex life cycle, including obligate association of most larvae with water, and vulnerability to anthropogenic shifts in wetland hydrology. Herpetofaunal surveys were conducted in four floodplain habitats between 1996 and 1999 to document habitat-specific abundance, community structure, and spatial and temporal patterns of reproduction prior to restoration. Visual encounter surveys (VES) indicate herps were most abundant in broadleaf marsh and woody shrub, moderately abundant in wetland forest, and least abundant in pasture. Habitat-specific species richness followed a similar trend, while species diversity and community evenness were low in all habitats. Larval salamanders were present on the floodplain only from December through April, while larval anurans were present 7 months of the year. Species richness of larval amphibians was greatest in broadleaf marsh (14) and woody shrub (10), and lowest in pasture (4). Species richness and abundance of larval and adult amphibians and reptiles are expected to increase following restoration of floodplain habitats. Twenty-four herp species are expected to occur in restored floodplain habitats, with larvae present during most of the year.

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Importance of Floodplain Wetlands to Restoration of the Kissimmee River Fishery

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Fishes are an ecologically important component of large river-floodplain ecosystems. They serve as critical links in the energy pathway between both primary and secondary producers and higher trophic levels as well as indicators of aquatic health or integrity. Channelization of the Kissimmee River eliminated seasonally fluctuating discharge and the associated historic river-floodplain linkage. The seasonal flood pulse, a predictable natural disturbance provides the floodplain varying degrees of hydrologic connectivity with the river channel and maintains a variety of wetland vegetation communities, thereby creating a mosaic of available microhabitats to fish species. Elimination of the flood pulse in the Kissimmee River ecosystem has negatively impacted floodplain fish assemblages through reductions in their density and diversity. Disconnection of the historic river-floodplain linkage also may be limiting recruitment through reduction in the areal extent of available spawning/nursery grounds and disruption of critical food web pathways within the system.

Reestablishment of historic hydrologic characteristics, including variable discharge and seasonal floodplain inundation frequencies will provide spawning, nursery, and foraging grounds for most fish species inhabiting the system. Food web linkages between river channel and floodplain habitats will be recreated through the transport of aquatic invertebrates, fishes, and particulate organic matter during periods of floodplain recession.

The Kissimmee River restoration evaluation project incorporates restoration expectations or pre-defined performance criteria or values for specific metrics to gauge restoration success. Restoration expectations for the Kissimmee River floodplain fish assemblage were generated using information from historic data and current literature on comparable blackwater river-floodplain ecosystems. Expectations for post-restoration floodplain fish assemblages will be discussed as an indicator of restoration success.

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The Effects of Desiccation Duration on Periphyton Mat Community Structure and Function after Rewetting

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Periphyton mats, a complex of algae and bacteria, are a prominent feature of Everglades marshes. Preliminary results suggest significant variation in mat structure and function between long and short hydroperiod communities. A series of experimental manipulations were performed to determine the effects of hydroperiod on periphyton structure and function. I predicted: 1) hydroperiod would affect periphyton mats structure and function after rewetting; 2) the greater the duration of dry down, the more similar that long hydroperiod mat communities become to short hydroperiod periphyton mat communities. I sampled floating periphyton mats associated with *Utricularia purpurea* from three long hydroperiod sites and benthic, epipelic periphyton mats from three short hydroperiod sites. Each sample was sectioned into four mat fractions and dried for varying durations. After drying, mats were rewet for one month. At each of the sample intervals replicate water samples were collected for water TN, TC, and TP analysis. A significant decline in diatom abundance was observed after one month of desiccation. Cyanobacterial filament abundance increased significantly after eight months of desiccation. Results indicate a significant change in periphyton community structure in the direction hypothesized, a significant increase in the release of TOC and TP from periphyton mats, and no significant change in organic content of the mats with increasing duration of desiccation. The results of this study provide experimental evidence of the response of periphyton communities to future hydroperiod manipulation during Everglades restoration activities.

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Phosphorus Removal Performance by Submerged Aquatic Vegetation-Dominated Wetlands in Response to Hydraulic Loading Pulses

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Large treatment wetlands, termed Stormwater Treatment Areas (STAs), are being constructed south of Lake Okeechobee to remove phosphorus (P) from lake water and from agricultural runoff. Because much of the STA inflow water is generated during rainfall events, the STAs will need to achieve low outflow total P concentrations over a wide range of hydraulic loads. It is critical for the STAs to provide adequate treatment during high flow "pulse-events", given the great potential for P mass transfer during these hydraulic events.

Submerged aquatic vegetation (SAV) has been recognized as a valuable component of STA vegetation communities. To date, most research on P removal performance by SAV communities has been conducted under steady-state hydraulic loadings. In this presentation, we describe results of research on P removal by SAV under pulse-loaded conditions.

Five outdoor mesocosms (25 m^2) containing SAV were established in April 2000. These mesocosms received agricultural drainage waters over a range of hydraulic loading rates (HLR). During periods in which HLRs were quickly increased (from 2 to 40 cm day^{-1}), mesocosm outflow P concentrations typically did not increase. Under sustained high HLRs of 40 cm day^{-1} and variable inflow TP concentrations (37-117 µg L^{-1}), the mesocosm communities provided relatively low outflow TP concentrations (31-49 µg L^{-1}), and removed P at a high rate (12.3-16.1 mg P m^{-2} day^{-1}). Similar performance has been observed in full-scale SAV-dominated cells of STA 1W and STA 2 during high hydraulic loading pulses.

Additional insight into the influence of loading rate on SAV outflow TP concentrations was gained by assessing the performance of mesocosms operated at constant hydraulic loads of 16 and 8 cm/day for 16 months prior to periods of variable flow. Prior loading history appeared to influence system P removal performance under pulsed hydraulic conditions. During flow pulses, mesocosms that historically received a low HLR provided lower outflow TP concentrations and higher mass P removal rates than mesocosms with a higher HLR history. This preliminary analysis suggests that SAV communities appear well suited to perform adequately over the range of flows anticipated for STA operations.

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Scientific Approach for Developing an Education Plan for Endangered Species Recovery: The American Crocodile in Belize and Florida

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The American crocodile (*Crocodylus acutus*) occupies the northernmost limit of its range in Florida and is also distributed throughout central Mexico south through portions of Central America, including Belize, to northern South America. According to the 1996 IUCN Red List this animal is listed as globally vulnerable, meaning that a decline of greater than 20% has occurred in the past three generations.

Even though their population was never high in Florida, the American crocodile was declared an endangered species by the United States Fish and Wildlife Service in 1975. The American crocodile had a historical range located as far north as Lake Worth, Florida but is now restricted mostly to the southernmost tip of the peninsula in Dade county, isolated areas in the Florida Keys, and Florida Bay. In Belize, American crocodile populations occur along the length of the Caribbean Sea coast as well as neighboring islands and cays. Crocodile hunting was completely outlawed in 1981; it is not known how much enforcement of this law is taking place. Off-shore islands and cays are now the stronghold for the American crocodile in Belize.

The Florida human population is now five times greater than it was in 1950 and the Belizean population is on the rise as well, leading to encroachment on prime crocodile habitat. Also, crocodiles are reoccurring in areas that were once natural but now inhabited by humans. This has lead to interaction of humans and crocodiles in low-lying wetland areas, and both intentional and accidental feeding of crocodiles. When these circumstances occur, crocodiles can pose a risk to humans and pets. In Belize, fatal and non-fatal attacks have called attention to the need for a crocodile management strategy (Finger et al. 2002) where residential development is taking place and tourism development is planned in wetland habitats. In Florida, increasing calls to state agencies about nuisance crocodiles shows evidence of concern within residential areas. Fear and lack of public education about crocodiles have resulted in crocodile mortality and relocation, safety concerns, and an unsatisfied public.

The value the public places on wildlife, particularly crocodiles, and their perceptions of the risk associated with these animals (whether insufficient or exaggerated) may be key factors in understanding public response (Zinn and Pierce 2002; Kellert 1983). Past research on attitudes towards animals indicates that non-mammalian species are generally less valued than mammals, and this may be particularly true when the non-mammal is perceived as dangerous (Driscoll 1995). Even when an animal is regarded favorably, however, this attitude may not translate into support for environmental policies. A study of Big Pine Key residents found that liking for Key deer did not correspond with support for land-use or other policies to protect their habitat (Liu, Bonzon-Liu, and Pierce-Guarino 1997). Perception of a common fate between human and nonhuman residents did, however, correlate with support for these policies.

Perceptions of risk from crocodiles may lead people to either overreact or fail to exercise appropriate caution. Past research indicates that risk perceptions are based on two components:

knowledge and dread (Trumbo 1999). Knowledge involves how well an individual understands the potential risk, how well experts are thought to understand the risk, and how observable the risk is. Dread involves perceived threat to self and others and the voluntary nature of the risk. Knowledge and dread may also be related; a study of saltwater crocodiles in Australia found knowledge and anxiety about these animals to be positively correlated (Ross 1989). Inadequate knowledge and understanding of risk may lead to dangerous behaviors such as feeding crocodiles, and tourists and seasonal or newly arrived residents may particularly lack this understanding. Research on ecotourism has indicated tourists may prefer to view wildlife, such as rhinoceroses, at very close, or even touching distances, often for the purpose of taking photographs (Hart 1997).

The solution to this dilemma lies in an education program that will increase the local population's awareness by teaching proper behavior whenever crocodiles are in close proximity, and protecting valuable habitat for these creatures from development. The cumulative effect of the general populations' actions clearly has potential for change in not only general public attitude, but policy making as well. However for this program to be successful, appropriate educational methods must be derived. The audience for this study includes those immediately affected by crocodile-human interaction, local residents, and tourists.

To evaluate the effectiveness of the educational delivery, the project will be evaluated in three steps. First we will evaluate if there has been an immediate increase in public knowledge. Second, if there has been any application of that knowledge has taken place. Finally it will be determined if the knowledge gained from the crocodile education program has made any difference in public awareness and behavior.

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Welcome to Your Watershed - A Model for Adult Environmental Education Programs

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The Nature Conservancy with support from the South Florida Water Management District has engaged in a successful public education project about water resources in the upper Kissimmee watershed. Based in the central Florida counties of Osceola and Polk, Welcome To Your Watershed is a two-day workshop designed specifically for adult community leaders with the overall goal of increasing the community's capacity to first face and then to solve environmental problems, particularly the loss of biodiversity. During the workshop, substantial time is spent in the field in hands-on exploration as well as workshop activities that encourage reflection and a sense of stewardship. The program is based at The Nature Conservancy's Disney Wilderness Preserve in Kissimmee. A total of 155 participants from 7 workshops since 1998 have included county commissioners, city managers, a state representative, leaders from civic organizations, local business leaders and government agency personnel such as planners and extension agents. The diversity of participants encourages a healthy dialog to develop among the participants, a dialog which continues productively after the workshop. Follow-up meetings and activities have been implemented, including electronic information sharing, field trips and events to maintain a connection to graduates in order to continue their "education".

WTYW is a workshop with 4 distinct, sequential themes as follows: what is a watershed and how does it function? exploration of the watershed, what are the threats to the watershed? and how can we work together to address the threats? Through structured field activities, participants discover the characteristics of four central Florida plant communities, their similarities and differences and their interconnections. A key objective is to foster ecologically based thinking; the watershed is composed of interconnected natural communities that provide free services to humanity such as a reliable supply of clean water. This message underscores all the work at the workshop. Threats and solutions to those threats are presented through a mix of presentations and workshop activities with discussion encouraged throughout. Case studies of successful local community conservation efforts are featured.

No special effort has been made to quantify the effects of this program on the human community. However post-workshop evaluations have been favorable and two focus group discussions with "alumni" have supported the premise that the program is a valuable offering within the community. Alumni are actively involved in the community serving on local boards and attending public meetings that have input on local environmental issues. Additionally, alumni are involved in recruitment activities and planning for future workshops. WTYW provides a rare opportunity for adults to learn, through hands-on activities, about local environments and dialog about environmental concerns.

This poster will display information about the program. The goals of the program, the methods used and both quantitative and qualitative results will be presented.

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Evaluation and Calibration of ATLSS SESI Models

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Donald DeAngelis
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A primary product of the USGS's Across Trophic Level System Simulation (ATLSS) Program is the set of Spatially Explicit Species Index (SESI) models developed for the Greater Everglades area. These models (eight as of 2002) produce values for habitat suitability ranging from 0.0 to 1.0 for all 111,000 cells of the 500 x 500 m array. These habitat suitability values are typically calculated for every individual year in a 31-year sequence, simulated using inputs from the South Florida Water Management Model (SFWMM) as processed by the ATLSS High Resolution Hydrology Model. Averages can also be computed over any set of years (e.g., wet years, dry years, all 31 years), and over a variety of sub-regions within the total region included. The SESI models are used for relative comparisons between alternative future scenarios, not for producing absolute evaluations of habitat quality.

The current versions of ATLSS SESI models were evaluated and calibrated with historical demographic observations to the maximum extent possible, given data availability and time constraints. Abundance data for many Everglades species are scarce/sporadic, and methods of collection and reporting are often inconsistent over time and space. The degree to which SESI model evaluation was possible has also been limited by delays in availability of calibration water data for the model for recent years, when more complete and consistent species abundance data have been collected. The lack of high-spatial-resolution water data continues to limit evaluation efforts.

As an example of using the best available data in SESI calibration, spatial abundance data were extracted for each group of wading birds from Systematic Reconnaissance Flight (SRF) records as they became available. The 3-level estimates of water depth recorded along with SRF observations (dry, transitional, wet) were used to approximate historical water depths. Abundance counts were summed and demographic trends were graphed over each sub-region. These trend graphs were compared to SESI output, graphed over model sub-regions, for year-to-year trends, and trends in wet, average, and dry periods. These evaluations were all made based upon the SFWMM Calibration/Verification data available through 1995.

There was no opportunity during the rapid cycle of model development to formalize and document these efforts to compare SESI model output to empirical observations and adjust model parameters to reflect historical biological responses to hydrologic parameters such as hydroperiod and water depth. This process is being formalized and improved as additional monitoring data become available and as restoration modifications proceed. The SESI model code is in an object-oriented structure that readily allows for model modification as data collection proceeds.

As with the SESI models, availability of new data has required testing and revisions of the SFWMD Hydrology Model which produces hydrology data sets used to drive ATLSS scenario evaluations. An expanded set of hydrologic calibration data, providing daily water depths over the model area during the period 1979 to 2000, will become available from the SFWMD. Generation of this data set has required hydrology model modifications and revisions that will result in output that differs from the original calibration hydrology data. Together with recent data documenting species abundances over the model area, this extended and modified set of hydrologic inputs will enable further testing, evaluation, and revision of SESI models. This activity is essential in order to increase the reliability of the relative predictions made by SESI models.

Some approaches to be used in current and further SESI model development, evaluation, and refinement include the following activities.

(1) Extensive model runs have already been performed to evaluate the sensitivity of the models to wet, dry and typical hydrological patterns as represented in both the F2050 base and the AltD13R scenario. These model runs were accomplished by creating new water data sets by extracting wet, dry and typical years of water data from the existing water files and recombining them to create multiple water files representing scenarios which were wetter, drier and more average for each of the F2050 and the AltD13R scenarios than the original F2050 and AltD13R scenarios. The model output for these resultant water files was then summarized for both the entire model region and selected sub-regions and compared to the summarized output for the original water file. Analysis of these results has indicated that the models do indicate the appropriate response to water level differences (index values increase on average across the region for the American Alligator under wetter conditions). These results also indicate a fairly consistent relative pattern of differences for the models (e.g., if the average index value from a model for AltD13R is higher than its value for F2050, this ranking usually holds true for scenarios comprised of wet, dry, and typical water years). An expansion of this methodology is planned to evaluate the sensitivity of scenario rankings to variation of model parameters.

(2) A web-based interface to the SESI models as an extension of the ATLSS Data Viewer will be made available that allows authorized users to make modifications to selected model parameters and execute models on an ATLSS computational server. The resultant output file(s) could then be downloaded to the user's computer and the ATLSS Data Viewer used to compare different model runs and compare abundance data. The ATLSS Data Viewer tool would be invaluable in comparing model output with empirical data, as this tool incorporates many of the spatial summary routines required for such analysis.

The original restoration science concept for South Florida included continuing feedback between modeling, monitoring, and management programs. This must incorporate open lines of communication among modelers, biologists, and managers. Long-range stable funding must be secured for model evaluation, updating, and analysis as new monitoring and calibration data become available. Planned, periodic version updates of SESI models should incorporate information from trends reflected in current monitoring data.

In order for modeling to play an effective role in the restoration process, the following tasks necessary for model development, updating, and effective use over the period of adaptive restoration management in South Florida should be explicitly planned and funded:

(1) Accumulation and timely distribution of monitoring data.

(2) Maintenance of links and dialogues with experts, ensuring that models continue to reflect what is known about modeled species as the knowledge base grows.

(3) Liaison with users of model output, explaining caveats and restrictions, what output represents and how it should be interpreted.

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Atrazine Exposure and the Occurrence of Reproductive Abnormalities in Field Caught *Bufo marinus* from South Florida

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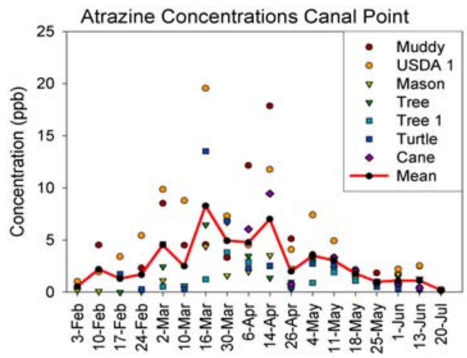
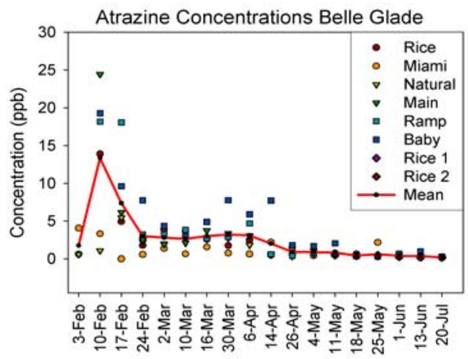
Many chemicals in our environment are suspected or known to influence endocrine system function. Endocrine disrupting chemicals (EDCs) have been broadly defined as exogenous agents that interfere with the production, release, transport, metabolism, binding, action, or elimination of natural hormones responsible for maintenance of homeostasis and regulation of developmental processes. Since hormones are important modulators of tissue differentiation, developing organisms are thought to be especially sensitive to EDCs. Indeed, many agricultural contaminants such as herbicides, fungicides, and insecticides have been shown to induce developmental toxicity through alterations in hormonal activity. For example, the insecticide DDT and its metabolite p,p'DDE are known to affect development through an anti-androgenic mechanism.

Atrazine is the most commonly used herbicide in the United States. Recent reports have suggested that environmentally relevant levels of atrazine can alter sexual development in laboratory exposed African Clawed frogs (*Xenopus laevis*), however, similar experiments have been unable to replicate these findings. The goal of the current study was to document whether similar reproductive system anomalies were common in anurans from Florida sugarcane agricultural areas, which have the highest per acre atrazine use in the U.S. The giant toad or cane toad (*Bufo marinus*) was chosen as the focal species because they posses a nonfunctional rudimentary ovary (Bidder's organ), which potentially makes them sensitive to EDCs that influence gonad development. They are an invasive species, so destructive sampling is not expected to cause negative impacts on local diversity, and they are found in large numbers in sugar cane fields were atrazine is extensively applied. The goal of the current study was to document whether exposure of frogs to sugarcane agricultural areas in South Florida would result in a higher incidence of intersex and/or developmental anomalies. Sugarcane agriculture has the highest per acre atrazine use in the U.S., which could represent the highest potential risk for exposure of native anuran species to atrazine.

To determine the distribution and concentration of atrazine at South Florida sites, multiple water samples were colleted from several canals/ditches at each of two agricultural sites every two weeks from February through June (Figure 1). Adult toads were collected from two sugarcane agricultural areas Canal Point (CP), and Belle Glade (BG) as well as from a University of Miami pond/canal (reference site with little to no atrazine use or agricultural input). Adult *Bufo marinus* were collected from these three sites: Canal Point (N=55) Belle Glade (N=50) University of Miami (N=24). Body weight, length, and coloration were recorded, blood was collected, and gonads were removed and weighed. This species is sexually dimorphic, with females having a mottled appearance and males having a solid coloration. Sex was identified as follows: the presence of ovarian tissue and absence of testicular tissue = female; presence of testes and absence of developing eggs, oviduct, and ovarian tissue = normal male; and presence of testes with developing eggs or oviduct or ovarian tissue = intersex . Macroscopic identification of additional testicular anomalies included: segmented testes, abnormal shaped testis, twisted or curled testes, and multiple testes. Gonads from each individual that had testicular tissue were both macroscopically and histologically examined. Blood plasma was analyzed for phospho-lipoprotein (an indirect measure of vitellogenin) and estradiol and testosterone concentrations were analyzed using RIA procedures.





Atrazine levels were highest at Canal Point during March, but were highest at Belle Glade in February**.** *B. marinus* tadpoles were potentially exposed to atrazine concentrations as high as 20ppb during development at Canal Point and 26ppb at Belle Glade during 2002. Toads collected from the nonagricultural /reference, University of Miami, site exhibited the characteristic gender-specific pattern which correlated to subsequent gonadal morphology and histology. However, all toads collected from both agricultural sites, Belle Glade and Canal Point, exhibited the distinctive female pattern, although subsequent gonadal morphology and histology demonstrated male, intersexed, and female toads. The frequency of males exhibiting “testis abnormalities” was not significantly different among sites. The frequency of intersexed animals was significantly different among sites: 39% and 29% of the individuals at the agricultural sites, Canal Point and Belle Glade. No individuals from the non-gricultural/reference site were intersexed. The types of abnormal female tissue found in association with testicular tissue varied between CP and BG. Plasma sex steroids did not differ between intersexed and normal males. However, plamsa phospho-lipoprotein (an indirect indicator of vitellogenin was increased in intersexed males to levels which were similar to those for vitellogenic females.

The purpose of this preliminary study was to determine if animals found in sugarcane exhibit reproductive abnormalities similar to those seen in African Clawed Frogs exposed to atrazine in the laboratory. The incidence of testicular anomalies, other than intersex were similar across sites. However, the incidence of intersex was increased for both agricultural sites as compared to the non-agricultural/reference site. Nonetheless, *Bufo marinus* adults were active and breeding at all sites. Data suggests that agricultural exposure, including exposure to atrazine, may explain the differences in the percent of intersexed individuals and length of oocytes between Canal Point and Belle Glade sites. However, we can not conclude that atrazine is responsible for these abnormalities, since other agricultural chemcials are likely present at both sites. In addition, water quality analyses were not conducted for the non-agricultural/reference site (University of Miami) and exposure to atrazine at this site is unknown. The University of Miami site is expected to have low levels of atrazine, but is probably not atrazine free. Further research should be conducted to determine whether atrazine is capable of causing the effects we have documented in *B. marinus* under controlled laboratory conditions as well as expanded field studies of these and other sites. Nonetheless, these results indicate an increased incidence of intersex in toads exposed to agricultural contaminants. The implications of these data to future and ongoing restoration is unknown, however, a redistribution of water resources in the greater everglades ecosystem could result in additional exposures for amphibian populations in this sensitive ecosystem.

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Florida's Wetland WebGIS and Geo-Database

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Introduction

Emerging geographic information technology enables us to integrate geospatial data of land and water resources derived from a variety of sources and to facilitate universal data sharing across the Internet. Sharing of information and spatial data with other users is outlined in the National Spatial Data Infrastructure (NSDI) (Clinton, 1994), a concept defined as the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and nonprofit sectors, and the academic community.

Burrough (1986) defines a geographic information system (GIS) as a powerful set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world. WebGIS provides interactive GIS functionality delivered to end-users via the Internet and it has the potential to make distributed geographic information available to a worldwide audience (Cobb and Olivero, 1997; Green and Bossomaier, 2002). Users can access the geospatial information and data via web-browsers without purchasing expensive, proprietary GIS software. Data and map services can be implemented using WebGIS. Data services provide interactive capabilities to retrieve spatial data and information from the Internet to local machines. For example, the Florida Geographic Data Library (FGDL) (http://www.fgdl.org/) provides a repository of spatial data for Florida to clients using the data service concept. In contrast, map services are constrained to online use and no data or information can be retrieved to local client machines. For example, the web site "Surf Your Watershed" developed by the U.S. Environmental Protection Agency provides map services to clients (http://cfpub1.epa.gov/surf/). An example of an interactive WebGIS site providing map services is the Florida Seminole County Watershed Atlas web site (http://www.seminole.wateratlas.usf.edu/help/aboutcontent.asp). The Southern California Wetlands Recovery Project Information Station (http://eureka.regis.berkeley.edu/wrpinfo/) and the Clinch River Environmental Restoration Program (CRERP) (http://research.esd.ornl.gov/CRERP/SUB/INDEX.HTM) web sites allow users to interactively explore all data and information related to specific wetland and river restoration projects.

Our objective was to develop an interactive web-based tool to integrate and visualize geospatial data and information for Florida's wetlands providing map and data services to users.

Methodology

We standardized and integrated 2130 geo-referenced point observations of 78 different soil physical, chemical, and biological attributes collected in Florida's wetlands from 1987 to the present. These datasets were collected by scientists and staff of the Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida and provide a valuable resource documenting historic and present environmental quality in Florida's wetlands. A WebGIS tool was created using ArcIMS software (ESRI Inc., Redlands, CA) to augment point observations with other GIS layers such as soils, geology, land use, and county boundaries providing query, selection, and navigation functions to users. Our server-side implementation allows clients to submit requests for data and map services to a Web server. The server processes the requests and returns data or a map to the remote clients' web-browser. A schema for metadata description was developed according standards outlined by the Federal Geographic Data Committee (FGDC-STD-001-1998 at http://www.fgdc.gov/metadata/metadata.html).

A graphical interface was developed using VBScript to provide data services to users. They can run SQL-based queries and select specific data records using one or all of the following constraints: (i) geographic location, (ii) projection, (iii) time period, (iv) depth of sample, (v) vegetation type, and (vi) soil property. The selected data can be downloaded to local machines.

Results from a geostatistical analysis were made accessible using one of the provided datasets. The analysis was conducted using ArcGIS Geostatistical Analyst. The quantitative spatial analyses were used to describe the spatial patterns of phosphorus. Different geostatistical techniques were employed to provide a better understanding of the spatial distribution and variability of soil quality parameters in the Everglades ecosystem.

Results and Discussion

Our global learning environment for Florida's wetlands is accessible at http://GISWetlands.ifas.ufl.edu (recommended web browser: Internet Explorer) (Fig. 1). Users without GIS knowledge can intuitively explore the data. GIS maps can visually enhance the spatial and temporal understanding of phenomena and improve our interpretation of soil-landscapes and wetland ecosystems. Geo-data can be downloaded to client machines and augmented with other environmental datasets to document the ongoing restoration efforts in the Greater Everglades ecosystem.

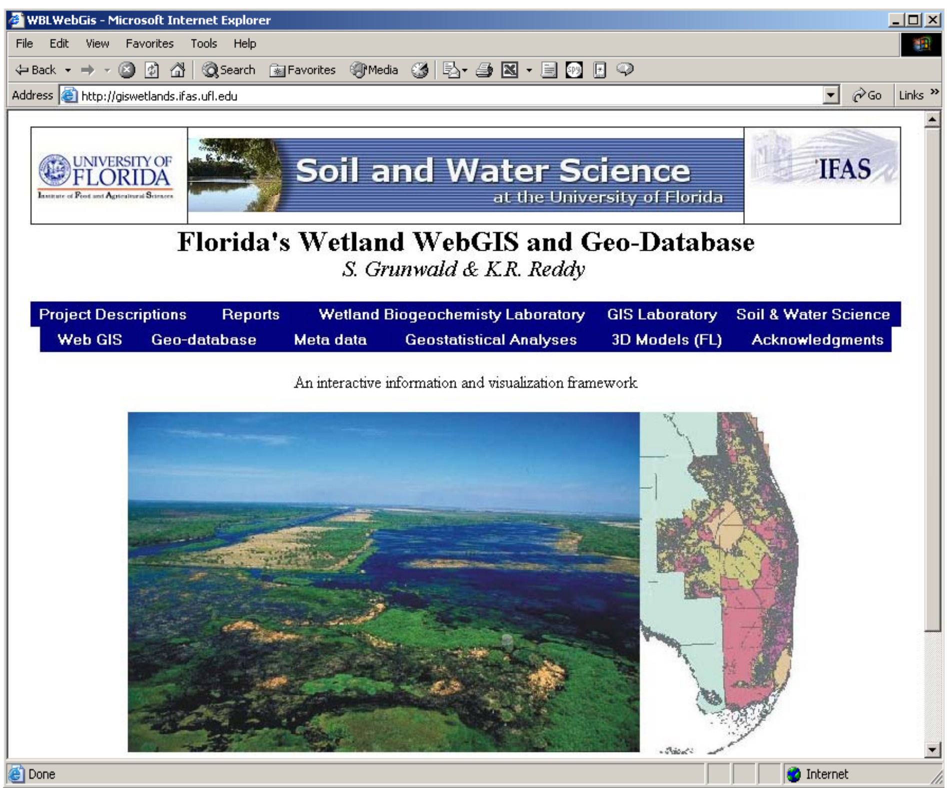

Fig. 1. Florida's Wetland WebGIS - URL: GISWetlands.ifas.ufl.edu.

Acknowledgements:

We would like to acknowledge the contribution of R.E. Jessup for his support with the ARC IMS based WebGIS implementation. The data integrated in the geo-database were derived from several research projects conducted by graduate students, staff and faculty of the Wetland Biogeochemsitry Laboratory, Soil and Water Science Department, University of Florida-IFAS.

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Linking Historic, Present and Future Spatial Variability of Soil Attributes in the Greater Everglades Ecosystem

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Introduction

Wetlands are known to accrete nutrients (N and P) and other contaminants. The Greater Everglades ecosystem has been impacted by agricultural and urban activities over several decades leading to phosphorus enrichment (DeBusk et al., 1994; DeBusk et al., 2001; Newman et al., 1997). The degree of nutrient enrichment depends both on nutrient loading and hydraulic retention time. This effect is distinct in many wetlands, and most notably in several hydrologic units of the Everglades, including water conservation areas, and the Everglades National Park.

Some variables, such as vegetation have visible patterns and their spatial scales are obvious. Remote sensing techniques can be employed to capture these patterns. However, many other biogeochemical attributes in the soil and water column are invisible, hence challenging to assess the spatial scales at which they vary without first sampling exhaustively. Attributes can also vary at scales that differ by several orders of magnitude simultaneously. Historic data are valuable to assess the spatial variability of floc/detrital plant tissue, surface water and soils attributes and guide future sampling designs and the assessment of environmental quality. The identified spatial scale and autocorrelation from historic surveys are beneficial to target future sampling locations reducing costs and labor. Our objectives were to assess the spatial variability of selected soil quality indicators in the Greater Everglades ecosystem using previous observations and to develop optimized sampling designs for future studies.

Methodology

The variogram is the cornerstone of geostatistics, and it is therefore vital to estimate it and model it correctly. Kriging requires the calculation of an experimental semivariogram to which a theoretical model is fitted. This provides a description of the spatial structure of the attribute (Fig. 1). The key features are the nugget semivariance which is representative of the measurement error and unmeasured variation at distances shorter than the smallest sampling interval. The other important feature is the range at which the spatial autocorreclation becomes 0. The range marks the limit of spatial dependence, i.e., the distance at which there is no spatial relationship between sampling points. Observations further apart than the range are spatially independent. The sill is the semivariance at the range and is the *a priori* variance of the process (Webster and Oliver, 2001). The formula to calculate the semivariance is presented below (Eq. 1).

Eq. 1: $$\hat{\gamma}(h) = \frac{1}{2m(h)} \sum_{i=1}^{m(h)} \left\{ z(x_i) - z(x_{i+h}) \right\}^2$$

where

$\hat{\gamma}$: estimated semivariance
$z(x_i)$: data values
h: lag vector (distance)
$m(h)$: number of pairs of data points separated by the particular lag vector

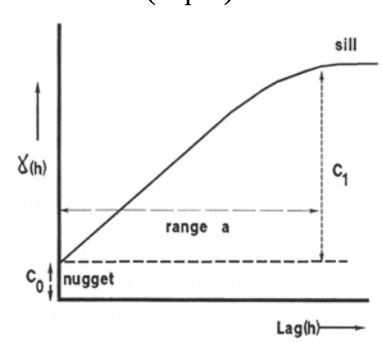

Fig. 1. An experimental semi-variogram and model parameters.

In this study we used previous observations of chemical soil attributes shown in Fig. 2 collected by the Wetland Biogeochemistry Laboratory (WBL), Soil and Water Science Dept. University of Florida and U.S. Environmental Protection Agency.

Survey	**Date**	**# Sites**
WCA-1 (WBL)	9/1991	103
WCA-21 (WBL)	7/1990	74
WCA-3 (WBL)	2/1992	100
WCA-3 (WBL)	6/1992	74
EPA	4/1995	120
EPA	9/1995	123
EPA	5/1996	123
EPA	9/1996	119
EPA	5/1999	121
EPA	9/1999	119

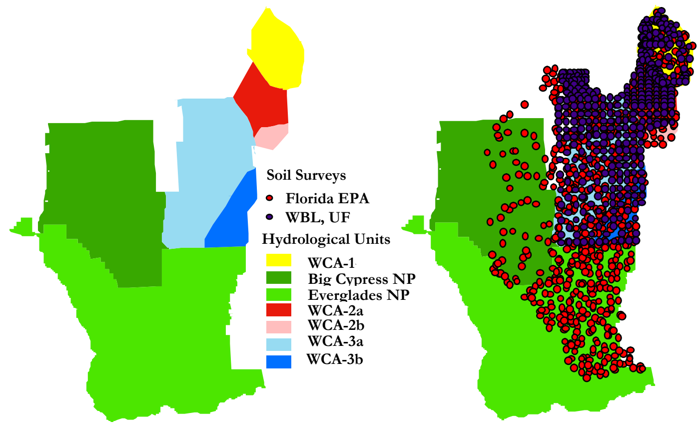

Fig. 2. Available soil attribute datasets used in this study.

Results

When designing a sampling scheme it is crucial to sample at distances smaller than the range, and also to sample at very small distances to adequately characterize the nugget semivariance. Therefore, the semivariogram parameters for soil properties from previous soil surveys were used to provide a guide to the required sampling density. A stratified random sampling design was chosen to identify sample locations. Zones within each hydrological unit were identified with k-means clustering of the kriged soil data (Hartigan & Wong, 1979). The number of zones within each hydrological unit was chosen subjectively based on prior expert knowledge of the study areas. Samples were randomly allocated within each zone where the proportion of samples per zone is equal to the product of the area and the within-zone standard deviation (SD) in total phosphorus (TP) 0-10 cm. This methodology was chosen to ensure that large zones with low variability were not over-sampled and small zones with high variability were not under-sampled. TP was chosen as it is the soil property of most interest in this study. In each hydrological unit approximately 80% of the sampling stations were identified using stratified random sampling. The remaining stations were allocated to characterize the short range variability. Results for Water Conservation Area 1 (WCA-1) are given below (Table 1 and 2). The same methodology was applied to the other hydrological units of Fig. 2.

Table 1. Semivariogram parameters for WCA-1 dataset (number of samples: 103; time of data collection: September 1991) (Reddy *et al.*, 1994a).

Attribute	Model	Nugget	Sill	Range (m)	Sample No.*
Total P 0-10cm	Spherical	92,662	71,892	21,675	19
Total N 0-10cm	Spherical	14,164,940	21,982,981	21,298	20
Total C 0-10cm	Spherical	8.94	12.91	20,591	21

*Sample number is based on a grid sampling scheme where the grid spacing is equal to one quarter of the range parameter in the semivariogram. Therefore, a sample number between 19 and 21 was needed to characterize the spatial variability of Total N, P and C. This is for a grid sampling scheme which have been found to be inefficient for characterizing spatial variability. Instead a stratified random sampling scheme is suggested.

Table 2. Cluster statistics for WCA-1.

Cluster	Area (ha)	Mean TP 0-10cm	SD TP 0-10cm	Sample No.*
1	21,916	465.0	78.2	35/4
2	10,844	717.9	123.1	28/4
3	23,944	334.3	34.7	17/2

* Number to the left of the dash is number of samples randomly allocated within the cluster; number to the right is the number of locations where short range variability will be sampled.

Discussion

Spatially explicit modeling of chemical, physical and biological attributes is essential to understanding the structure and function of biodiversity at the soil/water interface of wetlands. Characterization of these patterns is pivotal to improve our understanding of factors that drive phosphorus retention and mobilization across spatial and temporal scales. The suggested methodology facilitates to improve the documentation of the ongoing restoration efforts in the Everglades ecosystem.

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Analysis of Water Quality in a Constructed Treatment Wetland Designed to Reduce Nutrients in Everglades Agricultural Area Runoff

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The Everglades Nutrient Removal Project (ENRP) was a 3,819 acre (1,545 ha) treatment wetland built on former agricultural land in Palm Beach County, Florida (26°38'N and 80°25'W) and was operated by the District as a prototype stormwater treatment area (STA). The ENRP was composed of four treatment cells arranged as two parallel flow-ways; water moved separately from Cell 1 to Cell 3 (eastern flow-way) and from Cell 2 to Cell 4 (western flow-way). The ENRP began treating water in August 1994 and continued operation when it was incorporated into the footprint of a larger STA, STA-1 West in June 1999. We present results of water quality analyses based on nearly seven years of continuous operation of Cells 1-4 (August 1994 to April 2002).

The average inflow to the ENRP was 195 cubic feet per second (cfs) and ranged from 7 to 407 cfs. Water depth varied from 0.88 to 2.89 ft with an average of 1.95 ft. Nominal hydraulic retention time ranged from 9 to 99 days with an average of 25 days. The vegetation community in Cells 1, 2 and 3 was dominated by cattail (*Typha latifolia* and *T. domingensis*). Cell 4 was actively maintained as a submerged aquatic vegetation (SAV) community dominated by southern naiad (*Najas quadalupensis*), with lesser quantities of coontail (*Ceratophyllum demersum*) and pondweed (*Potamogeton* sp.).

Analysis of water quality was based on monthly or biweekly composite and grab samples collected from the ENRP's inflow and outflow and several interior stations. Ion concentrations at the ENRP inflow exceeded averages for North America freshwaters by several fold. Calcium (Ca), alkalinity, iron (Fe), aluminum (Al), dissolved oxygen (DO), total suspended solids (TSS), turbidity, sulfate (SO_4^{-2}), total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN) and chlorophyll a (Chl a) decreased as water moved through the wetland. Total organic carbon (TOC), dissolved organic carbon (DOC), conservative ions, conductivity and pH were relatively unchanged. Secchi disk depth was the only parameter where average outflow values were significantly greater than at the inflow.

Inflow Al and Fe concentrations, averaged 295 and 280 µg/L, respectively, and were reduced over 90% to 22 and 17 µg/L at the outflow. Possible sinks for Fe and Al include plant uptake, settling and co-precipitation with hydroxide and phosphate. Removal of Ca was also significant; an average of 11 mg/L of Ca was retained by the wetland. Two major sinks for Ca are precipitation to sediments and encrustation on periphyton and submerged aquatic vegetation (SAV) as $CaCO_3$. Co-precipitation with Ca was thought to be responsible for some SRP removal from the ENRP water column. The average inflow TP concentration of 118 µg/L was reduced by 81% to 23 µg/L, and SRP was reduced from 57 µg/L to 9 µg/L. Uptake by SAV and associated periphyton, settling and co-precipitation with $CaCO_3$, Fe and Al are believed to have been important mechanisms for P removal.

The average TSS concentration of 6.9 mg/L was reduced to 2.1 mg/L and may account for the improvement in water clarity as well as some reduction in TP concentration. The average water column Chl a concentration decreased from 17.6 µg/L to 3.5 µg/L and was attributed to severe nutrient competition by higher plants which dominated the plant community. Trend analysis indicates that Chl a continued to decrease while Secchi depth increased at the outflow over time.

Data analyses for the internal stations indicate varying levels of concentration reduction among the treatment cells. Both upper cells in each flow-way (Cells 1 and 2) removed TP as well as Fe, nitrate (NO_3^-), Chl a, TSS, Al, and SO_4 effectively. Cells 1 and 2 also had lower DO levels at their outflows relative to inflows, while Cells 3 and 4 increased DO in the overlying water column. Possible explanations for low DO levels in Cells 1 and 2 include high nutrient loading, Chl a and TSS which would lead to high DO consumption during mineralization of organic matter. Additionally, high turbidity may negatively affect photosynthesis by SAV and periphyton communities situated in the upper cells.

Cell 4 has proven to be more effective than Cell 3 in reducing TP and Ca concentrations in addition to having the highest P sediment accretion rate of the four cells. Furthermore, Cell 4 had a higher rate of Ca concentration reduction compared to Cell 2. It is probable that the SAV and periphyton biomass, which dominate the wetland, raised water column pH due to their higher photosynthetic rate, which further enhances $CaCO_3$-P co-precipitation. This would additionally account for the increased Ca removal noted in the back-end system of the western flow-way.

In summary, the ENRP achieved high concentration reduction of nutrients and suspended particles. Differences in removal efficiency among treatment cells were attributed to their location in each flow-way, surface area and plant community composition and coverage. To optimize P removal in the STAs, increased understanding of cycling pathways for major elements within treatment wetlands is needed.

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A Post Mortem Analysis of Coral Mortality in the Lower Florida Keys, Florida

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The Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project (CRMP) has sampled sixteen sites in the Lower Keys (Looe Key to Sand Key) annually since 1996 (Figure 1). Non-consumptive sampling methods characterize percent cover of stony coral and other benthic categories, stony coral species number and stony coral disease presence. The project added a census of bioeroding clionid sponge colonies in 2001 at the suggestion of the Environmental Protection Agency (EPA) Science Advisory Panel.

Between 1997 and 1999, the project documented significant declines in stony coral percent cover and species number at the majority of sites on the Oceanside of the Lower Keys. In contrast to the declines documented at sites on the Oceanside, the two sampling sites [Smith Shoal (24.7197°N, 81.9195°W) and Content Keys (24.8221°N, 81.4889°W)] in Florida Bight north of Key West, were relatively stable from 1996 to 2001. However, stony coral percent cover and species number at the two sites in Florida Bight dropped drastically (> 70% and >30%, respectively) from 2001 to 2002. In addition to the decline in stony coral percent cover and species number, the mean number of clionid sponge colonies decreased from a range of 12-16 in 2001 to zero in 2002. In sharp contrast, analysis of data from sites on the Oceanside of the Lower Keys showed no remarkable changes in stony coral percent cover, species number or number of clionid sponge colonies between 2001 and 2002.

Bleaching events were well documented in the Florida Keys in 1998 and are thought to be a contributor to stony coral decline observed from 1997 to 1999. NOAA's HotSpots program uses satellite data to predict areas where bleaching is likely to occur based on sea surface temperatures (SST). This program has been quite successful in predicting bleaching incidents worldwide. In addition to water temperature, satellite data can be used to track phenomenon such as red tide and other occurrences that are visible from space. Satellite data from 2002 revealed abnormally low water-leaving radiance values at the two CRMP project sites in the Florida Bight between March and May 2002. The low water-leaving radiance values were associated with a diatom bloom after a “black water” event. Field observations showed that the dark water mass contained the red tide organism *Karenia brevis* and high diatom concentrations. Water-leaving radiance levels at sites on the Oceanside were normal, suggesting that the black water event dissipated as it came around the Keys and was advected into the Florida current. Indeed, no significant declines in stony coral percent cover, species number or clionid sponge percent cover were documented between 2001 and 2002 at sites on the Oceanside of the Lower Keys. The satellite ocean color data suggest that the decline in benthic communities is related to the water patch that was identified by abnormally low water-leaving radiance levels at CRMP sampling sites in the Florida Bight. These results illustrate the potential of ocean color as an index to predict harmful impacts to coral reefs much as SST is used to predict coral bleaching. However, additional research is needed to quantify at what anomaly level/duration declines will likely occur.

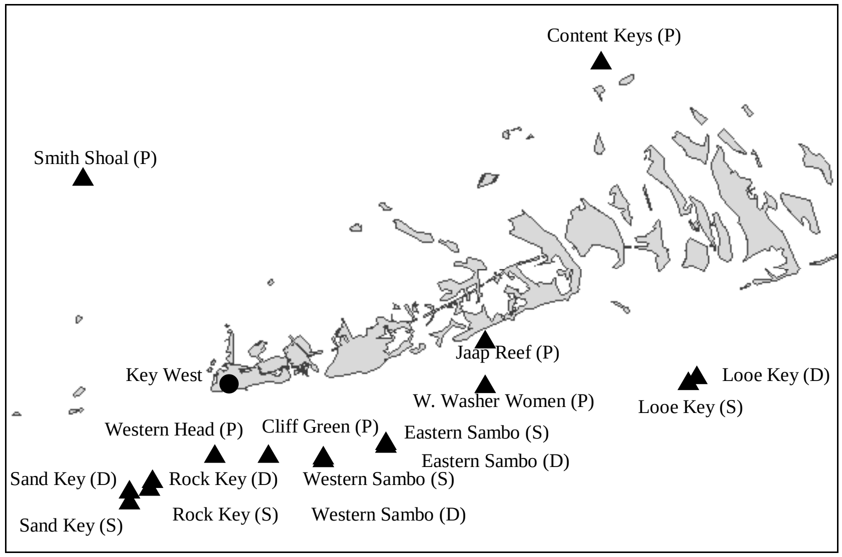

Figure 1. Distribution of CRMP sampling sites in the Lower Florida Keys

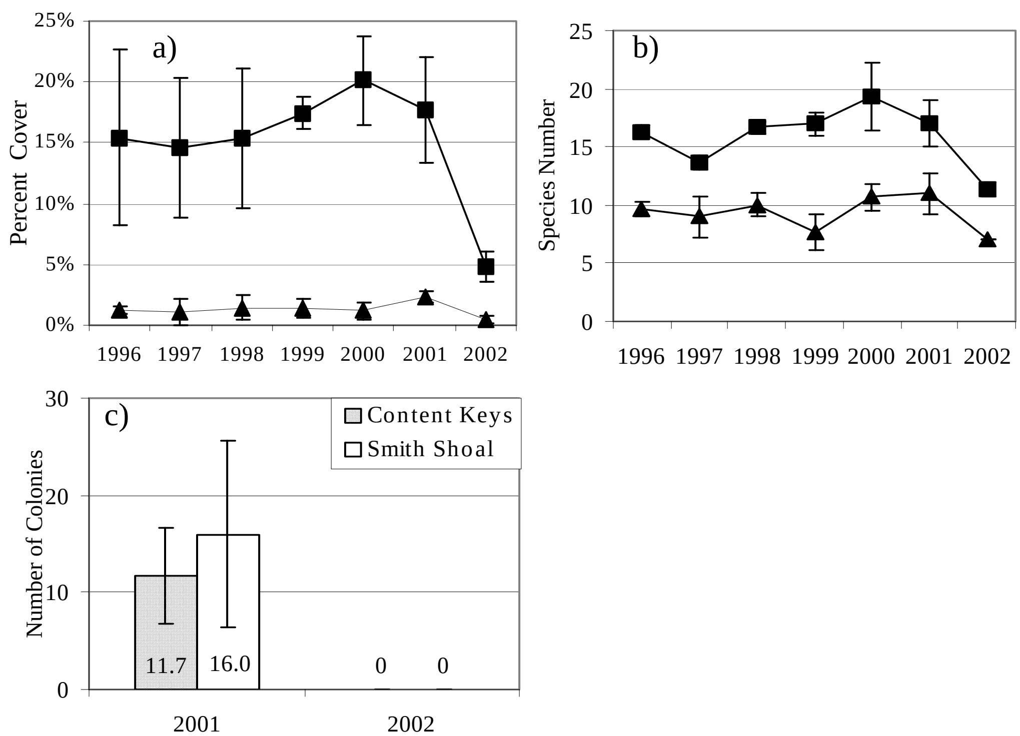

Figure 2. a) Stony coral mean percent cover +/- standard deviation (n=3 stations) and b) stony coral species number for Smith Shoal ( ) and Content Keys (▲); c) total clionid sponges colonies.

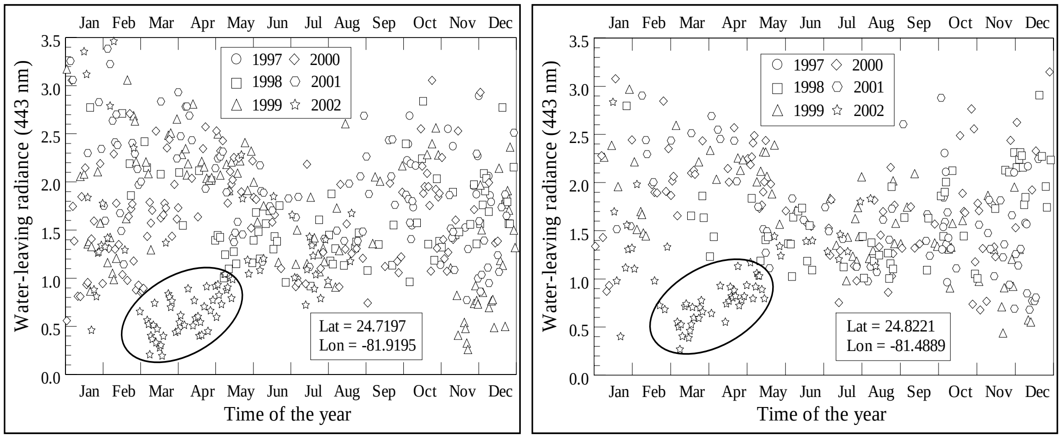

Figure 3. Water-leaving radiance at 443 nm for Smith Shoal (left) and Content Keys (right).

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Development of a High Performance Liquid Chromatography (HPLC) Protocol for Monitoring Periphyton in the Florida Everglades

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The taxonomic composition of periphyton assemblages respond rapidly (days-weeks) to changes in water quality; hence periphyton inhabiting the Florida Everglades are routinely used as a monitoring tool to assess current and future management practices. Current protocols employ taxonomic identification and biomass estimates, which are expensive and may not yield results within a suitable time frame required by managers. Therefore, an alternative protocol that is rapid and less expensive is desirable.

We are investigating periphyton chemotaxonomy as one such protocol for monitoring periphyton in the Florida Everglades. The basis of chemotaxonomic estimation of community structure derives from the ability to identify and quantify taxon specific pigments. In the Everglades, periphyton respones to minor changes in water quality occur not only at the species level but at the division level as well (e.g., Cyanophyta, Chlorophyta, and Bacillariophyta). Since algae in these divisions and classes within these divisions have distinct photosynthetic and photoprotectorant pigments, the use of chemotaxonomy seems an ideal protocol to investigate. Our ultimate goal is the development of an overall methodology that will allow the simple extraction and HPLC-PDA analyses of the algal/bacterial pigments and provide reliable data sets for the estimation of community structures under the principles of ‘chemotaxonomy’.

The objective of this study was to develop a standard method for the extraction of photosynthetic and photoprotectorant pigments from periphyton. In order to achieve this, we surveyed various extractants and extraction methodologies using fresh and freeze dried periphyton samples collected from WCA1 and WCA2. The methods entailed grinding, steeping and combinations. Extraction solutions were 90% aqueous acetone, acetone/methanol/water (45:45:10) and 90% aqueous dimethyl formamide (DMF). Identification of chlorophylls, chlorophyll derivatives and carotenoids was by HPLC separation using the 2D analytical technique of reverse phase high performance liquid chromatography (RP-HPLC) coupled with full spectral (330-800 nm) photodiode array detection (PDA).

Yields were better with all solvents if grinding / sonication followed by steeping was performed on freeze dried rather than fresh samples. Both DMF and acetone/methanol/water provided vastly superior injectate preparations when compared to acetone. That is, the highly polar pigments (e.g., scytonemin, chlorophyll-c, chlorophyllides, pyrochlorophyllides, fucoxanthinol, et cetera) were separated with baseline resolution whereas severe overlap and peak broadening was found with acetone. DMF yielded the highest epimerization of chlorophyll- and pheophytin-a. Additionally, DMF provided the lowest extraction of bacteriochlorophyll-/bacteriopheophytin-a and the chlorophylls-c.

Our results indicated that we can estimate the structure of Everglades periphyton at the division level using the following biomarker pigments: Cyanobacteria (echinenone), Chlorophyta (chlorophyll-b), Chyrsophyta (viz. diatoms: fucoxanthin), Pyrrophyta (peridinin) and

Cryptophyta (alloxanthin). Typically, cyanobacteria are estimated using zeaxanthin; however, based on recent work on epiphytes and microphytobenthos in Florida Bay and work here, we suggest that echinenone and canthaxanthin are superior cyanobacteria markers for Everglades periphyton. Two bacteriochlorphyll groups were identified: purple (bacteriochlorophyll-a) and green/brown (bacteriochlorophyll-c) sulfur bacteria. In the present study, the samples investigated yielded the following overall chemotaxonomic (cyano/chloro/diat/dino/crypto {oxygenic/anoxygenic}) distributions: WCA2A- 93/5/2/0.2/0 {~150:1}; WCA1- 65/20/15/0/0 {infinite}.

This study suggests that an HPLC-PDA protocol that yields reliable formulae with which to estimate the community structure of Everglades periphyton is possible. Such a protocol, in conjunction with traditional periphyton taxonomy monitoring methods, will provide a rapid objective monitoring tool with which to follow periphyton community changes induced by the restoration (CERP) process. Our further studies involve testing the CHEMTAX algorithm for data manipulation, one additional extractant (acetone/methanol/DMF/water), and field scale testing.

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Minimizing Ecological Impacts During the Siting of Comprehensive Everglades Restoration Plan Project Features: The Development of an Ecological Surface Value Model for the Lake Okeechobee Watershed Project

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The U.S. Fish and Wildlife Service's South Florida Ecological Services Office developed a multi-criteria GIS-based ecological assessment tool for one of the Comprehensive Everglades Restoration Plan projects, the Lake Okeechobee Watershed Project. The purpose of this planning tool is to aid project planners in siting project components (above-ground reservoirs and stormwater treatment areas) by determining the potential ecological costs when placing them on alternative site locations within the watershed. Using a three-tiered approach, we created ecological surface values by considering threatened and endangered species, general fish and wildlife habitat, and rare community types. The model incorporates data for three threatened and endangered species, species diversity, proximity of habitats to disturbed areas, and the degree to which the unique habitats within the project area are classified as rare, both in a state and global context. Use of the tool may aid in siting project elements on Lake Okeechobee Watershed lands that have the lowest value based on the ecological criteria included in the model.

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Pulley Ridge – The US's Deepest Coral Reef?

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Pulley Ridge is a 100+ km-long series of N-S trending, drowned, barrier islands on the southwest Florida Shelf approximately 250 km west of Cape Sable, Florida (Fig. 1). The ridge has been mapped using multibeam bathymetry, submarines and remotely operated vehicles, and a variety of geophysical tools. The ridge is a subtle feature about 5 km across with less than 10 m of relief. The shallowest parts of the ridge are about 60 m deep. Surprisingly at this depth, the southern portion of the ridge hosts an unusual variety of zooxanthellate scleractinian corals, green, red and brown macro algae, and typically shallow-water tropical fishes.

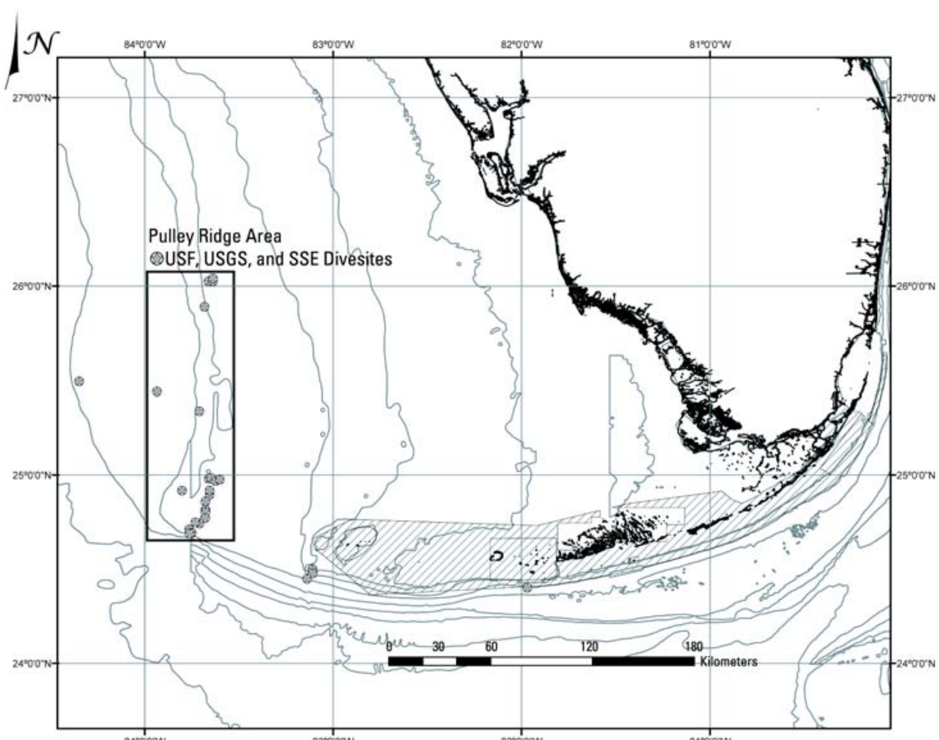

Figure 1. Location of Pulley ridge study area and divesites.

The corals *Agaricia* sp. and *Leptoceris cucullata* are most abundant, and are deeply pigmented in shades of tan-brown and blue-purple, respectively. These corals form plates up to 50 cm in diameter and account for up to 60% live coral cover at some localities. Less common species include *Montastrea cavernosa*, *Madracis formosa*, *M. decactis*, *Porities divaricata*, and *Oculina tellena*. Sponges, calcareous and fleshy algae, octocorals, and sediment occupy surfaces between the corals. Coralline algae appear to be producing as much or more sediment than corals, and coralline algal nodule and cobble zones surround much of the ridge in deeper water (greater than 80 m).

In addition to coralline algae other abundant macro algae include *Halimeda tuna*, *Lobophora variegata*, *Ventricaria ventricosa*, *Verdigelas peltata*, *Dictyota* sp., *Kallymenia* sp., and particularly striking fields of *Andaymonene menzeii*. The latter algae covers many hectares at densities of tens of individuals per square meter, constructing regions that appear like lettuce fields growing in the dusk at this depth on the sea floor.

The fishes of Pulley ridge comprise a mixture of shallow water and deep species sharing this unusual habitat. More than 60 species have been identified. Commercial species include *Epinephelus morio* (red grouper) and *Mycteroperca phenax* (scamp). Typical shallow-water tropical species include *Thalassoma bifasciatum* (bluehead), *Stegastes partitus* (bicolor damselfish), *Cephalopholis fulva* (coney), *Lachnolaimus maximus* (hogfish), *Pomacanthus paru* (French angelfish), and *Holacanthus tricolor* (rock beauty). The deepwater fauna is represented by *Chaetodon aya* (bank butterflyfish), *Sargocentron bullisi* (deepwater squirrelfish), *Bodianus pulchellus* (spotfin hogfish), *Pronotogrammus martinicensis* (roughtongue bass), and *Liopropoma eukrines* (wrasse bass). *Malacanthus plumieri* (sand tilefish) and several other species construct large burrows and mounds that serve as refuge for multiple species. Mounds and pits larger than $1m^2$ are apparent on side-scan sonar images and have been counted in excess of $200/km^2$ for parts of the ridge.

The extent of algal cover and abundance of herbivores suggest benthic productivity is moderate to high on parts of the ridge. Such productivity is unusual, if not unique at this depth in the Gulf of Mexico and Caribbean. Several factors help to account for the existence of this community. First, the underlying drowned barrier islands provided both elevated topography and lithified substrate for the hard bottom community that now occupies the southern ridge. Second, the region is dominated by the western edge of the Loop Current that brings relatively clear and warm water to the southern ridge. Third, the ridge is within the thermocline, a water mass that is known to provide nutrients during upwelling to shallow reefs in Florida.

Notwithstanding the positive factors for reef growth listed above, this largely photosynthetic community appears to be thriving on 1-2% (5-30 microEinsteins/m^2/sec) of the available surface light (PAR) and about 5% of the light typically available to shallow-water reefs (500 – 1000 microEinsteins/m^2/sec). The corals generally appear to be healthy, with no obvious evidence of coral bleaching or disease. Although the community is clearly one adapted to low light conditions, the variety and extent of photosynthetic organisms between 60 and 70 meters depth is impressive.

Is southern Pulley Ridge the US's deepest coral reef? That depends, of course, on one's preferred definition of a coral reef. There are deeper, ahermatypic coral buildups both in the Gulf of Mexico and Atlantic off Florida coasts. Classically, a coral reef is a wave resistant structure built by hermatypic corals and hazardous to shipping. From a geologist's point of view, Pulley Ridge corals appear to have built a biostrome, an accumulation at least a few meters thick, although corals may not account for the bulk of the topography. From that of a biologist, the most abundant corals in the ridge are hermatypic corals but they are lying, mostly unattached, on the surface. Clearly a ship's captain could not run his vessel aground on this reef, so mariners would not consider this a reef. Nevertheless, from the scientific perspective of a structure built from hermatypic corals, southern Pulley Ridge may well be the deepest coral reef in the United States.

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Environmental Indicators as Performance Measures in the Management of Coastal Ecosystems

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Environmental indicators have received an increasingly important role in communicating credible information about the status and trends in environmental conditions and sustainability of resources in coastal and marine waters. Indicators also serve as valuable performance measures for determining impacts of government programs designed to bate degradation of coastal ecosystems. The pressure-state-impact-response framework is proposed as a strategy to incorporate aspects of environmental decision making that is both scientifically sound and transparent in approach. The framework, including a suite of environmental and socio-economic indicators, is also suitable for establishing monitoring programs that are linked to coastal ecosystem management goals and objectives. It is recognized that time frame for implementing an environmental remedial strategy, for example, control of point source discharges or capping of contaminated sediments, can be very long. Depending on the spatial scale and severity of problem, and the cause-effect relationship between the stressor and its impact, ecosystem responses to such remedial measures occur at different temporal scales. In coastal water and estuaries, such responses many occur on the order of months, for example, significant reduction in biochemical oxygen demand, or decades, for example, lowered concentration of environmental persistent organic contaminants that strongly bind with the sediment, such as polychlorinated biphenyls.

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The Role of Invasive Plants in Restoring Fire to the Greater Everglades System

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Historically, fire was a critical component in the majority of the communities in south Florida. In the late 1950's a campaign to prevent large-scale fires was initiated and essentially suppressed natural fires from maintaining these communities. The 2050 Fire in the Everglades Working Group is using hydroperiods and fire regimes to broadly define the natural communities in South Florida. In the absence of fire, these communities changed from their natural character and may have succeeded into another community. This Working Group is examining the steps necessary to maintain these communities as they are today or, in some cases, restore these communities to their previous state using fire as one management tool.

The introduction of non-native species to these communities has altered: (1) community composition; (2) vegetation density; (3) fuel structure and loads; and, (4) soil composition. Models are being developed by this Working Group to address how invasive plants affect fire's role in the system and how restoration may still occur. When complete, these models can be applied to specific sites to assist managers with on-the-ground pyric restoration needs.

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Historic Conditions of Coastal Biscayne Bay and the Results of Anthropogenic Alterations on the Mangrove Ecosystem

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Historically, freshwater delivery to the Bay was sufficient to maintain freshwater marl producing prairies to within decimeters to a maximum of a few hundred meters from the shoreline. Mangroves dominated the shoreline and banks of tidal creeks. Presently, mangroves occupy almost the entire area west of the L-31E canal a distance between 600 and 1000m from the shoreline.

Fresh water historically reached Biscayne Bay by moving over or through the Miami Oolite Ridge. Four slough fed rivers in the north and numerous Transverse Glades in central and southern Dade County cut across the ridge to provide direct delivery to the bay. The Transverse Glades once unrestricted by the limestone ridge spread out into broad sloughs that turned into large tidal creeks near the Bay. Near and usually to the north of the mouths of these tidal creeks unique delta-like points frequently developed probably produced by prevailing energy conditions and extremely high organic production (mangrove peat) which were anchored by oyster shell deposits. Between deltas were coastal embayments differing in size and other physical characteristics. Many smaller tidal creeks produced and maintained by tidal action exist between large creeks.

Human intervention has lowered the system head by lowering Lake Okeechobee 6-10 ft, lowered levels in western Dade Co. by 4-6 ft (Parker, et. al., 1955) reducing available flow to the transverse glades. This means little flow makes it to the upper end of the transverse glade sloughs, and it also severely affects groundwater flow. Sloughs are now channelized and sheetflow is now controlled by structures. In addition, the L-31E canal and levee constructed in the 1960's eliminated freshwater discharge via the coastal wetland system. This resulted in extensive mangrove expansion, loss of the coastal estuarine zone and serious decline in export from the coastal wetland system.

Serial aerial photography and soil core analyses have documented this mangrove expansion; the infilling of abandoned tidal creeks, infilling of coastal basins with mangrove peats and permitted the estimation of the rates of expansion. Mangrove expansion rates were slow until 1940 when they picked up to 20-30cm/yr until 1965, when expansion rate increased to over 1m/yr.

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Distribution, Abundance, and Population Structure of a Broadly-Distributed Indicator Species, the Diamondback Terrapin (*Malaclemys terrapin*), in the Mangrove-Dominated Big Sable Creek Complex of Southwest FL, Everglades National Park

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Diamondback terrapins (*Malaclemys terrapin*) are long-lived turtles that exist as continuously distributed geographic populations along North America's Atlantic and Gulf coasts. Residing in salt marshes, mangroves, and tidal tributaries, the terrapin is the only North American turtle that lives exclusively in brackish water. One of the top predators of benthic macrofauna in the estuarine food chain, terrapins may play an important ecological role, and may thus be particularly suitable for monitoring as an indicator species. Additionally, the terrapin is a species of conservation concern. The historical harvest resulted in population crashes that, coupled with disappearing coastal wetlands, have greatly reduced the numbers of terrapins across their range.

Because the vital rates and population structure for terrapins are poorly understood, we initiated an in-depth mark-recapture study within the Big Sable Creek system of Everglades National Park, southwest FL. Short-term project goals are to characterize habitat use and movement patterns of individuals, and to estimate the size and geographic extent of the population. Long-term project goals are to compare the habitat use, demographic features and genetic profiles of selected Atlantic and Gulf coast populations of the species.

To date, we have conducted 3 weeklong sampling trips to the Big Sable Creek system to capture, mark, and recapture terrapins. Captures of terrapins have been concentrated in the upper reaches of creeks in the system. On each sampling trip, we surveyed the named creeks and their navigable branches systematically for terrapins at AM and PM low tides. We used dip nets to capture turtles, with new moon tides providing the best conditions for capture success.

Over the course of the first year of our mark-recapture study, we marked the first 50 terrapins in November 2001, an additional 96 individuals in June / July 2002, and 64 new turtles in December 2002. Thus far we have recorded 210 unique individuals of which 104 are females and 106 are males, for a population sex ratio of 1:1.

Recapture locations have been clustered around capture sites, suggesting that terrapins display extreme site fidelity, even across seasons—recapture locations are often only meters away from original capture sites. Our current recapture rate is 32.4%.

The summary recapture statistics together with the number of marked animals per sampling trip (Table 1) allow us to make initial estimates of population size.

Table 1. Mark-recapture summary statistics with Schnabel population estimate.

SAMPLING PERIOD	DATE	# MARKED	# RECAPTURED	SCHNABEL ESTIMATE
1	Nov. 2001	50	----	
2	June/July 2002	96	15	
3	Dec. 2002	64	53	N = 692

We used the Schnabel population estimator because it is appropriate for closed population studies with multiple mark and recapture periods. We assumed that every individual in the population has the same capture probability for a given sampling occasion, but that the capture probabilities can vary among sampling periods. We plan to update the population estimate after each of our next 2 sampling periods, scheduled for May and November 2003.

The Big Cape Sable terrapin population presently consists primarily of adult animals. Analysis of the age composition data revealed that 80% of females and 92% of males captured to date are in the adult life stage. We have recorded no females less than 5 years of age and no males less than 4 years of age, suggesting we have not encountered any juveniles during our surveys. Despite considerable and repeated efforts to sample as far up each creek as possible (to the limit of canoe penetration), we have not yet found young animals in the population.

We will continue to mark and recapture terrapins in the Big Sable Creek system throughout 2003. Additionally, we will study the movement of individual females by radiotracking 10 tagged individuals. We also hope to use satellite telemetry to better understand the movement of nesting females once they leave the Big Sable Creek system to find dry upland habitat suitable for egg-laying. Future analysis of microsatellites obtained from genetic samples will help to further define population structure and gene flow among individuals. In conjunction, these data will help to define the extent of a mangrove terrapin population and will delineate an ecologically and genetically relevant management unit for terrapin conservation.

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ATLSS Data Viewer: A Tool to Display and Analyze ATLSS Model Outputs

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Introduction

The ATLSS Data Viewer System (DVS) is an application developed to allow resource managers and scientists to display and analyze the outputs of some Across Trophic Level System Simulation (ATLSS) models.

ATLSS models

ATLSS is a set of models developed by the U.S. Geological Survey and other agencies to predict the responses of a suite of higher trophic level species to different alterations in the Everglades and Big Cypress (South Florida) hydrology regime. The goal is to help resource managers evaluate alternative restoration plans in comparison with no restoration efforts, and through this to aid development of appropriate monitoring and adaptive management schemes. The DVS allows the display of data from the following models: Hydrology, White-tailed Deer Breeding Potential Index, Cape Sable Seaside Sparrow Breeding Potential Index, Wading Birds Foraging Condition Index, American Alligator Production Index, and Snail Kite Index. The latest version of the DVS (2.0) also includes data from the ALFISH model. Except the Hydrology and the ALFISH, all other models are included in a subgroup of the ATLSS models called Spatially-Explicit Species Index (SESI), which allow the comparison of the relative potential for breeding and/or foraging across the landscape within-year dynamics of hydrology.

ATLSS data

SESI models produce a spatial distribution of indices (0 to 1 floating point values) representing environmental conditions during critical stages of the species. The outputs from the SESI models used in the DVS are annual averages representing a simulation between 1965 and 1995. The set of 31 annual grids is available for three different hydrologic conditions: the base 1995, the base 2050, and the alternative D13R. The DVS allows the comparison of alternative conditions for the same or different time periods selected inside the 31 years. The Hydrology model generates spatial distributions of annual hydroperiods (days of inundation) while the ALFISH model generates monthly data (#fish/sqm), both for the same three alternative hydrologic scenarios. ALFISH model produces 5 monthly datasets for each of the 31 years simulation period: Feb, Apr, Jul, Oct, Dec.

ATLSS DVS

ATLSS models generate a large amount of data, and the data are in a format that is often difficult to manage in PC-based applications. Furthermore, the data need analysis through functionality that commercial GIS software does not provide in standard tool sets. The USGS National Wetlands Research Center has developed a customized ArcView 3.2-based project in which the standard graphical interface and functions have been enhanced (see fig.1) to perform visualization and analysis tasks specifically designed for ATLSS data.

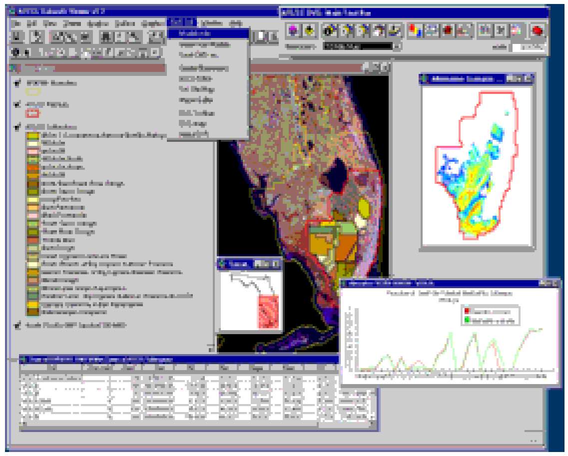

Fig.1 Graphical User Interface

ATLSS DVS allows users to:

1) Convert binary raster files, as they are generated from the ATLSS models, to ESRI-grids, which is the spatial format used by the system for visualization and analysis.
2) Process the model outputs by user-defined time periods and compare alternative hydrologic scenarios.
3) Analyze the result of processing model outputs and extract zonal statistics, such as mean index values or variances by user-defined zones of interest.
4) Generate exportable tables, line graphs, and maps representing the result of analyzing ATLSS model data.
5) Integrate base maps pertaining to particular project areas selected from a customizable list of layers.

DVS 2.0

The version 2.0 of the ATLSS DVS contains enhancement of the graphical interface and the expansion of functionalities to allow users to display and process ALFISH data.

1) The toolbar has been simplified by grouping some of the management tools in a "toolbox" dialog window.
2) ATLSS runs can be imported as monthly or even daily datasets inside the 31 years of simulation.
3) User-defined geographic coordinates, UTM, decimal degrees, or degree, minute, seconds, can be imported from an Excel worksheet and used to create a point theme. This theme may be used to extract cell values from model outputs and perform correlation analysis with empirical data collected for the same points.
4) Zonal means can be extracted from the model outputs and organized in an HTML page. These values may be used to detect correlations between model outputs and empirical data collected over the same areas.

Future directions

The ATLSS DVS will be expanded to include outputs from other ATLSS models, i.e. snail kite individual-based model, fish dynamics model, and SIMSPAR Cape Sable sparrow model. An ATLSS DVS Web site will also be developed to:

1) Provide details about the project, the application, contacts, and technical resources related to the ATLSS DVS;
2) Provide an on-line discussion forum where information, ideas, and suggestions on using the DVS can be posted;
3) Provide a support center for DVS users for technical information, current issues, and downloads of data and applications.

Component of the Web site will also be an on-line mapping system which will allow visitors to navigate base maps and model outputs and retrieve and display tabular information associated with spatial locations.

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Characterization of Solute and Fine-Particle Transport in Shark Slough, Everglades National Park by a Tracer Release in the FIU *In Situ* Flumes

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Experiments that introduce dissolved or particulate tracers into flowing water are useful to characterize rates of material movement and mixing. Parameters determined from tracer experiments, such as advection and dispersion, are especially needed in models that simulate the effects of flow and mass transport on biogeochemical reactions and water quality. Presently, there are few data or guidelines available to understand mechanisms that control transport of materials with flowing water in the Everglades. Recently, a group of USGS and university researchers conducted a tracer experiment in central Shark Slough at one of the FIU phosphorus dosing flume facilities. Each flume consists of 4 side-by-side channels, each enclosing a 3-m wide by 100-m long flow-way oriented with the natural direction of surface-water flow. More about flume design and results of the low-level phosphorus dosing can be found at several FIU websites (http://www.fiu.edu/~ecosyst/index.htm).

This abstract provides a brief description of a tracer experiment conducted from November 20-22, 2002 in flume A. The purpose of the experiment was to characterize transport of both solutes and fine-particles in Shark Slough, including surface-water exchange with subsurface water in the floc and underlying peat. The experiment was conducted in the westernmost channel of flume A. That channel receives the ‘middle’ level of phosphorus dosing being applied to determine the effects of added phosphorus on the Everglades ecosystem. At the time of the experiment, visible differences in macrophyte density were not apparent in the experimental channel when compared with areas immediately outside the flume. The depth of surface water was approximately 60 cm at the time of the tracer test and the location of the injection was 0.75-m upgradient of the 0-m reference point in the channel, which is the location where the ‘mixing’ reach for phosphorus dosing ends and the front edge of vegetation begins. The experiment consisted of a constant-rate injection for 22 hours of a sodium bromide (NaBr) solution made up in 0.2-:m filtered Everglades water. The injection was accomplished using two metering pumps to deliver the tracer; dividing the flow between four soaker hoses (2.65-m long) stationed horizontally across the channels at evenly spaced depths. After termination of the NaBr injection, fine particles composed of titanium dioxide (TiO_2) were injected into the flume for a period of six hours. The TiO_2, which has a density of 3.9 g/cm^3, was suspended in filtered Everglades surface water by stirring and delivered by metered injection through a single slotted tube, oriented horizontally and positioned at a depth of 30 cm. Sampling for the tracers began before the start of the NaBr injection and lasted for 48 hours. Concentrations of both dissolved and particulate tracers were monitored at four stations at distances of 6.8, 26, 43, and 86m down the channel from the injection site. At each monitoring station, small-volume (20-ml) water samples were repeatedly collected by suction at seven discrete points, which characterized horizontal and vertical variability in tracer distribution across the channel. In addition to sampling surface water, porewater was sampled at two locations at a distance of 6.3 m downstream from the injection site. Analysis of bromide concentration in each sample is being conducted by ion chromatography, while concentrations of TiO_2 particles are being determined by inductively coupled plasma-atomic emission spectrometry following acid digestion of the particles.

Results from the experiment are not available at this time, due to the limited number of analyses completed. A full presentation of findings will be prepared upon completion of the sample processing and simulation modeling. In addition to providing fundamental information about transport processes in the Everglades, the expectation is that results can be combined with complementary data to better characterize rates of biogeochemical reactions in the Everglades. Parameters describing solute and particle transport will also be available as inputs for the water-quality and landscape-process models that are currently guiding restoration planning in the Everglades.

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Significance of Microtopography as a Control on Surface-Water Flow in Wetlands

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Microtopography rarely has been considered in wetland surface-water flow models, even though the ground surface often undulates significantly. We define microtopography as topographic variations in the wetland occurring at a small spatial scale (1-m or less) between hummocks and depressions, as well as an intermediate spatial scale (tens or hundreds of meters) between the tops of ridges and the bottom of nearby sloughs. To our knowledge, no previous model of surface-water flow in the Everglades has considered how microtopography (1) decreases the cross-sectional area available for flow at low water levels, (2) increases surface-water exchange with sediment porewater, and (3) increases flow resistance due to flow over and around microtopographic features.

The goal of the present project was to expand on the concepts and modeling of Hammer and Kadlec (1986) and Kadlec (1990) by developing a governing equation that more explicitly isolates the effects of microtopography on surface-water flow in wetlands,

$$f_w \cdot S_s \cdot \frac{\partial h}{\partial t} + \left(1 - f_w\right) \cdot S_y \cdot \frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left(f_w \cdot K_f \cdot d^{\beta+1} \cdot \frac{\partial h}{\partial x}\right) + (P - ET + GW_i\,), \qquad (1)$$

where f_w is the fraction of free surface water normal to flow (a function of water level and microtopographic distribution), S_s is the surface-water storage coefficient, h is the surface-water elevation, S_y is the specific yield of the wetland sediments (i.e. subsurface-water storage coefficient), K_f is the flow conductance, d is the surface-water depth, β is the exponent on depth, P is precipitation, ET is evapotranspiration, and GW_i is ground-water inflow.

A schematic of Everglades topography (fig. 1) illustrates how the cross-sectional area available for surface-water flow is dependent on the microtopographic distribution as well as on surface-water stage. According to Harvey and others (this volume), the ground-surface elevation in Water Conservation Area 2A (WCA-2A) (fig. 2) varies as much as 0.4 meters vertically over a horizontal distance of 100 meters, which is one third of the typical vertical fluctuation in surface-water depth (1.2 m) in that part of the Everglades. Variability in topography and surface-water depth at WCA-2A makes this an ideal location for testing a model of the effects of microtopography on surface-water flow.

Three different models were applied and compared by selectively combining three effects of microtopography on surface-water flow. Model 1 was the base model simulation, which did not incorporate any of the effects of microtopography. Model 2 included the effects of microtopography on cross-sectional area of surface flow, and surface and porewater exchange. Model 3 included the depth-dependent influence of microtopography on flow resistance in addition to those considered by model 2. All three models used daily water levels measured by South Florida Water Management District at sites F1, F4 and U3 in WCA-2A and field measurements of f_w, d, S_s, S_y, P, ET, and GW_i. The two reaches that were modeled (F1-F4 and F4-U3) differed mainly in their vegetative characteristics (fig. 2). The inverse modeling program, UCODE (http://www.usgs.gov/software/ ucode.html), was used to objectively estimate the optimal values for K_f, and β for each model (table 1).

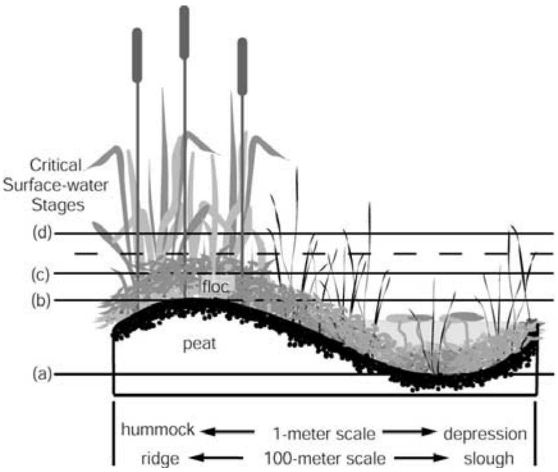

Figure 1: Schematic of wetland topography showing change in cross-sectional area for surface-water flow for "critical" surface-water stages.

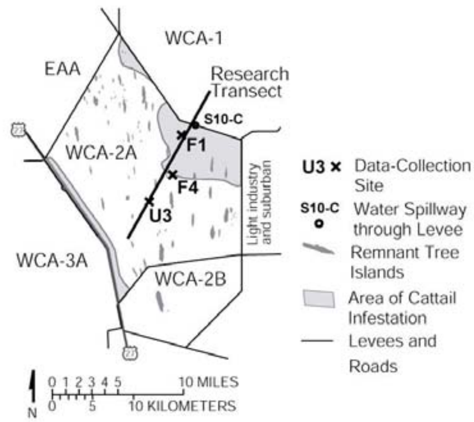

Figure 2. Water Conservation Area 2A, central Everglades, south Florida.

Table 1. Optimized flow parameters (K_f, β) for models 1, 2, and 3 as determined from inverse modeling. Notes: Model 3 parameters vary with critical stage (see fig. 1), Parameters vary linearly for depth ranges (c) to (d) and (a) to (b).

	Reach 1 (F1 to F4)		**Reach 2 (F4 to U3)**	
	K_f (m/d/m$^{\beta-1}$)	β	K_f (m/d/m$^{\beta-1}$)	β
Model 1	1.8×10^7	0.60	4.7×10^7	0.64
Model 2	3.4×10^7	0.41	8.9×10^7	0.16
Model 3				
Stages greater than (d)	2.5×10^7	0.39	5.6×10^7	0.56
Stages (c) to (b)	8.2×10^6	0.46	5.6×10^7	0.56
Stages less than (a)	0.98	0.00	0.98	0.00

Surface-water flow simulations from model 2 showed a 15 percent improvement of the Root Mean Squared Error (RMSE) over the model 1 results, demonstrating that consideration of the effect of microtopography on flow cross-sectional area and storage-exchange improves the accuracy of the surface-water flow model (fig. 3). We observed additional improvements in the model 3 simulation (40 percent decrease in RMSE from that of model 1) through incorporating stage-dependence in the flow parameters, K_f and β. The stage-dependent parameters were determined from separate inverse modeling runs of the low-stage period (first 45 days, fig. 3) and the high-stage period (remaining 65 days, fig. 3). Flow parameters in model 3 are varied according to the critical stages defined by field measurements of microtopography at sites F1 and U3 in WCA-2A (fig. 1).

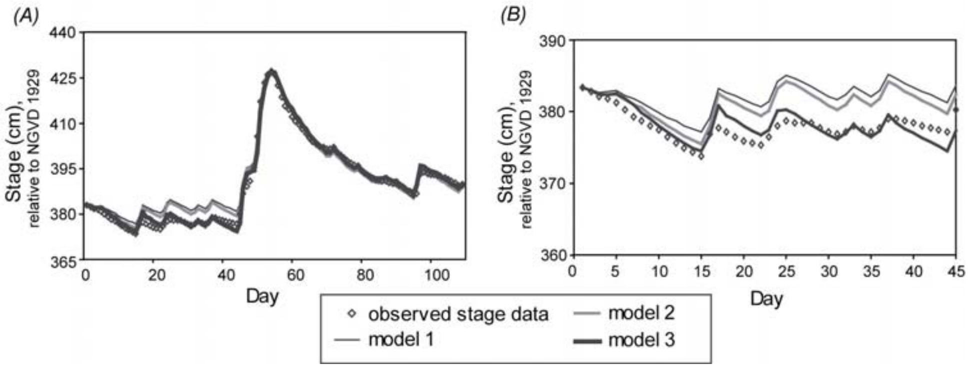

Figure 3: Comparison of simulation results from models 1, 2, and 3 at site F4 for the entire modeling period *(A)* and the low-stage modeling period *(B)*.

Results of this study indicate that microtopography is a significant control on surface-water flow in the Everglades, especially when the surface-water elevation declines to depths that begin to expose microtopographic highs. Our current modeling effort focuses on objectively determining the critical stages that affect stage-dependence in flow parameters through inverse modeling.

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An Ecological Risk Assessment of the Effects of the Everglades Restoration Project and Climate Variability on Biological Endpoints of Biscayne Bay and Everglades Ecosystems

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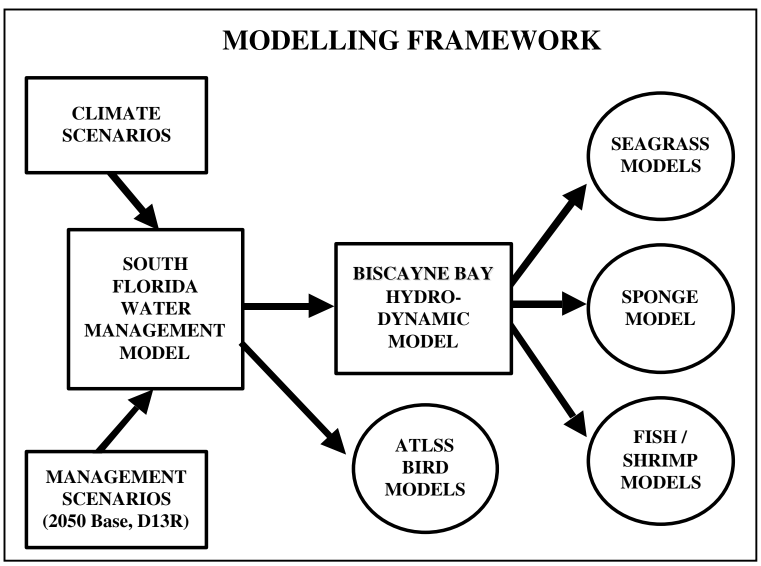
A series of presentations will be made on a multidisciplinary project led by the Center for Marine and Environmental Analyses (CMEA) at the University of Miami, with collaboration by the South Florida Water Management District and the USGS, that was conducted to evaluate potential effects of changes in precipitation and freshwater deliveries caused by climate change and by the Comprehensive Everglades Restoration Plan (CERP) on ecological systems of the South Florida landscape. A suite of linked simulation models were developed to simulate and evaluate potential impacts on: a) the regional surface and groundwater hydrology; b) the abundance and distribution of wading birds within the Florida Everglades; c) freshwater inputs into Biscayne Bay and associated salinity fields; d) seagrass and hardbottom community productivity and distribution; and e) population dynamics and stock abundance of estuarine fish. In a final step, the potential impacts of these changes on the regional economy will be evaluated by using economics models to estimate the value of changes in fisheries stock abundance to recreational users.



The hydrology of South Florida is controlled by an extensive system of canals, levies, and water control structures that regulate freshwater flows across the landscape. Direct links were created from outputs of the hydrological model, the South Florida Water Management Model (SFWMM) developed by the SFWMD to describe overland and groundwater flow dynamics for the region, and the Biscayne Bay hydrodynamic model, developed at CMEA. Similarly, the Biscayne Bay hydrodynamic model was linked to a series of ecological models developed at CMEA that describe the population dynamics of segrasses, sponges, and fisheries resources. In addition, the outputs from the SFWMM were used as inputs to the Across-Trophic Level System Simulation, developed by USGS, to simulate effects on the long-legged and short-legged wading birds of the Everglades. The seamless modeling framework developed with the support of NOAA Coastal

Ocean Program and the US EPA's Global Change Research Program enables us to simulate directly the effects of water management scenarios as well as different climate change scenarios on the hydrology of South Florida, and to evaluate the potential effects of these scenarios on important ecological and economic endpoints of Biscayne Bay and the Everglades.

The basis for our approach was the ecological risk assessment framework developed for the US EPA. A scenario-consequence analysis approach was used, in which paired scenarios were developed to characterize the effects on selected ecological endpoints from changes in precipitation caused by climate variability, from implementation of the CERP project, or from both. Our assessment was conducted as a sensitivity analysis where a realistic, plausible range of climatic conditions was explicitly simulated and tested. The following simulation scenarios were developed using historical precipitation and temperature data, based on the 1965-1995 record available for South Florida, modified by a set of global climate change scenarios developed at a climate change scenario workshop:

- 2050 BASE / D13R (CERP water management scenario, no climate change)
- 2050 BASE / D13R and 25% increase in rainfall (CERP plus climate change)
- 2050 BASE / D13R and 25% decrease in rainfall (CERP plus climate change)
- 2050 BASE / D13R and 2 ° C increase (CERP plus climate change)

Precipitation values were changed uniformly within each cell of the SFWMM. Similarly, the temperature scenario was used to modify the ET values of each cell. The output from the SFWMM, expressed as daily freshwater flows into Biscayne Bay from canal, overland, and groundwater sources, provided input for the Biscayne Bay hydrodynamic model. The hydrodynamic model provided input, expressed as daily salinity values, for the SEASCAPE model of benthic communities of Biscayne Bay. A Fish Trophodynamics Model, a spatial age structured predator-prey model, was also developed to assess seatrout (*Cynoscion nebulosus*) population risks from exploitation and environmental changes. The SEASCAPE model (100,000 grid cells, 100 x 100 m) was used to simulate the impacts of the scenarios on seagrasses and sponges of Biscayne Bay. Lastly, the impacts of the scenarios were simulated by predicting habitat suitability for wading birds across the Everglades landscape using the ATLSS model.

The results from the simulations indicate that interannual variability in precipitation is a dominant driver in South Florida, significantly affecting many of the ecological endpoints for Biscayne Bay and the Everglades. The potential reduction in precipitation from climate change could have as significant an effect on the ecosystems as the present difference between very wet and very dry years. The risk assessment of the CERP restoration scenario indicates that the incremental effects of implementing CERP would be significantly less than present interannual variability; however, the implementation of CERP would significantly reduce the adverse ecological effects of dry years.

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An Assessment of Mercury Exposure for Multiple Trophic Levels in the Greater Everglades Ecosystem

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The Everglades ecosystem comprised of peat soils and wetlands, is very sensitive to the accumulation of environmental contaminants. Scientists and managers are concerned that mercury is the most serious environmental threat to the health of aquatic and terrestrial resources. Although, studies have identified mercury in top predators of this ecosystem the extent of mercury distribution across trophic levels and potential adverse effects on wildlife inhabiting this ecosystem is unknown. The primary goals of the Everglades task force for restoration include the delivery of adequate amounts of quality water to protect and sustain the natural environment. However, restoration planning has not considered or evaluated the resulting potential exposures to wildlife and the adverse effects of restoration activities on contaminant distributions and subsequent wildlife exposures. The objective of this study was to evaluate mercury exposures for biota within the aquatic ecosystem of south Florida. For these analyses, largemouth bass (n=5 per site) and alligators (n=10 per site) were captured from 23 areas critical to the South Florida Restoration and analyzed for total Hg. All solid tissues were weighed and analyzed (i.e., without acid digestion) for Hg using combustion atomic absorption spectrometry with gold amalgamation (Milestone Inc., Monroe, CT). The mean Hg content in bass muscle contained levels as high as 4024.5 µg/Kg wet wt. Hg concentrations in most alligator livers contained levels above the 4700 µg/Kg calibration limit of this analytical method. Documentation of Hg exposure for biota within the aquatic ecosystem of south Florida will serve as a critical component for future assessment of risks, the goal of which will be prevention of adverse effects on wildlife within the Greater Everglades Ecosystem.

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Environmental Fluctuation and Population Dynamics of Two Species of Freshwater Crayfish (*Procambarus* spp.) in the Florida Everglades

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Much effort has been directed by theoreticians to determine the response of species to environmental fluctuations by treating the physical environment as an unpredictable or stochastic factor. Applied ecologists have increasingly sought to understand and even replicate the periodicity of natural environmental fluctuation as a management tool to attain or restore "natural" ecological regimes. Thus, understanding the role of environmental fluctuation in promoting species coexistence, or facilitating the dominance of a single species, has gained additional urgency in natural resource management. Two species of crayfish have been identified from the freshwater habitats of the Everglades, the Everglades crayfish (*Procambarus alleni*) and slough crayfish (*P. fallax*). Crayfish burrow in periodic environments, and this behavior may provide a mechanism for persistence in dry periods. Everglades crayfish typically burrow during the dry season, and they have been collected from burrows throughout their range. Slough crayfish on the other hand have been captured largely from flooded habitats. The population dynamics of each species may therefore be uniquely affected by hydrology. Hendrix and Loftus (2000) found that species composition was a function of flooding duration in both spatial and temporal domains. Yet, the mechanisms responsible for these observations are unknown. Using field samples and a mesocosm experiment, we investigated how drought frequency affected mortality and recruitment rates of two coexisting crayfish species, and how these mechanisms shaped patterns of their density and relative abundance in the Everglades.

The time series data were obtained from crayfish collected at a short (site 50, inundated < 180 days per year), a long (site 06, inundated approximately 360 days per year) and an intermediate hydroperiod site (site 23 affected by shifts in hydromanagement in the 1950's) between 1985 and 1998. Species relative abundance was calculated from adult males and regressed against the number of years since drought (fig 1). Everglades crayfish were the dominant species soon after drought events (species ratio < 0.5), whereas slough crayfish were dominant at relatively longer times since drought. Crayfish relative abundance responded differently to flooding at each site. Namely, site 50 shifted from Everglades crayfish-dominated to slough crayfish-dominated communities quicker than the other two sites as the years since a drought increased.

To examine the effect of drought on each species, we simulated a two-week dry-down event in mesocosm tanks. Each tank received six crayfish of a single species, which approximated average field densities of 1.91 m^{-2}. Tanks were checked three times weekly to measure water depth, feed crayfish dry commercial crustacean pellet food, estimate number of burrows, and collect mortalities. In mesocosm tanks, both species had higher survival in flooded tanks than in simulated drought events. Results of the experiment also suggested that relative survival was higher for slough crayfish in wet treatments, whereas survival of Everglades crayfish was higher in dry treatments. Everglades crayfish constructed more burrows in both treatments than slough crayfish.

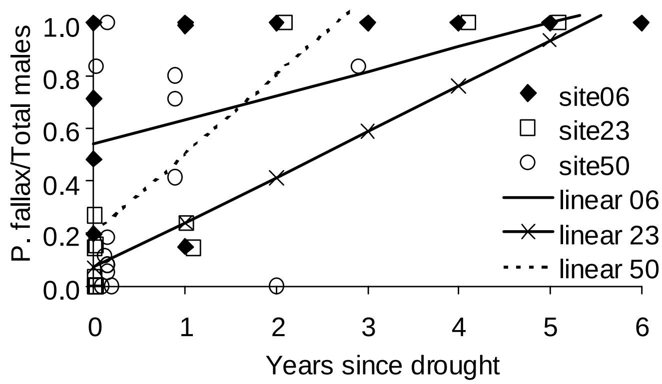

Figure 1. Species composition (slough crayfish males/total males) as a function of years since drought for sites 6, 23, and 50. Site 6 had the fewest drought events (N = 3), site 23 was intermediate (N = 5), and site 50 had the most droughts (N = 9) in a14-year time series from 1985-1998. Lines were fitted using logistic regression.

We estimated stock recruitment relationships for each species by examining the log –log relationship between adults and juveniles in wet (flooded for the duration of the calendar year) and dry (dry at least three days) years. Everglades crayfish recruitment was affected by the hydrologic conditions in the spawning year (best fit model includes a greater intercept term for dry than wet years, fig. 2). Conversely, slough crayfish recruitment was not affected by wet versus dry year types (the best model to describe the slough crayfish stock-recruitment relationship had a common intercept for both years, fig. 2). Both models had a common slope. The log-log linear model used here was a log-transformed Ricker recruitment function. The intercept term was associated with the slope of the Ricker function near the origin, thus larger intercept terms had steeper slopes and higher recruitment at low densities of adults. Everglades crayfish had higher recruitment at low densities in dry years than slough crayfish, however recruitment at low densities was similar for both species in wet years. The slope term of this log-log linear model is the stock density at which recruitment is maximized. The slope of the slough crayfish stock-recruitment relationship was higher than the Everglades crayfish model (fig. 2), indicating that maximum recruitment may occur at higher adult densities for the slough crayfish.

Species coexistence may be facilitated by disturbance in some ecosystems. Two species with different, but overlapping, environmental tolerances may coexist when conditions regularly fluctuate through the optima of both taxa. In the Florida Everglades, two species of procambarid crayfish coexist and we investigated how their population dynamics were affected by drought frequency. Crayfish relative abundance was determined by local hydrological conditions. Everglades crayfish (Cambaridae; *Procambarus alleni*) were dominant when droughts were frequent, whereas slough crayfish (*P. fallax*) dominated when droughts were infrequent. Differential tolerances to drought frequency were manifested in species-specific vital rates. Everglades crayfish population dynamics were limited by low recruitment in flooded years, whereas slough crayfish population dynamics were regulated by low rates of survival through droughts as short as two weeks. Because the crayfish assemblage of the Florida Everglades is sensitive to drought frequency, hydromanagement of the region can alter species relative abundance.

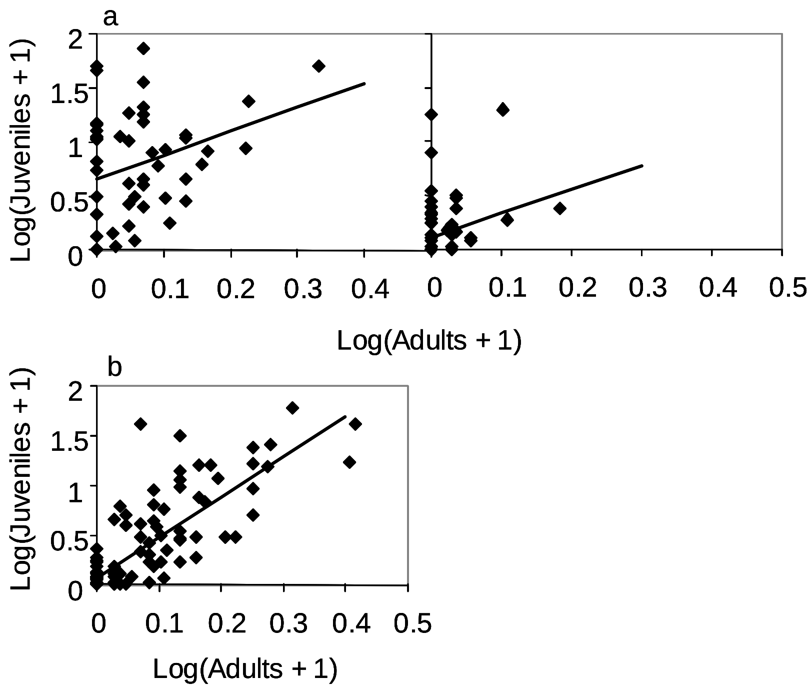

Figure 2. (a) Everglades crayfish stock-recruitment relationship. The estimated density of juveniles was analyzed in both wet and dry years. The best-fit model had similar slopes for wet and dry years, but significantly different intercept terms. (b) Slough crayfish stock-recruitment relationship. The estimated density of juveniles was analyzed in both wet and dry years. The best-fit model had a common slope for wet and dry years, and a common intercept term.

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The South Florida Information Access (SOFIA) Website -- http://sofia.usgs.gov/

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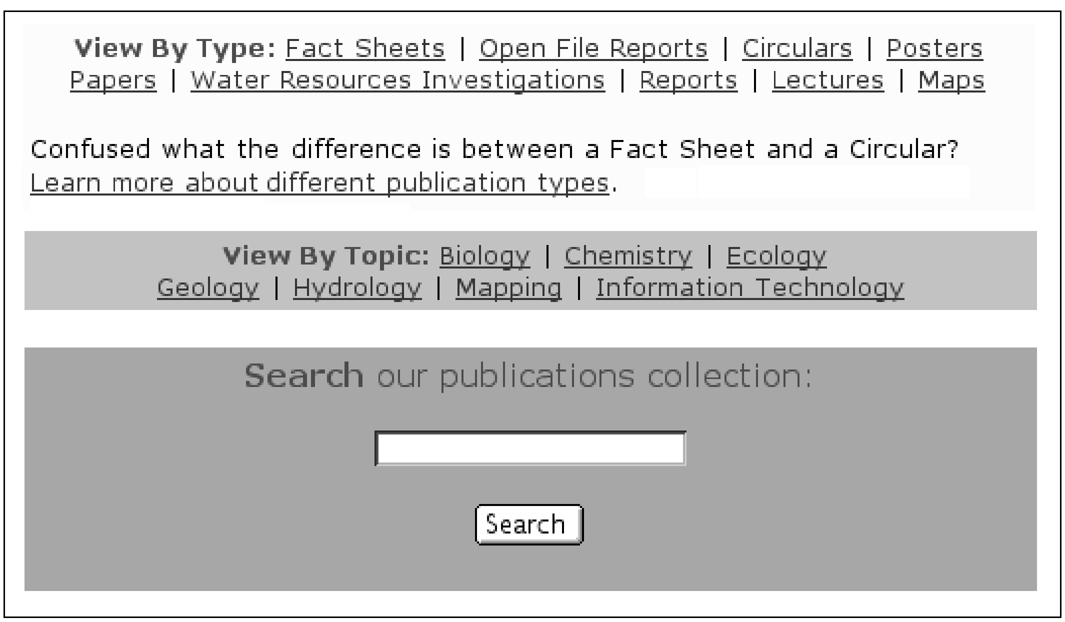
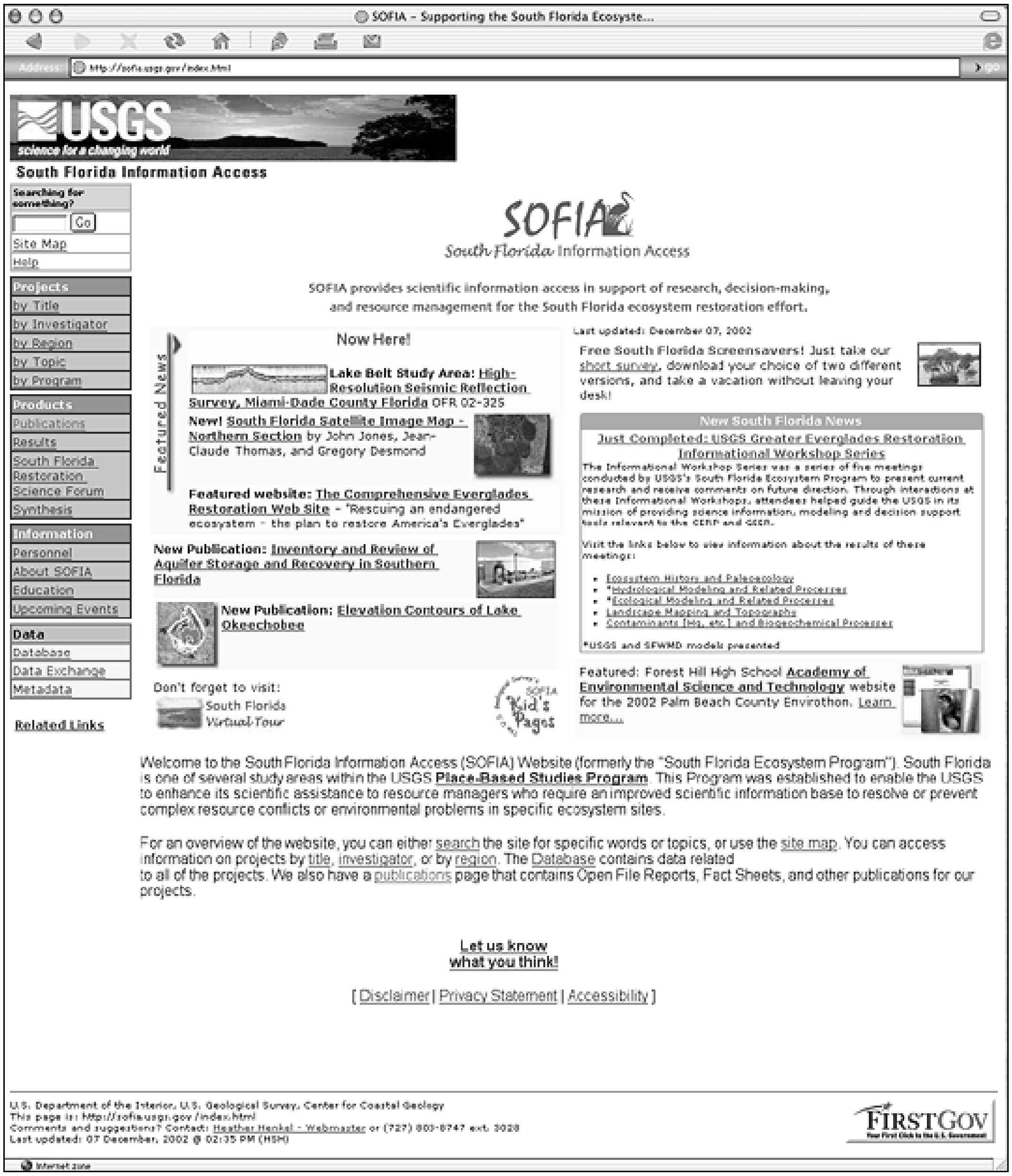
The south Florida ecosystem, encompassing the Kissimmee River Valley, Everglades, Florida Bay, urban areas, developed agricultural areas, rangelands, and wetlands, has been altered greatly over the past 100 years. Resource managers, Federal, State, and local agencies, and other groups are seeking to reverse environmentally damaging actions taken during that period. The U. S. Geological Survey (USGS) began a research program in support of the restoration of the Everglades and South Florida ecosystem in 1995. USGS personnel have been conducting research projects designed to provide sound scientific information upon which resource managers can base their decisions. The USGS also has recognized the need for a central site to provide all interested parties with information from this research and access to these data. The South Florida Information Access web site (SOFIA) was created as a 'one-stop-shopping' access point for research on South Florida. All USGS South Florida Place-Based Studies research projects, ranging from mercury contamination in the Everglades to coral reef decline, are online at this site. The site provides project descriptions, proposals, publications, data (through our data exchange site), presentations, and contact information, as well as general interest items, such as photographs and posters. The SOFIA site also is a portal through which you can access our extensive database and internet map server (IMS).

The SOFIA site has grown tremendously since it's initial development in 1996. The site increased from fewer than 100 pages in 1996 to over 3600 webpages in 2002. The site also contains over 250 publications: circulars, fact sheets, open file reports, lectures, papers, posters, and reports. Included are not only publications created by the south Florida program, but historical documents dating to the early 1970's as well. This effort involves locating and digitally scanning historical documents from all disciplines. By 2003 we will have an extended search interface to our publications that will allow users to customize their searches based on a variety of parameters.



SOFIA's current publications interface (2002).

Within the last year, we have enhanced our data exchange site and added new sections to the site, including the ability to view projects by topic, region, scientists or program. The data exchange site includes a variety of data, including hydrology, biology, ecology, mapping, and chemistry. We also maintain a robust metadata collection that is FGDC-compliant and acts as a member-node of the National Spatial Data Infrastructure (NSDI).



South Florida Information Access (SOFIA) homepage.

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The Effect of Water Velocity on Periphyton Taxonomic Composition of Experimental Mesocosms Receiving Water from Stormwater Treatment Areas

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Extensive anthropogenic alterations of the natural hydrology and water quality of central and southern Florida began more than a century ago, continuing most intensively within the past fifty years. The resulting hydrologic changes and increased nutrient loading, in particular phosphorus, have been associated with many observed ecological changes in the Everglades ecosystem including changes in periphyton community composition. The abundant calcareous (calcium-precipitating) periphyton mats typically dominated by blue-green algae and diatoms have been replaced in many areas by assemblages dominated by eutrophic cyanobacteria and filamentous green algae. This is of concern to restoration ecologists because of the essential role that the historic oligotrophic periphyton assemblages play in ecosystem processes. Numerous studies have shown that the structure and composition of periphyton communities in freshwater systems are extremely sensitive to phosphorus availability and enrichment as well as changes in water chemistry, temperature, concentrations of other nutrients and ions, substrate, hydroperiod, water depth, and water velocity. The Everglades periphyton community has been well studied with regard to most of these variables however, research examining the relationship of water velocity to taxonomic composition and P uptake in the Everglades is lacking.

The Comprehensive Everglades Ecosystem Restoration Plan includes the construction of over 16,000 ha of wetlands called Storm Water Treatment Areas (STAs). The STAs are designed to filter nutrient-loaded urban and agricultural effluent before it is discharged into natural areas. Several experiments are currently underway to determine the effects of different hydraulic loading rates, hydraulic retention times and water depths on STA performance. However, the effects of different velocities on phosphorus uptake and algal taxonomic composition in this system have not been evaluated.

Studies dating back to the 1960’s suggest that the rate of phosphorus uptake by freshwater algae is influenced by the rate of metabolic activity of a particular algal species and that species thus exhibit a differential uptake response based on current velocity. This species specific difference in nutrient uptake documented in other freshwater systems should hold true for the Everglades periphyton communities as well and should be reflected in taxonomic differences observed at different flow rates. The objective of this research is to investigate the effects of water velocity on the taxonomic composition of periphyton communities colonizing artificial freshwater mesocosms constructed within STA-1W. Several metrics including periphyton relative abundance and generic diversity, water column total phosphorus, pH and temperature, and dry weight biomass are being quantified during the course of the research.

Twenty-four experimental Plexiglas boxes measuring 1.22 m x 2.44 m x 0.31 m were installed at the outlet end of STA-1W. A pump station delivered water from the outlet canal of the STA to the study site. A total of 6 mesocosm units of equal size were created by connecting a set of 4 boxes together to form one flow-through treatment unit. These six units were comprised of 3 replications of a slow velocity treatment design and 3 replications of a fast velocity treatment design. This design, along with controlled water inlet volume, ensured an order of magnitude difference in channel velocity between the fast (approximately 2.0 cm s^{-1}) and slow (0.22 cm s^{-1})

treatments. These rates are achievable in an artificial treatment wetland such as an STA. The hydraulic loading rate, hydraulic retention time and colonizing surface were equal between treatments and replications, with the water flow rate being the single treatment variable.

A set of Plexiglas periphytometers was installed in each of the twenty-four treatment boxes on March 27, 2002. Samplers were located within boxes in such a way as to capture inlet, outlet and mid-treatment path taxonomic composition. A series of 6 sequential collections of the samplers was conducted over a 12-week period. A comparative analysis of generic taxonomic differences is being performed on composite sub-samples from both within and between fast and slow treatments, comprising a total of 12 sub-samples from each of 5 collection periods for a total of 60 samples. Species richness, relative abundance and taxonomic composition of sampled periphyton assemblages is being assessed by identifying and enumerating both diatoms and soft-bodied algae separately and computing metrics of interest using the natural unit or valve counts from a known volume of sub-sample. Microscopic analysis at 1000x magnification is being conducted using a compound light microscope with a blue filter, bright field illumination, epi-fluorescence and DIC (Nomarski) optics. Elucidation of algal indicator taxa for each velocity treatment will be attempted after statistical analysis. Preliminary analyses have documented approximately 70 genera in the fast treatment and 75 genera in the slow treatment with an approximate similarity of 85 percent. Concurrent sampling by co-researchers included collection of water and algal samples for analysis of TP, SRP, TKN, alkaline phosphatase, and dry weight (biomass).

The documented relationship between the ecology of the Everglades periphyton communities and P enrichment suggests that periphyton may provide a reliable measure of the phosphorus bioavailability and assimilative capacity of this wetland ecosystem. Studying the effects of water velocity on periphyton characteristics such as species abundance and composition, biomass, and P uptake should provide data that can be used to optimize STA design and establish greater nutrient removal efficiency of these treatment technologies. This optimization will contribute to achieving final post-treatment discharge concentrations of water-column total phosphorus that meet restoration goals and compliance with the Everglades Forever Act of 1994.

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Integration of Science and Engineering with Federal and State Policies and Regulations, and Public Opinion in Planning for the Lake Okeechobee Watershed Project, Comprehensive Everglades Restoration Program

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HDR Engineering, Inc.

The challenge that must be successfully addressed during the planning of the Lake Okeechobee Watershed (LOW) Project is the application of the best available science and engineering to a process that must:

- Comply with Federal and state policies and regulations; and
- Recognize social/political values.

This challenge is being met through a process that utilizes broad participation from a large interagency team and development of evaluation criteria that are based on the best available science and engineering.

The LOW Project consists of four of the sixty-plus components that collectively compose the Comprehensive Everglades Restoration Program (CERP). The purposes of the LOW Project are to capture and store stormwater runoff from the northern Lake Okeechobee Watershed and to reduce the total phosphorus loads to the lake to protect and enhance the ecologic values of Lake Okeechobee and downstream water bodies.

Similar to all CERP Projects, the LOW Project planning process is lead by the Project Delivery Team (PDT). The LOW PDT is composed of approximately 60 individuals from 5 Federal agencies, 4 state agencies, 2 county governments, and one Native American Tribe. The current role of the PDT is to identify and generate information that is required for sound decision-making in the planning process. Each individual member of the PDT represents their respective agency with a specific area of technical expertise and/or knowledge of agency policies and regulations.

Active participation by the PDT members, in addition to a proactive public outreach program, is helping to minimize the probability of significant issues arising late in the planning process. The goals are to avoid significant schedule delays associated with unresolved issues and to build broad project support during the planning process. The approach being utilized by the LOW Project consists of the following components:

- Monthly meetings are conducted for the purposes of reviewing project progress, discussing planned methodologies for upcoming activities, and obtaining PDT comments on draft work products.
- PDT reviews are conducted on an iterative basis with a single product sometimes undergoing three (or more) reviews before it is finalized. Major project deliverables are subdivided into smaller work products so the PDT has increased involvement on an ongoing basis.

- Technical subteams have been formed to address specific technical project issues. Input and guidance from those subteams is incorporated into the draft and final work products that are reviewed by the entire PDT.
- Active involvement by participating agencies is solicited whenever practicable. Several agencies have agreed to develop major work products that are required for the project. The US Geological Survey, US Fish and Wildlife Service, and Florida Department of Environmental Protection are each supporting major activities required for the project.

This approach does not come easy -- it requires intensive planning and coordination. The numerous reviews and iterations add significant time requirements. However, this investment of effort and time will be more than offset during the review and approval process for the PIR.

The Lake Okeechobee Watershed (LOW) Project is in the planning phase. The major elements of the project planning process are consistent with the Corps Planning Process and include: 1) identification of problems and opportunities, 2) identification of Future Without Project Condition, 3) development of evaluation criteria, 4) identification of alternative plans, 5) evaluation of alternative plans, and 6) comparison of alternative plans and selection of the recommended plan. A project implementation report (PIR) will document the planning process and will be integrated with an Environmental Impact Statement (in compliance with the National Environmental Policy Act (NEPA). Following completion and approval of the PIR, detailed design and land acquisition will lead to construction.

Initial identification of problems and opportunities was performed for the LOW Project during the project planning process that developed the CERP. Early work in the LOW Project has focused on compiling a list of issues that should be considered in the planning process. The issues were linked to evaluation criteria to be used to compare alternative plans. Development of evaluation criteria was performed in conjunction with the scoping process that is required by NEPA and included input received from public and other stakeholders during public meetings.

Evaluation criteria are a comprehensive list of factors and predictive assessments that will be used to compare alternative plans and select the recommended plan. The evaluation criteria address the goals and objectives of the project, as well as potential impacts of project implementation. The evaluation criteria are organized in a hierarchy that establishes relationships between major factors and the supporting criteria. The LOW Project identified three major categories that comprised the first level of the hierarchy: 1) enhance ecologic values; 2) enhance economic and social well being; and 3) optimize performance and efficiency.

Development of the evaluation criteria represents the integration of public opinion and concerns, agency requirements and responsibilities, and defensible engineering and science. For example, evaluation criteria were developed to address:

- Project goals and objectives,
- Issues that were important to the public,
- Regulatory or permitting information needs,
- Corps of Engineers planning requirements,
- NEPA requirements, and
- US Fish and Wildlife Coordination Act requirements,

Once the evaluation criteria hierarchy was established, scientists and/or engineers prepared a fact sheet for each of the criteria at the lowest level of the hierarchy. The fact sheets consist of a description of the evaluation criteria, a discussion of the rationale for why the criteria is significant to the decision process, a target for what the project seeks to accomplish, and a methodology for how to evaluate the criteria.

Each of the evaluation criteria that has been developed will be used to evaluate each of the alternative plans that will be considered. This information will be used to complete a matrix that contains the results of all the evaluations for each alternative plan. The evaluation matrix represents all the information that should be needed to compare the alternatives and select the recommended plan. It will be based on a process that identified the issues that are important to meeting the project goals and objectives, meeting public expectations, complying with all Federal and state laws, regulations, and policies and applying the best available science and engineering in the evaluation.

The LOW PDT is meeting the challenges of planning the LOW Project by utilizing a broad interagency consensus building process, to develop evaluation criteria based on sound science and engineering.

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The Sustained Ecological Research Related to the Management of the Florida Keys Seascape (SEAKEYS)

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Florida Institute of Oceanography, Long Key, FL.

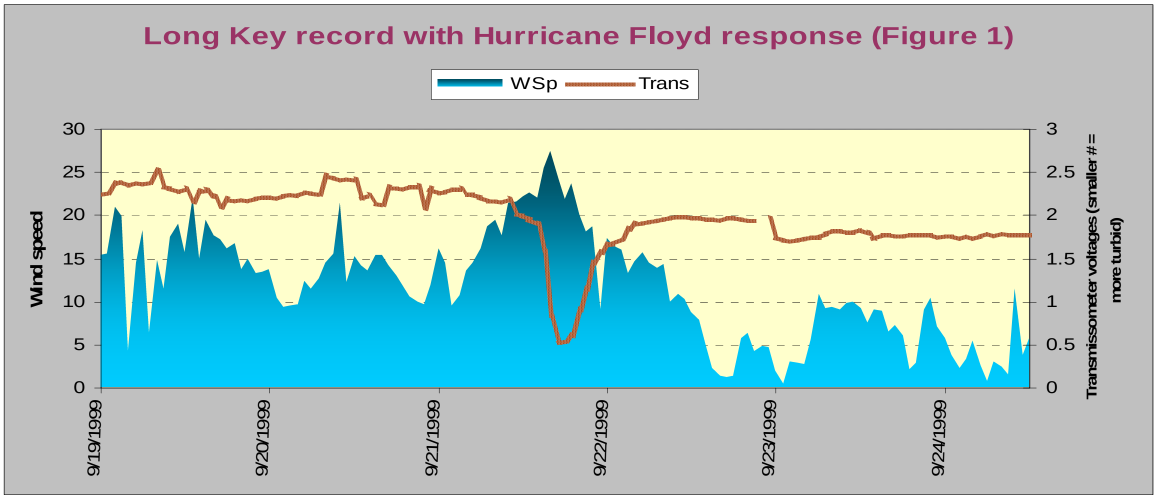
Dr. Jim Hendee
Atlantic Oceanographic and Meteorological Laboratory, Key Biscayne, FL.

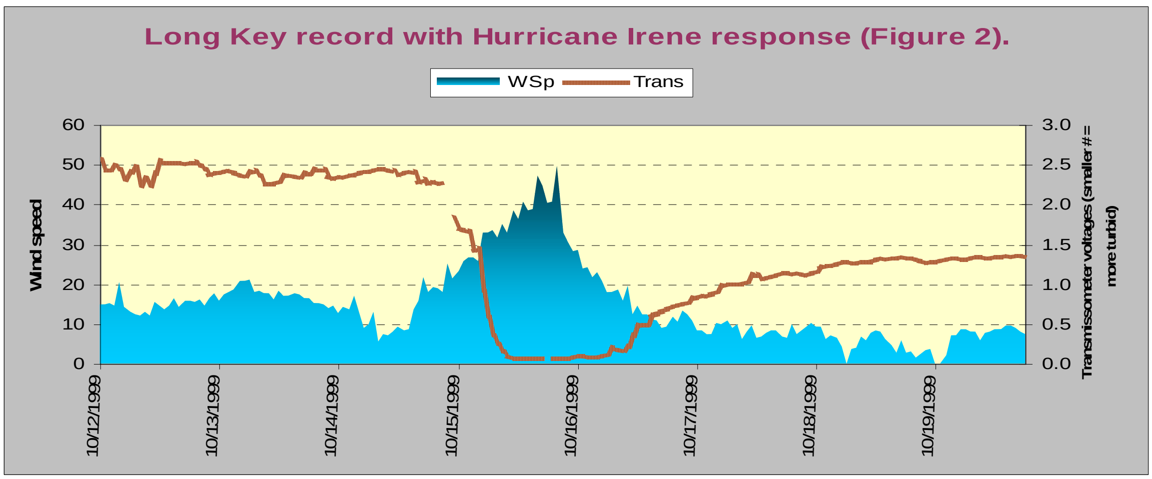
Ecological processes vary greatly over varied environments. The life long argument of which happens first and the ensuing causes have always been up for interpretation. One's perception on a day to day basis may actually be a lot different than the true environmental trends. Long-term data sets have always helped put some black and white or "real" trends into the gray areas of resource management.

The SEAKEYS environmental monitoring program, an oceanographic extension to the meteorologically oriented Coastal-Marine Automated Network (C-MAN) of NOAA, has accumulated an unparalleled long-term database of meteorological and oceanographic data from the Florida Straits and Florida Bay. SEAKEYS 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 Modeling (SFERPM) program, which is administered by the National Oceanic and Atmospheric Administration (NOAA).

The SEAKEYS network is comprised of six C-MAN stations and one Coastal Ocean Monitoring and Prediction (COMP) station in cooperation with the University of South Florida's College of Marine Science. The COMP station is the northwestern most station of the SEAKEYS network and the southern most links to the COMP system. Together, the two near-real time systems create an unprecedented coverage of the Florida Keys environment. 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.

Severe conditions reported by the SEAKEYS stations include Hurricanes Andrew, Georges, Irene, tropical storm Mitch, Storm of the Century, and the1998 Ground Hog Day storm. During such meteorological events the modeling community has gained insight into wind stressors in the Florida Keys environment. For example, wind events during Hurricanes Irene and Floyd show similar wind stress responses under similar conditions. (Figure 1,2.) The monitoring network was also designed to track patterns and their changes between average years and extra ordinary occurrences. During the summer of 1993 record floods occurred in the Mississippi river eventually resulting in depressed salinity in the Loop current in the Gulf of Mexico and hence the Florida Current. Abrupt drops in salinity were recorded over the entire SEAKEYS network C-MAN stations during the month of September (Ogden et. al., 1994). The 1997-98 El Nino and La Nina Southern Oscillation events (ENSO) were captured and quantified using the SEAKEYS Oceanographic data. For example, sea temperatures peaked at 32.1 C in 1998, a full degree centigrade warmer than the year before. Sea temperatures were also two degrees centigrade cooler than the year before at the same site during winter conditions (figure 3).


Long Key record with Hurricane Floyd response (Figure 1)
WSp
Trans
Wind speed
Transmissometer voltages (smaller # = more turbid)
30
25
20
15
10
5
0
3
2.5
2
1.5
1
0.5
0
9/19/1999
9/20/1999
9/21/1999
9/22/1999
9/23/1999
9/24/1999


Long Key record with Hurricane Irene response (Figure 2).
WSp
Trans
Wind speed
Transmissometer voltages (smaller # = more turbid)
60
50
40
30
20
10
0
3.0
2.5
2.0
1.5
1.0
0.5
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10/12/1999
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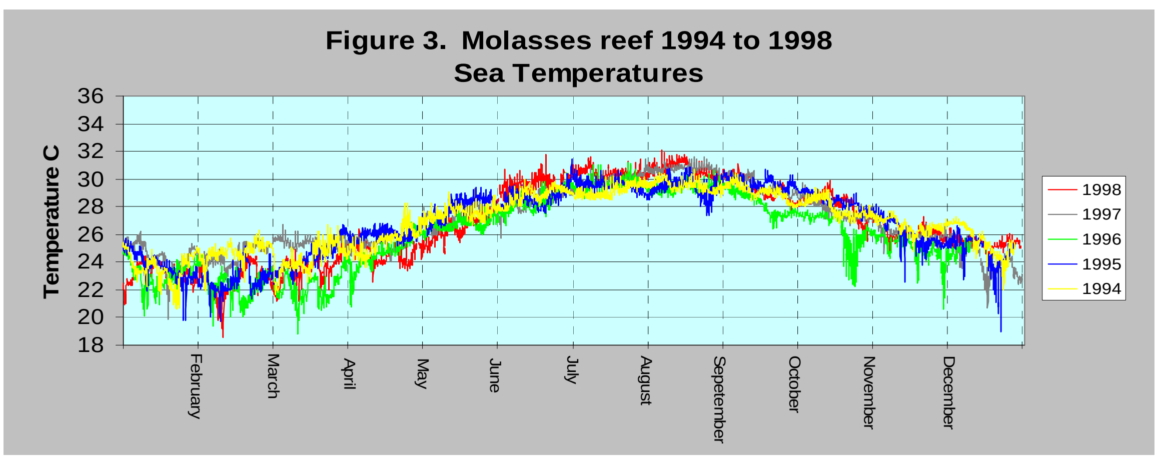
Figure 3. Molasses reef 1994 to 1998
Sea Temperatures
Temperature C
36
34
32
30
28
26
24
22
20
18
February
March
April
May
June
July
August
Sepetember
October
November
December
1998
1997
1996
1995
1994

The SEAKEYS network has long been known for its reliable and sometimes lone existent data in the Florida Keys. The SEAKEYS program's presence has become an essential tool for weather forecasters, marine sanctuary managers, hurricane research staff, physical oceanographers, modelers, remote sensing platforms, emergency management, law enforcement, and commercial shipping traffic. Several of the SFERPM models use the SEAKEYS network data. One of the many models that use the SEAKEYS network is NOAA's Coral Reef Early Warning System (CREWS) (Hendee, et.al. 2001). CREWS, which utilizes the near real-time hourly 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 e-mail to researches and posted to the Web at http://www.coral.noaa.gov/sferpm/seakeys/es. CREWS, coupled with NOAA's space-based Sea Surface Temperature (SST) derivations, utilize SEAKEYS data to extend the predictive capabilities through ground truth measurements within the Florida Keys region.

Monitoring of the Florida Keys Coastal environment is important for scientific, economic, and management reasons. The SEAKEYS program's involvement in these projects shows its commitment to understanding the Florida Keys environment. By continuing to upgrade and improve program abilities and capacities to monitor the environment, the SEAKEYS should be better equipped to assist users in answering future management questions.

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An Ecological Model to Predict *Vallisneria americana* Michx. Densities in the Upper Caloosahatchee Estuary

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The growth of *V. americana* Michx., a salt-tolerant freshwater submerged aquatic angiosperm, is evaluated using a numerical model developed for the upper Caloosahatchee Estuary**.** This model includes the effects of salinity, light, and temperature and predicts several measures of growth including biomass, shoot density, and blade density**.** A unique feature of this model is the ability to determine the densities, not previously reported in submerged aquatic vegetation models.

The model consists of a system of three simultaneous differential equations (finite difference), one for each of three state variables, solved by Euler numerical integration with a time step of 1 day. State variables represented in the model are the following: total mass, number of shoots and number of blades. The domain of the model is a spatially averaged $1m^2$ single layer water column. Forcing functions are water temperature, incident PAR, secci disk depth, and salinity.

Known information about the growth and survival of *V. americana* at two sites in the Upper Caloosahatchee Estuary is synthesized in the model. Monthly field monitoring of *V. americana* density and water quality parameters has been conducted at these sites since 1998. The model is calibrated based on measured *V. americana* densities, water temperature, transparency, and photosynthetically active radiation for the period 1998-2002. Flows generated by hydrodynamic modeling are used to compute the daily salinity input. The model successfully reproduces *V. americana* density and biomass at the two locations within the Estuary over the 5- year period and is robust within the observed range and variability of environmental parameters. The importance of the three different environmental variables (i.e. salinity, light, and temperature) is evident in the results, illustrating the need to consider multiple variables when establishing estuarine performance measures.

The application of the model provides improved understanding of the factors influencing growth and reestablishment of *V. americana*. The information generated can be used to: develop a set of habitat requirements for *V. americana* survival and growth, optimize timing and quantity of freshwater releases, and assess management strategies in the Upper Caloosahatchee Estuary. The mechanisms responsible for habitat decline can be elucidated and conditions required for restoration and survival evaluated. Compilation of existing data and sensitivity analysis within the model framework can further highlight areas of data needs and can guide and prioritize future work efforts.

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Habitat Suitability Indices for Linking Hydology to Ecology

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Conceptual models, which define the chain of cause and effect between water and land management actions and the impacts on the Everglades ecosystem, are an important first step in evaluating the relative impact of alternative water management scenarios on ecology. These conceptual models are not inherently quantitative, but nevertheless, help identify important links between hydrology and the relative condition of particular indicator species or landscape features of the ecosystem. Habitat Suitability Indices (HSIs) can be used as a first approximation toward quantifying the relationships identified in the various ecological conceptual models. HSIs have been developed since the early 1980s to define, in relative terms, the quality of the habitat for various wildlife species.

Creation of Habitat Suitability Indices for the Everglades started with informal discussions between hydrologists, biologists and ecologists at the December 2000, Greater Everglades Ecosystem Restoration Conference. Relationships between hydrologic variables and impacts to species habitat or landscape features, defined during these discussions, were used to produce initial values of HSIs for six key indicator species or landscape features (i.e. ridge and slough landscape, tree islands, periphyton, fish, wading birds, alligators). The establishment of these initial functions was based on field research, historical references, models or combinations thereof. Hydrologic output from the South Florida Water Management Model (SFWMM) and Natural System Model (NSM) was used to produce time series of HSIs for several different model simulations. The HSIs were refined at a series of workshops, held in early 2001, attended by the experts in the particular field of each HSI. Production of HSIs for base simulations and calibration/verification simulations allowed the experts to compare HSIs with their conceptual models and field observations and make modifications to the relationships between the hydrologic variables and the suitability indices.

The process of developing the above six HSIs is for the Everglades is presented to show how the process was instrumental in contributing towards increasing knowledge and understanding of the relationship between hydrological variables and habitat suitability. The suitability functions developed for the different indicators are time and/or space dependent, have different levels of complexity, and have been subject to different degrees of calibration and verification. Limited calibration and verification of the HSIs, which occurred through the process, is also shown. Furthermore, sensitivity of the Ridge and Slough landscape suitability to the conceptualization of the relationship between the suitability index and the hydrologic variable is presented. This illustrates how best professional knowledge of the Ridge and Slough landscape under current and pre-drainage conditions, compared with results of the sensitivity analysis, can be used to refine the conceptual hydrology/suitability index relationship.

The habitat suitability functions presented are not final and will evolve as the links between hydrology and ecology are better defined and understood. In their present form, however, the Habitat Suitability Indices have the potential to provide useful information in the evaluation of alternative water management strategies. This simple approach provides preliminary insights into the relative tradeoffs between water management plans or policies and ecological habitat impact. More complex landscape and ecosystem models will be needed to improve our understanding of the Everglades ecosystem and to provide more detailed information about the impact of water management practices.

HSIs for the six species or landscape forms, presented herein, can be viewed on the web at: http://www.sfwmd.gov/org/pld/hsm/reg_app/hsi.html

Acknowledgements
The contributions of the following, arranged according to their area of contribution, are gratefully acknowledged. Hydrologic modeling and programming of HSIs: Raul Novoa, Sharika Senarath, Lehar Brion, Jenifer Barnes and Danielle Lyons. Periphyton: Evelyn Gaiser, Dan Childers, Joan Browder, Sue Newman, Linda Blum, and Rebecca Sharitz. Alligators: Ken Rice, Laura Brandt and Frank Mazzotti. Ridge and slough landscape: Chris McVoy. Tree Islands: Lorraine Heisler, Yegang Wu, Carl Fitz and Fred Sklar. Wading Birds: Dale Gawlik and Gaea Crozier. Fish: Joel Trexler and Bill Loftus.

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Long-Term Reference Evapotranspiration and Solar Radiation Estimation Methods for Hydrologic Modeling in South Florida

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Long-term daily (1965-2000) Reference Evapotranspiration (ET_o) at several sites is required as input to the South Florida Water Management Model (SFWMM) and the Natural System Model (NSM). In these models, actual evapotranspiration is calculated by spatial interpolation of ET_o between the sites, and by the application of landscape specific crop coefficients which are a function of water depth.

The Penman-Monteith method (Monteith, 1981), which combines energy balance and mass transfer methods, has been used extensively in both arid and humid climates to provide estimates of ET_o. This method depends on many variables that are usually hard to measure or estimate accurately. Due to the lack of a comprehensive meteorological database for South Florida several simpler methods for estimating ET_o were examined and compared against values of ET_o from the literature. Since solar radiation (R_s) is typically the most important parameter controlling evapotranspiration in South Florida, simpler ET_o estimation methods with R_s as the only variable are a viable option. The South Florida Water Management District's (SFWMD) Simple Method (Abtew, 1996, defined by Equation 1) was selected for estimating long-term ET_o for modeling purposes.

$$ET_o = \frac{K_1 * R_s}{\lambda} \qquad \text{Eq. (1)}$$

where:
K_1 is a coefficient (0.53)
ET_o is the reference evapotranspiration (mm/day),
R_s is the solar radiation (MJ/m^2/day),
λ is the latent heat of vaporization (MJ/kg).

Using the Simple Method does not entirely solve the problem of lack of meteorological data for ET_o estimation in South Florida. R_s measurements or a method for estimating R_s when it is not measured is still required.

Long-term (1965-2000) daily measurements of solar radiation in South Florida are very scarce. The only long-term dataset of measured R_s that could be found is for Miami International Airport. Additional R_s data has been collected by the SFWMD for relatively short periods of time at several stations. Several methods for estimating historical solar radiation based on widely-available maximum and minimum surface temperature measurements were examined including Allen's (1997) self-calibrating (K_r) method and modifications to the Bristow-Campbell (1984) method found in the literature. There was greater consistency in the performance of the self-calibrating method compared to other more complex methods. The self-calibrating method requires the estimation of a single parameter (K_r) and it was found that this parameter does not change significantly across South Florida. Although some of the methods examined matched the variability of the measured data better than the self-calibration method, the self-calibration method was selected for its simplicity and small spatial variability of its parameter (K_r). Results for Miami International Airport show that the self-calibrating method explains approximately 40 percent (R^2=0.4) of the variation in solar radiation with the best performance during the dry season (R^2=0.45) compared to the wet season (R^2=0.22).

The various ET_o estimation methods examined are presented and compared to values found in literature for South Florida. R_s estimation methods and statistical measures used to select the most appropriate R_s estimation method are also presented.

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Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project: Long-Term Status and Trends

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Marine protection legislation (HR5909) designated over 2,800 nmi^2 of coastal waters as the Florida Keys National Marine Sanctuary (FKNMS). The National Oceanic and Atmospheric Administration (NOAA), US Environmental Protection Agency (EPA), and the State of Florida implemented a Water Quality Protection Program to monitor benthic habitats: seagrass, coral reefs, and hardbottom communities; as well as water quality. The Coral Reef Monitoring Project (CRMP) sampling strategy and methods were developed in 1994. The major criteria for coral reef monitoring included FKNMS-wide spatial coverage, repeated sampling, and statistically robust findings to document status and trends of the different coral communities. Results are reported annually to resource managers to provide information for decision making and protecting living marine resources of the FKNMS.

Forty CRMP sampling sites, including inshore hardbottom habitats, mid-shelf patch reefs and offshore bank reefs were selected using EPA e-map protocols. Installation was completed during 1995 and annual, non-consumptive sampling began in 1996 at 160 permanently marked stations (4 stations per site) throughout FKNMS. In 1999, three sites (12 stations) were added in Dry Tortugas. Stony coral species richness and disease presence are documented at each station. Point Count (image analysis) was conducted on approximately 180 images (1800 points) from each transect annually (Figure 1). Analysis of digital data was used to compute percent benthic cover for macroalgae, sponges, octocorals, and stony corals.

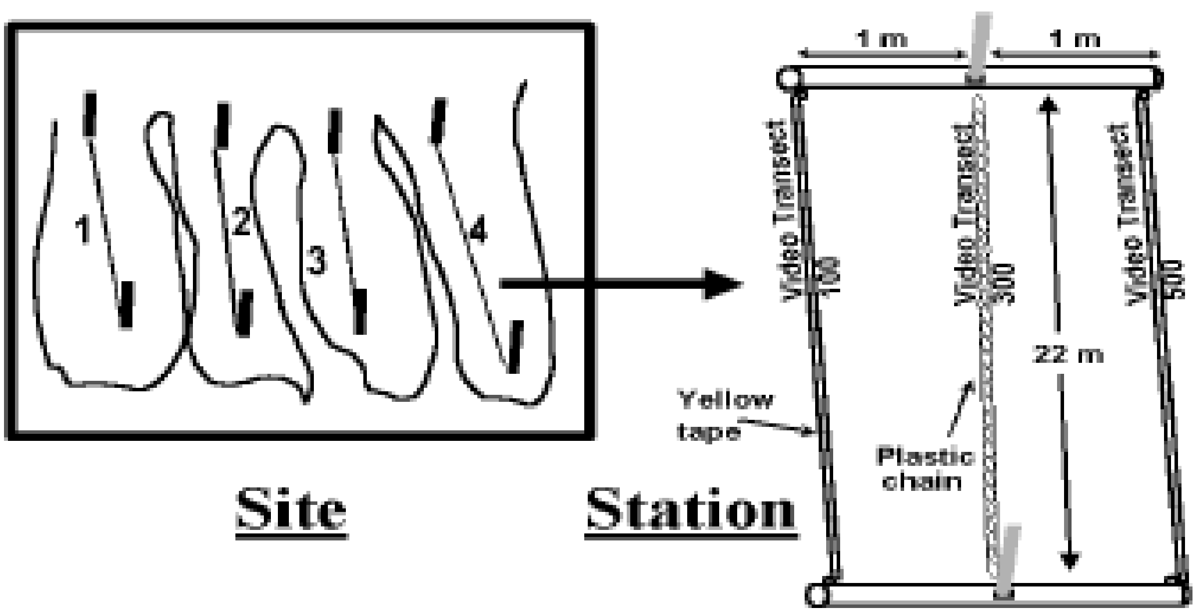

Figure 1. Sampling site and stations: species richness and disease sampling occurs within the rectangular station polygon; video transects are filmed following the 100, 300, and 500 lines.

Deep and patch reef stations were richest in stony coral species, whereas hardbottom stations were impoverished in stony corals but rich in algae (Figure 2). Between 1996 and 2000, the CRMP reported a 37% reduction in stony coral cover Sanctuary-wide (Figure 3). Hypothesis testing revealed that 63.9% of the stations suffered a significant loss in stony coral cover, while only 3.5% showed a significant increase.

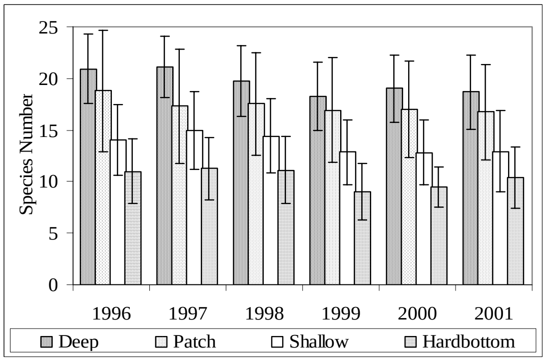

Figure 2. Stony coral species richness, mean and standard deviation.

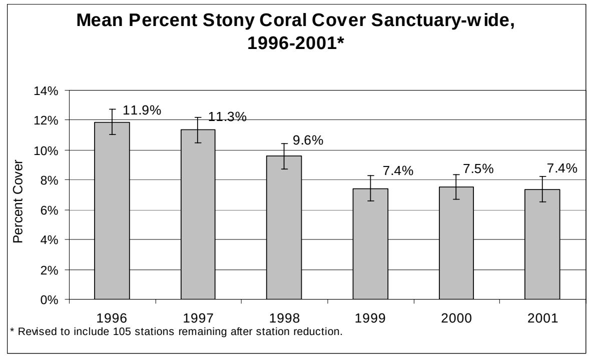

Figure 3. Percent stony coral cover, FKNMS, 1996-2001.

The number of stations where disease was documented increased from 26 in 1996 to 131 in 2000 and the number of species infected by disease increased from 11 to 36. Algal cover fluctuated as a result of nutrient upwelling and as well from storm events; however, sponge and octocoral cover was relatively stable (Figure 4).

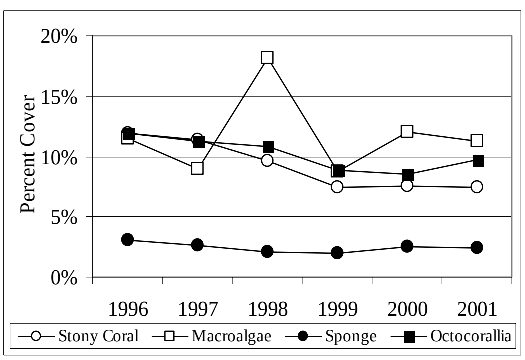

Figure 4. Trends in cover for algae, sponge, octocorals, and stony corals.

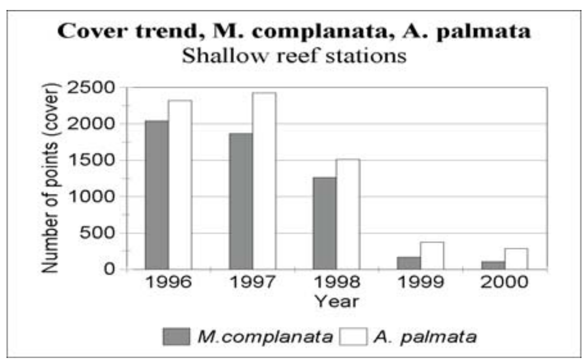

Figure 5. Decline in cover of two species that contribute substantial material to shallow reefs.

Coral recruitment was sampled at 49 stations in 2001; 32 taxa and 1,095 juvenile corals < 3 cm in diameter were inventoried; density was 4.46 m^2. The census indicates that reef building genera such as *Montastraea*, *Diploria*, and *Colpophyllia* are uncommon in juvenile populations.

These trends are alarming; however, they are reasonably consistent with trends documented by researchers elsewhere in the Caribbean basin. Multiple stress disturbances acting at local, regional and global scales are contributing to coral decline in Florida. Two principal causes for the steep decline following 1997 were Hurricanes Georges (1998), Irene (1999), and coral bleaching events in 1997 and 1998 (Figure 4). The increase in disease is seasonal, with high incidence during late summer.

The enhanced Coral Reef Evaluation and Monitoring Project (CREMP) will include the described strategies to document stony coral cover, species richness, bleaching, and disease; sampling has been expanded to collect data on bioeroders, temperature, human enteroviruses, and scleractinian coral population dynamics (abundance and size classes).

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Phosphorus Removal Performance of Native and Exotic Submerged Aquatic Macrophytes in South Florida

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Submerged aquatic vegetation (SAV) communities have proven to be effective for removing water column phosphorus (P) in Everglades Stormwater Treatment Areas (STAs). The common SAV in south Florida wetlands include the native species *Najas guadalupensis*, *Certaophyllum demersum*, *Chara zeylanica*, *Potemogeton illinoiensis*, and the exotic macrophyte *Hydrilla verticillata*. Several STA cells are dominated primarily by native SAV species (typically *N. guadalupensis* and *C. demersum*), whereas others have become dominated by *H. verticillata*.

Cell 5 of STA-1W, for example, initially was colonized with native SAV species, but within three years became dominated by *H. verticillata*. Other SAV cells, such as Cell 4 of STA-1W and Cell 3 of STA-2, have little *H. verticillata* present. The factors that cause dominance by various species of SAV are not well understood. Moreover, there are no comparative data on the P removal performance of the native and exotic SAV species.

In this presentation, we describe results of a mesocosm study in which we compare the P removal performance of *H. verticillata* with other native SAV species, including *N. guadalupensis*, *C. demersum* and *C. zeylanica*. Mesocosm testing was performed for six months in 2002 using both STA inflows (Post-BMP agricultural drainage waters) and STA outflows (Post-STA waters). Under a hydraulic loading rate (HLR) of 10 cm/day for Post-BMP waters (average total P concentration of 138 µg/L), 1.0 m deep mesocosms containing a mixture of *N. guadalupensis* and *C. demersum* provided lower outflow total P concentrations (27 µg/L) than those containing *H. verticillata* (36 µg/L). Shallow (0.45 m deep) mesocosms exhibited the same trend, with native and the exotic species providing outflows of 24 and 30 µg/L, respectively.

The native SAV species also were more effective than the exotic in treating the Post-STA waters. Inflow total P levels of 29 µg/L were reduced to 24 µg/L by *H. verticillata*, and to 22 and 19 ug/L by *N. guadalupensis* and *C. zeylanica*., respectively, in shallow (0.45 m deep) mesocosms. These initial findings suggest that native SAV species will provide superior P removal performance to *H. verticillata* in both inflow and outflow regions of STA wetland cells.

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A Preliminary List of Chironomidae (Diptera) Present in Everglades National Park

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The midge family, Chironomidae, are typically the most species rich and abundant macroinvertebrate group in freshwater ecosystems. They are a major component in the Everglades food web, linking plant, algal, and microbial production to higher trophic levels. Chironomid midges are abundant in a variety of substrates including periphyton mats, and along with the Ceratopogonidae, are the most important invertebrate group linking this algal resource to fish and other fauna. Chironomid midges have also long been recognized as exceptional indicators of nutrient enrichment (Rosenberg 1992, Lindegaard 1995), and are increasingly being used to assess a variety of environmental disturbances (e.g., Williams et al. 2001). Because of their high species richness, the great diversity of microhabitats that they occupy, and their wide collective tolerances for physical and chemical conditions, studying chironomids alone can be as effective as using a larger group of invertebrate taxa in bioassessment (King and Richardson 2002, Ruse 2002).

Despite their important role in the Everglades ecosystem, and their extraordinary usefulness in bioassessment research, the chironomid fauna of the Everglades was almost completely unknown up until ten years ago. Prior to our collections, a total of 60 species had been reported from the entire Everglades system, and only 2 species were documented for ENP. Over the past 4 1/2 years, we have made extensive collections of chironomids, primarily by skimming the water surface for their distinctive pupal exuviae, from a variety of habitats and localities in ENP including: sawgrass and slough habitats in the Shark River Slough and Taylor Slough basins, marl prairie and solution hole habitats in the Rocky Glades, brackish waters along the Wilderness Waterway, canals, burrow pits, and phytotelmata in the Park.

In this paper, we provide a list of 131 chironomid taxa collected within ENP, highlight exciting taxonomic discoveries (e.g., Jacobsen and Perry 2000, 2002), and point out taxonomic problems that require further study. We offer some biogeographical observations on the fauna in ENP, and briefly discuss the primarily environmental gradients (hydropattern, salinity) and factors (karst landscapes, artificial habitats) that contribute to species richness in ENP. Finally, we provide an updated total, and a projected estimate, of the total invertebrate species richness in the Everglades system based upon integrating : (1) our collections of Diptera from ENP [190 species], (2) records of Copepoda collected in ENP by Dr. M. Cristina Bruno [38 specie], and (3) the extensive list of invertebrates collected by King (2001) from WCA-2A [approx. 270 species].

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Responses of Midges (Diptera: Chironomidae & Ceratopogonidae) to Canal Inflows, and to Phosphorus-Dosing in Flume Arrays, in Everglades National Park

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Structural modifications and additions planned for the Central and South Florida Project as part of the Comprehensive Everglades Restoration Plan (CERP), will alter water deliveries into Everglades National Park (ENP). The increases of flow into Northeast Shark River Slough, and changes in sources of water will increase the potential for reductions in water quality and subsequent alteration of marsh community composition and function in ENP. Effective biomonitoring methods need to be developed for wetlands and implemented to ensure these modified water deliveries do not inadvertently degrade marsh systems in ENP.

Chironomid and ceratopogonid midges have excellent potential as indicators of enrichment in freshwater wetlands. Midges are the most species-rich invertebrate group in the Everglades, and are known to be sensitive to a variety of stressors including nutrient enrichment. King & Richardson (2002) found that chironomid midges, when identified to species, were clearly the most informative group for detecting nutrient enrichment in the northern Everglades. However, their research was conducted in WCA-2A along a nutrient gradient that is far 'steeper' than those to be expected within ENP. Many of the indicators of water quality that he found in WCA-2A may be either absent or unresponsive to biological changes along nutrient gradients in ENP.

In this study, we used pupal exuviae sampling to examine midge species and community responses to water quality gradients created by canal inflows into ENP. Our objective was to identify species indicative of either high water quality or impaired water quality, and search for community attributes that may be useful for detecting impairment. The responsiveness of these potential water quality indicator species to P-enrichment was then examined in Shark R. Slough P-dosing flume experiments and compared with: (1) the midge species King (2001) found to be responsive to enrichment in WCA-2A, (2) a composite list of species from both studies, and (3) an ideal composite list of species from either ENP or WCA-2A, augmented by select species that were highly responsive to enrichment in the flumes, but that have not been shown to be indicators in other Everglades studies.

<u>Effect of canal inflows on midge community composition</u>: Quantitative samples of midge pupal exuviae, as well as water, soil, and tissue samples of *Eleocharis* and *Cladium*, were collected along 4 suspected nutrient gradients in ENP produced by canal inflows into: Taylor Slough, northeast Shark River Slough (2 inflows), and the Rocky Glades west of the S332B detention pond. Mean water total-P levels were significantly higher at sites near inflows than those from interior sites, but total-P levels at all sites were very low (near inflows: 6.7 ppb TP, interior: 3.6 ppb TP; paired-T = 2.83, P=0.022). *Eleocharis* tissue percent total-P was significantly higher near inflows (near inflow: 0.058%, interior sites: 0.032%; paired-T = 6.14, P=0.009), but *Cladium* tissue total-P levels were equal. Soil total-P showed only a slight rise near inflows.

Midge community abundance, species richness, and Shannon-Wiener diversity showed no consistent relationship with relative proximity to canal inflows. Indicator species analysis (INSPAN) found 8 species to be significantly indicative of interior sites (*Ablabesmyia* sp. A, *A.* sp. B, *Cladotanytarsus* sp. A, *C.* sp. C, *Nilothauma babiyi*, *Polypedilum simulans*, *Pseudochironomus articaudus*, and *Parakiefferiella coronata*); 7 of these species were also sensitive (intolerant) to nutrient enrichment in Water Conservation Area 2A (WCA-2A) (King 2001). Seven species were significantly indicative of sites near canal inflows (*Asheum beckae*, *Chironomus* (*Lobochironomus*) sp., *Polypedilum falciforme*, *P. tritum*, *Tanytarsus* sp. B, *Tanytarsus "Nimbocera"* sp. D, and Ceratopogonidae sp. C), none of these species were significantly tolerant of enrichment in WCA-2A. This discrepancy in tolerant species probably reflects differences in species responses to low nutrient gradients in ENP versus the much steeper gradient in WCA-2A.

<u>Midge community response to experimental P-enrichment</u>: Midge response to experimental P-enrichment was examined at each of the 3 flume sites in Shark R. Slough in 1999 and 2001. Community abundance, species richness, and Shannon-Wiener diversity showed no significant change with enrichment. Significant changes in individual species' abundance with increasing P-enrichment indicate that: (1) *Dasyhelea* c.f. *cincta*, "*Nimbocera*" sp. A, and possibly *Cladotanytarsus* sp. A, may be sensitive to phosphorus enrichment; (2) *Chironomus stigmaterus*, *Ch.* sp. B, *Dicrotendipes* sp. A, and *Pseudochironomus richardsoni* appear to benefit from enrichment. However, species' responses appear to be at least partially related to the relative position of treatments within the flumes, suggesting that preexisting, or flume-related, habitat gradients may exist at these sites, which may hamper detection of responses to enrichment.

The group of species identified as sensitive of enrichment in nutrient gradient studies in ENP were more responsive to P-enrichment than the taxa King (2001) listed as being sensitive to enrichment in WCA-2A (Fig. 1). Tolerant species in the ENP gradient study were rare and inconsistently responsive to P-dosage (Fig. 2), whereas WCA-2A tolerant species (King 2001) showed increases in abundance in high-dose channels relative to controls at all flumes, except Flume C in 2001. The greater responsiveness of ENP-sensitive species and WCA-tolerant species may reflect differences in the nutrient gradients sampled in the process of selecting these species as indicators.

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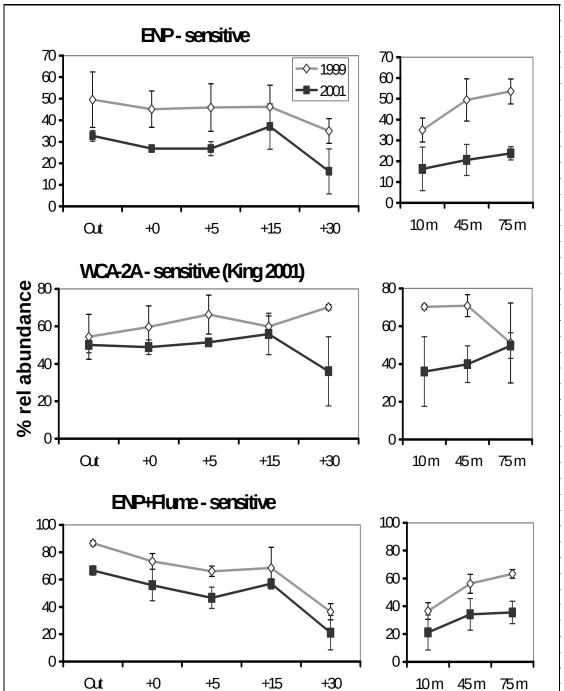

Fig. 1. Responses of groups of sensitive taxa in Shark R. Slough flumes.

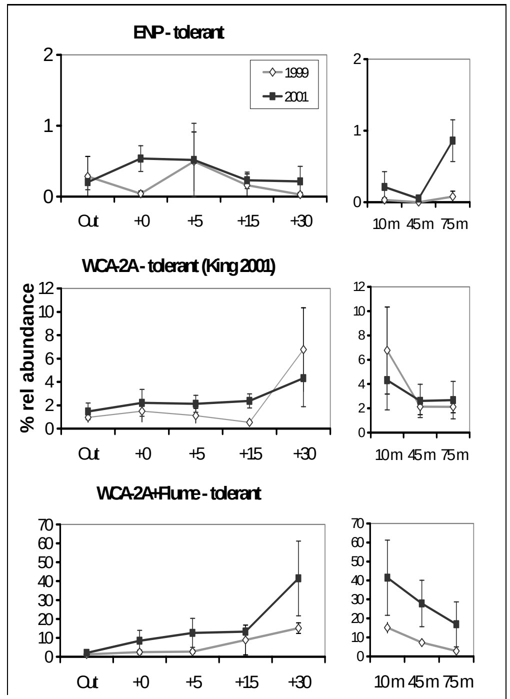

Fig. 2. Responses of groups of tolerant taxa in Shark R. Slough flumes.

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Characterizing Flow and Phosphorus Loads for Lake Okeechobee Watershed Using WAM

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Watershed Assessment Model (WAM) was set up and calibrated / validated for simulating the existing conditions within the 20 basins in the Lake Okeechobee Watershed (see Figure 1). This was done as part of the larger Lake Okeechobee Comprehensive Everglades Restoration Plan (CERP) project to first develop the hydrologic/water quality characterization of tributaries, and then to use WAM to assess various management scenarios for phosphorous reduction. WAM is a useful tool that provides both ease of use and the robustness and technical defensibility of a complex solution. Because WAM was designed to assess current conditions and to analyze the impacts of land use and management alternatives, it was selected as the primary analytical tool for this project. Modeling efforts included the simulation of flows and phosphorus loadings for every stream reach within the watershed. The basins within the watershed contain a variety of land uses including forests, wetlands, dairies, beef pastures, row crops, citrus, residential, and commercial. As part of the overall project, conservation easements, agricultural BMPs, and reservoir-assisted storm water treatment areas (RASTAs) were included in the final WAM model.

Figure 1. Project Basin Locator Map

South Florida Water Management District (SFWMD) maintains an environmental database named "DBHydro" which contains hydrological, meteorological, hydrogeological, and water quality data. WAM was calibrated for flow and phosphorus concentration for the 20 basins using available data from DBHydro and average annual measured loads provided by the District (see Figure 2). Measured average annual water flows and phosphorus loads for the period 1995-1999 were provided by SFWMD for 4 basins (see Table 1). Since direct measurements of phosphorus loads were unavailable, loads were calculated from daily measured flows and phosphorus concentrations. Daily flow data were only available for a few sites, whereas phosphorus concentrations were available for over 100 sites. Most concentration measurements were obtained from bi-weekly grab samples. Samples taken during periods of no flow were eliminated from the load concentrations. Daily concentrations were calculated by interpolating between the grab samples. This technique gives reasonable estimates of phosphorus loads; however, the errors associated with this technique are expected to range between 25 and 50% of actual loads.

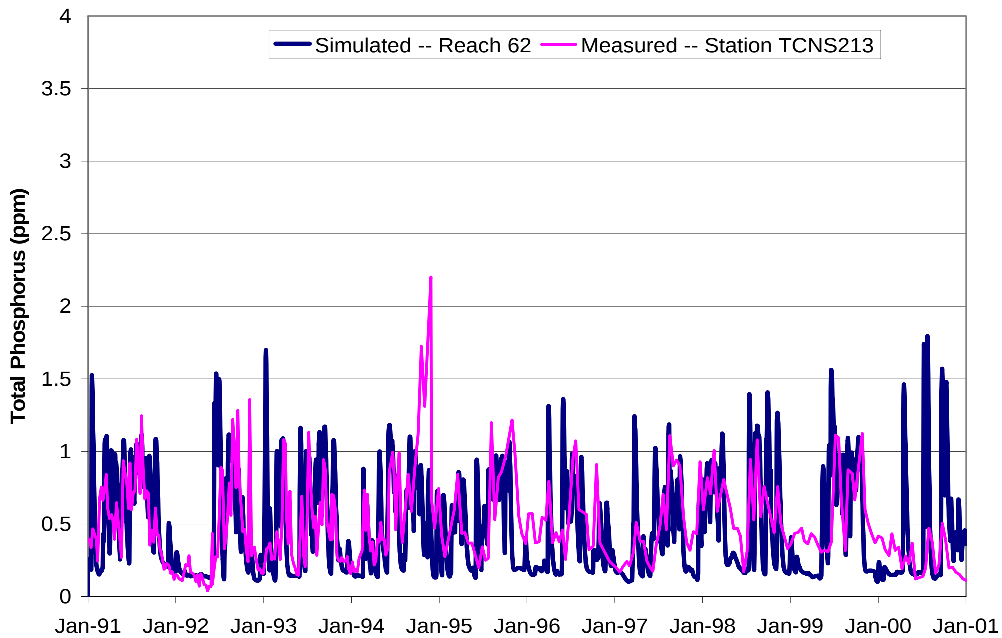

Figure 2. Total Phosphorus Concentration for Basin S-191 Station TCNS213

Table 1. Measured and Simulated Phosphorus Loads and Concentrations

Basin	Source	Discharge (acre-feet)	Phosphorus Concentration (ppb)	Phosphorus Load (tonnes)
S-191	Measured	113,467	653	91.2
	Simulated	119,237	617	90.2
S-154	Measured	31,885	828	32.5
	Simulated	30,867	540	20.8
C-41	Measured	52,630	433	28.0
	Simulated	76,718	286	27.1
Fisheating Creek	Measured	249,378	176	54.1
	Simulated	265,654	197	64.5

Since WAM is a process-based model, traditional model calibration was not utilized. However, all possible field parameters which can be physically measured to ensure accurate model rendering of the basin were considered. For example, locations of culverts and other flow control structures were determined and accurately reflected in the simulated physical representation. Also, site visits and stage data were used to improve stream profile definitions. Stage, flow, and phosphorus data were gathered and quality checked for use in model verification. Daily stages, flows, and phosphorus loads were simulated for each stream reach in each basin for the period 1991 through 2000. Based on visual comparisons of simulated and measured phosphorus concentration levels, responses to rainfall events, and the accuracy of the measured data, the simulated values matched the measured values quite well.

The comparisons of measured and simulated values indicate that WAM can reliably simulate flows and phosphorus loads and concentrations discharged from the basins. Since many subbasins and basins have little or no measured data, these simulations are the best estimates of current flows and loads available. WAM's demonstrated ability to simulate the impacts of land use and management makes it a powerful tool in assisting planners and decision makers to develop strategies to maintain and improve water quality.

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Arbuscular Mycorrhizae and their Role in Plant Restoration in Subtropical Florida

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In southern Florida, there is high plant biodiversity due to the floristic mixing of warm temperate SE North America and tropical Caribbean. Arbuscular mycorrhizal fungi (AMF) were found in the roots of native plants in the families Anacardiaceae, Arecaceae (Palmae), Cactaceae, Convolvulaceae, Cycadaceae, Euphorbiaceae, Fabaceae, Lauraceae, Rubiaceae, Simarubaceae and Smilacaeae that grow in the coastal maritime and inland hammocks of southern Florida. In greenhouse experiments, seedlings of the following genera: Amorpha; Coccothrinax; Gymnanthes; Hamelia; Jacquemontia; Licaria; Nectandra; Opuntia; Picramnia; Psychotria; Rhus; Sabal; Serenoa; and Zamia were inoculated with AMF and showed enhancement of growth and phosphorus uptake on local sandy, nutrient poor soils. Most native species depend on AMF under natural conditions of poor or no soils, phosphorus limitations and often water stress. Restoration projects are now planned for endangered species of Amorpha (Fabaceae), Jacquemontia (Convolvulaceae), Opuntia (Cactaceae) and Pseudophoenix (Arecaceae), and AMF should be considered when producing plants for restoration.

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Interactions of Vegetation, Hydrology, and Soils in Everglades National Park Tree Islands: Phosphorus Biogeochemistry of Soils

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It is commonly known that soils serve as a media for plant growth, exchange and storage of nutrients. Also, their structural profiles provide a record of soil formation and site history. In this project, we are interested in understanding the interactions of three key components of tree islands ecosystems - hydrology, vegetation, and soils. How are the recent changes in hydrology affecting the vegetation mosaic and soils? Are these soils functioning similarly to the adjacent marsh soils? Are these soils nutrient sinks or sources? Do they differ in their elemental composition? And how does this elemental composition affect vegetation? With these questions, we describe physical and chemical properties of soils from three tree islands - Black, Gumbo Limbo, and Satinleaf Hammocks.

Composite surface soil samples at 0 to 10 cm depth were collected from three tree islands in November 2001. Each tree island consists of hardwood hammock, bayhead, and bayhead swamp communities. To evaluate spatial variation in soils within each island, soil samples were collected at 5-25 meter intervals along a transect traversing the length (North-South) of the island, and covering marsh, hardwood hammock, bayhead, bayhead swamp, and again marsh communities. Soil samples were also collected at 25-meter intervals along three transects traversing the width (East-West) of the island, and covering hardwood hammock, bayhead, and bayhead swamp communities. By using a 10 cm diameter soil auger, several 0-10 cm deep cores were taken at each sampling spot, composited in a 4 mill thickness sampling bag, and transported to the laboratory for physical description and physicochemical analysis. Soils were homogenized in the bag and refrigerated until further analysis. Sub-samples from each bag were transferred to a plastic sample cup, weighed wet (g), and measured for sample volume (cm^3). Later, these samples were analyzed for dry weight (80•C), sample bulk density (g dry cm^{-3}), fractional water content, total C, carbonate content, inorganic and organic C, organic matter content, total N, and total P. Another set of sub-samples from the bag was diluted with distilled, deionized water to a nominal 1:1 dilution and homogenized in a blender for 90 s. The pH and EC of the soil slurries was recorded. Selected soil samples were analyzed for particle size distribution and labile forms of N and P.

We have established baseline physicochemical properties of soils on three tree islands, Black Hammock, Gumbo Limbo, and Satin Leaf. Gumbo Limbo Hammock seems to be different from Black and Satinleaf Hammocks in several soil properties. In general, soils in the hardwood hammock communities, particularly the raised part of the community, have alkaline pH, low organic matter, abundant carbonate minerals, and low nitrogen. The phosphorus content seems to be very high in all three tree islands, especially in the hammock portions. Based on the high levels of total P in these soils, we postulate several theories that are being tested in our research, with field and laboratory data. One theory suggests that animal (birds) inputs may account for elevated P levels. Alternatively, we believe that dissolved phosphorus/particulate phosphorus may be carried with the ground water stream into the tree islands, especially during the dry season. Here, the P may build up over long periods of time, due to adsorption onto soil particles in alkaline conditions as calcium phosphate. A third factor may involve the dynamics of organic matter in the hardwood hammock. As the leaf litter undergoes decomposition, carbon and nitrogen is cycled into the gaseous phase (low total carbon and nitrogen in hardwood hammock). Phosphorus doesn't have such kind of cycle and it is relatively immobile element. We therefore cannot rule out the possibility of phosphorus accumulation as a byproduct of organic matter decomposition. The mineral composition of the tree island soils and the origin of these minerals are certainly proving an interesting and important component in the ecology of Everglades tree islands.

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Thermally-Driven Vertical Mixing in the Everglades

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Vertical mixing in most natural freshwater bodies is driven predominantly by boundary shear stresses such as wind stress on the free surface of a lake or bed friction on the channel bottom and banks of a rapidly flowing river. However, in the slowly flowing wetlands of the Everglades, thermally-driven convection is the dominant mixing mechanism. This diel mixing has potential implications for mercury methylation, evapotranspiration, oxidation, nutrient and contaminant transport and cycling, and other processes of concern in the Everglades wetlands.

Flow-velocity measurements and temperature profiles collected within an area of medium-dense spike rush on the edge of a large area of dense sawgrass in lower Shark River Slough within Everglades National Park reveal the behavior, timing and extent of thermal mixing. Flow velocities were sampled using an acoustic Doppler velocity meter capable of resolving very low velocities to an accuracy of 1 mm/s over a range of a few cm/s. Two 600-sample measurement bursts are depicted in Figure 1. Each burst was collected at 10 Hz and, therefore, represents a one-minute sample. There are two plots for each burst. The first shows the three components of flow velocity: east-west, north-south and up-down. The second shows a signal quality statistic, correlation, which can be considered an indicator of small-scale turbulence in the acoustic pathway. Lower correlations indicate higher turbulent mixing.

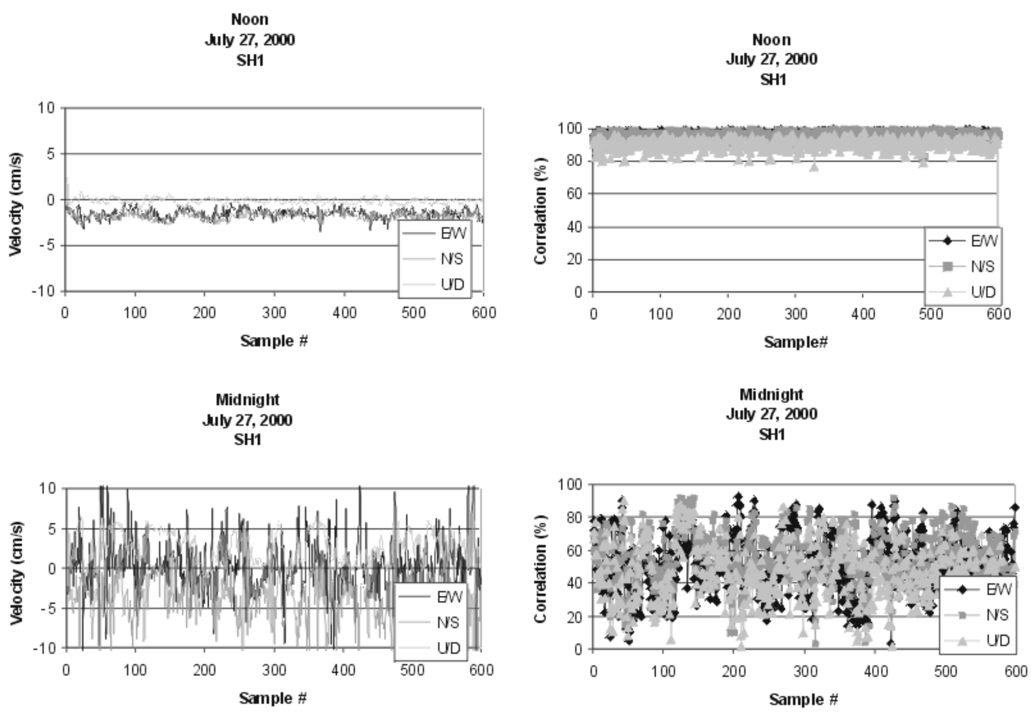

Figure 1. Typical flow velocity and signal correlation at SH1.

Velocity data in the first pair of plots, collected during the daytime, fluctuate minimally about their median values and have very high correlations. In strong contrast, velocity data in the second pair of plots, collected at midnight, fluctuate wildly and have substantially more variable and lower correlations. This phenomenon is typical and constitutes a pattern observed nearly every day.

Highly variable flow velocities in the hours after sunset can be linked to thermal convection by considering temperature data obtained from a set of thermistors, having an accuracy of 0.1 deg C, cabled vertically 10 cm apart in a string deployed near the velocity meter. Thermistor data show the heavily vegetated water column to be isothermal at the beginning of each day (fig. 2). Initial heating of the water surface at sunrise is followed by progressive heating of the water column with depth throughout the day, resulting in increasing stratification throughout the late morning and early afternoon. Maximum stratification occurs at mid-afternoon and averages approximately 3 °C through 60 cm of the water column (5 °C/m). Typically, the water column reaches its maximum temperature around mid-afternoon. The water column cools through the remaining daylight hours, but remains stratified until approximately sunset when the air temperature begins to fall sharply and eventually drops below the water temperature at the surface.

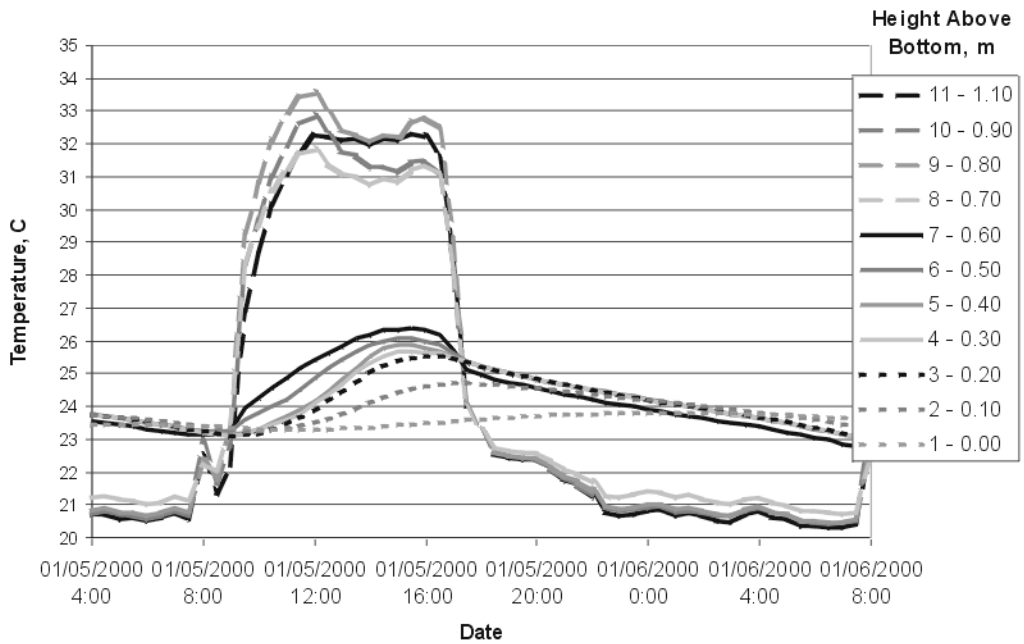

Figure 2. Typical temperature at SH1 (curve 1=plant litter, 2-7=water, 8-11=air).

Diel coincidence of the thermal destratification and pronounced velocity fluctuations indicates the onset of mixing in the water column driven by thermal convection. The mixing process begins abruptly within approximately the upper 40 cm of the water column. Temperatures within this layer coincide through the remainder of the night. This mixed layer continues to cool and deepen throughout the night, not warming until just after sunrise the next day. A thin layer at the water surface remains slightly cooler than the mixed layer through the night, providing a constant source of negatively buoyant water that drives the mixing process. The mixing process continues until the air temperature rises above the temperature of the water at the surface.

The thermally-driven mixing process also affects the temperature structure within the upper portion of the plant-litter layer at the bottom of the water column. The slow exchange of mass and heat across the water-column/litter-layer boundary causes temperatures in the plant-litter layer to lag temperatures in the water column. Decreased heat exchange causes the peak temperature in the litter layer to occur after midnight and the minimum temperature to occur around noon. There is a brief time just before sunrise when the temperature in the litter layer is greater than in the water column. The daily range of temperatures in the litter layer (approximately 0.5 °C) is much smaller than the range of temperatures at any particular point in the water column (approximately 3-5 °C).

Individual daily temperature profiles in the Everglades wetlands are observed to vary only slightly with meteorological conditions and indicate that daytime destratification rarely occurs. Thermally-driven mixing appears to dominate at SH1 during more than 90% of the days. Only in the case of persistently strong winds, heavy rainfall or dramatic drops in air temperature is the water column in the Everglades wetlands thermally well-mixed during the daytime. The presence of vegetation appears to be the primary factor increasing the consistency with which thermally-driven convection dominates the vertical mixing process in the Everglades. The ubiquitous nature of this mixing implies a likely role in a number of important processes in the ecologically stressed Everglades wetlands.

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Benefit of Kissimmee River Restoration to Lake Okeechobee Phosphorus Control

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The Kissimmee River is the largest inflow to Lake Okeechobee and accounts for over 30% of phosphorus entering the lake. Channelization of the river, accompanied by loss of wetlands, ditching, and altered flow regimes, facilitated transport of phosphorus to the lake from a developing agricultural watershed. Dairy and pasture runoff, especially to the river's lower reach, raised mean total phosphorus (TP) concentrations to more than 100 ppb.

Restoration of sloughs and marshes along the river is expected to increase retention of P inputs from upland watersheds and headwater inflow. Filling of lateral ditches and removal of cattle from the floodplain also will help to lower P loads from tributaries. Mean discharge-weighted TP concentrations are expected to decline to 20 ppb at water control structure S-65C and to ≤ 67 ppb at S-65D. Phosphorus loads through these structures will decline by 10-60 percent. In addition, restoration of natural, seasonal flows will delay most P loading until later in the year, when potential impact on Lake Okeechobee productivity may be lower.

These expectations assume that TP concentrations in the river's headwater will continue to center around the historical average of 43 ppb, but higher TP loading from Lake Kissimmee in the late 1990s raised concern that upper basin development might be increasing P loading from the headwater lakes. Elevated concentrations, coupled with high discharges from El Niño storms, resulted in disproportionately large P input to the river in 1998. However, the cause of this higher loading appears to have originated in the south end of Lake Kissimmee instead of the main body of the lake. Pelagic concentrations remained low during this time, and temporal variations in lake TP were related to seasonal algal blooms rather than input from lakes upstream. More recent data show that concentrations at the lake's outlet have declined, but abrupt spikes in TP continue to point toward the influence of a nearby source.

Two years after completion of the first phase of river restoration, TP concentrations at the downstream end (S-65C) of the restored area are still near the baseline average of 50 ppb. Lower concentrations are not expected until natural floodplain hydroperiod and wetland vegetation become re-established. Despite the reduced P loading predicted from restoration, phosphorus management still depends largely on control of agricultural runoff downstream of the restoration project.

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The South Florida Satellite Image Map Series: A Tool for Research, Monitoring, and Education

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Satellite image maps provide an empirical foundation for the study of the temporally dynamic and spatially complex nature of Everglades land surfaces. They help laboratory and field scientists plan instrument placement and field experiments. They provide spatial context for the interpretation of data related to Everglades research, modeling, and restoration activities. They constitute baseline data for Everglades monitoring. Several satellite image maps covering the region south of Lake Okeechobee have been distributed as USGS Miscellaneous Investigations Series publications (Jones and Thomas 2001, Thomas and Jones 2002, Jones and Thomas, in review). Each map (e.g., fig.1) covers the largest area possible given high-quality, mass-printing limitations for 1:100,000 scale National Mapping Accuracy Standards. Every map was designed to meet a variety of needs. For example, the first publication (fig. 2) was constructed with both scientists and the general public in mind. Driven by research requirements, the boundaries of its western sheet encompass a focus area for hydrologic modeling. The eastern sheet allows the general public to view the urban development of the Atlantic Coast adjacent to the Everglades wetlands and contains descriptions of the map's development and interpretation in terms that can be understood by a broad spectrum of readers. Together, these two parts serve as an intuitive backdrop for discussion of important environmental, economic, and social issues. They allow viewers to understand some of the interrelationships among Everglades wetland condition and agricultural, industrial, and residential activities. Some environmental features like the impact of fires and the status of nutrient removal areas are obvious (fig 1). Others require closer image map inspection. For example, visual comparison of the first and third maps in the series uncovers subtle, high frequency variations. Their source images were collected only 9 days apart (i.e., 2/5/00 and 1/27/00, respectively). However, water level data recorded in an area of image overlap show that water levels dropped approximately 8cm over that short period (fig. 3), creating impacts that are detected with careful examination of full-resolution renditions of the image maps.

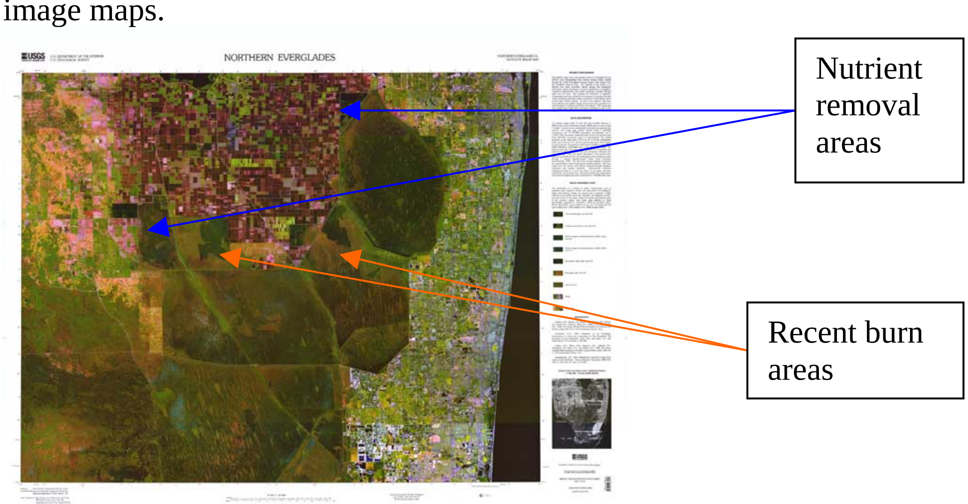

Figure 1 A thumbnail view of the Northern Everglades image map in the series of 1:100,000 scale image maps distributed in both printed and digital forms as part of the USGS Miscellaneous Investigations Series.

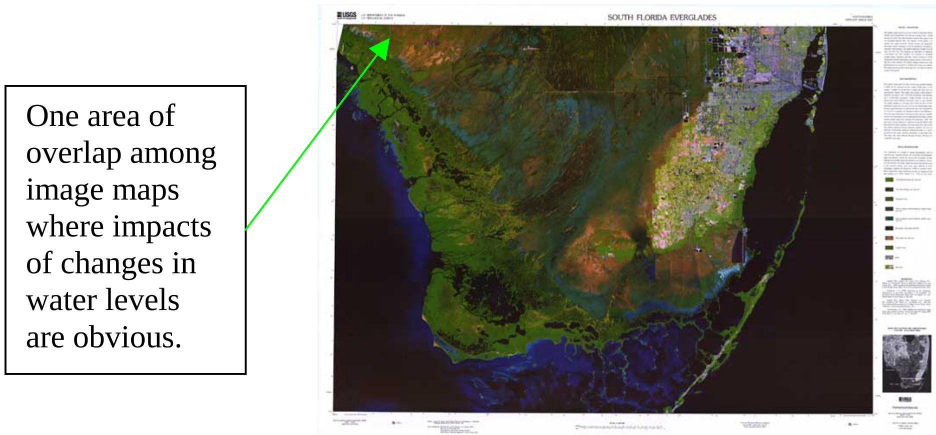

Figure 2 A mosaic of the two Southern Everglades image maps in the series. While this area is printed on two 1:100,000 scale maps, the maps were combined before digital distribution.

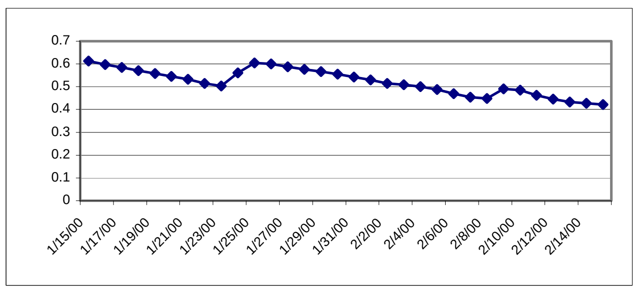

Figure 3 Recorded stage for one Big Cypress National Preserve station number 8.

The creation of such information-rich satellite image maps required a great deal of research and forethought. Multivariate statistical analysis was combined with the knowledge of remote sensing physics to select a combination of satellite measurements that yields desired colors, minimizes adverse impacts of the Earth's atmosphere on image clarity, and maximizes contrasts and information content. Image colors change as the data are transferred from digital to paper formats. Therefore, previous experience and repeated trials were used to further digitally manipulate the data to produce visually appealing, easily interpreted colors across all final image maps. Project research also developed a mathematical procedure to sharpen urban and other features by merging multiple satellite image data sets. To make the image maps as useful as possible in the field, the classroom, and the conference room, they've been made widely available in a variety of formats. Printed maps can be obtained at low cost through the U.S. Geological Survey's Earth Science Information Center (1-800-ASK-USGS). In addition, following Library of Congress policies, printed image maps were scanned with sufficient resolution to reproduce them to scale without loss of information. Also, these output files were sub-sampled for other uses. Finally, one file for each map was converted to Geotiff format for use in Geographic Information Systems. Each map has been featured on the South Florida Information Access website upon publication, where all digital files are freely available (sofia.usgs.gov).

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Water Velocities and Total Suspended Solids Transport in the Southern Everglades

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Changes in Everglades soil topography are regulated by physical and biological processes. Soil topography acting with hydroperiod governs plant type and distribution. Lower water levels in some parts of the Everglades have led to oxidation of soils and possibly a narrowing of this topographic difference between a ridge and slough or wet prairie. It is believed that this long-term decrease in hydroperiod has led to sawgrass (*Cladium jamaicense* Crantz) colonization of sloughs, or a conversion of sloughs into wet prairies. In order to prevent further transformation of Everglades habitats, it is important to understand the mechanisms affecting soil topography. Water flow may play a role in transporting particulates through the Everglades, helping to influence soil topography. This study measured water velocity and total suspended solids (TSS) to estimate TSS loading rates in three habitat types (ridge, slough, and wet prairie) in Water Conservation Area 3A (WCA 3A) and Everglades National Park (ENP). This may help explain the role of particulate transport in shaping the soil topography of the Everglades.

Four locations (WCA 3A1 (high flow site-2 km south of Alligator Alley), WCA 3A2 (low flow site-16 km north of Tamiami Trail), ENP1 (low flow site-east of the L-67 extension), ENP2 (high flow site-southern Shark Slough)) were monitored once every two months for one year, which covered a full wet and dry season. The ENP sites had ridges adjacent to wet prairies, while WCA 3A sites had ridges adjacent to sloughs. Visual observations of flow velocity and direction were conducted using a dye tracer (fluorescein) over the course of one minute in each habitat type. In addition, water depth was measured and water samples were filtered for total suspended solids.

Results of this preliminary study are shown in Table 1. Microscopic analysis of filter paper suggests that most particulates are diatoms, spicules, algae, and plant fragments. All of these exist naturally in the water column, indicating they were probably not scoured from the soil surface and brought up into the water column. A much greater water velocity may be required to physically dislodge and transport sediment.

Table 1. Flow velocities and TSS calculations at four Everglades sites.

		11-May-02	*18-Jul-02*	*23-Nov-02*	*4-Jan-03*	*4-Jan-03*	*4-Jan-03*	*4-Jan-03*
	Location and	**velocity**	**velocity**	**velocity**	**velocity**	**water**	**TSS**	**TSS loads**
Site #	**habitat type**	(cm/sec)	(cm/sec)	(cm/sec)	(cm/sec)	**depth** (cm)	(mg/L)	(mg/sec/m)
1	WCA3A1-ridge	no data	1.23	0.56	0.54	24	0.04	0.05
1	WCA3A1-slough	no data	1.76	0.43	0.45	39	0.42	0.73
2	WCA3A2-ridge	no data	0.46	0.14	0.01	51	0.29	0.01
2	WCA3A2-slough	no data	0.42	0.12	0.02	72	0.17	0.03
3	ENP1-ridge	0.35	no data	0.13	0.40	28	0.21	0.23
3	ENP1-prairie	0.11	no data	0.37	0.68	37	0.35	0.88
4	ENP2-ridge	no data	2.16	1.26	1.06	21	0.49	1.10
4	ENP2-prairie	no data	1.46	0.83	1.00	39	0.41	1.59

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Landscape-Scale Conservation Planning for the Florida Panther

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The Florida panther (*Puma concolor coryi*) is an endangered, wide-ranging predator currently limited to south Florida. For over a decade, the panther has been a subject of controversy as its habitat needs have conflicted with a rapidly growing human population. The goal of this project was to identify habitat areas needed for a self-sustaining panther population before key habitats are developed for human uses. Analyses of Florida panther radio-telemetry data with respect to land cover reveal that panthers prefer forests as daytime resting sites, but other natural and disturbed cover types also are present in the landscape where panthers are found. An updated model of habitats likely to be selected by Florida panthers was created using the following criteria: forest patches >2 ha; non-urban cover types <200 m from forest patches; and exclusion of lands <300 m from urban areas. The potential habitat map, telemetry data, satellite imagery, and home range polygons were used to delineate the boundaries of a Primary Zone, lands most important to a self-sustaining panther population. Least-cost path models were constructed to identify landscape linkages most likely to be used by panthers dispersing out of south Florida. Model results were used to delineate the boundaries of a Dispersal Zone, an area needing protection from development to accommodate future panther dispersal. The contextual quality of the landscape surrounding the Primary Zone was modeled, and the results were used to identify a Secondary Zone, an area where existing habitat coupled with restoration could significantly enhance the viability of the panther population. Estimates of population density indicate that the three zones (Figure 1) could support 79-94 panthers. Population viability models suggest that a population of this size would have a low probability of extinction over the next 100 years, but it may remain stable or decline gradually, and would be subject to genetic problems without management intervention.

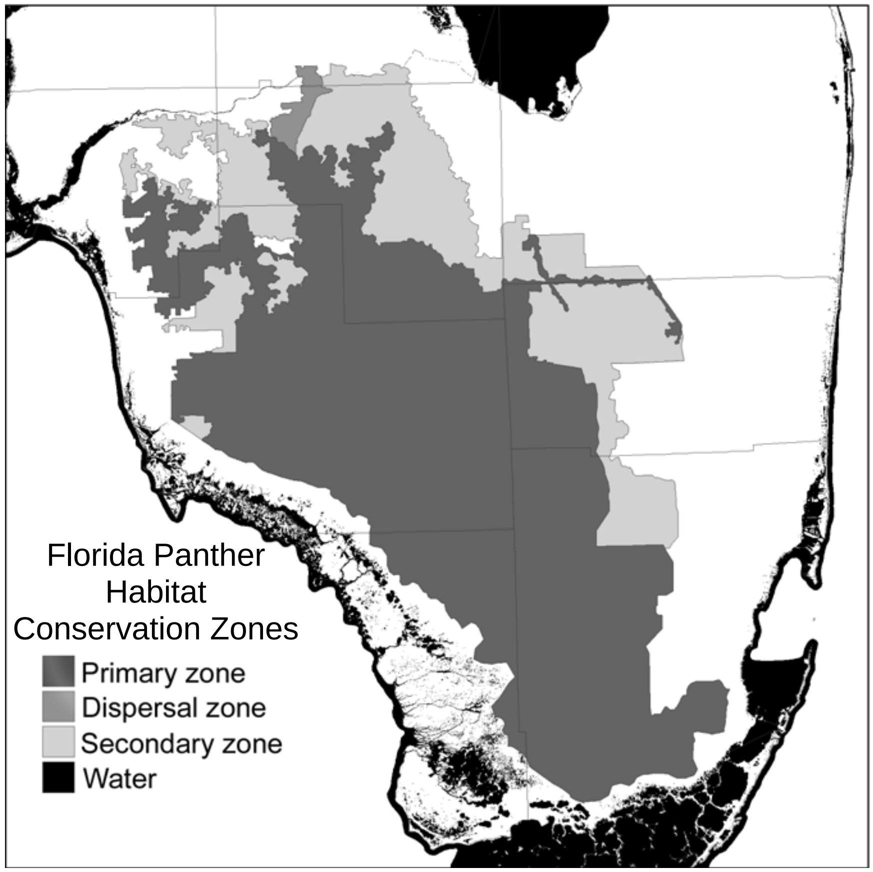

Figure 1. South Florida landscapes identified for conservation of Florida panther habitat by the Florida panther sub-team of MERIT.

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Biogeochemical and Hydrologic Controls on Food Web Structure in the Everglades

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A clear understanding of the aquatic food web -- the relative trophic positions of different fish, birds, and other aquatic life -- is essential for determining the entry points and subsequent biomagnification pathways of contaminants such as methyl-mercury (MeHg) in the Everglades. Anthropogenic changes in nutrients and sulfur can significantly affect the entry points of MeHg by changing food web structure from one dominated by algal productivity to one dominated by macrophytes and associated microbial activity. These changes in the base of the food web also influence the distribution of animals within the ecosystem, and subsequently the bioaccumulation of MeHg up the food chain. We are attempting to use the $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ of biota in marshes and canals in the Everglades as (1) indicators of local environmental conditions that may impact water quality and biota, and (2) indicators of food web structure.

The isotopic compositions of several thousand sediment, plant, invertebrate, and fish samples collected in collaboration with several agencies from several hundred sites in the Everglades show strong spatial patterns on a landscape scale. The spatial variability of $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ values reflects spatial variability of reducing conditions in the marshes that promote methane production, sulfate reduction and denitrification. The isotopic compositions of aquatic plants integrate the variability in water column isotopic compositions, and the resulting spatial patterns are incorporated throughout the food web. Therefore, organisms that live in sites where geochemical conditions are dominated by particular redox reactions have distinctive isotopic compositions. The temporal and spatial variability in the isotopic compositions of aquatic plants at the base of the food webs complicates the use of isotopic techniques for determining food web structure in the Everglades. In particular, the isotopic effect of these biogeochemical reactions must be removed from the isotopic compositions of biota before it is possible to evaluate temporal and spatial changes in food webs.

The temporal and spatial variability of biota isotopic compositions provide very useful insight into seasonal and spatial changes in biogeochemical and hydrological processes across the Everglades. For example, aquatic vegetation and detritus samples collected in September 1998 and March 1999 from various sites along two parallel transects in WCA 2A show that $\delta^{15}N$ values of vegetation tend to decrease (from around +5‰ to around 0‰) with distance from the canal, while $\delta^{13}C$ values show an increase with distance from the canal (from –30‰ to –26‰). Shrimp and other invertebrate samples collected at the same times also show a ~2‰ decrease in $\delta^{15}N$ and ~5‰ increase in $\delta^{13}C$ along the same gradient. Also, we find that plants and macro-invertebrates collected from microhabitats (such as open-water sloughs, cattail marsh, sawgrass marsh and spikerush stands) within 100 m of site U3 in WCA2A have 0.5 to 1‰ variation in $\delta^{13}C$ and a 1 to 2‰ variation in $\delta^{15}N$ between marsh types. The differences in isotopic composition of biota within microhabitats at each site suggest that local influences, such as differences in the relative rates of photosynthesis and respiration, and differences in nitrification and denitrification, strongly affect the $\delta^{13}C$ and $\delta^{15}N$ (respectively) of local biota. Temporal changes in these same processes, as well as changes in species composition, cause algae samples collected weekly from 3 slightly different microhabitats near U3, to have $\delta^{13}C$ values that range from –32‰ to –27‰, and $\delta^{15}N$ values that range from +2‰ to +6‰ during the fall of 1997.

The δ values of organisms collected at the same site usually show an inverse relation between $\delta^{13}C$ and $\delta^{15}N$ over time. Seasonal shifts in water level can cause shifts in biogeochemical reactions and nutrient levels, with corresponding variations in the δ values of biota. For example, small changes in water level may change the balance of photosynthesis, respiration, and atmospheric exchange reactions that control the $\delta^{13}C$ of dissolved inorganic C (DIC). Such changes will probably also affect the $\delta^{15}N$ of dissolved inorganic N (DIN) because of corresponding changes in N uptake and redox conditions. During the dry season, the marshes probably become more anoxic because of shallower water levels, less photosynthesis, and increased quantities of decaying vegetation. At some sites, the $\delta^{13}C$ and $\delta^{15}N$ of algae show strong positive correlations with water level fluctuations. These oscillations are substantially damped up the food chain, probably because of the longer C and N integration times of animals vs. plants.

Our large dataset of $\delta^{13}C$ and $\delta^{15}N$ analyses of samples collected at 15 sites studied by the USGS ACME (Aquatic Cycling of Mercury in the Environment) team during multiple trips in 1995-1999 was used to calculate the differences in $\delta^{15}N$ and $\delta^{13}C$ between all possible consumer-diet pairs. The difference in $\delta^{15}N$ between consumer and diet ($\Delta\delta^{15}N$) is a proxy for the length of the food chain between the species at a particular site and date, and the difference in $\delta^{13}C$ ($\Delta\delta^{13}C$) reflects differences in the base of the food webs of the species. An evaluation was then made of how often the $\Delta\delta^{15}N$ and $\Delta\delta^{13}C$ values differed between types of sites. There were no statistically significant differences in $\Delta\delta^{15}N$ values between high and low nutrient sites, suggesting that there was no evidence for shorter food chains at high nutrient sites. However, there are statistically significant differences in $\Delta\delta^{13}C$ values between low and high nutrient sites.

We find that $\delta^{13}C$ values provide a powerful tool for distinguishing between sites where algae is the dominant base of the food web vs. sites where macrophyte debris (and the bacteria living on it) is also a significant food source. The $\delta^{13}C$ values of organisms from relatively pristine marsh sites sampled by the USGS are consistent with algae being the dominant food web base most of the time (perhaps depending on water levels). At the more nutrient-impacted sites, the $\delta^{13}C$ and $\delta^{15}N$ values of scavengers such as shrimp and crayfish are consistent with macrophyte debris being an important food source most of the time. The $\delta^{13}C$ values of samples collected by the EPA REMAP program in September 1996 also show spatial differences in the importance of algae as a base of the food web. Macrophyte debris appears to also be important to the mosquitofish food web at about half of these sites.

The $\Delta\delta^{15}N$ calculated for periphyton and mosquitofish pairs at the REMAP sites showed no correlation with region or latitude, and no significant correlation with mosquitofish Hg levels, suggesting a lack of evidence for spatial differences in food chain length. However, the $\Delta\delta^{13}C$ values showed strong spatial patterns, including statistically significant differences between data from different regions ($p = 0.04$) and latitudes ($p < 0.01$). One likely explanation for the patterns is that they reflect spatial differences in the relative importance of algae vs. macrophyte debris to the mosquitofish food web. In general, the spatial patterns of $\Delta\delta^{13}C$ values are very similar to spatial patterns interpreted by Stober et al. (2001) as differences in food web structure. Hence, two very different sets of samples and data from the same regional assessment agree that there are similar spatial differences in some aspect of the food web structure, but disagree about whether this difference is mostly due to trophic variations or food base differences.

Several chemical parameters measured at the sites by the REMAP program show significant differences between sites where the food webs are predominantly algal versus ones with appreciable contributions from macrophyte debris. These data are consistent with macrophyte-impacted sites generally having more anoxic conditions than sites where algae is the dominant base of the food web. The general agreement of the REMAP data with the conceptual model developed to explain temporal and spatial variability in food webs at USGS sites provides moderate evidence that spatial differences in the dominant food web base across the Everglades are related to environmental conditions such as nutrient availability, redox conditions, and hydroperiod.

Applications of our isotopic investigations to the Everglades Restoration include: (1) Biota isotopes provide a map of the current spatial distributions of the extent of several biogeochemical reactions (especially sulfate reduction) affecting nutrient and Hg uptake. (2) By comparing the spatial patterns in the biota with those in the shallow sediments, recent anthropogenic changes in biogeochemical processes at the landscape scale can be demonstrated and dated. (3) Isotopes provide detailed information about temporal and spatial changes in trophic relations that complements traditional gut-contents analyses used by the FFWCC (and others) for understanding food webs and the bioaccumulation of contaminants. (4) The preliminary synthesis of the biota isotopes at USGS and 1996 REMAP sites provides a mechanism for extrapolating the detailed food webs developed at the intensive USGS sites to the entire marsh system sampled by REMAP. (5) Biota isotopes provide a simple means for monitoring how future ecosystem changes affect the role of periphyton (vs. macrophyte-dominated detritus) in the mosquitofish food chain, and for predictive models for MeHg bioaccumulation under different proposed land-management changes.

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Is Food Web Structure a Main Control on Mercury Concentrations in Fish in the Everglades?

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Many lake studies have found good correlations of the mercury (Hg) concentrations in fish and the relative trophic positions of fish as determined by analyses of gut contents and/or stable isotopes. But is this true in dynamic marsh ecosystems such as the Everglades? Based on the extensive REMAP assessment of the Everglades ecosystem, Stober et al. (2001) concluded that spatial (especially N-S) differences in "food web structure" are a likely cause of spatial differences in Hg concentrations in mosquitofish. Food web structure is a general term that encompasses differences in food chain length, food web complexity, and food web base. The extensive isotope and gut contents datasets assembled by several agencies can be used to evaluate this hypothesis.

Over 5000 algae, macrophyte, invertebrate, and fish samples were collected at 15 sites studied by the USGS ACME (Aquatic Cycling of Mercury in the Environment) team during multiple trips 1995-1999. These samples were analyzed for $\delta^{13}C$ and $\delta^{15}N$ to determine temporal and spatial differences in food web structure; a smaller subset was also analyzed for $\delta^{34}S$. Samples consisted of both composites and individuals. Most samples were analyzed in bulk; however, muscle tissue was analyzed for most large fish. This large dataset was used to calculate the differences in $\delta^{15}N$ and $\delta^{13}C$ between all possible consumer-diet pairs. The difference in $\delta^{15}N$ between consumer and diet ($\Delta\delta^{15}N$) is a proxy for the length of the food chain between the species at a particular site and date, and the difference in $\delta^{13}C$ ($\Delta\delta^{13}C$) reflects differences in the base of the food webs of the species. An evaluation was then made of how often the $\Delta\delta^{15}N$ and $\Delta\delta^{13}C$ values differed between types of sites. There were no statistically significant differences in $\Delta\delta^{15}N$ values between high and low nutrient sites, suggesting that there was no evidence for shorter food chains at high nutrient sites, as found by Stober et al. (2001). However, there are statistically significant differences in $\Delta\delta^{13}C$ values between low and high nutrient sites. One likely explanation for the $\Delta\delta^{13}C$ differences is a difference in the dominant base of the food webs at such sites. Food webs at low nutrient sites appear to be more algal dominated while macrophyte debris appears to be a significant contribution to the base of the food webs at high nutrient sites.

Samples of periphyton, mosquitofish, and sediment samples collected during September 1996 at about 100 REMAP marsh sites were analyzed for $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$. The $\Delta\delta^{15}N$ calculated for periphyton and mosquitofish pairs ($n = 68$) showed no significant correlation with region (Above Alligator Alley, Between Alligator Alley and Tamiami Trail, Below Tamiami Trail) ($p = 0.67$) or latitude ($p = 0.20$), and no correlation with mosquitofish Hg levels ($p = 0.55$), suggesting a lack of evidence for spatial differences in food chain length. However, the $\Delta\delta^{13}C$ values showed strong spatial patterns, including statistically significant differences between data from different regions ($p = 0.04$) and latitudes ($p < 0.01$) (fig. 1).

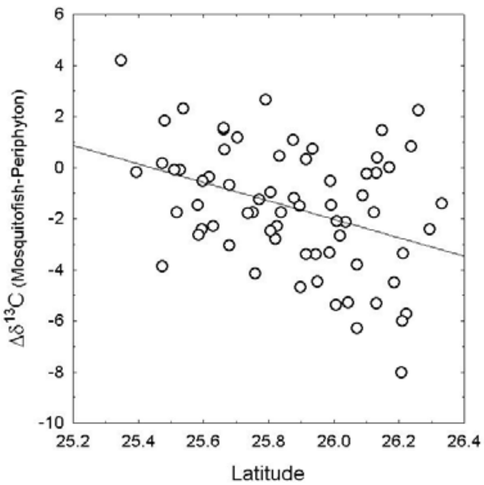

Figure 1. Graph showing significant correlation of $\Delta\delta^{13}C$ with latitude ($n = 68$; $p < 0.01$; $R^2_{adj} = 0.13$).

One likely explanation for the patterns is that they reflect spatial differences in the relative importance of algae versus macrophyte debris to the mosquitofish food web. In general, the spatial patterns of $\Delta\delta^{13}C$ values are very similar to spatial patterns interpreted by Stober et al. (2001) as differences in food web structure. Hence, two very different sets of samples and data from the same regional assessment agree that there are similar spatial differences in some aspect of the food web structure, but disagree about whether this difference is mostly due to trophic variations or food base differences. An evaluation of the gut contents of mosquitofish collected in 1996 and 1999 at the same REMAP sites, indicated that these data did not support the hypothesis that trophic position could be used to explain spatial differences in Hg concentrations (Stober et al., 2001). We are currently re-evaluating the isotope data in conjunction with the gut contents data to see if this will provide new insights into causes of spatial variations in food web characteristics.

This work was made possible by contracts from and collaborations with the US Geological Survey, US Environmental Protection Agency, and Florida Fish and Wildlife Conservation Commission.

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Demise of the Brain Coral, *Colpophyllia natans* at Bird Key Reef, Dry Tortugas National Park, Florida

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The Dry Tortugas is a remote group of islands approximately 110 kilometers west of Key West. In 1992, the Dry Tortugas National Park was created (and replaced the previous designation of Fort Jefferson National Monument) to protect marine, terrestrial, and historical resources. In the last several decades, the coral reef ecosystem of the Florida Keys has declined significantly while marine resources of the Dry Tortugas have remained relatively "pristine". In the past decade, visitor utilization has dramatically increased within the park. This increase in visitor usage dictates careful monitoring of natural resources to ensure their management and protection.

Bird Key Reef is approximately 2 kilometers south of Garden Key (location of historic Fort Jefferson). The Florida Marine Research Institute has participated in coral reef research at Bird Key Reef since the inception of the Tortugas Reef Atoll Continuing Research Project in 1975. In 1999, four permanent stations were established adjacent to historic stations in the spur and groove zone at about 20 meters depth, as part of the Florida Keys Coral/Hardbottom Monitoring Project (CRMP). Each station is 22 to 25 meters long. Transects were created to delineate the left, middle, and right side of each station. An underwater video camera was used to film the three transects at each station. The video camera, positioned 40 centimeters off the bottom, recorded a 0.5 meter swath of the benthos. This video data was then "captured" to create a series of continuous frames of each transect. These video frames were analyzed to determine percent cover of stony coral, octocoral, sponge, substrate, and other benthic categories.

The boulder brain coral, *Colpophyllia natans*, is present at all stations at Bird Key Reef. From 1999 to 2001, the mean percent cover of *C. natans* ranged from 3.0% to 3.5%. In 2002, percent cover dropped to 1.1% (69% decline between 2001 and 2002). Such a precipitous decline led to additional video analyses targeting recently dead *C. natans* colonies. Review of this image analysis data showed 2.2% cover attributable to recently dead *C. natans*. Most of the living colonies viewed were obviously afflicted with some type of disease. Mucous samples of affected and unaffected boulder corals were collected for analyses to identify the causative organism(s).

No comparable decline of *Colpophyllia natans* has been documented in the Dry Tortugas over such a short time period. In addition to the decline of *C. natans*, image analysis revealed a 33% decline in mean percent cover of the boulder star coral, *Montastraea annularis*, between 2001 and 2002. Furthermore, CRMP data show a 20.6% to 15.0% decline in total stony coral cover at Bird Key from 1999 to 2002. Documentation of these declines emphasize the importance of continued monitoring and applied research in Dry Tortugas National Park.

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Southern Biscayne Bay Nearshore Fish and Invertebrate Community Structure

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Loss and/or degradation of coastal wetlands and nearshore estuarine habitats are long-term threats to Biscayne Bay's ecological function and its production of natural resources. Because of its clear, shallow waters, Biscayne Bay's benthic community is a principal source of its productivity and diversity. The seagrass/algae associated animal community, consisting of small forage fish, juvenile gamefish, and invertebrates such as pink shrimp, *Farfantepenaeus duorarum*, is particularly well developed in the shallow nearshore zone adjacent to the mainland and may be dependent upon freshwater inflow. The purpose of this study is to describe the spatial patterns of faunal community composition and species abundance in relation to salinity in the shallow, nearshore habitats of southern Biscayne Bay and ultimately to evaluate the influence of freshwater discharge on community structure.

A random stratified sampling design is being employed to characterize the spatial and temporal patterns of fish and invertebrate community structure in nearshore habitats and to facilitate a throw-trap/commercial roller trawl comparison in the adjacent deeper water commercial fishing zone. At present 54 randomly selected sampling sites, distributed on an areal basis among three salinity strata and an Elliot Key western shoreline control site, are being sampled bi-monthly. The three salinity strata are each subdivided into zones north and south of Black Point, while a subset of these sampling sites in deeper water are associated with the gear comparison.

A 1m^2 throw-trap suitable for sampling across the full range of water depths observed in Biscayne Bay is being used to collect quantitative samples of fish and macroinvertebrates. A commercial shrimper, using a 4.4 m roller trawl, is sampling in water deeper than 1 m. Throw-trap and roller trawl sampling is coordinated to affect the gear comparison. All fishes, caridean and penaeid shrimp collected are identified, counted and sized as appropriate in the laboratory. Each throw-trap sample is associated with habitat quantitatively using a variety of techniques: visual, quadrat harvest and Braun Blanquet. An emphasis in this study on coupling habitat (seagrass, algae, hardbottom) with fish and invertebrate community structure recognizes the importance of habitat, particularly seagrass habitat, in organizing benthic communities and to the nursery function of the bay.

Sampling was initiated in the fall of 2002. Preliminary fish results are available characterizing the fish community in southern Biscayne Bay. Similar results are available for caridean shrimp and the pink shrimp. Figure 1 compares fish caught in the roller trawl net enclosed in a smaller mesh net referred to here as a sock. The sock captures fish and shrimp that might otherwise pass through the roller trawl net. Fish abundance in the collections was relatively low with averages/trawl of less than 8 for the most abundant species, *Lagodon rhomboides*, the pinfish, and the yellowfin mojarra, *Gerres cinereus*. Figure 2 compares fish caught with the throw-trap. The Elliot Key area serves as a potential control for the western shoreline of Biscayne Bay where changes in salinity patterns due to restoration of freshwater flow are expected. The fish fauna observed in Biscayne Bay is similar to that observed in western Florida Bay with the exception that parrotfish are present but absent in Florida Bay. With the exception that densities are lower the fish community along the western shore of Biscayne Bay, dominated by the rainwater killifish, *Lucania parva*, is typical of the seagrass associated fish community in Florida Bay.

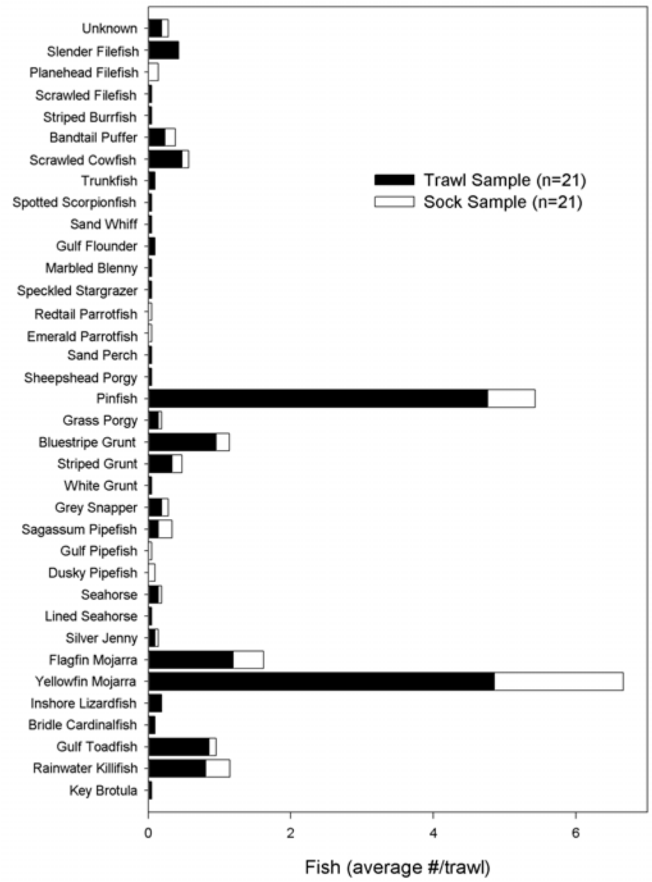

Figure 1. Comparison of the fish caught with the roller trawl versus the sock.

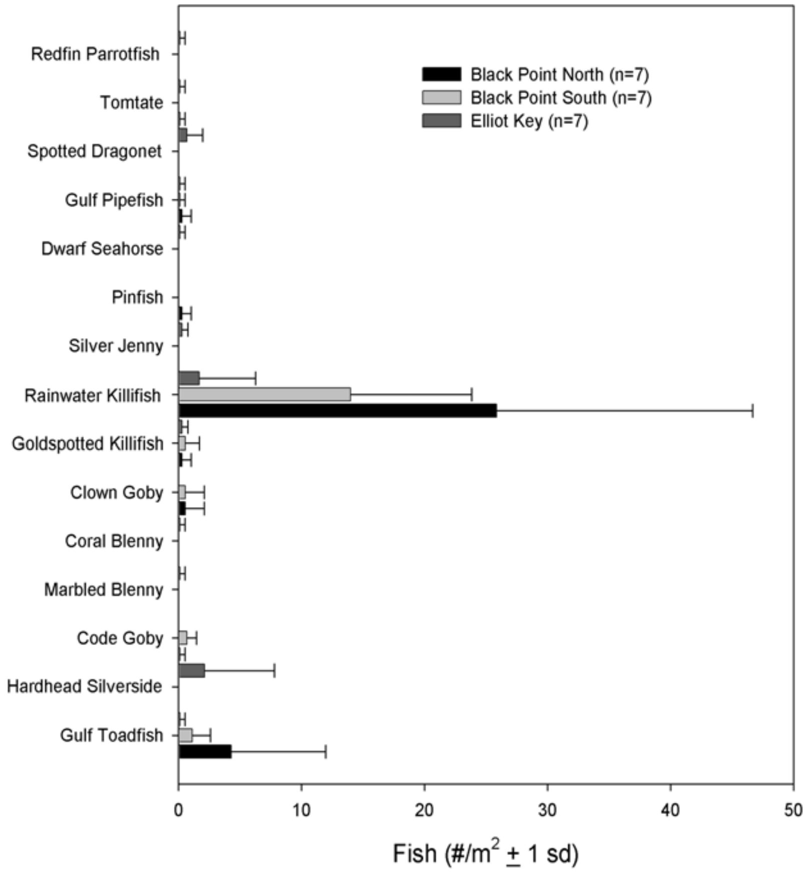

Figure 2. Comparison of the fish caught with the throw-trap north and south of Black Point and along the western shore of Elliot Key.

These results are preliminary. More detailed analyses focusing on evaluating the relationship of fish and invertebrates to salinity and habitat and comparing the throw-trap and roller trawl gears will be presented.

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Temperature and Hypoxia Tolerances of the Indigenous Dollar Sunfish (*Lepomis marginatus*) and the Non-indigenous Black Acara (*Cichlasoma bimaculatum*)

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Wetlands that are being restored as a part of the Big Cypress Seminole Indian Reservation Water Conservation Plan (WCP) provide ideal sites for studying native and non-native fish population dynamics. The WCP, a designated Critical Project of the Comprehensive Everglades Restoration Plan, involves construction of a network of surface water management structures designed to improve hydrology and water quality within the Reservation. The wetland restoration sites are bordered by agricultural and stormwater drainage canals which provide the initial influx of water and aquatic fauna into the newly created wetlands. Along with various native fish species, these canals contain several non-indigenous Cichlidae species (such as red oscar, black acara, blue tilapia, Mayan cichlid and spotted tilapia). The objective of this study was to compare the temperature and hypoxia tolerances of two similar trophic-level fish, the indigenous centrarchid, the dollar sunfish (*Lepomis marginatus*) with the non-indigenous cichlid, the black acara (*Cichlasoma bimaculatum*).

We hypothesized that the non-native black acara would be more tolerant of low dissolved oxygen levels than the native dollar sunfish. We also hypothesized that the black acara would be less tolerant of exposure to cold temperatures in the range that occurs commonly in South Florida waterways. To address these questions, we measured the behavioral responses to various hypoxia regimes for both species at three different acclimation temperatures and quantified the temperature tolerances at normal oxygen levels.

Juvenile specimens were collected from canals and borrow ponds located on the Big Cypress Seminole Indian Reservation. Each trial set of fish (*n*=20) were acclimated for at least seven days prior to the trial date at 20, 25, or 30°C. For the temperature tolerance trials, dissolved oxygen levels were kept constant while temperatures were lowered/raised from the acclimation temperature at a constant rate of 0.15°C min^{-1} until loss of equilibrium (LOE-failure to maintain dorsal-ventral equilibrium for 30 seconds).

To investigate hypoxia tolerance, ventilation rate and proportion of time spent undergoing aquatic surface respiration were recorded for specimens exposed to both gradually induced hypoxia and acute anoxia. During the gradually induced hypoxia trials, dissolved oxygen levels were lowered to anoxia at a constant rate over four hours. For the acute anoxia trials, dissolved oxygen levels were abruptly lowered to anoxic levels. Temperature were maintained at the specimens' acclimation temperature throughout the hypoxia tolerance trials.

We found that for all acclimation temperatures, dollar sunfish and black acara differed in their tolerance to extreme temperatures. When temperatures were raised above 35^{o}C, the LOE temperature for black acara was significantly higher than for dollar sunfish ($p<0.01$). Conversely, when temperatures were dropped to below 10^{o}C, dollar sunfish had a significantly lower LOE than black acara ($p<0.01$). These results suggest that, as observed for several other non-indigenous tropical fish in South Florida, the northern expansion of black acara will be significantly limited by cold intolerance.

The hypoxia trials showed black acara to be more tolerant of anoxic conditions. During gradually induced hypoxia, dollar sunfish significantly increased ventilation rates while black acara ventilation rates were not significantly different. During acute anoxia, dollar sunfish increased ventilation rate and lost equilibrium before the end of the trial period. In contrast, black acara exposed to acute anoxia decreased ventilation rate and were able to maintain equilibrium. These results may help to explain why cichlids are able to maintain viable populations despite hypoxic conditions frequently encountered in South Florida during the summertime diel cycle of dissolved oxygen.

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Landscape Analysis of Gramminoid Habitats to Water Quality and Hydrology in Arthur R. Marshall Loxahatchee National Wildlife Refuge

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The northernmost remnant of the intact Everglades habitat is located in the 57,235 ha (200 square mile area) of the Loxahatchee National Wildlife Refuge. Historically, this system was comprised of a spatially complex mosaic of wet prairies, saw grass stands, tree islands, alligator holes, and sloughs. However, upon completion of the extensive Army Corps of Engineers' Central and South Florida Project, the refuge began to experience large scale habitat conversions associated with altered hydroperiods and agriculturally derived pollution (i.e., contaminants and nutrients). This area has been subject to a rigidly imposed regime of water deliveries and severely degraded water quality as a result of the conversion of its primary watershed to agricultural land uses.

A multi-year interdisciplinary study (1986-91) was conducted to resolve the issues of hydrological alterations and nutrient loading impacts on this important piece of the Everglades system. As a result of altered hydrologic regimes and excessive nutrient loading, the vegetative habitats of the refuge have responded by conversion to massive monospecific stands of cattails in areas influenced by runoff waters. There has been a tendency to drown habitats in the south of the refuge and desiccate those of the north. This study defined gradients of nutrient addition effects and hydroperiods resulting from the management of water on the refuge. The study employed a community-level investigation of vegetative associations in response to the environmental gradients with a spatial characterization of the environmental variables in the GIS. We developed a spatial hydrological simulation model, a vegetative cover database from classified satellite imagery, a spatial coverage of water column/substrate nutrient concentrations, and landscape topography, all geo-spatially articulated in a GIS. Simultaneous studies of wading bird and forage fish distributions in response to habitat conditions were conducted to examine the influence of hydroperiod and water quality on wading birds and their prey base.

In order to spatially portray the various water depths and hydroperiods imposed on the wetlands and examine vegetative responses, a spatially articulate hydrological model was adapted from an existing model and applied very successfully to the area. The model incorporated approximately five hundred 1 km cells and was verified with field data. This capability provided a means hind-casting into the past and recreating the hydroperiod regimes for the past 16 yrs. Patterns of habitat use were influenced strongly by seasonal variation in water levels and decapod and fish assemblage structure varied among habitats. The bottom line results of the study were that there were indeed impacts and vegetative change resulting from hydrological alterations, but the principal agent responsible for the conversion of approximately 8000 acres to cattail was principally phosphorus in the substrates proximal to agricultural inflows.

This work was an innovative approach for its time, employing a hierarchical approach spanning landscape level to community ecology level techniques with GIS technology. The study was however conducted approximately 15 years ago and needs to be upgraded with better imaging, modeling techniques, and community analysis techniques.

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Vegetative Habitats of Water Conservation Area-3A: Hydrologic Impacts of IOP

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A vegetation monitoring study has been initiated in Water Conservation Area-3A (WCA-3A) to document impacts of a new hydrologic regulation schedule implemented 1 July 2002 under the Interim Operation Plan for the Protection of the Cape Sable Seaside Sparrow, Everglades Park – Alternative 7R (IOP-Alt.7R). This study was implemented to address the concern that IOP-Alt.7R could adversely affect the endangered snail kite (*Rostrhamus sociabilis)* and their habitat in WCA-3A, the largest and most consistently utilized of designated critical habitats. Much of the area is already currently seriously degraded. Various studies have documented the conversion of wet prairies (preferred foraging habitat) to aquatic sloughs in that area along with losses of interspersed herbaceous and woody species essential for nesting habitat. The concern is carrying capacity (habitat quality) will be further impaired from elevated water depths and increased hydroperiods indicated by hydrological predictions.

The principal objective is to separate plant community responses due to typical seasonal and year-to-year variances from effects due to new and /or predicted hydrologic regimes. The vegetative community structure of these sites is an expression of *both* recent past and current hydrological conditions. It is critically important to determine how the species associations within these communities respond differentially to changes in hydrology through time and over space. Given the immense area of WCA 3A, this study focuses on areas represented by 2 Indicator Regions (IR's 14 and 17). The areas include major gauging stations (GS 63, 64, and 65) and traditional foraging and nesting regions used by kites.

A multi-tiered approach was required to determine community change through time and space while differentiating seasonal responses from projected hydrologic changes.

1) Spatial Patterns and Change Detection at the Broad Vegetation Class Level- (example, sawgrass strands, tree islands, cattail patches, and wet prairie/slough). Aerial or satellite imagery will be used to remotely sense spatial distributions, extent, and patterning of broad major vegetation classes. Change detection will conducted on at least 3 sets of imagery, 4-5 years pre-project, at project onset, and 3-4 years post-project.

2) Development of "modeled-topographic" database and hydrologic characterization of Indicator Regions. Stage information generated by SFWMM model for the units comprising each Indicator Region is gridded 2 mi. on a side. Stage duration curves generated from this data are determined from estimated ground surface elevations generalized from a weighted mean over the 4 sq. mi. area of each grid. This level of detail is far too generalized for assessment impacts to habitat suitability of wetland vegetation for subtle changes in hydroperiods and inundation depth regimes. To resolve this issue, we have located 10 sample complexes (1 kilometer on a side) within each of the indicator regions (14 and 17) (Fig. 1) using a stratified random approach (peat depths, general elevation, and snail kite nest density). Water levels will be continuously monitored in each complex. Each complex is subdivided into a grid 100-m on a side. Replicate ground surface elevations will be measured (survey-grade GPS) in each major plant community types (as per vegetation maps as per above) near the intersection points in the grid. Elevations

will be surfaced for each of the plant types separately in each grid by confining kreiging routines for the elevations for that plant type only within polygons labeled for that type. This is repeated for each plant type and each cell. Polygons are re-composited and merged in a GIS providing a topographic database driven by plant community types. Stage data for the sample complex will be relativised to elevation data specific to each plant community type creating stage duration curves for each vegetation type in the individual cells. Long term and predicted hydroperiod and depth duration data for each vegetation type in each cell will be generated by statistical regression with the nearest permanent gauging station.

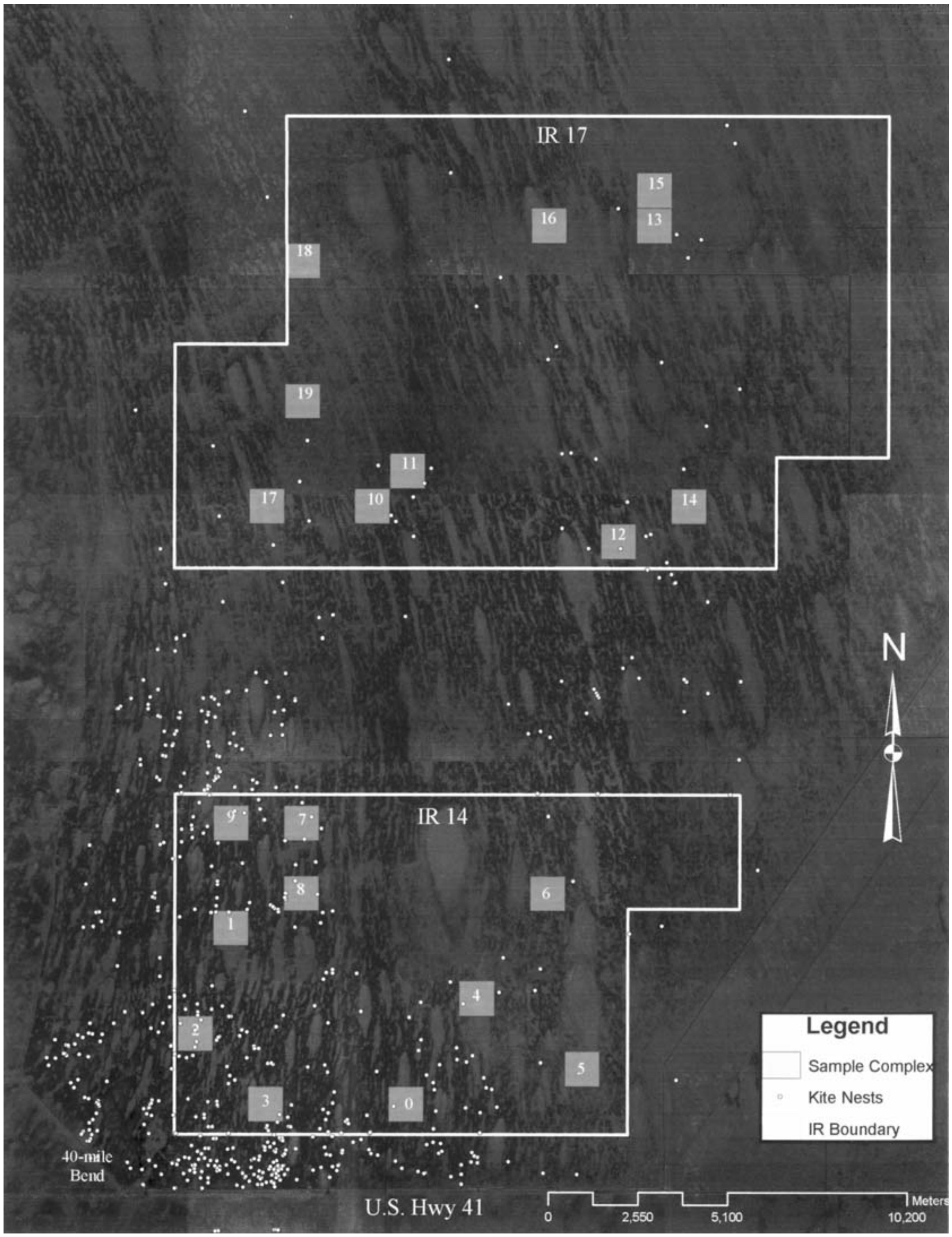

Figure 1. Image of WCA-3A indicating IR and sample complex locations.

3) Establishment of permanent transects plots across elevation gradient in each Indicator Region. Permanent monitoring plots (combinations of quadrats and transects) have been established in the sample complexes across the local elevation gradient in each complex. Regularly placed multiple or replicate quadrats arrayed as continuous belts along a transect perpendicular to the elevation gradient within each sample complex. Each site is sampled seasonally (3 times/yr) for species numbers, stem counts and biomass (both living and standing dead). Water depths are monitored continuously within each sample complex for determinations of hydroperiods and depth duration curves. Each complex consists of three belt transect complexes, 5 plots of the principal habitat types (sawgrass, wet prairie, sloughs), and 5 permanent tree island/shrub heads plots sites typical of kite nest habitat. Multivariate techniques (NMS and multivariate regression tree, and structural equation models) will be used to resolve relationships between plant community structure and hydrology. Structural equation modeling (SEM) will define statistical correlations among species and associated hydrologic and other environmental parameters and provide probabilistic measures for environmental mechanisms involved in plant community succession.

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Monitoring Fishes in Everglades National Park with Emphasis on the Rocky Glades

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Fish assemblages are an integral link in Everglades food webs, providing food for wading birds, larger fishes, otters, alligators, and other wildlife. However, the construction of canals, imposition of agriculture, and the encroachment of urban development has highly impacted the Everglades ecosystem by loss of habitat and unnatural water quality, quantity, and timing. Current and proposed water delivery projects (e.g., Modified Water, CERP) have not been field tested for their effects on much of the Everglades biota. Understanding the influence of habitat and hydrology on fish assemblages will help to provide the knowledge needed to guide restoration programs in the Everglades.

Fish monitoring efforts in Everglades National Park (ENP) have been focused in the *Eleocharus* spp. marshes of the slough regions with little emphasis on the higher elevation marshes and marl prairies of the Rocky Glades in eastern Everglades National Park. Positioned at the eastern edge of ENP, the Rocky Glades may be more vulnerable to disturbance due to close association with canal systems and water management practices. The complex substrates and solution hole habitats associated with the karst topography in the Rocky Glades limit the effectiveness of traditional Everglades fish sampling techniques such as throw trapping. Examining the use of alternative sampling techniques that can be used across multiple habitats in ENP will provide complementary information to understanding Everglades freshwater fisheries.

Presently, we are sampling fishes within multiple habitats of ENP and relating aspects of the fish assemblage to hydrological and habitats variables. Our work includes examining the use of minnow traps across major habitat types such as sloughs and Rocky Glades, comparison between sampling methodologies, collecting baseline data on fishes in the marl prairies west of Shark River Slough, and examining the effects of water management on fish assemblages. We will present results obtained in an ongoing study in the Rocky Glades.

We sampled monthly from April 2001 to the present using minnow traps and collected 25 species of fishes (16 native and 9 exotic) at 19 Rocky Glades sites. These sites consisted of marsh surface, and shallow and deep solution hole habitats. Combining these data with those that we collected from June 1999-September 2000, we will be able to examine the seasonal dynamics of Rocky Glades fish assemblages, relate aspects of fish catches in minnow traps with hydroperiod, and examine the potential influence of minimum water levels on fish assemblages.

Understanding how fish assemblage structure relates to hydrology is important for predicting the effects of restoration programs on fish assemblages of ENP. Future directions for investigation include assessment of sampling across multiple habitats relating aspects of the fish assemblage structure to habitat, hydrology, and water quality, and examining fish assemblage structure in areas associated with canals and newly constructed detention areas on the north and eastern boundaries of Everglades National Park.

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The Role of Seasonal Hydrology in the Dynamics of Fish Communities Inhabiting Karstic Refuges of the Florida Everglades

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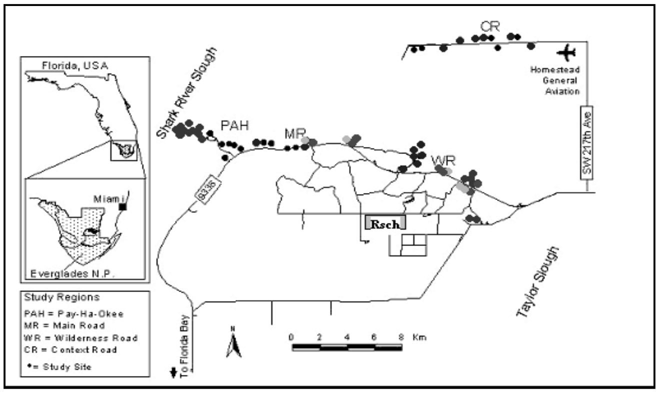

Figure 1. Map of sampling locations in Everglades N.P.

Our goal is to understand the influence of altered surface flooding on access to groundwater refuges for surface-dwelling aquatic animals, primarily fishes, in the karstic wetlands east of Shark River Slough, Everglades National Park, Florida, USA. The current management proposal for these wetlands call for water levels to not fall more than 46 cm (1.5 ft) below ground level for greater than 90 days per year at an average periodicity of no more than once in three years. This study includes four areas in the extreme southeastern Everglades (fig. 1) and is in its fifth year. We will present the results of data collected in 1999-2000 in addition to those from 2001-2002. We suggest that the impact of groundwater management on dry-season refuges should be considered when establishing criteria for species management.

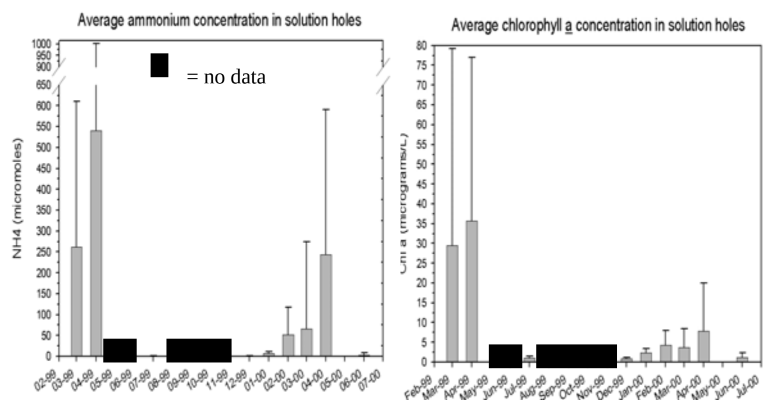

Figure 2. The concentration of nutrients in solution holes by month.

The solution hole environment became more lethal to fishes as water levels receded. From analysis of a number of factors, temperature, pH, dissolved oxygen, and chlorophyll a were most significant in structuring dry-season fish communities in 1999 and 2000. These factors changed on a seasonal basis, with nutrient concentrations increasing (fig. 2) and dissolved oxygen decreasing in holes during the dry season. In our four study regions, 84 percent of solution holes were less than 46 cm deep, and those deeper than 1 m were rate (< 3 km^{-2}) (fig. 3).

The capture of fishes in solution holes increased as water levels fell until mid-dry season. This was followed by a significant decline in the late dry season, and a subsequent increase in early wet season (fig. 4). This pattern indicates that fishes are surviving in solution holes until conditions become critical. Mortalities then occur, but holes are repopulated by subsequent re-invasions of foraging and nesting species upon inundation. Native cyprinodontiforms were abundant in shallow solution holes that dry annually under current management, while predatory species (often non-native) tended to dominate deeper holes. The percentage non-native of all fishes captured varied by season and across regions, with a maximum of 63 percent occurring at the Wilderness Road region, and an average of 23 percent non-native across all regions and seasons (fig. 5).

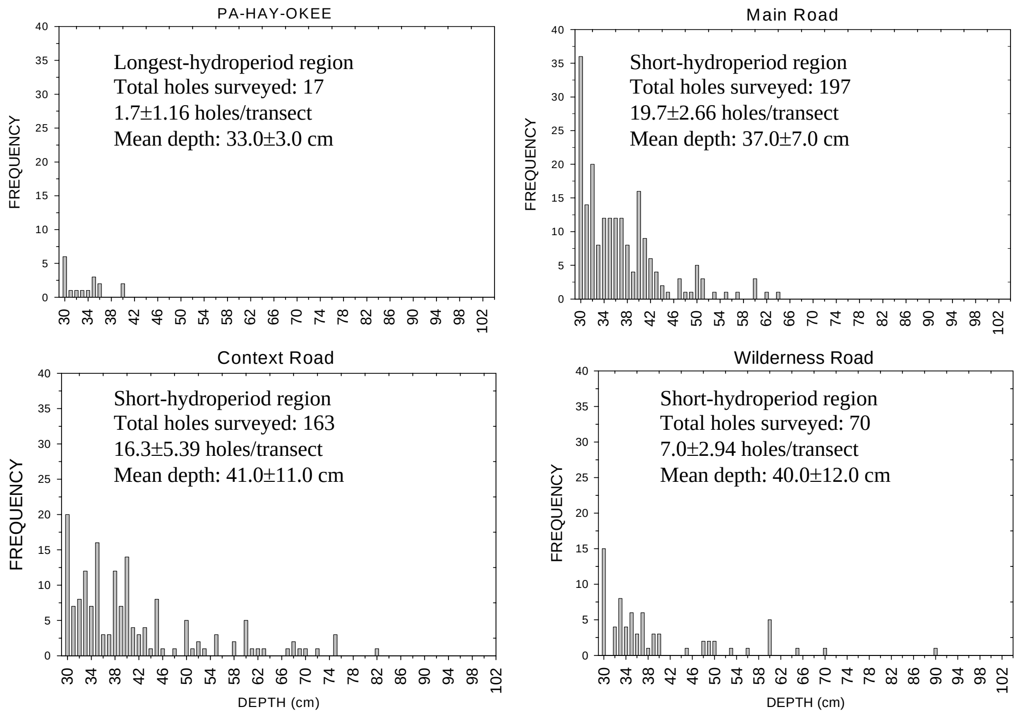

Figure 3. Depth frequency of holes by region.

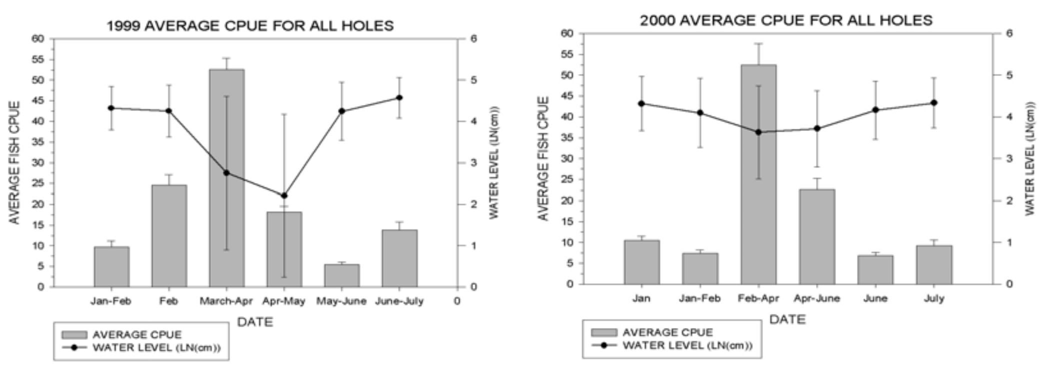

Figure 4. Average catch-per-unit-effort (CPUE) of fishes and average water depth across all regions in 1999 and 2000.

Our work suggests that solution holes serve as necessary dry-season habitat and that an immense loss of fish biomass occurs when water levels fall 46 cm below ground surface within our study regions. We recommend that the effect of groundwater management on dry-season and drought refuges should be included while developing criteria for minimum flows and levels for the management of the Everglades and other aquatic ecosystems.

This research was funded through the Critical Ecosystem Studies Initiative by agreement between the U. S. Geological Survey (USGS) and the U. S. National Park Service.

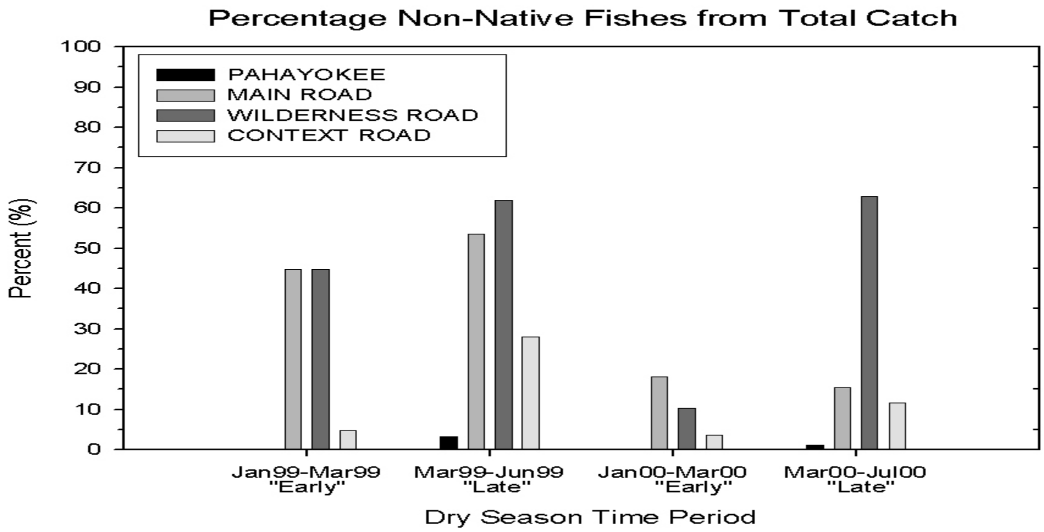

Figure 5. Percentage of non-natives in total fishes captured in holes by "early" (January-March) and "late" (March-July) dry-seasons for 1999 and 2000.

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Using Aquatic Invertebrates to Assess Restoration of the Kissimmee River Ecosystem

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Aquatic invertebrates were identified as a critical biological component for assessing restoration of ecological integrity within the Kissimmee River ecosystem. Aquatic invertebrates play an integral role in ecosystem processes, decomposition of detritus, and energy flow to higher trophic levels. Aquatic invertebrates also have a long history of use in biomonitoring and can serve as indicators of biotic integrity and ecosystem health.

Channelization of the Kissimmee River eliminated flow through remnant river channels and altered aquatic invertebrate community structure. Most aquatic invertebrate taxa inhabiting remnant river channels are characteristic of lentic (non-flowing) habitats and adapted to low levels of dissolved oxygen. Restoration of the Kissimmee River will reestablish important habitat characteristics such as current velocity, increased levels of dissolved oxygen, and a sand substratum. These habitat characteristics are expected to lead to reestablishment of an aquatic invertebrate community characteristic of unmodified southeastern Coastal Plain rivers.

Baseline (pre-restoration) aquatic invertebrate community structure characteristics will be briefly discussed. Expectations for restoration of aquatic invertebrate community structure within river channel habitats will be presented along with a discussion of initial responses following reestablished flow.

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The Effects of Hydroperiod on Life-history Parameters of Two Species of Livebearing Fishes (Poeciliidae) in the Florida Everglades

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Ecologists often make assumptions about the "stressfulness" of habitats based on fluctuation in the physical environment and its presumed effects on organismal vital rates such as age-specific survivorship or fertility. In aquatic habitats, fluctuations in water level leading to dry-down events are often considered stressful for fishes because it is assumed that reduced habitat area and crowding have adverse effects on survivorship and fertility. However, the degree of drying, as demonstrated by variations in minimum surface-water depths, is rarely constant among years in the Everglades. That variation may produce dramatically different effects on the fish community, depending on factors such as availability and quality of refuges that remain wetted. Furthermore, organisms typically have physiological and behavioral adaptations to compensate for environmental variability, including synchronization of reproductive and migratory patterns with environmental fluctuation, and phenotypic plasticity. Consequently, the matching of recurrent "stress" with measures of survivorship and reproduction are critical to produce predictive demographic models. While comparative statements about the relative stressfulness of habitats are common in the literature on life histories, the ability to make such comparisons without age-specific survival and fertility data is questionable. The utility of management models such as ATLSS would be improved by estimating explicitly the effects of hydroperiod on demographic rates of two of the most common species in the Everglades, the sailfin molly and the least killifish (Poeciliidae) (fig. 1).

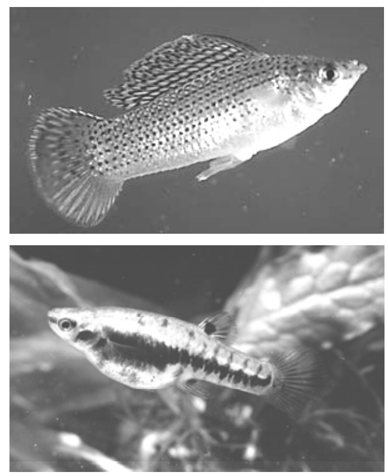

Fig 1. Top: sailfin molly (*Poecilia latipinna*); bottom: least killifish (*Heterandria formosa*)

We used estimates of age-length relationships to estimate age-specific survival and fertility for sailfin mollies and least killifish from six sites in the Everglades that experience a gradient of hydrological conditions (fig. 2). These six sites are the focus of long-term monitoring of fish communities, and samples collected from 1997 to 1999 were used to estimate age-specific survivorship curves and fertility schedules. From those data, we constructed life tables to compare patterns in vital rates of each species with hydroperiod. Also, we compared the idealized estimate of population growth rate from the life table to real population dynamics over the same time period. We used otoliths (fig. 3) to determine the relationship between size and age for male, female, and juvenile sailfin mollies from the six study sites (fig. 4).

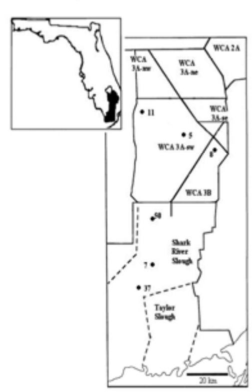

Fig. 2. Map showing six study sites.

Calibrations indicated that this method was very accurate for juvenile fish, but tended to under-estimate age in older, mature specimens. We also dissected female fish from the long-term field collections to estimate size-specific fertility for females of each species. The otolith data were used to estimate the age of females based on size to transform these data into age-specific fertility tables for each study site.

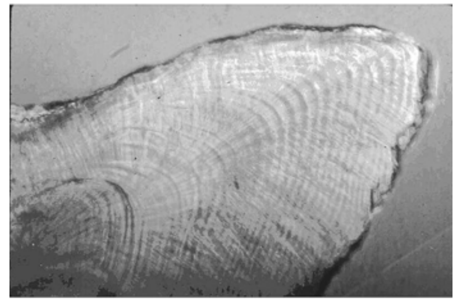

Fig. 3. Cross-section of a sailfin molly otolith. The number of rings indicates the fish's age in days.

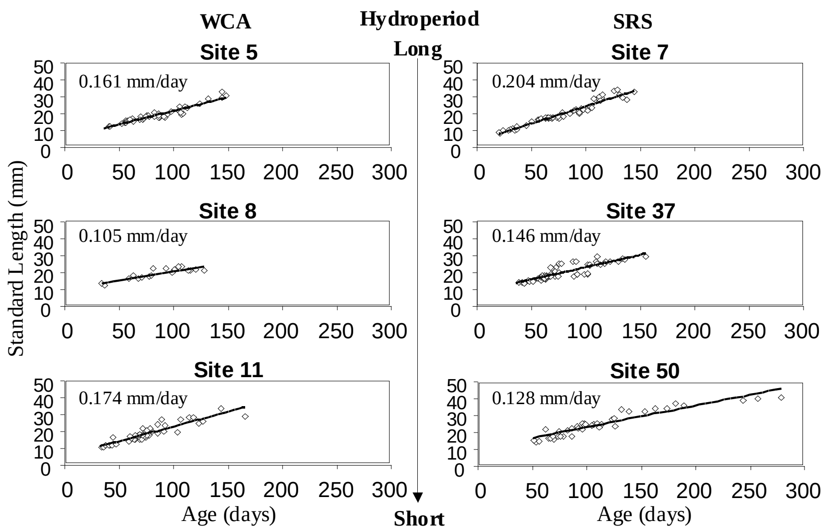

Fig. 4. Size-age relationships for female sailfin mollies from our six study sites. The slopes of each line are indicative of growth rate.

The analyses indicated that growth rate and age-specific fertility differed among locations, and that some patterns could be explained by hydroperiod. However, many of the patterns were not consistent with the expectation that short-hydroperiod sites are more stressful for these two species. For example, the longest life expectation and highest lifetime fertility were noted at the short hydroperiod sites for both taxa. These results yielded greater estimates of population growth rate (r) for the two short-hydroperiod sites. Either both species have adaptations that permit them to circumvent the conditions that make these sites appear stressful to ecologists, or immigration is subsidizing populations in short-hydroperiod sites yielding a more favorable demographic profile than is actually realized by residents of the site. Ongoing research on dispersal by similar species before and after droughts suggests a complex pattern that may include dispersal from long-hydroperiod sites to the short-hydroperiod sites, and persistence in local refuges. The exact role of dispersal in re-establishing short-hydroperiod fish populations appears to depend on local topography and ambient rainfall. However, our data are consistent with the long-held hypothesis that small fish species experience less predation from piscivorous fish in short-hydroperiod than in long-hydroperiod habitats. This hypothesis predicts that these fishes should experience longer life spans in short-hydroperiod sites, as we observed. More research is needed on the relative role of immigration as a mechanism to sustain small fish populations in short-hydroperiod marshes of the Everglades. This study suggests that management models of fishes must incorporate rapid recovery from drought events. Some species may experience greater population growth rates in short-hydroperiod habitats, although ultimate population sizes may be limited by periodic dry down, site productivity, and other factors.

This research was funded through a cooperative agreement between the U. S. Geological Survey (USGS) and FIU under the Place-Based Studies initiative of the USGS (CA 1445-CA09-95-0112, Sub-agreement No. 12).

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Unraveling the Complexities of Mercury Methylation in the Everglades: The Use of Mesocosms to Test the Effects of "New" Mercury, Sulfate, Phosphate, and Dissolved Organic Carbon

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Mercury (Hg) contamination of the Everglades ecosystem is one of the most severe cases in the published literature. Currently, no human consumption of any Everglades' sport fish is recommended. Although it is widely recognized that mercury contamination of aquatic ecosystems is largely the result of atmospheric mercury emissions, long-range transport and subsequent deposition, providing a scientific understanding of this problem with the necessary detail to prescribe appropriate corrective measures has remained unclear. From 1995 to 1999, the Aquatic Cycling of Mercury in the Everglades (ACME) project studied the biogeochemical cycling of Hg in detail at a series of sites spanning most of the north-to-south extent of the Everglades, and many of the major sub-ecosystem types. The ACME project revealed that mercury and methylmercury (MeHg) distributions in water, sediment and biota show complex seasonal and spatial trends, and that the cycling rates of Hg and MeHg are so rapid that many measurements need to be conducted on a diel basis in order to provide an adequate understanding of the controlling factors. These studies revealed relations between biogeochemical factors and the production rate of MeHg, which is the most bioaccumulative and toxic form of mercury, and thus is central to understanding the mercury problem in the Everglades and elsewhere. Specifically, through field experiments and laboratory studies, we established links between MeHg production and several key ecosystem factors, including: hydroperiod, atmospheric Hg loading, sulfate loading from Everglades Agricultural Area (EAA) runoff, and dissolved organic carbon (DOC) levels in surface water. However, because all these driving factors of MeHg production co-vary spatially across our study sites, definitive quantitative assessments of which parameters are most important for limiting future methylmercury production remained unclear. In addition, because all of these factors are likely to be altered by the Everglades Restoration Project, a more "controlled" experimental approach was developed to estimate how this ambitious project might affect mercury toxicity for the Everglades in the future.

One approach for sorting out the complex responses of MeHg formation to alterations in critical water quality constituents (Hg, sulfate, phosphate and DOC) is through the use of in situ mesocosms (or wetland enclosures), in which dosing studies can be conducted. Such an approach has the advantage of maintaining many of the qualities of natural ecosystems that are very difficult to replicate in a laboratory setting, such as soil structure, redox, rainfall inputs, diel temperature and light cycles, as well as indigenous flora and fauna. On the other hand, mesocosms do potentially suffer from so called "wall" effects, and thus strict monitoring of the enclosed and native environment must be maintained to validate results. Starting in May 2000, the ACME Phase II project initiated mesocosm experiments at four of our long-term study sites

(F1, U3, 2BS, and 3A15) located in Water Conservation Areas (WCA) 2A, 2B and 3A. Initial experiments were limited only to mercury dosing to quantify the ecosystem response to changes in mercury loading. At each site, we added mercury to mesocosms at 0.5, 1.0, and 2.0 times the current ambient loading rate (about 22 $\mu g/m^2/y$), and dedicated two mesocosms as experimental controls. At each site we also constructed clear plastic "roofs" for two mesocosms, which excluded mercury deposition from contemporary rainfall, but allowed for exchange of air and light to promote algal and plant productivity.

To distinguish between "new" and "old" (previously existing) mercury, mesocosm dosing was conducted using stable isotopes of mercury (e.g., ^{202}Hg, ^{202}Hg), which can be distinguished from ambient, mercury using a mass spectrometer. The examination of new versus old mercury was also tested by adding multiple Hg doses in the same mesocosms but at different times, and using different isotopes for each addition. It had been hypothesized that the mercury contamination problem may continue for very long periods of time if existing mercury pollution in soils and sediment sustained the mercury cycle. Results of these types of experiments, therefore, are significant for assessing the potential effectiveness of mercury emissions reductions on mercury cycling in the Everglades.

Results from the mercury dosing experiment revealed several important findings. First, there is a positive and linear relation between mercury added and the production of MeHg in the Everglades. Second, there is an exceptionally close tie between mercury added and bioaccumulation of the added mercury in fish (Gambusia); the relation has a coefficient of determination greater than 0.9. Last, there is an "aging effect" for new mercury added to the ecosystem, such that more recent doses of mercury isotopes are more likely to be bioaccumulated than older mercury. All these results support the conclusion that recent mercury additions are proportionally more responsible for sustaining mercury exposure to wildlife and humans in south Florida, and any attempts to reduce current loading rates would likely have rapid and positive effects.

In 2001 we expanded the experimental design of our mesocosm experiments to examine the effects of sulfate, phosphate and DOC dosing on mercury cycling. In addition, a new experimental site in Loxahatchee National Wildlife Refuge (WCA1) was added. Because DOC and sulfate levels in WCA2 and WCA2B are elevated due to runoff from the EAA, sulfate and DOC dosing could only be performed at our sites in WCA 1 and 3, where more pristine conditions exist. Also, because ecosystems can require extended periods of time to achieve a new equilibrium after the addition of phosphate, phosphate-dosing mesocosms previously established by researchers from the South Florida Water Management District were accessed and sampled. Lastly, in some mesocosms, we conducted mixed addition experiments (mercury and sulfate, and mercury and DOC) to test for possible synergistic or antagonist effects of co-dosing.

The mercury, sulfate, DOC and phosphate addition experiments revealed several novel observations. Surprisingly, the addition of DOC alone stimulated the production of additional MeHg from "old" mercury in sediments. In the mixed DOC plus mercury addition experiments we observed greatly elevated methylation of the added mercury isotope, about 4 to 8 times greater than when mercury alone was added. These results suggest DOC is directly involved in the methylation process, rather than the common assumption that DOC is simply an attractive ligand for mercury in aqueous solution. Finally, when compared against the mercury-only dosed mesocosms, the mixed sulfate plus mercury mesocosms, yielded significant additional isotopically-labeled MeHg. However, high sulfate dosing levels gave rise to lower overall

MeHg formation, which consistent with our previous field observations in WCA2 where very high levels of sulfate contamination exist, and reduce mercury methylation rates by sulfide inhibition. Lastly, no clear trend could be observed between phosphate dosing level and MeHg formation and accumulation.

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Woody Debris in South Florida Mangrove Wetlands

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Volume of woody debris in forests provides an often overlooked, yet important, ecosystem service. The slow recovery, or decomposition, of woody debris following a major disturbance, such as a hurricane, has led to speculation that coarse woody debris serves to influence positively the long-term persistence and supply of nutrients in a forest ecosystem. Hence, immediately after a disturbance an acute flux of nutrients via litter and small woody debris fall occurs. This initial flux is followed by a gradual decrease in the supply of nutrients to some steady state whereby larger woody debris provides a source of nutrients during the ensuing forest recovery period when nutrients are most needed.

Woody debris is abundant in hurricane-prone forests. With a major hurricane impacting south Florida mangroves approximately every 20 years, carbon storage and nutrient retention may be influenced greatly by woody debris dynamics. In addition, woody debris can influence seedling regeneration in mangrove swamps by trapping propagules and enhancing seedling growth potential.

This research reports on line-intercept woody debris surveys conducted in mangrove wetlands of south Florida 9-10 years after the passage of Hurricane Andrew (1992). The volume of woody debris for all sites combined was estimated at 67 m^3/ha, and varied from 13 - 181 m^3/ha depending upon differences in forest height, storm circulation quadrant, and maximum model-generated wind velocities. The greatest amount of woody debris was found in the eyewall region of the hurricane, with a projected necromass of about 36 t/ha. Approximately half of the woody debris biomass was associated as small twigs and branches (fine woody debris) since much of the coarse woody debris > 7.5 cm was fairly well decomposed. Regressions of woody debris relative to forest height and maximum Hurricane Andrew windspeeds were developed so that woody debris can be added to existing ecological simulation models for the region. Including woody debris in model simulations may be important in accounting for a substantial amount of additional carbon within the system.

Cases of Caribbean mangrove tree mortality have been reported but have not included estimates of downed wood. Downed woody debris as a component of mangrove forest structure has been explored in two investigations from the Old World tropics but have less relevance to Neotropical mangrove swamps. This research provides those data for hurricane-prone regions of south Florida and provides the associated link to ecological simulation models.

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Recharge and Discharge Measurements in the Everglades using Short-lived Radium Isotopes

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The Everglades peat layer acts as an interface between groundwater and surface water, a zone where the interactions between physical, chemical and biological processes are enhanced, influencing the cycling of elements between water and sediments. Common methods for measuring exchange across the peat layer are prone to complications. For example, hydrologic approaches yield results with high variances when small hydraulic gradients are encountered, especially over short distances. Likewise, direct seepage meter measurements tend to be imprecise at low seepage rates. Furthermore, some geochemical approaches (e.g. radon and chloride) rely on the measurement of fine scale gradients that are frequently affected by processes independent of recharge or discharge (e.g. methane ebullition or mechanical disturbance of the surface sediments). We present here a new method to quantify these slow vertical fluxes through the peat layer by modeling the pore-water profiles of ^{223}Ra and ^{224}Ra.

^{223}Ra ($t_{1/2}$ = 11.4 d) and ^{224}Ra ($t_{1/2}$ = 3.7 d) are naturally occurring isotopes of radium which are useful tracers for quantifying rates of groundwater recharge and discharge in wetlands, particularly for time scales of a few days to weeks. Near the interface between peat sediments and the underlying aquifer, or near the interface between the peat and overlying water, pore-water radium activities are commonly different than the amount expected from the radium production rate (Figure 1). This disequilibrium results from vertical transport of radium by pore water. In situations where groundwater recharge or discharge is significant, the rate of vertical water flow can be determined from this disequilibrium using a combined model of radium transport, production, decay, and exchange with solid phases.

$$\frac{\partial C}{\partial t} = \underbrace{D\frac{\partial^2 C}{\partial Z^2} - v\frac{\partial C}{\partial Z}}_{\text{transport}} + \underbrace{\frac{\hat{P}}{(1+K_D)}\frac{n}{1-n}}_{\text{production}} - \underbrace{\lambda C}_{\text{decay}} - \underbrace{\rho_s \frac{1-n}{n}\frac{\partial C^*}{\partial t}}_{\text{exchange}}$$

We have developed and tested this technique at three sites in the freshwater portion of the Everglades by quantifying vertical advective velocities in areas with persistent groundwater recharge or discharge, and estimating a coefficient of dispersion at a site that is subject to reversals between recharge and discharge (Krest and Harvey 2003). Groundwater velocities (*v*) were determined to be between 0 and -0.5 cm d^{-1} for a recharge site, and 1.5 ± 0.4 cm d^{-1} for a discharge site near Levee 39 in the Everglades (Figure 2). Our approach has a distinct advantage in the Everglades because strong gradients in ^{223}Ra and ^{224}Ra usually occurred at the base of the peat layer, which avoided the problems of other tracers (e.g. chloride) for which greatest sensitivity occurs near the peat surface – a zone in which gradients are readily disturbed by processes unrelated to groundwater flow.

This technique should be readily applicable to any wetland system with different production rates of these isotopes in distinct sedimentary layers or surface water. The approach is most straightforward in freshwater systems because constant pore-water ionic strength can usually be assumed, which simplifies the modeling of radium exchange with solid phases. In estuarine or marine systems, changing ionic strength could be addressed with additional data and an extended model.

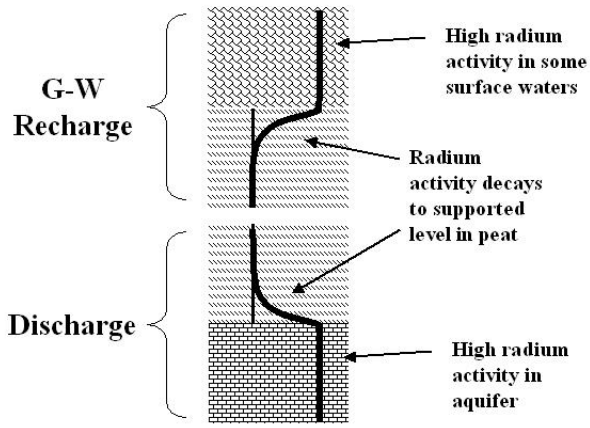

Figure 1: Idealized profiles showing the expected radium activities in surface water and peat pore-water for the cases of groundwater recharge (top) and groundwater discharge (bottom). Mixing due to dispersion could look similar to either of these profiles.

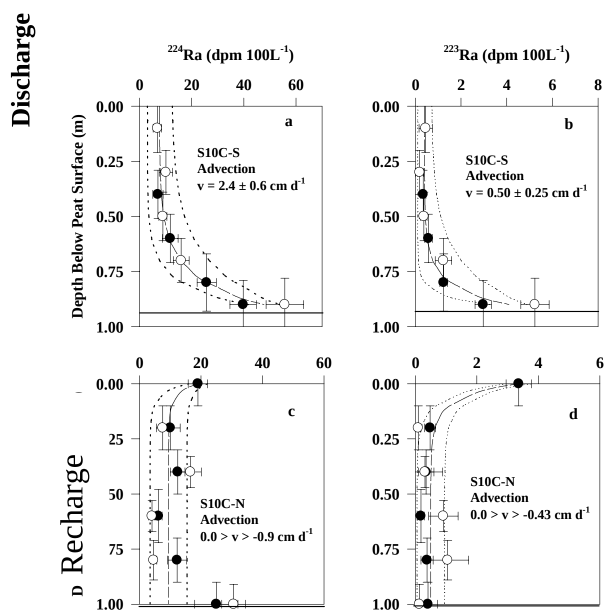

Figure 2: Pore-water radium activities as a function of depth. a) ^{224}Ra and b) ^{223}Ra activities at site S10C-S are highest at the base of the peat and decrease upwards as the excess radium in discharging groundwater decays to a level supported by its equilibrium production and exchange with the adsorbed fraction. c) ^{224}Ra and d) ^{223}Ra activities at S10C-N are elevated only in the upper portion of the peat, suggesting that recharge occurs at this site.

References:

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RAVEN View^{TM}: Video Capture Tool Used for the Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project

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RAVEN View^{TM} is a video tool that facilitates researcher's ability to capture video, generate high-resolution mosaics and georeference video clips. RAVEN View^{TM} was originally developed for the US Department of Defense in conjunction with aerial video for mine detection, infrastructure assessment, and location of geospatial data. The software also has been used in commercial applications to collect aerial images of roadways, shorelines, power grids and pipelines. Ground video has been used for surveillance, crime scene documentation, and emergency response analysis. In 2001, Observera Inc. collaborated with the Florida Marine Research Institute's coral reef monitoring team to adapt the RAVEN View^{TM} for use in underwater video interpretation.

The CRMP uses video extensively for analysis of coral reef conditions at sampling sites within the Florida Keys National Marine Sanctuary and Dry Tortugas . RAVEN View^{TM} captures live or recorded video from an analog input, or video capture cards can be used to input video imported from other systems. Captured video can be played back or manipulated using RAVEN View^{TM}'s other tools. CRMP researchers use a method called framegrabbing. Still images are grabbed from the full motion video clips of the coral reef sampling stations for data analysis. To ensure that the sampled area is not double counted, or skipped, frames that have no overlap or gaps between adjacent frames are selected. RAVEN View^{TM} quickly generates mosaic images from the stored video clips which are used to grab images with a specified overlap (down to 0%). This gives analysts the best possible selection of imagery.

Mosaic images are also used to create time-series comparisons of coral sampling stations (Figures 1-4). RAVEN View^{TM} can create a mosaic from any video imagery; however, panoramic views produce the best results (Figures 1 and 2). Mosaics can be printed, exported in a variety of formats, and transferred to other image tools (e.g. Image Pro, PointCount, Premiere or Adobe Photoshop) for further analysis. We have tested planimetric analysis of mosaics using PointCount for Coral Reefs^{TM}, and ImagePro. Planimetric analyses of large mosaics are effective for survey of relatively large-scale features, but cumbersome for small-scale changes.

RAVEN View^{TM} also has capability to add geographic information to video. When a map or reference image of the region is also shown in the video, RAVEN View^{TM} can produce a mosaic image with a known geographic location. Mosaics that have been geolocated can be displayed as overlays on a map or used to determine approximate geographic locations of features visible in the mosaic or video from which it was produced. CRMP researchers have recently begun testing this georeference tool and determined its application for more effectively monitoring and mapping location of large diseased or bleached coral heads from year to year.

The RAVEN View^{TM} software is currently being used by many different organizations world-wide. RAVEN View's tools could also be used for other research applications such as wetland monitoring, coastal surveys, and marine habitat damage assessments.

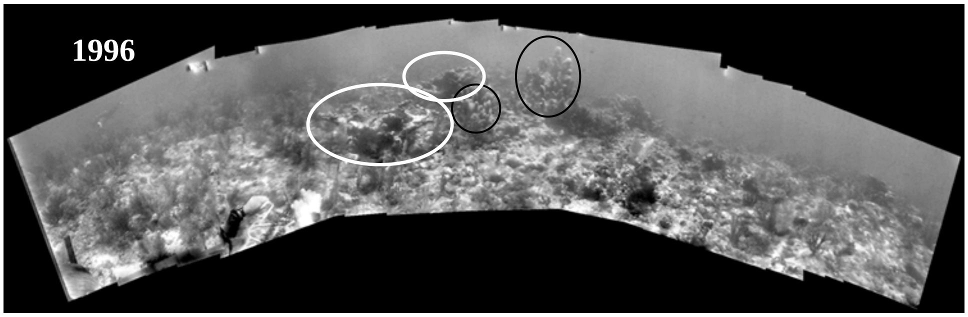


Figure 1. Panoramic view at Conch Deep Reef in 1996. *Dendrogyra cylindrus* (black circles) and *Acropora palmata* (white circles) are present.

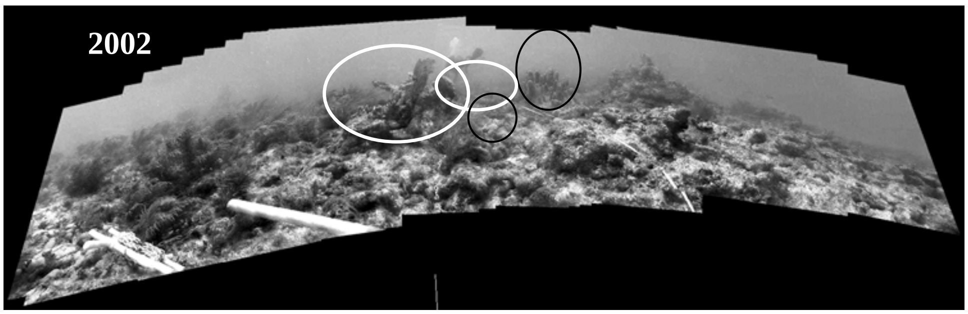
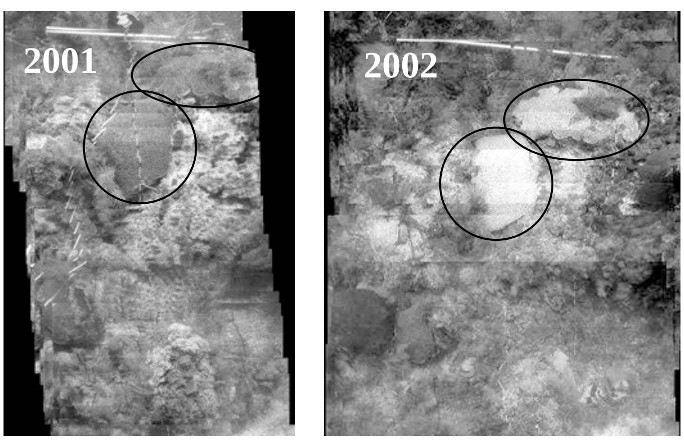


Figure 2. Panoramic view at Conch Deep Reef in 2002. The *Dendogyra cylindrus* (black circles) seen in 1996 is mostly absent in 2002. One stand of *Acropora palmata* (white circles) seen in 1996 is missing and the other is present 2002.



Figures 3. Time-series comparison showing bleaching of coral between 2001 and 2002 at Bird Key Reef in Dry Tortugas.

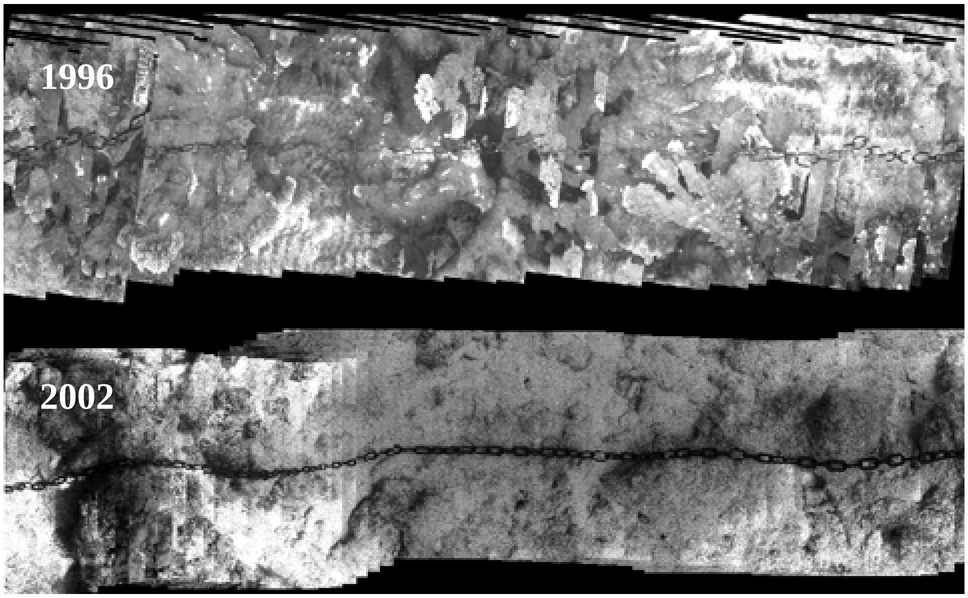


Figure 4. Time-series comparison at Western Sambo Deep sampling station. *Acropora palmata* was present in 1996 and absent by 2002.

A copy of the poster may be obtained by requesting the following reference. Kupfner, S. and Lybolt, M. 2003. RAVEN View^{TM}: Video capture tool used for the Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project. Florida Marine Research Institute, St. Petersburg, FL. IHR#2003-003.

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Thoughts on the Modeling of Human Operational Influences on Regional Hydrologic Models

***Wasantha Lal**, Randy Van Zee* and *Joseph Park*

Human intervention on a hydrologic system is not limited to introduction of new hydraulic components, but extends to various intentional and unintentional operations of the components such as structures and pumps in managing the system. Modern hydrologic models have to simulate these effects accurately if the results are to be verified against observed records. Simulation of management in urban and agricultural areas is important because water levels in these areas depend mostly on the management rules than the natural hydrology. It is not an easy task because management comes under more than one agency, and more than one water management plan. Some of the plans are time and issue sensitive and are invoked depending on conditions such as droughts and floods. Even when the management plans are fairly well defined, there is substantial flexibility in the rules, and also the occasional equipment and human failure to follow rules. All these factors make the simulation of management extremely difficult.

The management simulation engine MSE developed for the RSM has to accommodate many of the operational features of the South Florida system, as well as a new thinking in modeling management. There may even be times when the success of a model doesn't have to rely solely on its data fit, considering operational unknowns data problems. This paper describes some of the key components of the proposed MSE, and some of their features can be accommodating such conditions when simulating the complex system of South Florida. These ideas are intended to improve the way RSM and other models are applied in South Florida. The objective is also to make it possible to achieve realistic defensible modeling goals under various study conditions.

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Florida Panther Conservation and Genetic Restoration

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Florida panthers (*Puma concolor coryi*) are endangered by a combination of population and habitat factors (USFWS 1987). Loss and fragmentation of habitat and unregulated killing over the past two centuries have reduced and isolated populations in the southeastern United States to the point where only one population, estimated in the late 1980's at 30-50 adults, exists on approximately 8,810 km^2 (2.2 million acres) of habitat in south Florida (Maehr 1990). Small population size and geographic isolation increase the chance for extinction of Florida panthers due to demographic instability inherent in small numbers and erosion of genetic diversity from restricted gene flow and inbreeding. Genetic diversity is the basis for production of fit individuals as well as providing population elasticity in order to respond to changing environmental and habitat conditions. A unique opportunity exists to implement conservation and management strategies for Florida panthers and evaluate results that will benefit Florida panthers as well as other imperiled species.

Natural exchange of genetic material occurred historically among the Florida panther population in the southeastern United States and contiguous populations of *P. c. couguar* to the north, *P. c. hippolestes* the northwest and *P. c. stanleyana* to the west (Young and Goldman 1946). Genetic exchange between populations ceased as the coastal plain was gradually cleared and settled. Florida panthers steadily declined in abundance and distribution as a result. Inbreeding increases when dispersing potential breeders can no longer move among fragmented populations, and declining population size compounds demographic and genetic factors. Implications include inbreeding depression, loss of genetic variation, declining health, reduced survivability, lower numbers, and eventual extinction.

Land acquisitions that have protected panther habitat began with the creation of Big Cypress National Preserve and the Fakahatchee Strand State Preserve in 1974 that protected over 700,000 acres. Since 1974, another 870,000 acres have been purchased by State and Federal entities and include the Florida Panther National Wildlife Refuge, Okaloacoochee Strand State Forest, Picayune Strand State Forest and Corkscrew Regional Ecosystem Watershed. Other lands that contain quality panther habitat are listed as Florida Forever projects. Even with adequate habitat conservation, genetic diversity and health of the Florida panther population needs to be restored to ensure survival. A plan for genetic restoration and management of the Florida panther was developed in September 1994 (Seal 1994) and implementation began in 1995 with the release of 8 female Texas cougars into areas occupied by Florida panthers. Five of the 8 cougars have produced a total of 17 offspring and many of these offspring have reproduced. The remaining Texas cougars will be removed from the wild in the spring of 2003.

The Florida Fish and Wildlife Conservation Commission has handled and radiocollared 115 panthers since 1981 and handled another 142 panther kittens at dens. FWC and the National Park Service have collected over 60,000 locations of radiocollared panthers. We will to continue monitoring panther genetic restoration by comparing reproductive performance, survival, phenotypic traits, and genetic characteristics among Texas and Florida descendants. Our goal is to develop of a long-term management plan based on our study results to maintain genetic diversity, health, and long-term survival of the south Florida panther population.

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Phosphorus Load Reduction under Agricultural BMPs for South Florida Histosols

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The Everglades Agricultural Area (EAA) is comprised of 220,000 ha of cultivated land with about 80% of the land farmed in sugarcane. Histosol is the predominant soil order in the EAA. Flat topography, shallow soils and an impermeable marl/limestone bedrock limit water storage options throughout the region. These organic soils are artificially drained by pumping water through a system of farm and main basin canals. Basin drainage is the responsibility of the South Florida Water Management District (SFWMD). Concerns regarding the quality of agricultural drainage water from the EAA to the Everglades wetland ecosystem led to a regulatory program that requires phosphorus (P) loads in the water leaving the EAA basin to be reduced by at least 25% relative to historic trends. Growers in the EAA are required to adopt BMPs to reduce P loads off their farms into the main canals. These BMPs must add up to at least 25 points assigned by the SFWMD.

The objective of this research was to quantify the effects of BMPs implemented on selected farms on farm drainage P concentration levels and P load components. Ten farms, which represented a range of EAA sugarcane-vegetable-rice-sod cropping systems with respect to farm size, drainage capacity, soil depth, and choice of BMP implementation, were chosen for monitoring of P concentration in water discharge, discharge volume and P loads. The BMPs included banding of P fertilizers, P fertilizers rates according to soil test, avoiding drainage activity until a pre-determined amount of rainfall, and establishing particulate matter control measures such as reduced velocities near pumps.

Project farms in general reflect the same reduction as the EAA basin as a whole. The BMPs implemented by each farm are different reflecting differences in soils and crops. Some soils are shallow and need to be drained more frequently. Sugarcane can tolerate flooding and higher water tables, which allows farmers to maintain higher water tables and delay pumping. Hydrologically adjusted farm-level load reductions, expressed as adjusted unit area loads, averaged 55% for the farm sites over 7 years compared to pre-BMP levels. Drainage pumping volume per unit of rainfall decreased by an average of 9.5%. The BMPs implemented in the EAA have reduced P loading by approximately 50% from 1995 to 2001 and exceeded every year the 25% reduction mandated by the regulatory program.

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Spatial and Temporal Patterns of Mercury Bioaccumulation in Largemouth Bass in the Everglades

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We observed varying spatial and temporal patterns of mercury bioaccumulation in largemouth bass in the Florida Everglades between the late 80s to present. Recent declines in mercury concentrations in sport fish have resulted in the downgrading of health advisories warning against consumption of largemouth bass in the water conservation areas (WCA). Previous advisories urged “no consumption” of largemouth bass in WCAs 2 and 3; however, current advisories (FLDOH 2003) recommend limited consumption of largemouth bass under 14 inches in length while maintaining the “no consumption” advisory for largemouth bass greater than 14 inches. “No consumption” advisories for all sizes of largemouth bass in the Shark River Slough in Everglades National Park (ENP) remain in effect.

Mercury concentrations in largemouth bass varied spatially. The lowest concentrations were observed in the northern WCAs and increased to the south into ENP. Maximal concentrations were observed in central WCA 3 at site 3A15; however, concentrations remained relatively high south into ENP in the Shark River Slough. Concentrations decreased to the east in the urban canals along the coast and to the west in Big Cypress National Wildlife Refuge. Similarly, concentrations of mercury in sediments, periphyton, and small prey fish (Cleckner et al. 1998) and alligators (Rumbold et al. 2002) followed parallel trends.

Long-term monitoring of mercury concentrations in axial muscle tissue of largemouth bass was conducted between 1989 and 2002 along a transect between Loxahatchee National Wildlife Refuge south into Shark River Slough has shown significant declines in mercury bioaccumulation in some areas (Figure 1). Mercury concentrations are reported as standardized to age-3 in axial muscle tissue (EHg3) to account for variations in mercury concentrations among sizes and sex of largemouth bass (Lange et al. 1994). The largest decreases were in WCAs 2 and 3, including the L-67A Canal where concentrations decreased 79% between 1990 and 2001. In WCA2, decreases in the L-35B Canal and at marsh site U3 were similar at 58% and 62%, respectively, between 1993 and 2001. In WCA3, at marsh site 3A15, concentrations decreased 44% between 1993 and 2000; however, trends in the data may be masked by small sample sizes during many years. The longer period of record at site L67A may explain the greater decreases since concentrations there peaked in 1992, a year before sampling was initiated at the other three sites. Notwithstanding, largemouth bass mercury concentrations have decreased in WCAs 2 and 3, with the most significant among-year declines occurring during the 1996 and 1997 sample events. Less dramatic decreases were observed in Loxahatchee National Wildlife Refuge and no changes in axial muscle concentrations have been observed in Shark Slough in ENP.

Between 1996 and 1999 we conducted food web studies in canals, marshes, and a constructed wetland to determine if variations in trophic structure (i.e. length and complexity of food webs, trophic position, and fish growth) were responsible for the variations in mercury concentrations observed in the northern Everglades. Observational food habits data for largemouth bass and other species were employed to assign numeric trophic classifications and to evaluate routes of mercury uptake in the diet. We observed strong relationships between trophic classification and mercury at each site with ontogenetic shifts in diet in largemouth bass and variations in diet among species explaining the variability in mercury concentrations (Figure 2). However, trophic classification did not accurately describe the variability in mercury concentrations in largemouth bass among sites (Figure 3). We believe that spatial variations in the availability of methyl-mercury for bioaccumulation in the food web is more important than variations in trophic structure in explaining the variations in mercury bioaccumulation across the Everglades landscape.

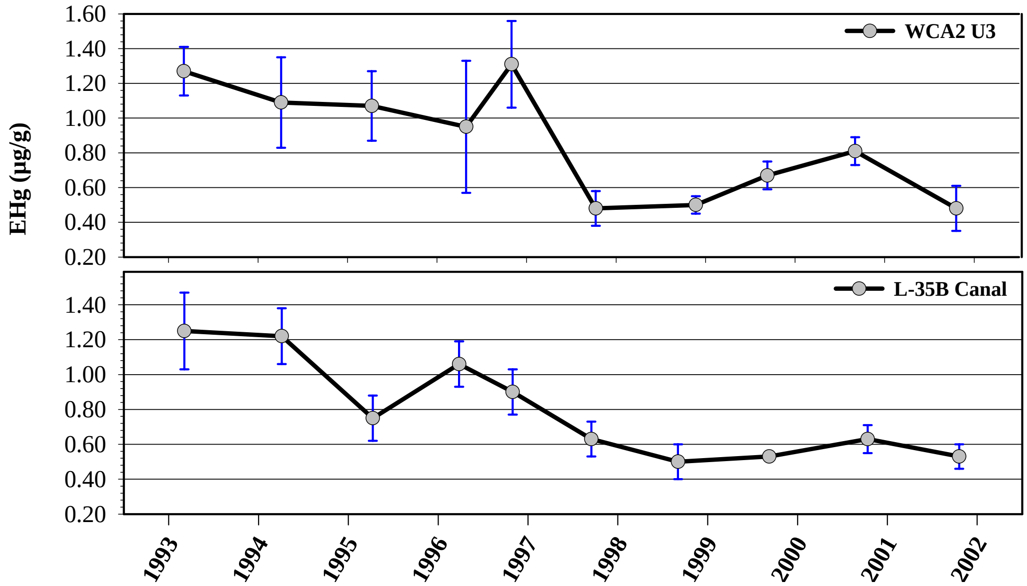

Figure 1. Trends in EHg3 in annual collections of largemouth bass from sites U3 and L35B Canal in WCA 2 between 1993 and 2001. Error bars represent the 95% confidence interval around the age standardized mercury concentration in muscle tissue calculated from regression of mercury in muscle tissue with fish age.

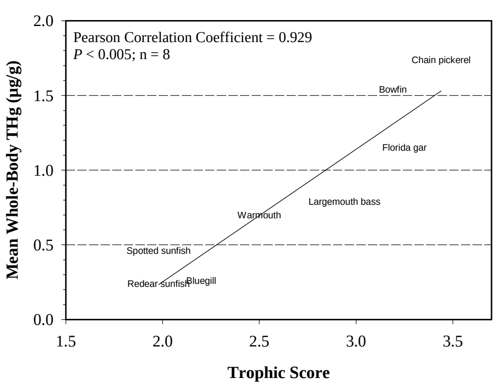

Figure 2. Correlation between trophic classification and mercury among species at site WCA 3A15. Species names represent means of actual measurements.

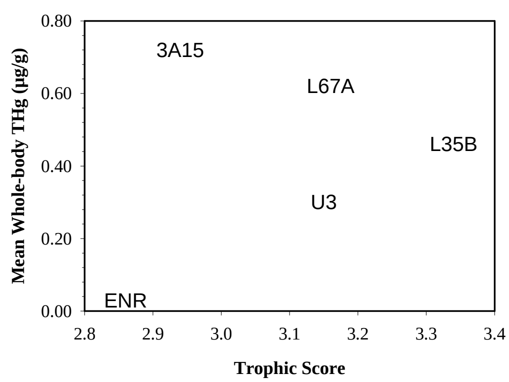

Figure 3. Correlation between trophic classification and mean largemouth bass mercury concentrations at study sites. Site names represent means of actual measurements.

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Using Strip-Transect Aerial Surveys to Estimate Manatee Abundance and Population Trend in the Ten Thousand Islands Region of Southwest Florida

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Terry J. Doyle
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Strip-transect aerial surveys have been used extensively in Australia to estimate trends in offshore dugong populations (Marsh and Sinclair 1989). The use of strip–transect methods in estimating manatee population size and trend, however, has been limited (Miller *et al*. 1998). Manatee surveys have typically not been designed to sample quantified survey areas, or to produce estimates of abundance. While useful in obtaining minimum manatee counts and distribution information, the latter surveys do not permit statistical comparison of survey results over time (Lefebvre et al. 1995). Our objective in this study is to determine if manatee density and distribution in the nearshore waters of the Ten Thousand Islands and the Everglades National Park change in response to restoration of natural hydrologic patterns in southwestern Florida. The Ten Thousand Islands region is of particular interest because of proposed changes to the Southern Golden Gate Estates and Faka Union Canal drainage. We want to statistically compare pre- and post-restoration indices of manatee abundance. We also believe that strip-transect methods are likely to be successful in the Ten Thousand Islands region, unlike many other regions of Florida, in which manatees may be highly aggregated at winter sites, or their density may be too low and distribution too linear to permit this approach.

Six surveys were conducted between 25 July and 22 October 2000, eight were conducted between 15 July and 30 August 2001, and eight were conducted between 20 June and 17 September 2002. We established parallel transects, 1 km apart, with a survey strip width of approximately 250 m. Transects flown during July-October 2000 were oriented perpendicular to shore, between Palm Bay and the Ferguson River (fig. 1A). Based on results from these surveys, we omitted 5 transects (26-30; fig.1A) and established 5 new transects (31-35; fig.1B) near Cape Romano for the 2001 and 2002 surveys. Transect lengths ranged from 6.6 to 8.4 km in 2000 and 3.4 to 8.4 km in 2001 and 2002, respectively; water area surveyed ranged from 0.79 to 1.53 km² per transect in 2000 and 0.83 to 1.53 km² per transect in 2001-2002. Manatee locations were plotted on topographic maps, and flight paths were recorded on a Trimble Basic Plus GPS. Surveys were conducted from a Cessna 172 at an altitude of 153 m, traveling at approximately 120-140 km per hour. Perception bias, which occurs when some of the manatees visible within a strip transect are missed by an observer, was estimated by applying a Petersen mark-recapture model to counts made by two observers (Pollock and Kendall 1987; Marsh and Sinclair 1989). We did not attempt to develop a correction factor for manatees that were not visible within the transects (availability bias), thus our results are underestimates of actual manatee numbers and densities.

The corrected number of manatee groups (a group = 1 or more individuals in the same location) sighted on transects ranged from 7.0 to 25.7, 12.9 to 27 and 15.0 to 20.4 per survey during 2000, 2001, and 2002, respectively. The corrected number of individuals counted ranged from 10.0 to 39.8 in 2000, 15.1 to 61.7 in 2001, and 24.6 to 61.2 per survey in 2002. Mean group size per survey ranged from 1.0 to 2.0, 1.1 to 2.3, and 1.4 to 3.0 during 2000, 2001, and 2002 respectively. Survey-specific population estimates in this study were 1.09 to 4.57 per km² in

2000, 1.62 to 6.64 per km² in 2001, and 2.65 to 6.58 per km² in 2002. Excluding the Cape Romano transects, the overall distribution of sightings was somewhat bimodal, with average (mean = 0.44 groups per transect) or higher than average number of groups sighted on transects 1-9 and 17-21 during 2000. Transect 6 starts near the mouth of the Barron River, and Transects 19 and 20 start near the mouth of the Faka Union Canal. Virtually no manatee sightings were made on transects 25-30, at the western end of the study area during 2000. The replacement of these five transects with five transects near Cape Romano (31-35) in 2001 produced a somewhat higher estimate of manatee abundance in the region. The Faka Union Canal is known to attract large numbers of manatees, particularly in the winter, presumably because of the availability of freshwater at its head and thermal buffering provided by its depth. In this study, we considered the canal to be a separate, high-density stratum, analogous to the "hot spots" described by Miller *et al*. (1998). When manatee counts from this stratum were added to the transect-based estimates, estimates for the whole study area on all dates ranged from 39 to 187 in 2000, 59 to 247 in 2001, and 95 to 235 in 2002.

Population estimates and densities in this study were similar to those for the Banana River, an important area for manatees on the Atlantic coast in the warm season. The latter estimates ranged from 112 to 209, or approximately 0.67 to 1.26 per km² (Miller *et al*. 1998). Mean group size per survey in Ten Thousand Islands (1.62) was lower than in Banana River surveys (2.19). Group size was ≤ 2.00 in 18 of the 22 Ten Thousand Island surveys and ≥ 2.00 in 13 of 15 Banana River surveys (Miller *et al*. 1998). These findings suggest that poorer water clarity in the Ten Thousand Islands than in the Banana River, where the bottom can be seen in most of the survey area, may contribute to greater variability and smaller observed group size in our surveys.

To assess the potential for detecting statistically significant trends in the Ten Thousand Islands population, we used the TRENDS software (Gerrodette 1993) with estimated CVs of 0.30 and 0.15, based on observed survey results. We determined that we would need a minimum of 8 surveys per year for a minimum of 4 years to detect an annual rate of change of 10% per year. Variation in group size and population estimates is a reflection of the challenging survey conditions presented by the Ten Thousand Islands, as well as additional variability caused by weather. Nevertheless, the strip-transect approach shows promise for monitoring the manatee population using this region during the warm season, if weather-related variability can be minimized.

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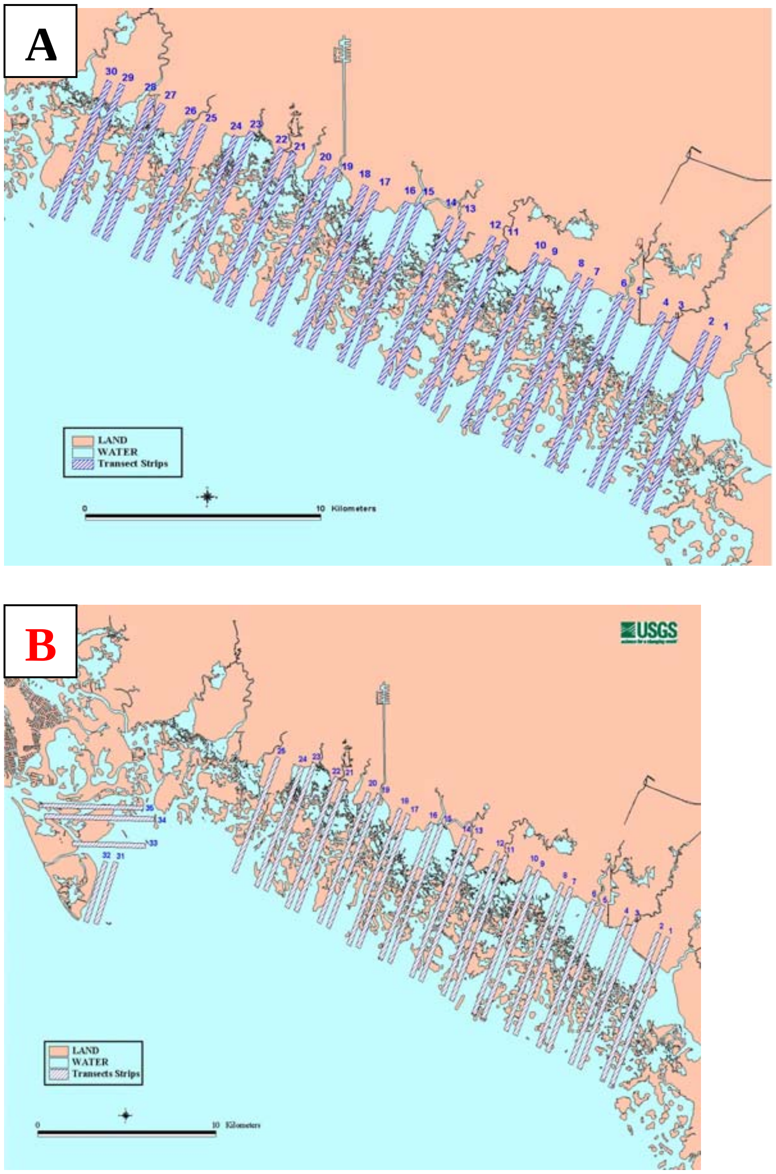

Figure 1. Spatial arrangement of 30 manatee aerial survey strip-transect polygons in the Ten Thousand Islands during flights July-October 2000 (A) and July 2001-September 2002 (B).

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Effects of Litter Quality on Landscape Scale Vegetation Patterns in Shark River Slough, Florida Everglades

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Shark River Slough consists of a vegetative mosaic that includes extensive stands of sawgrass (*Cladium jamaicense* Crantz) interspersed with open water sloughs and wet prairies containing floating leaf macrophytes, emergents, and periphyton. This area includes the topography-defined landscapes such as the ridge and slough communities of central Shark River Slough. The term ridge and slough describes the elevation differences of the peat soil surface and associated communities. *Cladium* stands cover the higher peat ridges, and the lower elevation sloughs are characterized by openwater and macrophytes (*Eleocharis* and *Nymphaea* species).

Due to the hydrogeomorphology of Shark River Slough, water levels do not differ significantly east and west. However, because soil elevation has a significant influence on the hydropattern of any given location, and therefore influences the vegetative community present, it is critical to understand factors that may influence rates of soil accretion.

The vegetative mosaic found in Shark River Slough is thought to be determined by allocthonous (external and typically abiotic) and autocthonous (internal and typically biotic) factors. It has been reported that autocthonous factors, such as primary productivity and biomass, are greater in sawgrass marshes (ridges) than in sloughs. This may result in higher rates of litter and soil accretion in ridge communities relative to sloughs. Organic matter decomposition, also an autocthonous factor, may also affect soil elevation. Because litter quality is an important regulator of organic matter decomposition, many factors related to litter decomposition, such as litter nitrogen content, phosphorus content, C/N ratio, C/P ratio, and lignin/cellulose ratio may indirectly affect soil accretion rates and vegetation pattern.

In this investigation, average litter N content was 0.757% and 0.997% for ridge and slough vegetation respectively. Litter P content was .015% and .024% for ridge and slough vegetation respectively. On average, the data suggest litter N and P content was higher in slough vegetation. Conversely, litter carbon content was higher in ridge vegetation (38.5% sloughs, 44.2% ridge). As a result, higher C/N ratios and C/P ratios were observed in ridge vegetation. This, along with higher lignin content in ridge vegetation (9.8%) versus slough (4.0%), might partially explain the observed elevation differences in the Shark River Slough ecosystem.

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BMPs and Water Quality in Miami-Dade County

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A tremendous effort is underway in south Florida to find a way to restore the natural ecosystems. Agriculture is one of the important compounds of the restoration. Agricultural lands buffer natural systems from urban areas, inhibit urban sprawl, provide jobs and agricultural products with sales of over $2 billion for Palm Beach, Hendry, St. Lucie, and Miami-Dade Counties alone. However, chemical use and water management practices for crop production directly affect natural ecosystem in south Florida. Our research group is working on Best Management Practices (BMPs) to protect our ecosystem and sustain crop production. We will present research information on crop nutrient/pesticide and irrigation management in Miami-Dade County.

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Assessment of the Effects of the Everglades Restoration Project and Climate Variability on the Growth and Survivorship of Seagrasses and Sponges of Biscayne Bay

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An integrated modeling framework developed by CMEA scientists was used to translate climate change and water management scenarios into ecological changes for biological endpoints of Biscayne Bay. In this modeling framework, the South Florida Water Management Model was linked to the Biscayne Bay hydrodynamic model to simulate salinity patterns within Biscayne Bay under different climate change and Everglades restoration scenarios. The output from the Biscayne Bay hydrodynamic model, expressed as daily salinity values, provided direct input into the SEASCAPE model of benthic communities of Biscayne Bay. The spatially explicit SEASCAPE model is comprised of over 100,000 cells (100 x 100 m) and contains several biological components, including the seagrass growth model and a sponge population model that will be described in this presentation.

The seagrass growth model simulates above-ground biomass of the three most common seagrass species (turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*)) within Biscayne Bay. Daily growth is simulated as a species-specific maximum growth rate modified by light availability, temperature, sedimentation, nutrient concentrations, and salinity. The sponge population model is a stage-based matrix population model of the commercially harvested Glove Sponge (*Spongia graminea*). The sponge model assumes that salinity limits population size as exposure to fresh water is known to damage marine sponges. Output from the hydrodynamic model is used to determine the number of days sponge populations are exposed to salinities below threshold values under different simulation scenarios.

Major changes in canal, overland, and groundwater flows into coastal bays can result from modifications to water management practices and natural interannual variability in precipitation. These changes in freshwater flows can lead to significant differences in the salinity fields within Biscayne Bay as simulated in this project. Areas where canal influences are prevalent (i.e., central bay) can experience significant reductions in mean salinities for extended periods of time under "wet" scenarios, while areas with restricted circulation (i.e., southern bay) can experience periods of hypersalinity (> 40 ppt) under "dry" conditions. In contrast, minor changes in salinity patterns were simulated for those areas in eastern Biscayne Bay where oceanic influences prevail.

Our initial simulations indicate that increased freshwater delivery to Biscayne Bay can damage sponge populations in western Biscayne Bay by increasing the frequency of low-salinity events. Similarly, reduced salinity can influence growth and abundance seagrass communities. Species such as *Thalassia testudinum* that are more susceptible to reduced salinity could be lost or out-competed from present locations, and replaced by less-susceptible species like *Halodule wrightii*.

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Fish Community Colonization Patterns in the Rocky Glades Wetlands of Southern Florida

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As part of a larger effort to assess the role of aquatic refuges and subterranean habitats in system restoration, we began collecting baseline data on the ecology of constituent aquatic communities of the Rocky Glades in the wet season of 2000. The Rocky Glades is a threatened, short-hydroperiod habitat that remains intact structurally only within Everglades National Park (ENP), but even there its hydrology has been adversely affected by drainage. Pre-drainage accounts indicate that this region once had higher water levels that likely provided a richer habitat for aquatic species. Little has been published about the species composition of animals that survive below-ground through the dry season, their community patterns once above-ground, and their movements back into holes as water recedes in autumn. The highly eroded landscape offers dry-season refuge to aquatic animals in solution holes, which also allow them access to groundwater. As soon as rains flood the area in the early summer, fishes and invertebrates immediately appear on the wetland surface. We are investigating whether recolonization of the surface is a function of survival in local refuges, results from rapid, long-distance dispersal, or a combination of both.

In the early 1990s, we observed mass, early wet-season fish movements in the Rocky Glades, which sparked this study of the fish communities and dispersal. In the first project year, we tested methods designed to detect directional dispersal by using drift fences and funnel traps along a hydroperiod gradient. Several questions arose from these preliminary observations of dispersal in the Rocky Glades: How rapidly do different species appear in the arrays? Are the movement patterns of animals related to water flow?; Do the animals disperse from the main sloughs to recolonize the Rocky Glades or, Are the Rocky Glades acting as a source of animal colonists for the sloughs?; Do roadways act as barriers to movement?; How do composition, size-structure, and recruitment of aquatic animals change during the flooding period?

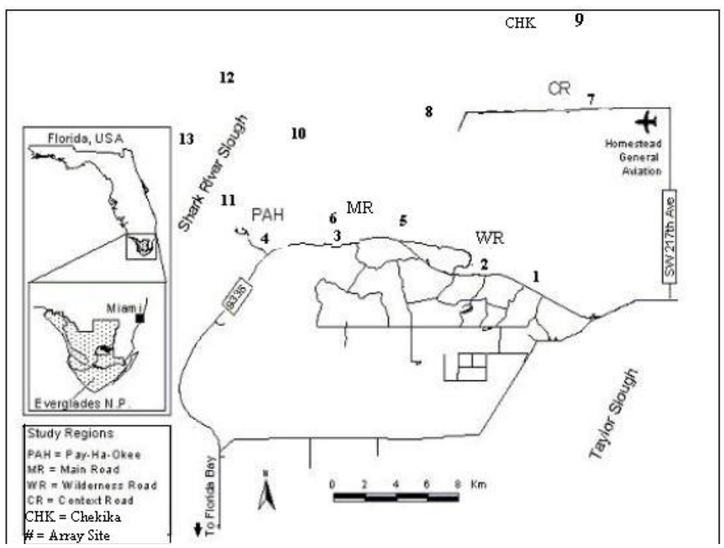

Figure 1. Drift-fence Arrays 1-13 in ENP.

In 2000, we erected four x-shaped drift-fence arrays (Arrays 1 to 4: fig. 1), with 12 m wings made of black plastic cloth, along the main park road of ENP. The wings of the fences directed animals into traps that face the compass directions (fig. 2). When the wetlands flooded in June, we made daily collections for the first two weeks, reduced the frequency to twice weekly for

Figure 2. Trap retrieval at Array 4.

three weeks, and to weekly collections until dry-down. We identified, weighed, and measured all animals in the lab. In 2001, a more spatially expansive study was implemented

The number of animals in each trap on a particular day seemed to be related to the water flow and depth, with the highest number taken during the highest flows. Most animals dispersed rapidly after the wetlands flooded. Preliminary assessments of the data indicated that the direction and degree of rheotaxy varied by species. Fishes and crayfish often reappeared in the traps on the same day that the wetlands flooded, supporting the case for local subterranean refuges. However the largest numbers of fishes appeared within two weeks of flooding (fig. 3). It remains unclear whether they may have been able to disperse for tens of kilometers across the heavily vegetated wetland landscape from Shark Slough and its estuarine creeks in that time. Hypotheses about dispersal patterns will be tested in 2003-2004 using methods such as stable isotope and otolith microchemistry analyses, and radio-tracking of larger species.

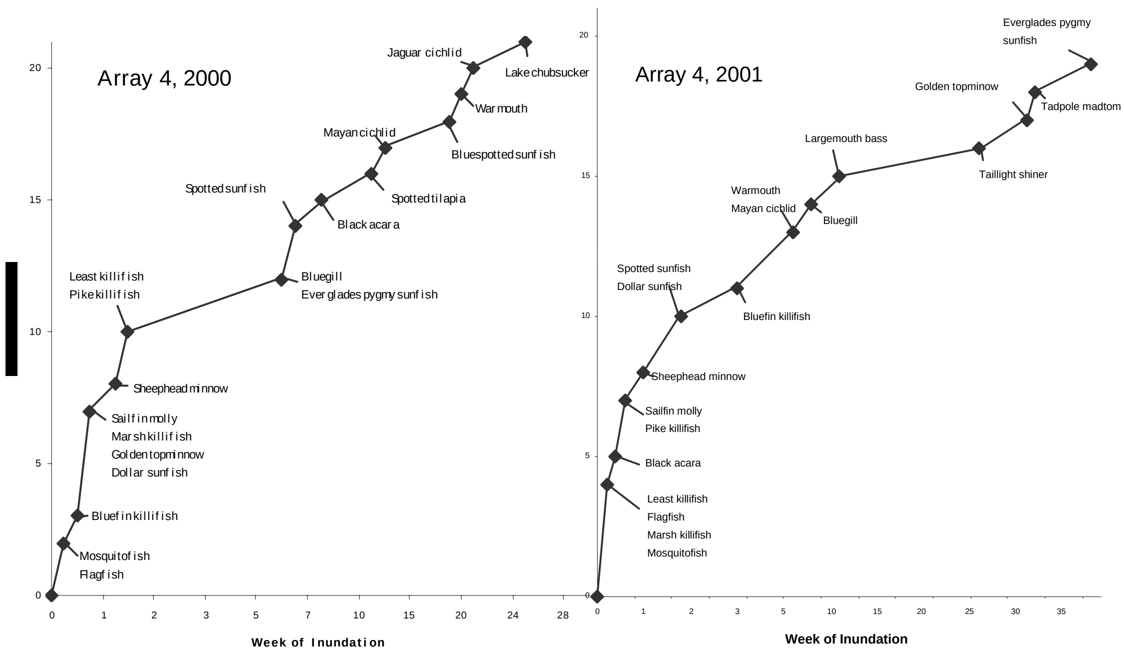

Figure 3. Appearance of fish species by week of sampling at Array 4 in 2000 and 2001.

Subsequent sampling provided data on community-succession patterns as new species appeared in the traps and relative abundances changed. Size-structure data have been used to document the onset of reproduction. Most fishes emerging onto the surface were adults that began reproducing with one or two weeks. Small juveniles appeared in the traps within a month of flooding.

The study of ecological interrelations between surface and subterranean habitats will help determine how human management has affected this region and what benefits can be anticipated by the restoration of natural hydrology. The temporal dynamics of the use of Rockland habitats in relation to hydrology have just begun to be described. This project will provide data important to simulation models, such as whether solution holes in the Rockland function as sources or sinks for fishes and how hydropattern affects trophic structure and the composition of aquatic animal communities in this landscape**.**

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Recent Fish Introductions into Southern Florida Freshwaters, with Implications for the Greater Everglades Region

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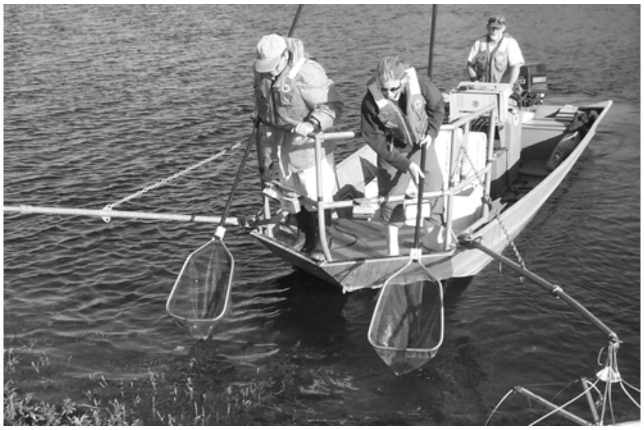
Much has been published about introduced fishes in Florida, particularly their ability to invade and potentially disrupt natural aquatic communities. Approximately 20 species have been recorded as establishing populations in the extreme southern part of the state, with many others having been collected without evidence of establishment. Recent papers have examined data collected in southern Florida to evaluate the distribution and relative abundance of introduced fishes across a variety of habitats. Two sampling programs in the Everglades provided systematically collected density information over a 20-year period, and documented the first local appearance of four introduced fishes based on their repeated absence in prior surveys. Freshwater canals, and natural tidal creeks surrounded by mangrove-dominated wetlands, held the largest introduced-fish populations in the southern Everglades region However, these combined studies reported fewer species of introduced fishes from the Everglades region when compared with studies conducted in canals along the developed Florida east coast, indicating that the most likely sites of introduction for most species is in those canals. Recent information on the appearance of additional species, and range expansions by established fishes, demonstrates that colonization of the Everglades region is continuing. The eight established species of introduced fishes known from the Everglades in the 1990s have since been joined by additional species. What are these fishes, how were they introduced, why are their ranges expanding, and what other species are likely to colonize the Everglades?

The native inland fish community of the Everglades region is comprised by about 35 temperate species with wider distributions in Florida and the southeast US. Most previously introduced fishes in the Everglades were tropical in origin, illegally released, often from aquaria, and belonged to the family Cichlidae. One species each of livebearer and clariid catfish also were established there. Records indicate that most of those introduced species were released east of the Everglades and used the canal system to move into the Everglades system. Although many became widespread in the system, the majority did not achieve great numbers except in local situations. We hypothesize that a combination of cold winter temperatures and unfavorable habitat structure may have limited success in natural habitats by some previously established species.

Pike killifish (Belonesox belizanus). L. G.

Several widespread sampling programs employing electrofishing, trapping, and netting, and shorter-term research studies, continue to provide information on introduced species in the Everglades region. Those studies, and ongoing ichthyofaunal surveys of the Big Cypress NP and Biscayne NP, are continuing to collect data from canals, marshes, swamps, and detention areas.



In recent years, several new species have been collected either in the Everglades or in canals that border the system. Although several are cichlids (jewelfish, banded severum, jaguar cichlid, peacock bass), others belong to families not formerly found in this region (Asian swamp eel-Homestead population, armored catfishes). In addition, other species are established in the canal system to the east, from which dispersal towards the Everglades is likely (Asian swamp eel – Miami population, snakehead, grass carp, various cichlids). While some of these recent introductions are probably aquarium releases, others appear to be illegal introductions for food or marketing purposes. Apart from the accidental release of blue tilapia from a Miami-Dade County aquaculture facility, this class of food-fish planting by amateurs is a novel vector for fish introduction.

Analysis of Everglades data collections found evidence for mainly local effects by introduced fishes, but the long-term effects of introductions, particularly with the continuing accumulation of species, are unclear. Experimental research into the biotic interactions of introduced fishes and native species is needed, as is modeling research to identify species that may pose problems if they were to be introduced. There should be emphasis placed on additional monitoring of under-sampled habitats such as canals. We also suggest that more efforts be made to educate the public about introduced species and in closing newly identified pathways for the introduction of additional species identified as potential threats.

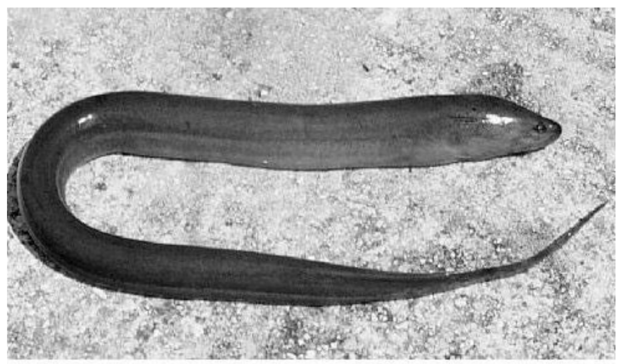


Photo Credit: Leo G. Nico, USGS, Gainesville, FL

Asian Swamp Eel (L. G. Nico Photo)

Although there have been no dramatic ecosystem effects such as extinctions or large-scale population declines in native species identified in southern Florida, we are uncertain that this condition will continue under the cumulative effects of future invasions or environmental change. What can be done to limit the numbers, spread and effects of introduced fishes? At present, there are few options available to deal with introduced fishes in the open habitats of southern Florida. Once a population has expanded beyond its point of introduction into the main canal system or into the Everglades marsh, nothing can be done to eliminate or even control them at this time. Control may be effective in local situations to meet specific management

objectives. Even then, it will have to be a sustained effort because of the pool of recruits that exists in the canal reservoirs. Unlike the research and management funding used to find and deliver controls for plant or insect pests, there has been little funding applied to research into controls for fishes. Increased emphasis on finding innovative methods for dealing with fish invaders should be a priority. At present, the best way to prevent the continuing introduction of fishes may be through better public education. We ask water managers and engineers to think of the consequences when planning pump stations, detention areas, new canals, and other constructs that will foster growth, dispersal, and delivery of non-native fishes, snails, and plants into natural wetland areas. Just "getting the water right" is not enough if it means the delivery of those waters will change the character of the Everglades biota.

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The Growth and Physiological Ecology of Two Invasive Non-Indigenous Fern Species, *Lygodium microphyllum* and *Lygodium japonicum*

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Throughout the world, invasions by non-indigenous plant species threaten the survival of many natural plant communities. This is particularly true in Florida where 125 plant species are listed as invasive by the Florida Exotic Pest Plant Council. Two of these species are *Lygodium microphyllum* (Cav.) R. Br. (Schizaeaceae) and *L. japonicum* (Thunb.) Swartz. Both species have a climbing habit and are capable of smothering native vegetation, resulting in the displacement of native understory vegetation, and in extreme infestations, shrub and canopy vegetation as well. This is especially notable in *L. microphyllum*, which can form rachis mats up to a meter thick, effectively eliminating most understory vegetation.

This study examines the growth and physiological ecology of both *Lygodium* species, as well as two native vines, *Vitis rotundifolia* and *Parthenocissus quinquefolia*. The four species were grown in shade houses under three different light treatments (70, 50 and 20 percent full sunlight). Two harvests were performed, the first at 90 days and the second at 180. At each harvest photosynthetic light response curves were completed on a sub-sample of each species. Harvested plants were divided into roots, stems, and leaves and all tissues were dried and weighed. Relative growth rate (RGR) and its allocational and morphological determinants, i.e. leaf area ratio, specific leaf area, root weight ratio, stem weight ratio, and leaf weight ratio were calculated. The RGR of *L. microphyllum* was significantly greater in both the low- and medium- light treatments as compared to the other three species. For example, under low light conditions the RGR of *L. microphyllum* was 22.6 mg g^{-1} day^{-1} as compared to 18.8 mg g^{-1} day^{-1} for *L. japonicum*, 17.0 mg g^{-1} day^{-1} for *V. rotundifolia*, and 9.7 mg g^{-1} day^{-1} for *P. quinquefolia*. Large differences in biomass allocation were observed between the two non-native vines versus the two native vines. Under all three light treatments the non-native ferns allocated significantly less resources to their climbing frames (5-20%) as compared with the native vines (40-60%). This allows both *Lygodium* species to allocate greater resources to either their leaves or roots. For example, under low light conditions *L. microphyllum* averaged 5,000 cm^2 of leaf area per plant as compared to 3,000 cm^2 for *V. rotundifolia*. A similar pattern was also observed in roots under low-light conditions, where *L. microphyllum* averaged 17.5 g belowground per plant as compared to 6.4 g belowground in *V. rotundifolia*. Despite these large differences in allocation, leaf physiology appears to play an even greater role in explaining the differences in growth among the four species. In both the low- and medium-light treatments, leaf photosynthesis was significantly greater in the two non-native vines, particularly so in *L. microphyllum*, compared to the two native vines.

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Abundance of Octocorals at Stations Selected from the Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project

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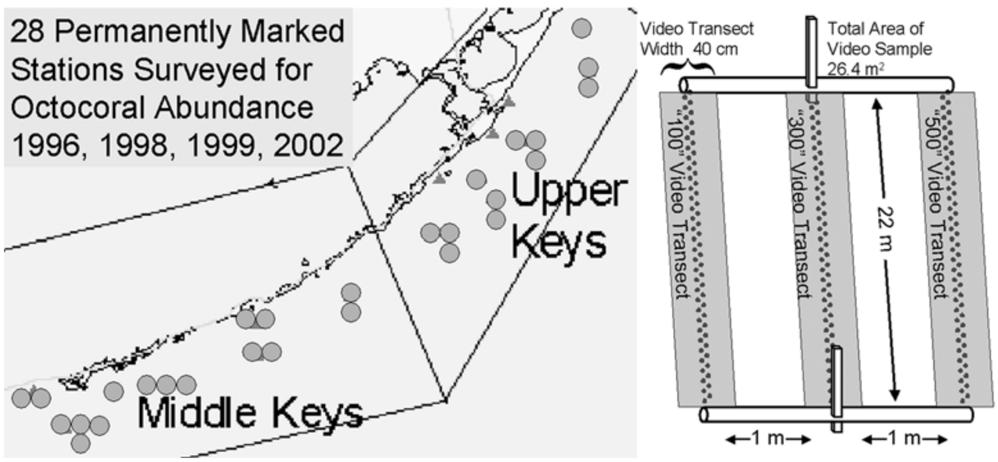
Stations analyzed for octocoral abundance were selected from Coral Reef Monitoring Project (CRMP) sampling stations. A total of 107 stations have been sampled annually in the interval 1996 to 2002. At each station, three parallel video transects (approximately 22 meters long and 60 cm apart) are filmed. Filming is conducted from a standard height of 40 cm, perpendicular to the benthic under-story. Visible width of imagery filmed from this height is 40 cm. Total average area sampled by video at one station is 26.4 m^2.



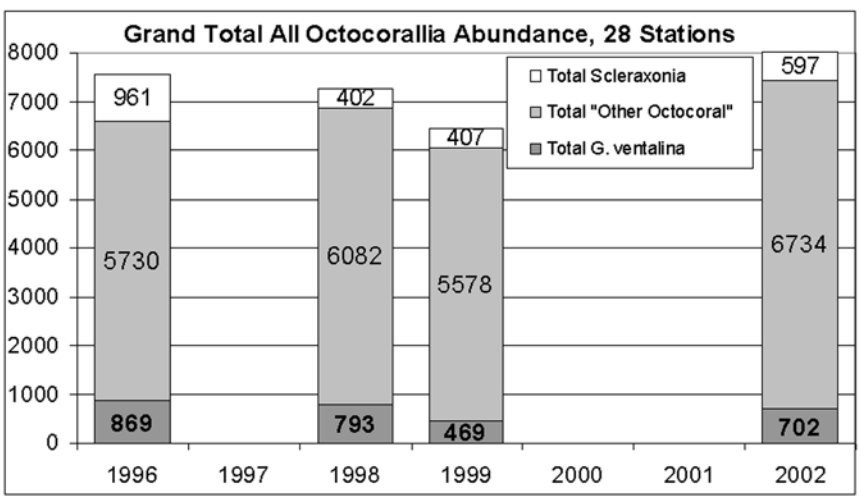
Octocoral abundance was measured at 28 stations each year, 1996, 1998, 1999, and 2002. The stations were equally distributed by habitat type: 4 patch, 4 offshore shallow, and 4 offshore deep reef stations in the Upper keys and 4 hardbottom, 4 patch, 4 offshore shallow, and 4 offshore deep reef stations in the Middle keys. Stations were selected according to a stratified random scheme. Video-derived octocoral abundance was determined, from the 1996 video data set, for all stations where average octocoral percent cover was greater than 5%. From each habitat type, one station was randomly selected from each of the maximum and minimum abundance quartiles. Two stations were randomly selected from the middle abundance group, 25% to 75%. These selection criteria provided 28 stations for collection of octocoral abundance. Abundance data were collected from 1996 and 2002 video, to maximize the temporal span of data. Years 1998 and 1999 were also selected to assess the impact of hurricane Georges. Thus, octocoral abundance was measured at 28 stations each year, 1996, 1998, 1999, and 2002.

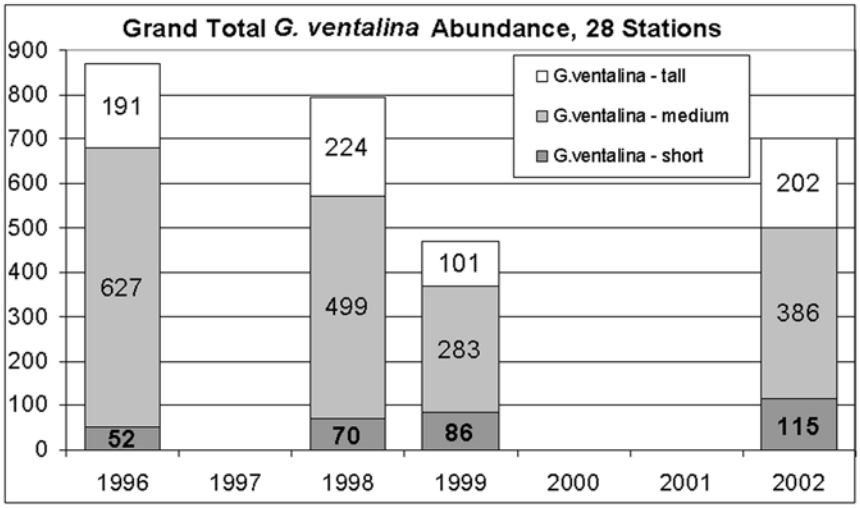
Video was played on a color monitor and the number of octocorals in view was tallied. Only colonies with their holdfast clearly visible within the field of view were counted. Each station was counted twice. The census counted the number of Scleraxonians, the number of *Gorgonia ventalina* in three size classes, and the number of "other octocorals" in three size classes. Size classes were defined as <10cm(short), 10-40cm (medium), and >40cm (tall). The delineations of size classes are estimates, based on scaling items in the video image (e.g. chain link size and 40cm average height of camera lens).

The total abundance of all octocorallia surveyed was surprisingly stable from 1996 to 2002, increasing 6%. Scleraxonia abundance decreased 38%, from 961 in 1996 to 597 in 2002 (sum of 28 stations). Total abundance of *G. ventalina* decreased 19%, from 869 to 702 colonies. Decline in the previous two categories was offset by an 18% increase in the total abundance of "other octocorals", from 5730 to 6734 colonies. This increase was driven by a 191% increase in the abundance of short "other octocorals," from 545 to 1585 colonies.

From 1996 to 2002, the total abundance of *G. ventalina* decreased 19%, from 869 to 702 colonies. This decrease was driven by a 39% decline in the abundance of medium *G. ventalina*, from 627 to 386 colonies. The magnitude of this decline obscured increases in the abundance of short and tall *G. ventalina*. The abundance of short *G. ventalina* increased 120%, from 52 to 115 colonies. Tall *G. ventalina* increased 6%, from 191 to 202 colonies.

Changes between 1998 and 1999 reflect, in part, the effects of hurricane Georges. 1998 field video data collection was completed in late August, and hurricane Georges crossed the Keys one month later on September 25, 1998. Between 1998 and 1999, the total abundance of all octocorallia decreased 11% from 7277 to 6454 colonies. The total abundance of *G. ventalina* fell 41%, and the total "other octocoral" abundance decreased 8%. *G. ventalina* and "other octocoral" abundance declined in nearly every size class. The drop in *G. ventalina* abundance was driven by declines in medium (-43%), and tall (-55%). The decrease in "other octocoral" abundance was driven almost entirely by a 41% decline in tall colonies, from 1090 to 646. When all erect octocorals are pooled by size, the 1998 to 1999 change is striking. Short octocorals declined 9%, from 812 to 742 colonies. Medium octocorals declined 4% from 4750 to 4559 colonies. Tall octocorals declined 43% from 1314 to 747 colonies. This differential mortality implies that tall octocoral colonies are selectively removed by storm energy. Scleraxonia abundance reinforces this suggestion. The abundance of these encrusting octocorals was essentially unchanged, from 402 to 407 colonies.





A copy of the poster may be obtained by requesting the following reference: Lybolt, M. 2003. Abundance of Octocorals at Stations Selected from the Florida Keys National Marine Sanctuary Coral/Hardbottom Monitoring Project. Florida Marine Research Institute, St. Petersburg, FL. IHR#2003-004.

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Data Issues in Computing Long-Term Reference Evapotranspiration for Hydrologic Modeling

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In South Florida, Evapotranspiration (ET) losses for much of the natural landscape, including open water, nearly equal the rainfall contribution. Hence both are significant inputs for hydrologic modeling. Accurate estimates of ET are essential to ensure the accuracy of model output. The lack of meteorological data for the extended periods is the main limitation to obtaining accurate ET estimates needed for long-term (1965-2000) hydrologic modeling. Although there are several different methods used to estimate ET in South Florida, all require the use of meteorological data. The Penman-Monteith (PM) method (Monteith, 1981) is one of the more commonly used methods for estimating long-term reference evapotranspiration. Inputs to the PM and other methods include, but are not limited to, temperature, solar radiation, wind, and relative humidity.

The availability of long-term measured solar radiation, wind, and relative humidity data in southern Florida is sparse. Of these variables temperature data is more readily available at more stations and for longer periods of record than the other data. However, there are still significant missing or erroneous temperature data at key meteorological stations. The availability of meteorological data at several site locations, and the condition of these data are summarized herein. Differences between data from different sources at the same site and for the same period of record illustrate problems with the quality of the data. Data at the selected stations was checked for missing values, errors, outliers and unrealistic trends and corrected using data from adjacent stations. The result is a comprehensive data set of more accurate meteorological input data for use in the reference evapotranspiration estimation.

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Population Dynamics of the Snail Kite in Florida

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The snail kite (*Rostrhamus sociabilis plumbeus*) is an endangered raptor that inhabits flooded freshwater areas and shallow lakes in peninsular Florida and Cuba (Sykes 1984, Sykes et al. 1995). The historical range of the snail kite covered over 4000 km^2 (2480 mi^2) in Florida, including the panhandle region (Sykes et al. 1995), but is now restricted mainly to the watersheds of the Everglades, Lake Okeechobee, Loxahatchee Slough, the Kissimmee River, and the Upper St. Johns River. These habitats exhibit considerable variation in their physiographic and vegetative characteristics, and include graminoid marshes (wet prairies, sloughs), cypress swamps, lake littoral shorelines, and even some highly disturbed areas such as agricultural ditches or retention ponds (Bennetts and Kitchens 1997). Three features that remain constant in the variety of selected habitats are the presence of apple snails, areas of sparsely distributed emergent vegetation (Sykes 1983, 1987), and suitable nesting substrates, all of which are critical to the nesting and foraging success of the snail kite.

Snail kites are dietary specialists, feeding almost exclusively on one species of aquatic apple snail, *Pomacea paludosa* (Sykes 1987, Sykes et al. 1995). The snail kite's survival depends on those hydrologic conditions that support these specific vegetative communities and subsequent apple snail availability in at least a subset of wetlands across the region each year (Bennetts et al. 2002). Wetland habitats throughout central and southern Florida are constantly fluctuating in response to climatic or managerial influences, resulting in a mosaic of hydrologic regimes.

The aim of the snail kite project is to monitor the response of the birds to those changes. This research essentially focuses on the most critical demographic parameters: survival, reproduction, recruitment and population growth rate (Bennetts et al. 1999; Dreitz et al. 2001; Bennetts et al. 2002; Dreitz et al. 2002). Because those demographic parameters are so heavily influenced by the behavior of the birds (i.e. their ability to move and select suitable habitats), movement studies constitute the other major aspect of the research. The objectives are two folds, first try to evaluate the likelihood of biological hypotheses, which help understand the underlying mechanisms and processes driving the population dynamics of the kites, and second provide reliable estimates of demographic parameters and movement probabilities, which are helpful for decision making using management models (see below). The statistical framework selected for parameter estimation is maximum likelihood estimation for its well recognized good statistical properties (Burnham and Anderson 1998). The empirical data consists of mark-resight and radio telemetry data.

The long term data set already available offers the potential to investigate the effect of hydrological variations across time and space. Low water years have substantial effects on the number of nests detected, but do not seem to greatly affects nesting success (Dreitz et al. 2001), which suggest that when the hydrological conditions are unfavorable for kites, birds simply do not breed. Thus far there is no evidence for an effect of local drying event on adult survival, although this aspect needs to be investigated for juvenile.

There is no strong evidence for a very substantial effect of a fairly widespread drought event (however, low in intensity), on adult survival (the 2000-2001 drought, Fig. 1). In contrast the 2000-2001 drought considerably affected juvenile survival (Fig. 1).

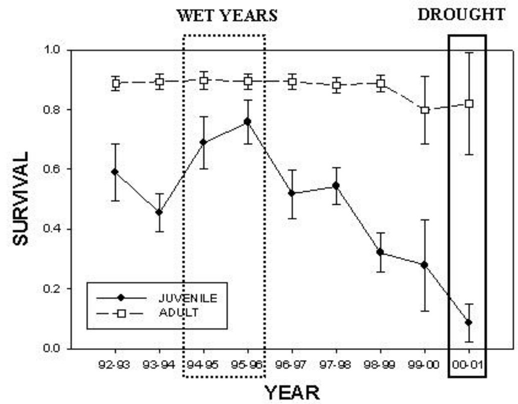

Figure 1. Survival estimates, for adult and juvenile (first year bird) snail kite in Florida between 1992 and 2001, the error bars correspond to the sampling error..

It was also interesting to note that it is during the wettest year that the highest estimates of juvenile survival were observed. Bennetts et al. (2002), explain this observation by suggesting that during high water year, more sites are likely to be suitable for foraging. Hence, during the dispersing period, when juveniles are most vulnerable, an increase in the surface area of suitable habitat, would reduce the chances of the dispersing juveniles encountering unsuitable habitat. An important point to make here is that the results provided in this abstract are preliminary. Those estimates will be refined by incorporating the 2003 field data. Nonetheless, the estimates that this analysis already provides, are already valuable for further modeling effort, in particular in the context of the Across Trophic Level Simulation System (ATLSS), which evaluates the effect of various hydrological regimes on the whole Everglades ecosystem (DeAngelis et al. 1998; DeAngelis et al. 2002). Indeed the present version of the spatially explicit individual based kite model that will be incorporated into ATLSS (Mooij, Bennetts et al. 2002), is presently lacking robust estimates for survival during drought events.

Another aspect presently under investigation is the response of the bird in terms of movement. By combining radio telemetry and mark-resight data under a multistate modeling framework (Williams, Nichols et al. 2001), we intend to estimate yearly movement probabilities between critical habitats, and test biological hypotheses about the processes driving the long term movement patterns. This information together with some further investigation of within year movement patterns, should help improve the predictive performance (in particular the spatial component) of the spatially explicit individual based kite model.

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Ecology of Everglades Alligator Holes

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As a keystone species, the American Alligator (*Alligator missippiensis*) plays a critical role in shaping the ecosystem of the Florida Everglades. One of the many ways they impact this ecosystem is through construction and maintenance of deeper water areas, or alligator holes. The Everglades is subject to seasonally fluctuating water levels, and crocodilians, requiring water for reproduction and survival, often wallow out organic muck as water levels drop. These holes serve many functions and are characterized by three major components; a depression, water to fill the depression, and an alligator(s) to maintain the hole. Not only do these holes provide water necessary for mating, they also provide foraging habitat for both female alligators and their young. Alligator holes also increase the overall diversity and productivity of the Everglades by 1) acting as a dry season refuge for aquatic organisms when the surrounding marsh dries down; 2) serving as an area of concentrated organisms to provide a foraging site for wildlife; and, 3) providing a disturbance site for plant enrichment through soil enrichment and removal of vegetation.

Until recently, only one alligator hole has been quantitatively studied and no systematic inventory or mapping effort has been made. Consequently, this project aimed to map alligator holes throughout the Everglades ecosystem, ecologically characterize them, determine relative distribution and abundance of alligators, and spatially analyze how alligators and alligator holes are arranged (Figure 1).

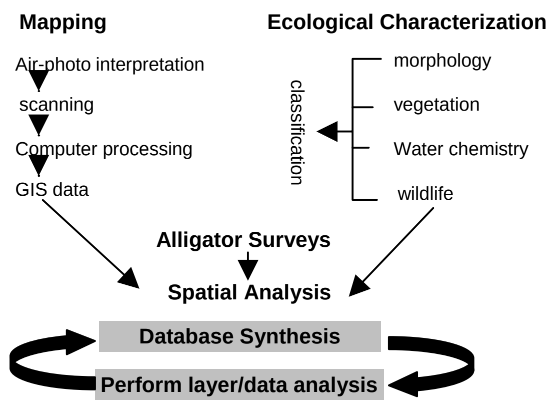

Figure 1. Methods for mapping and ecologically characterizing alligator holes.

Mapping of alligator holes was accomplished in Water Conservation Areas (WCA) 2 and 3 using color infrared (CIR) aerial photographs at a scale of 1:24,000, and is underway in Arthur R. Marshall Loxahatchee National Wildlife Refuge. In WCA 2 and 3 alligator holes greater than 5 meters in diameter appeared as clearly defined black spots on the photographs. Locations of the holes were marked on acetate overlays and the overlays were then scanned and spatially referenced using image processing software, and imported into a geographic information system. Each point, line and/or area was identified, digitized, and tied to data collected on individual holes. Once in a database, holes were easily compared to others in the landscape with three types: those with a surrounding zone of woody vegetation, those without a surrounding zone of woody vegetation, and those artificially formed from the construction of tree islands.

To perform an ecological characterization of alligator holes, three types of data were analyzed; morphology, vegetation, and wildlife. Morphology was characterized using attributes such as size, shape, and basin contour. Water and muck depths at half-meter intervals were also determined to help distinguish any variations or patterns among alligator holes. Vegetation was evaluated using CIR field-map enlargements as well as collecting field data using the line-transect method. Wildlife occurrence was determined through observations of alligators and other wildlife, as well as dip netting and setting minnow traps. Here we report the results of mapping and characterizing alligator holes in WCA 3.

We mapped 845 alligator holes larger than 5 m diameter in WCA 3. Six hundred and forty holes were natural and 205 were created incidental to the construction of tree islands for deer. Holes were mapped with a spatial accuracy of 60 m and 83 % were correctly classified. Holes ranged form 5 to 15 m in diameter and 20 to 150 cm in depth. Alligator holes surrounded by trees (both natural and man-made) were larger, deeper, and created a greater disturbance in the marsh matrix than holes that only consisted of a central pond. The open water of the pond increases habitat diversity in the Everglades landscape and increases plant diversity by providing hydrological conditions different from the surrounding marsh. Contrary to expectation more alligators were observed in ponds at the end of the wet season than in the dry season. Larger alligators and hatchlings occurred in the larger tree lined ponds and juvenile alligators were found in the smaller marsh ponds. The separation of adults and juveniles is common in crocodilians and suggests that alligator holes may serve as social refugia as well as aquatic refugia.

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Multi-Species/Habitat Ecological Evaluation Modeling

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The U.S. Fish and Wildlife Service's South Florida Multi- Species Recovery Plan (MSRP), outlines recovery objectives for threatened and endangered (T&E) species and their habitats in South Florida and is specifically designed to recover multiple species through the restoration of ecological communities in South Florida. Incorporation of this information into map layers that can be manipulated using GIS (Geographic Information Systems) to examine regional patterns of potential habitats and habitat protection needs will assist in the development of an implementation plan for the MSRP.

The University of Florida in cooperation with the U.S. Fish and Wildlife Service has developed habitat models for the 22 terrestrial vertebrate T&E species listed in MSRP. An ArcGIS user interface provides quick access to the most common tasks that are anticipated with using the MSRP models for decision-making.

Potential habitat models are spatial analyses that map habitat for a particular species based on the species' range, land cover affinities, dispersion distances and minimum critical area requirements. The land cover classification used as the base for species modeling is the Florida Gap Analysis Program (FL GAP)(Pearlstine et al. 2002) land cover classification of 1993-94 Landsat Thematic Mapper satellite imagery. The land covers are ranked in 4 categories: preferred, suitable, used if adjacent to preferred or suitable habitat, and not used. Range maps were adapted from the Rare and Endangered Biota of Florida series (Humphrey 1992, Rodgers, *et al*. 1996, Moler 1992).

Less detailed potential habitat models also were adapted from the FL GAP for all of the State's terrestrial vertebrate species. Combining these modeled data layers with conservation land boundaries from the Florida Natural Areas Inventory mapping program allows evaluation of how protection of potential habitat for individual T&E species can contribute to the protection of potential habitat for other T&E species and all other terrestrial vertebrates (Mazzotti et al. 2001). This type of analysis can be used to assess the potential impacts of changes in land use from development or restoration (Figure 1) on T&E and other species, and can be used to help set priorities for acquisition, protection, and management of areas.

Modeling proceeded in the ArcObjects/Visual Basic programming environment. This included conversion of existing models to ArcObjects. The modeling objective was to keep the models current with the direction of ESRI GIS software development. In general, the object-oriented programming environment allows for considerably improved efficiency, improved ease of updating, and prepares the models for integration into user and management-friendly interfaces.

The user interface sits on top of the ArcGIS program and all the functionality of ArcGIS is still available to the user, however, it is not necessary for users to know how to use ArcGIS to take advantage of the spatial analysis tools available in the MSRP User Interface. Opening the MSRP Habitat Modeling Tools in ArcGIS presents options for running the T&E species or FL GAP species models within selected areas of interest and for alternative base land uses/land covers, comparing the differences in potential habitat among different scenerios, and generating reports of species richness, habitat overlaps (i.e., what species are protected when a particular species' habitat is identified and protected, Table 1), and habitat areas.

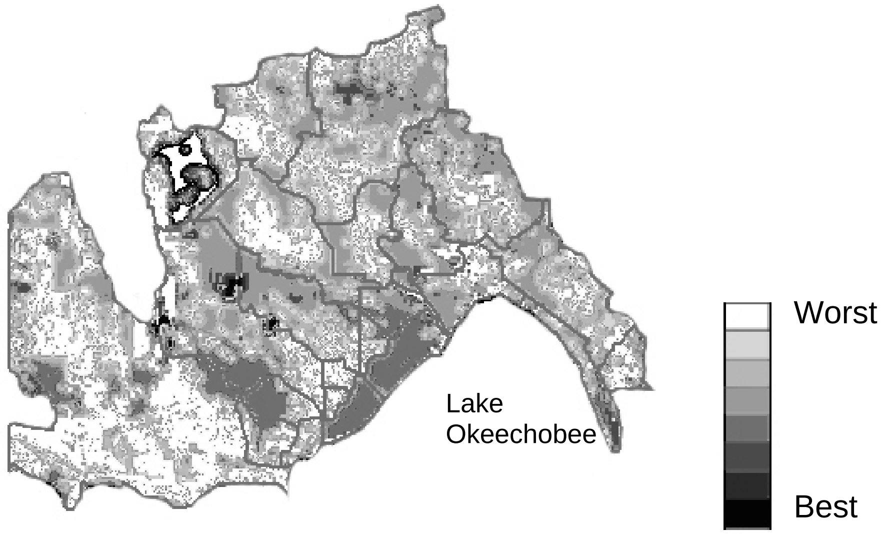

Figure 1. Site selection rankings for a CERP project storage reservoir north of Lake Okeechobee. In this example, the ranking was based on distance away from overall species richness of T&E and FL GAP habitats.

Table 1. Example of species habitat protection in South Florida. The second column is the number of vertebrate species protected when habitat is protected for the T&E species in column one and was set where 50% of the area had at least that richness value.

Species name	Number of other vertebrate species protected	Amount of habitat outside of existing conservation lands
Florida Panther	92	High
Sand Skink	18	High
Everglade Snail Kite	62	Moderate
Key Largo Woodrat	76	Moderate
American Crocodile	72	Low
Cape Sable Seaside Sparrow	79	Low

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Status of the American Alligator (*Alligator mississippiensis*) in Southern Florida and its Role in Measuring Restoration Success in the Everglades

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The American Alligator (*Alligator mississippiensis*) was abundant in the pre-drainage Everglades. Alligators once occupied all wetland habitats in south Florida, from sinkholes and ponds in pinelands to mangrove estuaries during periods of freshwater discharge (Craighead, 1968; Simmons and Ogden, 1998). Nearly all aquatic organisms in the Everglades are affected by alligators (Beard, 1938). As a top predator in their ecosystem, alligators undergo an extraordinary change in body size, consuming different prey items as they grow (Mazzotti and Brandt, 1994). As ecosystem engineers, alligators create trails and holes that provide aquatic refugia during the dry season, concentrating food items for predators. Alligator nests provide elevated areas for nests of turtles and snakes, and for germination of plants less tolerant of flooding (Craighead, 1971; Kushlan and Kushlan, 1980; Enge et al., 2000). Alligator activity also keeps many small creeks in the freshwater mangrove zone and areas around tree islands from becoming overgrown with vegetation. It is possible the activity creates firebreaks that provide protection for woody vegetation and various animal species (Craighead, 1968; Simmons and Ogden, 1998). Water present in holes during the dry season provides critical habitat for nesting female and juvenile alligators (Mazzotti, 1989; Kushlan and Jacobsen, 1990) and provides open water necessary for alligator mating (Garrick and Lang, 1975).

In Everglades National Park, alligators were abundant in the rocky glades and in the freshwater mangrove zone. Land development and water management practices have reduced the spatial extent and changed the hydropatterns of these habitats (Mazzotti and Brandt, 1994). As a result of these habitat alterations, alligators are now less numerous in the marl prairie, rocky glades, and mangrove fringe areas. For alligators, an important alteration was the construction of canals. Many alligators initially displaced by development or drainage now reside in canals. The effects of artificial habitats such as canals on creation and maintenance of alligator holes had not been studied until recently. Everglades canals serve as alligator refugia throughout the greater Everglades ecosystem. Adult alligator density (especially of males) is higher in canal habitats than in the natural marsh interior (FFWCC, unpub. data; Morea, 1999). The canals may provide suitable habitat for large alligators, but unlike alligator holes, they are not suitable for smaller alligators, smaller marsh fish, or foraging wading birds. Though this trend may be remedied by proper management practices, characteristics of alligator habitats have changed with the creation of canal systems now present in the Florida Everglades (Kushlan, 1974).

Restoration of hydrologic patterns and ecological function in the Everglades is now underway. The relationships among dry season refuge, aquatic fauna, wading birds, and alligators have been identified as key uncertainties in the Comprehensive Everglades Restoration Plan (CERP; U.S.

Army Corps of Engineers, 1999). Alligators were chosen as an indicator of restoration success due to their ecological importance and sensitivity to hydrology, salinity, habitat productivity, and total system productivity. A number of biological attributes (relative density, relative body condition, nesting effort, and nesting success) can be measured and standardized methods for monitoring have been developed. These attributes can be used to determine success at different spatial and temporal scales, and are instrumental for constructing ecological models used to predict restoration effects. The relative abundance of alligators is expected to increase as hydrologic conditions improve in over-drained marshes and freshwater tributaries. As canals are removed, densities of alligators in adjacent marshes and occupancy of alligator holes is expected to increase. As hydrological patterns approach more natural conditions, nesting success, alligator growth, and body condition are all expected to improve.

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Establishment of Minimum Flows and Levels for the Everglades: Project Status and Future Directions

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The Everglades Minimum Flow and Level (MFL) project, which established minimum flows and levels for the five Water Conservation Areas (WCAs), the Holey Land and Rotenberger Wildlife Management Areas and the freshwater portions of Everglades National Park (ENP), commenced in 1996. The Technical Documentation to support MFL development was published in February 2000, and the final rule was adopted by the South Florida Water Management District Governing Board in September 2001. State Law defines the minimum level as the "…level of groundwater within any aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area…" (Section 373.042 (1) Florida Statutes). Significant harm is defined as the temporary loss of water resource functions, which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm. The minimum level criteria and definition of significant harm for the Everglades were based on protecting the following six water resource functions: 1) providing hydropatterns that will support Everglades ecosystems; 2) preventing saltwater intrusion of the Biscayne aquifer; 3) providing natural biological filtering and nutrient cycling; 4) providing refugia for aquatic wildlife; 5) preventing invasion by undesirable species; and 6) maintaining desired salinities in coastal estuaries. The proposed minimum water level criteria focused on protection of the two dominant hydric soil types (peat and marl) found within the Everglades as follows:

*Water levels within wetlands overlying organic peat soils within the WCAs, Rotenberger and Holey Land Wildlife Management Areas, and Shark River Slough should not fall 1.0 feet or more below ground level for more than 30 days duration, at specific return frequencies, as defined for 15 gauge locations shown in **Table 1**.*

*Water levels within marl-forming wetlands that are located east and west of Shark River Slough, the Rocky Glades, and Taylor Slough within Everglades National Park should not fall more than 1.5 feet below ground level for more than 90 days duration, at specific return frequencies, as defined for 4 gauge locations shown in **Table 1**.*

The final Everglades MFL Rule language included the stipulation that additional wetland research would be conducted to confirm or refine the MFL return frequency criteria that will not cause significant harm to marl-forming wetland plant and animal communities. The return frequencies defined for marl soils represented the expert opinion of District staff based on management targets developed in the Comprehensive Everglades Restoration Plan (CERP) and Lower East Coast (LEC) planning processes, and output of the Natural System Model version 4.5 F (NSM v 4.5 Final). It was the expert opinion of Everglades National Park staff that NSM v 4.5 Final may not properly simulate hydrologic conditions within the Rockland Marl marsh and Taylor Slough and that the proposed return frequencies defined by District staff may not necessarily protect these marl-forming wetlands from significant harm.

Table 1. Minimum Water Levels, Duration, and Return Frequencies for Key Water Management Gauges Located Within the Remaining Everglades.

Area	Key Gauge	Indicator Region	Soil Type	Minimum Depth (ft) and Duration (days)	Return Frequency (years)
Water Conservation Areas					
WCA-1	1-7	27	Peat	-1.0 ft >30 days	1-in-4
WCA-2A	2A-17	24	Peat	-1.0 ft >30 days	1-in-4
WCA-2B	2B-21	23	Peat	-1.0 ft >30 days	1-in-3
WCA-3A North	3A-NE	21	Peat	-1.0 ft >30 days	1-in-2
WCA-3A North	3A-NW	22	Peat	-1.0 ft >30 days	1-in-4
WCA-3A North	3A-2	20	Peat	-1.0 ft >30 days	1-in-4
WCA-3A North	3A-3	68	Peat	-1.0 ft >30 days	1-in-3
WCA-3A Central	3A-4	17	Peat	-1.0 ft >30 days	1-in-4
WCA-3A South	3A-28	14	Peat	-1.0 ft >30 days	1-in-4
WCA-3B	3B-SE	16	Peat	-1.0 ft >30 days	1-in-7
Everglades Agricultural Area					
Rotenberger WMA	Rotts	28	Peat	-1.0 ft >30 days	1-in-2
Holey Land WMA	HoleyG	29	Peat	-1.0 ft >30 days	1-in-3
Everglades National Park					
NE Shark River Slough	NESRS-2	11	Peat	-1.0 ft >30 days	1-in-10
Central Shark River Slough	NP-33	10	Peat	-1.0 ft >30 days	1-in-10
Central Shark River Slough	NP 36	9	Peat	-1.0 ft >30 days	1-in-7
Marl wetlands east of Shark River Slough	NP-38	70	Marl	-1.5 ft >90 days	1-in-3
Marl wetlands west of Shark River Slough	NP-201 G-620	12	Marl	-1.5 ft >90 days	1-in-5
Rockland Marl marsh	G-1502	8	Marl	-1.5 ft >90 days	1-in-2
Taylor Slough	NP-67	1	Marl	-1.5 ft >90 days	1-in-2

A literature review is being conducted by District staff to summarize the results of recent research efforts by scientists at various universities, the United States Geological Survey, and ENP to better understand marl forming wetland ecosystems and the water level regimes required to prevent significant harm of the resource. The literature that has been reviewed so far, includes long-term vegetation studies that examine the species composition of sites with varying hydroperiods; macroinvertebrate and small fish studies, which investigate how species composition, abundance, distribution, growth rate, overall size, dormancy patterns, dispersal patterns and survivorship vary between short, intermediate and long hydroperiod sites; and studies that examine the interactions of the aquatic-animal community with the geologic structure and hydrologic elements of the Rocky Glades.

District staff are also analyzing recent water level data from each key gauge listed in **Table 1** to document the water level conditions experienced within the various indicator regions and to determine the duration and magnitude of MFL exceedances that have occurred in recent years, including the 2000-2001 regional drought. The results of these analyses will be compared to the CERP Adaptive Management Program (Restoration, Coordination and Verification - RECOVER) performance measures to serve as background measurements of the water level conditions prior to the implementation of various CERP Projects. Elements of the CERP and the

LEC Regional Water Supply Plan (LEC Plan) constitute the District's MFL Recovery Plan, which is required for water bodies that are not expected to meet the MFL criteria as per Chapter 373.042 (1) F.S.

In 2005, all of the MFL criteria set for the five Water Conservation Areas, the Holey Land and Rotenberger Wildlife Management Areas and the freshwater portions of Everglades National Park will be reviewed in conjunction with the update of the LEC Plan. The MFL technical documentation will be revised, if necessary, to incorporate changes required by additional research, changes in CERP projects or components, and the results of ongoing monitoring efforts. Furthermore, the minimum level, duration, and return frequency components defined for the marl marsh habitat will be compared to the updated version of NSM and the performance measures that are being developed for RECOVER, once these work products become available.

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Extinction-Colonization Dynamics Structure Genetic Diversity of Aquatic Species in the Florida Everglades

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The Everglades is a south flowing river with a braided structure of relatively deep sloughs separated by densely vegetated shallow ridges, and bounded by short-hydroperiod wetlands. The slough habitats are routinely fragmented by seasonal dry-down events that temporarily reduce and/or eliminate connections between them (separated by hundreds of meters to kilometers) and concentrate aquatic organisms into deep-water refuges (Loftus and Kushlan 1987; Trexler *et al*. 2001). Starting before 1900 and culminating in the late 1960's (reviewed in Blake 1980; Light and Dineen 1994), canals that may enhance fish dispersal and levees that may limit or preclude migration by fish have subdivided the ecosystem into regional management units covering hundreds of square kilometers.

These two forms of habitat fragmentation, seasonal dry-down events and structural fragmentation, differ in their implications for population genetic structure. Seasonal dry-downs may cause the local extinction of populations, and colonists may re-populate local habitat from a variety of sources. Additionally, dry-downs may encourage mixing by relatively long-range movement of fishes into refuge habitats. Movement of individuals into deep-water refuges from a diversity of marsh sites during a dry-down event may result in population mixing revealed genetically by deviation from Hardy-Weinberg predicted equilibrium and deficiency of heterozygotes (Wahlund effect: Hartl and Clark 1997). Structural fragmentation by canals may create corridors that facilitate directional movement while levee barriers may reduce the dimensionality of movement through the habitat. Thus, structural fragmentation may create either corridors that homogenize populations or barriers to gene flow facilitating genetic differentiation of subpopulations on either side.

We have used F-statistics to identify the population genetic structure for the spotted sunfish (*Lepomis punctatus*) and the eastern mosquitofish (*Gambusia holbrooki*) in the Florida Everglades. We combined analyses of allozyme and microsatellite loci to test the hypothesis that two levels of population structure may be present for spotted sunfish in the Everglades: one of local variation resulting from extinction and colonization; and a second of regional variation resulting from barriers to gene flow by levees superimposed over the historical pattern of a large unimpeded river. If extinction and colonization are important, relatively greater F-statistics should be seen among sites that are subject to extinction-colonization dynamics compared to sites that are stable. Further, if levees are important barriers to gene flow, significant F-statistics should be noted at the regional management-unit level. In this case an island model may be appropriate to describe genetic diversity (Slatkin 1977; Wade & McCauley 1988).

We collected spotted sunfish and mosquitofish between 1996 and 1997 from canal and marsh-pond sites distributed throughout Shark River Slough and Taylor Slough in Everglades National Park (ENP) and Water Conservation Areas 3A (WCA-3A) and 3B (WCA-3B). We made a second collection of mosquitofish in 1999 to add a temporal component to our interpretation of weak patterns of regional population structure detected in the 1996 samples. We used starch-gel electrophoresis to document patterns of allozymic variation and surveyed five polymorphic microsatellite loci in spotted sunfish, and three polymorphic microsatellite loci in mosquitofish.

Allozymes and microsatellites revealed consistent and significant genetic structure among sites within regions. In total, the data for neither species were consistent with use of regional-scale island models (at the spatial scale of water management units or greater) to describe the population structure for these species. The data suggested that spotted sunfish and mosquitofish populations are best described as metapopulations that are not at equilibrium between gene flow and genetic drift. We propose that local-scale population dynamics driven by hydrological fluctuation have a significant effect on the population genetic structure of both spotted sunfish and mosquitofish in the Everglades. These local disturbance events exceed any additional regional-scale affects on genetic variation. There are three possible sources of the lack of regional structure in these species: historical population structure has been lost because of the homogenizing effects of canals as conduits for dispersal; the ecosystem historically had high gene flow and the canals and levees have not altered that situation; or, no genetic structure existed historically and, though the modern management system now limits gene flow, inadequate time has passed for the large regional populations to differentiate.

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Water Quality Considerations in the Study of the Groundwater – Surface Water Interactions Occurring During the Kissimmee River Restoration

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The historic Kissimmee River was a slow moving, meandering river flowing through a wide, marshy flood plain from Lake Kissimmee to Lake Okeechobee. Channelization of the river during the first half of the 20th century dramatically altered the flow and hydrologic characteristics of the surrounding floodplain. Restoration of the river to a state more closely resembling its historic characteristics has again caused significant changes in the surrounding areas. One of the major considerations in the restoration effort is the interaction between the surface water systems and the underlying Surficial aquifer.

Scientists from the South Florida Water Management District have conducted an investigation of the interactions between the surface water and the shallow aquifers in the historic floodplain to assess the interactions between the two water bodies and the potential effects of those interactions on the water flowing into Lake Okeechobee. That study involved hydrology, hydrogeology and water quality analyses conducted at six different sample sites in the floodplain, three of which were located in and adjacent to historic oxbows of the river, with the other three located in and adjacent to the excavated channel. Each of the sites consisted of a location in the water body, a cluster of wells near the channel, and another cluster of wells located 100 to 300 yards away from the channel. Wells were constructed to sample deep, mid depth and shallow strata. Each set of wells were sampled for water quality analyses and were measured to assess water levels and flows.

In addition, Krupaseep seepage meters were placed in the channel at several sites to assess flow across the groundwater – surface water boundary and to allow collection of water quality data. These seepage meters have been designed to electronically monitor flow quantity of seepage going either direction and to collect real time water quality data using in-situ multi-parameter instruments located both inside and outside the seepage meter domes.

Water samples were collected at approximately three month intervals from September 1997 through October 2000 and were analyzed for in-situ parameters, nutrients, general water quality analytes, and a limited list of metals. Analysis of the data obtained from the analyses have resulted in a number of observations that allow further definition of the Kissimmee River system.

Water quality analyses indicates that the water in the river is more typical of rainfall and surficial runoff, whereas the water quality of the water in the Surficial aquifer is more typical of groundwater in the area, having higher conductivity, dissolved solids and hardness than the surface water. Analysis of the data also indicated that there were some isolated, relatively shallow pockets of significantly different groundwater characterized by higher dissolved solids and significantly higher sulfate content than the surrounding aquifer. Nutrient levels were generally high in surface waters and the shallow portions of the Surficial aquifer with concentrations generally decreasing with increased depth. Water quality considerations indicate that there is relatively little exchange between the surface water and the Surficial aquifer in the Kissimmee River flood plain.

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Fish Assemblages of Tidally-Flooded Mangrove Forested Habitat along a Salinity Gradient in Shark River

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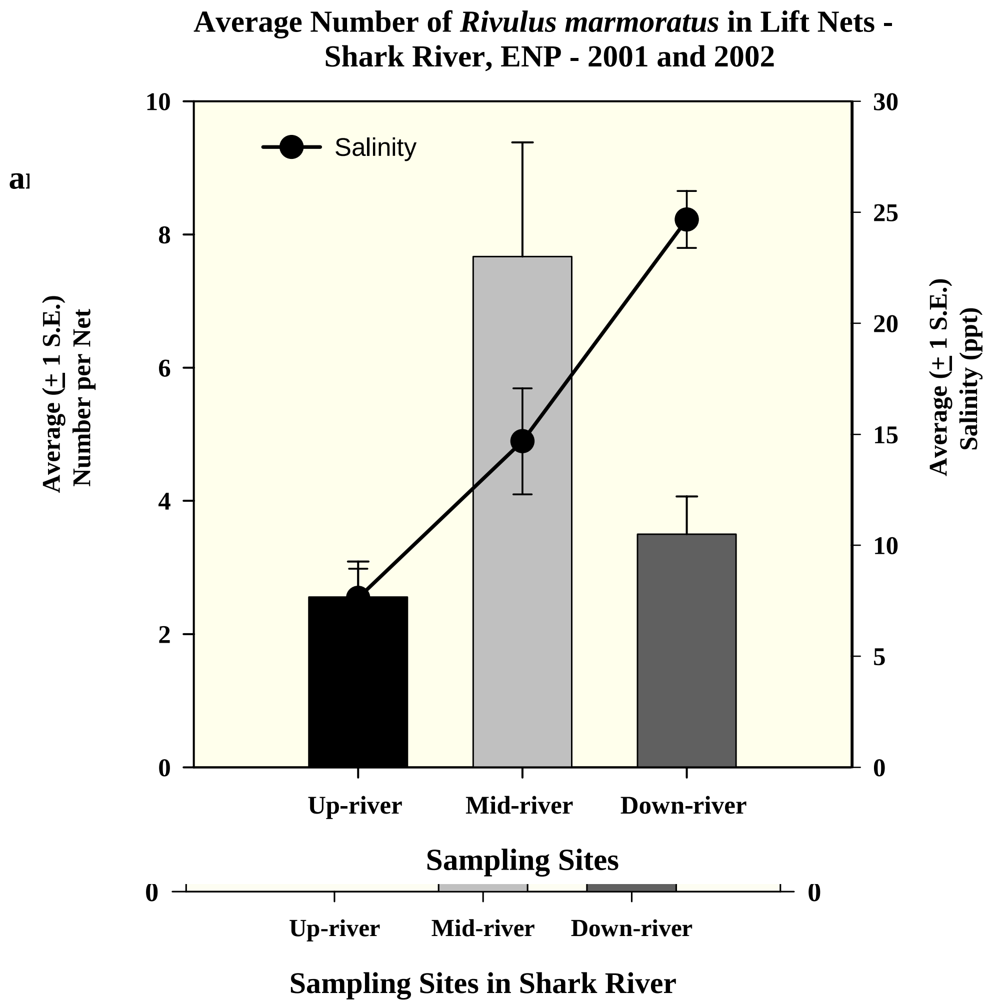
We have been sampling fishes that directly use tidally flooded mangrove forest habitat along Shark River for three years. We sample every other month using two passive sampling methods: 2 X 3 m^2 bottomless lift nets and 1 X 1.5 m block nets across the mouths of intertidal rivulets. Lift nets are located within the first 16 meters of fringing forests and yield density data; intertidal rivulet nets are located at the forest/river bank interface and yield CPUE (catch per unit effort) data as they drain an unknown and variable area. Sites are fixed, and located off Tarpon Bay upriver (S2), midway along the Harney River (S4), and downriver near the mouth of Shark River about 3 km upstream of Ponce de Leon Bay (S3).

The 18-month period January 2001 - June 30, 2002 is representative. We captured 25 fish species from 16 families on 8 sampling dates. Average catch per rivulet net was 13.8 fish; average density per lift net was 3.4 fish /6 m^2. Five families dominated the mangrove forest assemblage. Gobies (frillfin, crested), mojarras (silver jenny, tidewater mojarra), rivulins (mangrove rivulus), anchovies (bay anchovy) and killifishes made up 92% of the catch. Introduced species (walking catfishes, pike killifish, cichlids) were rare, as were juveniles of estuarine transient species that spawn offshore, e.g., gray snapper, pinfish, and mullets.

Frillfin goby (*Bathygobius soporator*) and mangrove rivulus (*Rivulus marmoratus*) were the most abundant species. Frillfin gobies appear to be best suited to higher salinities, showing a monotonic decline with decreasing salinity upstream in Shark River (fig 1). Mangrove rivulus, once considered a species of special concern in Florida, is common along the entire salinity gradient sampled (fig 2). This species is the most frequently captured species in our bottomless lift nets. Rather than being rare, it is actually a habitat specialist poorly captured by traditional sampling methods. Unlike other fish species, mangrove rivulus remains in the forest over low tide by a combination of aerial respiration and use of damp refuges, e.g., crab burrows, under wet leaves and wood. Although data analysis is incomplete, 3 trends are apparent in rivulus distribution along Shark River:

- Individuals tend to be smaller upriver.
- The greatest density occurs at the mid-river location.
- Rivulus have the highest condition factors downriver.

The relative abundance and distribution of these two common species (frillfin goby, mangrove rivulus) can be used as part of a larger monitoring effort to judge the effects of hydrological modifications made upstream in the catchment as part of restoration activities.



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Water Quality in Big Cypress National Preserve and Everglades National Park --Trends and Spatial Characteristics of Selected Constituents

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The National Park Service (NPS) maintains hydrologic monitoring stations for measuring water level (stage) and water quality in Big Cypress National Preserve and Everglades National Park **(**fig 1**).** The data collected at these stations provide a historical baseline for assessing hydrologic conditions and making a wide range of management decisions. We have assessed selected water-quality data at these stations and at nearby canal sites for the period of record, 1959-2000, to define baseline conditions and to evaluate whether long-term trends have occurred.

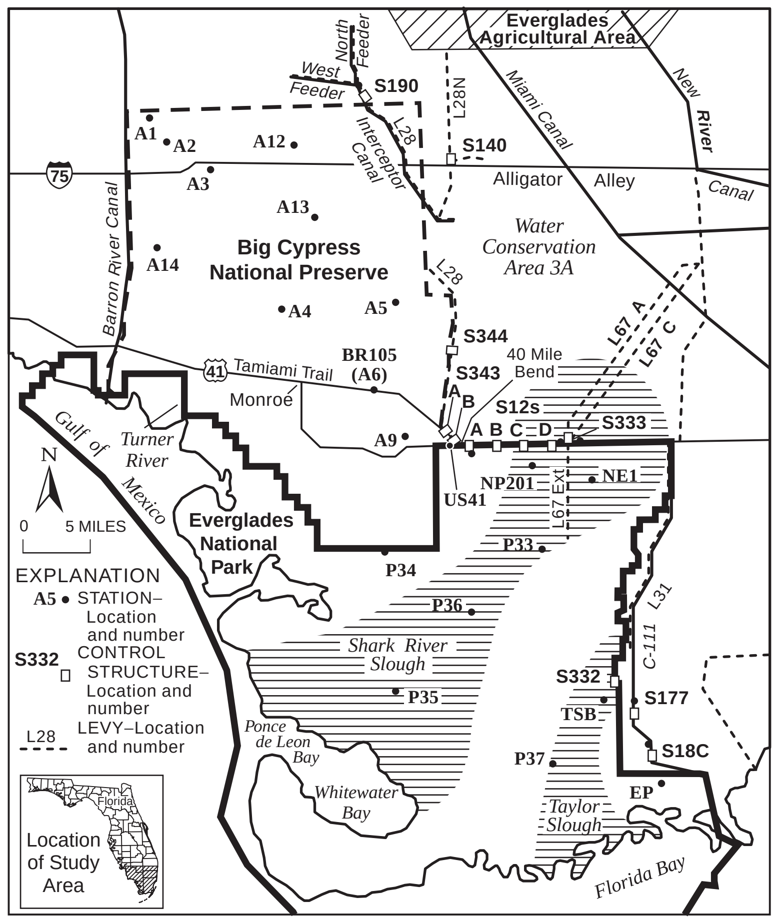

Figure 1. Hydrologic monitoring stations in Big Cypress National Preserve and Everglades National Park.

Seasonal changes in water levels and flows in Big Cypress National Preserve and Everglades National Park affect water quality. As water levels and flows decline during the dry season, physical, geochemical, and biological processes increase the breakdown of organic materials and the build-up of organic waste, nutrients, and other constituents in the remaining surface water. For example, during much of the year, concentrations of total phosphorus in the marsh usually are less than 0.01 milligrams per liter (mg/L), but during the dry season, concentrations sometimes rise briefly above this value and, occasionally under drought conditions, exceed 0.1 mg/L.

Long-term changes in water levels, flows, water management, and upstream land use also affect water quality in Big Cypress National Preserve and Everglades National Park, based on analysis of available data (1959-2000). Specific conductance and concentrations of chloride increased in the Taylor Slough and Shark River Slough in the 1980s and early 1990s; for example, chloride concentrations more than doubled from 1960 to the 1990, primarily due to greater canal transport of high-dissolved solids into the sloughs. Some of the long-term trends in sulfate and total phosphorus were likely attributable to the high percentage of values reported as “less-than” and “zero”, and to changes in reporting levels over the period of record. High spikes in nutrient concentrations were evident during dry periods of the 1980s and attributable to (1) increased canal inflows of water that is nutrient-rich relative to marsh inflows, (2) increased nutrient releases from breakdown of organic bottom sediment, or (3) increased build-up of nutrient waste from concentrations of aquatic biota and wildlife in remaining ponds. Long-term changes in water quality over the period of record are less pronounced in the western Everglades and the Big Cypress Swamp, however, seasonal and drought-related changes are evident.

Water quality varies spatially across the region because of natural variations in geology, hydrology, and vegetation and because of differences in water management and land use. Nutrient concentrations are relatively low in Big Cypress National Preserve and Everglades National Park compared with concentrations in parts of the northern Everglades that are near agricultural and urban lands. Concentrations of total phosphorus generally are higher in Big Cypress National Preserve (median values, 1991-2000, were mostly above 0.015 mg/L) than in Everglades National Park (median values, 1991-2000, below 0.01 mg/L), probably because of higher phosphorus in natural sources such as shallow soils, rocks, and ground water in the Big Cypress region than in the Everglades region. Concentrations of chloride and sulfate, however, are higher in Everglades National Park (median values in Shark River Slough, 1991-2000, mostly above 2 mg/L sulfate and 50 mg/L chloride) than in Big Cypress National Preserve (median values, 1991-2000, less than 1 mg/L sulfate and at most sites less than 20 mg/L chloride) probably because of the canal transport system that conveys more water from an agricultural source into Everglades National Park than into Big Cypress National Preserve.

Trace elements and contaminants such as pesticides and other toxic organics are in relatively low concentrations in Big Cypress National Preserve and Everglades National Park compared with concentrations in parts of the northern Everglades which are near agricultural and urban sources. Concentrations rarely exceeded aquatic life criteria in Big Cypress National Preserve and Everglades National Park. Atrazine was the only pesticide that exceeded the criteria (in 2 out of 304 samples). The pesticides p, p′-DDE, lindane, and heptachlor expoxide exceeded criteria in canal bed sediments in 16, 2, and 1 percent of the samples, respectively.

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Pre-Drainage Relation of Lake Okeechobee to the Everglades

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Previously available descriptions of the hydrological connection between Lake Okeechobee and the Everglades suggested that when the lake reached high stages it would overflow by passing over an elevated custard apple rim. Our recent research suggests that this description needs refinement and that the revisions have significance for understanding water and nutrient balances of the pre-drainage Everglades.

Initial clearing of the custard apple swamp forest that originally bordered the southern portion of Lake Okeechobee for agriculture began around 1900. As a result, working estimates of its pre-drainage extent necessarily have been based on two vegetation maps: Davis (1943) and Harshberger (1914). At the time of Harshberger's observations, patches of the original forest were still present, but Harshberger's mapping was casual and has proven inconsistent with detailed land surveys conducted 1914-1916. Davis' map was generally more detailed, but he acknowledged having had to estimate the original custard apple extent, as essentially none of it was left by the 1940s.

We used a combination of historical sources--land surveys commissioned by the Trustees of the Internal Improvement Fund (State of Florida) in 1914-1916, General Land Office surveys (federal) made in 1860-1907, an 1892 agricultural drainage map, 1915 and 1948 soil maps, along with pre-drainage and early post-drainage shoreline descriptions--to create a pre-drainage map of the southern shore of Lake Okeechobee where it bordered the Everglades.

Of the 47 miles of shoreline from the vicinity of Fisheating Creek on the west to the former Pelican Lake on the east, the eastern 30 miles were custard apple swamp forest. Based on the 1914-1916 land surveys, the width of the custard apple swamp forest was only about 1 to 2 miles; considerably narrower than the 3 to 4 mile width estimated by Davis in 1943. The western 17 miles of the shoreline was formed by sawgrass directly bordering the lake. Along this portion, a level peat surface came up to the edge of the lake; the water surface extended smoothly from sawgrass marsh into the lake. No intervening band of forest or mineral soil was present between the lake and the Everglades in this area.

In the custard apple portion of the shoreline it is possible that the ground was slightly elevated above the ground surface of the Sawgrass Plains south (downstream) from the custard apple. However, there is also evidence suggesting that this apparent rim may be an artifact of drainage. An early drainage engineer noted that post-drainage subsidence was greater in the sawgrass rather than in the custard apple soil, due to the much greater mineral fraction in the custard apple soil. Available historical accounts are not precise about the relative pre-drainage elevations of the sawgrass versus the custard apple portions of the shoreline. Descriptions of the full southern shoreline overflowing at the same time would suggest that the elevation of sawgrass and custard apple portions may have been more similar than not. As peat soils, both were likely in equilibrium with longterm average lake stages.

The presence of an extensive length of shoreline where sawgrass directly bordered the lake significantly clarifies the relation of pre-drainage lake stages relative to ground surface of the Everglades. The known water depth requirements of a sustained sawgrass stand constrain the possible longterm average lake stages. For example, lake stages could not have been consistently two to three feet above (Everglades) ground surface, because this would have converted the stand into slough-like vegetation. Similarly, the lake surface cannot have dropped below ground surface for long portions of each year, because this would have caused invasions of weedy and then woody species, e.g., dog fennel (*Eupatorium capillafolium*), careless weed (*Amaranthus australis*), willow, elderberry, etc.

The presence of sawgrass at the shoreline suggests that lake stages typically rose to 1.5 to 2 feet (45-60 cm) above the ground surface, and typically fell to 0.5, perhaps as much as 1 foot (15-30 cm) below ground surface. Non-zero lake outflows would have continued for eight to ten months during a typical year.

The presence of sawgrass directly bordering Lake Okeechobee also indicates that, under pre-drainage conditions, persistance of the Sawgrass Plains was not dependant on separation from the lake by an intervening band of custard apple forest.

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Paleoecological Determination of the Western Biscayne Bay Coastal Zone Salinity Regime Prior to Anthropogenic Alterations to the System and Estimates of Freshwater Discharge Required to Reproduce an Estuarine Condition

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Historically, freshwater was delivered to the Bay primarily by tidal creek discharge via transverse glades and secondarily by sheet flow generated by local rainfall and from overflow from transverse glade-tidal creek systems. A third freshwater source was springs found along the contact between upland limestone and coastal marl soils. Three types of tidal creeks are identified which are related to origin, transverse glades-sloughs (which produce the largest tidal creek and are usually associated with shoreline projections or points), spring fed and tidal action alone (the smallest). The presence of dead Crassostrea virginica shell accumulations, the common oyster, at larger tidal creeks along the western BB shoreline are strong indicators of an estuarine type environment with typical changing salinities but normal brackish water conditions.

Based upon the salinity requirements of the common oyster throughout its range a pre-development salinity range of between 5 and 19ppt is determined. The lower salinity is the target during the rainy season and the maximum salinity target for the dry season is 19ppt. Salinities over 20ppt result in serious predation and limits oyster production and survivability.

The volume of freshwater discharge delivered through transverse glades is estimated by the crude method of measuring the width of select transverse glades, determining average water depth (based upon the distribution of marl soils of known Hydroperiod) and estimating water velocity. At the lowest water velocities imaginable (1cm/sec) flows through one transverse glade is calculated at 1200 acre ft/day. This suggests that a great deal of freshwater was available to coastal Biscayne Bay prior to drainage and changes in water delivery patterns.

Calculation of freshwater needs in two different coastal basins suggests that no easy single model will work for calculating required freshwater flow to maintain the target salinity regime. This is due to differences in the size of the basin and basin water renewal time.

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Developing Systemwide Performance Measures for the Comprehensive Everglades Restoration Plan

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The scope, complexity, and significance of the Comprehensive Everglades Restoration Plan (CERP) warrant the establishment of tools to measure, assess, and report progress towards achieving the goals and objectives of the Comprehensive Plan established by the Water Resources Development Act of 2000. The goals of the Comprehensive Plan are to “enhance ecologic values,” and to “enhance economic values and social well being” in the South Florida ecosystem (USACE and SFWMD 1999). To evaluate and assess the CERP and help demonstrate compliance with all applicable federal and state laws and regulations, performance measures have been developed by Restoration Coordination and Verification (RECOVER), a team of scientific multidisciplinary, interagency experts. RECOVER has developed a specific set of hydrologic, biological/ecological, and water quality performance measures corresponding to the natural and human systems in South Florida that should be measured in order to determine the success of the CERP. The performance measures have been specifically designed to determine how well CERP projects meet the restoration, water supply, water quality and flood protection goals and objectives set forth in the Comprehensive Plan. These performance measures will be used to determine baseline conditions, identify ecological trends and impacts resulting from natural and anthropogenic factors, predict plan performance, track plan performance and progress, and improve plan performance through adaptive management strategies. The measures have been developed through a multiyear, iterative process. The development, review, revision and use of the CERP performance measures are dynamic and the measures will be periodically reviewed and refined as needed.

Many of the performance measures are based on conceptual ecological models. The use of conceptual ecological models is a key element of the Applied Science Strategy (Gentile et al. 2001) and a primary foundation for the development of performance measures. Conceptual models illustrate the links among societal actions, environmental stressors and ecological responses, and provide the basis for selecting and testing the set of causal hypotheses that best explain why the natural systems in South Florida have been altered. The conceptual ecological models identify the key attributes of the system. These attributes are the biological and ecological elements that best indicate responses in the natural system to the effects of stressors. These attributes and stressors will be modeled and/or monitored and the results will be compared to a desired endpoint direction of change that the plan is expected to provide in the South Florida ecosystem.

Performance measures have two functions: to evaluate performance and assess impacts. Therefore, these measures are broken into two categories: evaluation measures and assessment measures. Evaluation measures are used to evaluate the predicted systemwide performance as simulated by computer modeling of alternative plans. The selection of evaluation measures is constrained by the modeling tools that are available to the evaluation teams. Each evaluation measure can be used to predict how well a component and/or combination of components will meet one or more goals of the plan. The assessment performance measures are designed to measure real responses in the natural and human systems as components of the plan are implemented. Each assessment measure identifies one or more elements to be monitored and is designed to assist in determining whether project objectives are being attained. Ideally, an assessment performance measure will include a desired endpoint. This endpoint is the expected and desired condition of the element being measured once the CERP has been fully implemented. The assessment measures have been used to determine the design of the CERP monitoring and assessment program (RECOVER 2002a) and are the key features of the CERP adaptive management program.

Performance measures will be used to predict and assess performance at both the project and systemwide levels. Systemwide performance measures enable evaluation and assessment of the natural and human systems. Also, interactions between the physiographic regions in South Florida can be evaluated and assessed. RECOVER teams have developed the set of performance measures to be used to measure the progress and success of the CERP from a regional (systemwide) perspective. These measures will be used to evaluate systemwide performance, identify shortfalls and improve systemwide performance through the adaptive management process. The overall CERP goals and objectives also apply to each component of the Comprehensive Plan. The goal for individual CERP projects is to optimize the performance of the CERP by refining the design and operation of components such that the systemwide performance equals or exceeds the performance of the Comprehensive Plan recommended by the Restudy (RECOVER 2002b). To accomplish this, project delivery teams formulate and evaluate alternatives to determine which plans will best meet the targets of the project-level performance measures. Project-level performance measures will be consistent with and complement systemwide performance measures. Project delivery teams will develop project-level performance measures for the purposes of predicting the performance and impacts of alternative plans in their project area; and monitoring local performance of CERP components in meeting the systemwide goals and objectives of the CERP.

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Using Natural System Model and South Florida Water Management Model to Determine Tree Island Performance Measures

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Tree islands are a fundamental part of the Everglades landscape and ecosystem function. Restoration of the Everglades will not be successful without protecting their place and character. Currently our knowledge of tree islands is insufficient to predict how they will respond to changing water management and restoration. Although several studies are underway to provide a better understanding of the fundamental processes that occur in the formation and maintenance of tree islands, restoration projects are currently being designed that are likely to have a significant effect on tree islands. Tree Island performance measures are needed to apply to hydrologic simulations of alternative plans for restoration in order to screen for alternatives that favor persistence and restoration of tree islands. In light of the current incomplete understanding of tree island hydro-ecology, it is advantageous to explore the characteristics of the pre-drainage hydrology in which, presumably,tree islands formed and flourished. By combining current knowledge of tree island characteristics with knowledge of pre-drainage hydrology, a range of hydrologic conditions can be identified that would be expected to sustain healthy tree islands.

The Natural System Model (NSM) is the best available tool for describing pre-drainage Everglades Hydrology. In addition, the NSM is the target for many restoration performance measures. An NSM query tool is used to characterize pre-drainage hydrology of tree islands in Everglades National Park. This query tool uses NSM stages, with more detailed topography to produces maps of frequency contours that represent the percentage of years that meet the criteria specified by the user. Criteria include maximum and minimum flow depth and duration, and average and minimum hydroperiod. Frequency contours are superimposed on the historical tree island distribution to allow for matching high frequency contours with areas where tree islands are found. From this “parameter fitting” exercise a suite of possible performance measures are derived. Using topographic data from tree islands in Everglades National Park, the range of criteria that can be used for performance measures is further limited and can be used to construct a performance measure for screening alternatives using hydrologic models.

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Techniques Development for the ReEstablishment of the Long-Spined Sea Urchin, *Diadema antillarum*, on Two Small Patch Reefs in the Upper Florida Keys

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A project funded through FKNMS was begun in the fall of 2001 offshore of the Upper Keys to explore the feasibility and ecological results of translocating juvenile long-spined sea urchins, *Diadema antillarum*, from areas with relatively high settlement and extensive winter mortality, the reef crest rubble zones, to nearby deeper water (about 25 feet, 7.5 m) patch reefs at densities approaching those on Florida reefs before the *Diadema* plague of the early 1980s. Four patch reefs: two experimental and two controls, varying in size from about 44 to 96 sq. m were selected for the study. During the period from September 2001 to December 2001, 434 juvenile long-spined urchins were placed on experimental reef # 1 (96 sq. m), a total potential density of 4.5/m^2, and 262 were placed on experimental reef # 2 (88 sq. m), a potential density of 3.0/m^2. The translocated populations were evaluated for number and placement of surviving urchins 10 times on reef # 1, and 11 times on reef # 2 over various intervals during the period from September 8, 2001 to February 5, 2003.

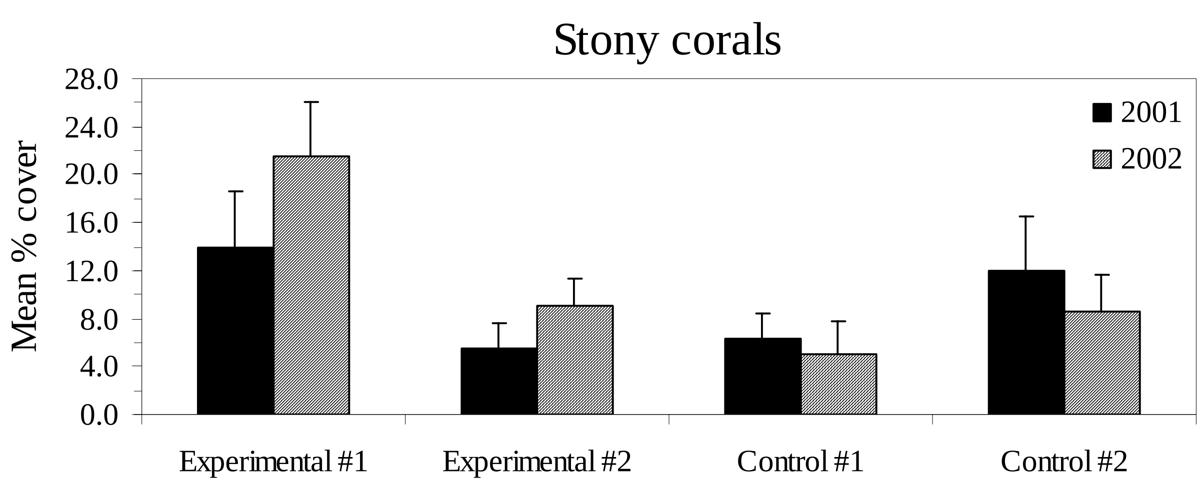
Percent survival of the *Diadema* urchins was roughly similar on both experimental reefs from the first count on 09/08/01 through the final count on 02/05/03. Initial survival rates over the first three days of 80% and 90% dropped to about 40% to 45% on both reefs from 11/09/01 to 05/29/02, and then, on experimental reef # 1, survival remained at about 30% from 08/08/02 to the last count on 02/05/03. On experimental reef # 2, survival remained at 40% on 08/08/02, dropped to 30% on 10/08/02 and then dropped again to 17% at the count on 11/30/02. Survival was 20% on the final count on 02/05/03 due to placement of 16 urchins on this reef late in the study (10/23/02). The average density of urchins over the entire 17 months of the study was 1.6m/^{2} on experimental reef # 1 and 1.0/m^2 on reef # 2. The highest density on reef # 1 (2.1/m^2) was achieved on 02/26/02 and the highest density on reef # 2 (1.4/m^2) occurred on 10/24/01 and on 02/26/02. The final density on 02/05/03 on reef # 1 was 1.2/m^2 and on reef # 2 was 0.6/m^2. Decline in survival and density on both reefs was generally gradual and stable at a similar rate of decline during the last 12 months of the study. Reef # 1 lost 87 urchins, a survival of 57% over the last 345 days of the study. The total loss in urchin density on reef # 1 over this period, 02/26/02 to 02/05/03, was 0.9/m^2, which was a decline in density of 0.0026/m^2 per day. Reef # 2 lost 67 urchins during this 345-day period, a survival of 45% and a loss in density of 0.8/m^2; which was a decline in density of 0.0023/m^2 per day (This data for reef # 2 includes 16 urchins released on reef # 2 on 10/23/02).

The gradual mortality over the term of the project indicated that predation was the main cause of population decline and not mortality due to storms or plague. Population counts before and after two instances of tropical storm conditions in the fall of 2001 indicated that these storms did not cause mortality in the translocated urchin populations on the experimental deep reefs, and no evidence of plague caused *Diadema* urchin death was observed.

Although evidence of some movement between reef quadrants and some concentration of urchins on the more rugged and complex areas of reef # 1 was evident, in general, urchins remained broadly distributed over all reef areas on each experimental reef.

NURC (NOAA's National Undersea Research Center) conducted a rapid habitat assessment of the four project reefs on 08/31/01 and 09/01/01, before translocation of the urchins and again on 09/18/02, about one year after translocation of the urchins.

The benthic ecology of the experimental reefs changed considerably during the period of exposure to "normal" pre plague density of *Diadema* urchins. The results of the NURC assessment showed that the percent stony coral cover increased on the experimental reefs from 9.8% to 15.3% (+ 56% relative increase) and decreased on the control reefs from 9.1% to 6.8% (-26% relative decrease). Sponge cover decreased on the experimental reefs from a mean of 7.4% to 5.3% and increased on the control reefs from 5.3% to 6.0%. Algal turf cover decreased slightly on the experimental reefs from 28% to 24% (- 16.2% relative decrease) while algal turf increased on the control reefs from 23.4% to 27.8% (+18.7% relative increase). Crustose coralline algae exhibited the most significant change. Coralline algae cover increased on the experimental reefs from 7.5% to 19% (+ 153% relative increase) while coralline algae cover decreased on control site 1 (reef # 3) and slightly increased on control site 2 (reef # 4), a total change of 7.8% to 8.8% (+ 6.5% relative increase) on the control sites. The presence of crustose coralline algae has been shown to stimulate settlement of certain species of stony corals. Green calcareous algae (mostly *Halimeda* spp.) showed little change on the experimental reefs (a decline from 3.8% to 3.1%), but increased on the control sites (an increase of 1.8% to 3.8%). Brown foliose algae, mostly *Dictyota* spp., greatly declined on the experimental reefs a decrease of 10% to 5.1%, a – 48% relative decrease) and increased slightly on the control reefs (an increase of 4.5% to 5.9% increase, + 31% relative increase). Brown foliose algae declined on experimental reef # 1 to a remarkable extent (11% to 1.8%, a – 511.1% decrease), and also declined on control reef # 4 (which hosted a small population of *Diadema* urchins) from 3.0% down to 1.0%. Experimental reef # 2 showed a small decrease in brown foliose algae from 9.0 to 8.5%, while control site 1 (reef # 3) showed an increase in brown foliose algae from 6.0% to 10.8%. Brown foliose algae are important competitors with corals for space and sunlight, and reduction of these algae is critical to coral recovery. The density of juvenile corals increased on the experimental reefs from an average of 6.2 juveniles/m^2 to 15.3 juveniles/m^2, a relative increase of + 147%. Average (mean) densities also increased on the control sites (reefs # 3 and # 4) but to a lesser degree, 6.6 juveniles/m^2 to 9.9 juveniles/m^2, a relative increase of +51%.



These positive changes over the short term of one year show a marked reduction in algal prevalence and signify a return to a coral dominated ecology. These changes in the ecology of the experimental reefs are what was expected from a return of *Diadema* urchins to the reefs, and reflect the changes that have occurred on limited areas of Caribbean reefs where populations of

Diadema have returned naturally. This study presents evidence that translocation of *Diadema* urchins from environments with high risk of mortality to deeper reef areas results in survival and population densities that can affect change in the ecology of coral reefs, moving reefs areas from algal expansion back toward dominance of coral growth.

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Modeling the Upper Kissimmee Chain of Lakes for Operational Hydrology

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Water managers at the South Florida Water Management District (SFWMD) need analytical tools to help in the understanding of how daily operational decisions affect the objectives of maintaining water supply and a healthy environment. The key to proactive management is the ability to model the hydrology and management of all components of the system with an adequate set of climatic inputs. The SFWMD has extensively used the South Florida Water Management Model (SFWMM) in operational hydrology. Only until recently the Upper Kissimmee Chain of Lakes model (UKISS) was converted to this class of models.

The UKISS model was developed in 1981 by the SFWMD to simulate the operations of the lakes in the Upper Kissimmee River Basin, Florida. The model serves as a management tool to predict the lake conditions so that alternative management schemes, aimed at achieving specific objectives, can be evaluated. A water budget computation is used to route flows through the system. Routing proceeds from the uppermost lake (Alligator) to the lowermost lake (Kissimmee) by solving the mass balance equation in daily time steps.

The capability of using the UKISS model in Position Analysis (PA) mode is a desirable step in the operational hydrology of the lakes. The purpose of this study was to have the UKISS model running in PA mode. In PA mode, all the storage areas in the model, including soil moisture levels, are initialized to current or specific conditions. Once the initial conditions are set, the model simulates, under different climatological input scenarios (rainfall and evapotranspiration) and current or given operational practices, different outcomes (stage and flow) of the system. Statistical analysis of the results provides information on the future response of the system, given the initial and the operational conditions.

The UKISS in PA mode allows an improved evaluation of S65E inflows entering Lake Okeechobee and the risks associated with operational decisions (e.g., drawdown of lake stage). Lake initial stages and antecedent moisture conditions for a specific day are specified in UKISS model in PA mode. Simulated flows from Lake Kissimmee, once corrected according to the Lower Kissimmee contribution, are passed as input to the SFWMM model in PA mode.

This presentation will provide a brief summary of the recent efforts to incorporate the UKISS model in PA mode into the Operational Planning project of the SFWMD. First, a brief overview of UKISS model and calibration results are presented, along with the description of the model initialization. The model is run from January 1, 1965 through December 31, 2001. Finally, model results are presented, as percentile stage time series and percentile average flows for each lake, given the conditions of the system on January 1, 2003. As an example, percentile flows from Lake Kissimmee are shown in Figure 1.

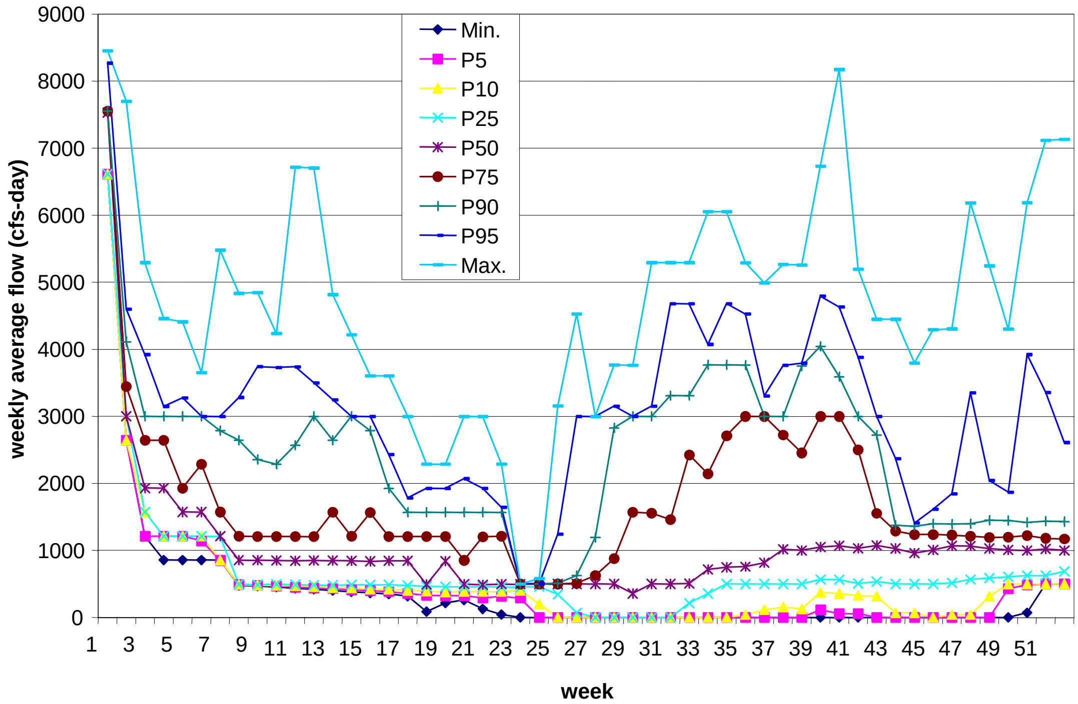

Figure 1. Percentile Flows from Lake Kissimmee on January 1, 2003

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Projecting Future Population Dynamics of the Florida Snail Kite in Relation to Hydrology by Means of a Suite of Models

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The basic information for any model that projects future population dynamics should be good empirical studies. A large number of empirical studies have been done on the Florida Snail Kite. Such studies provide basic information on the biology of the species. They also provide the correlative relationships between specific aspects of the snail kite life-history and behavior with the hydrology of the system. These relationships form the building blocks of any hydrology-driven population-dynamical kite model.

Opinions differ on whether the best approach to modeling the life history of a population should be by means of a system-wide deterministic matrix model or, alternatively, a spatially-explicit stochastic individual-based model. We argue that rather than choosing among these two approaches, it is better to implement both concurrently. Next to the system-wide deterministic matrix model and the spatially-explicit stochastic individual-based model two other versions were implemented: a system-wide stochastic matrix model and a spatially explicit deterministic individual-based model. With these four tools in hand we approached the challenge of making reliable projections of future population development of the snail kite under various hydrological scenarios.

Next to having a rigorous and transparent model structure, two issues are central to getting a reliable kite model: how to parameterize the model and how to set ranges of uncertainty to its output. The preferred statistical framework to solve both issues would be maximum likelihood estimation. In principle, the Maximum Likelihood Method provides a formal and rigorous approach to deal with the five sources of uncertainty: structural uncertainty, uncertainty in the hydrological input, uncertainty in the biological parameters, uncertainty due to demographic stochasticity and finally uncertainty due to errors in the empirical data on basis of which the model is parameterized.

There is optimism that the kite model will be among the first applied population dynamical models that succeeds in disentangling and integrating these sources of uncertainty in a formal way. The current implementation of the model (Everkite 3.00), that has already been applied to evaluate hydrological scenarios and is ready to analyze new scenarios as they come, provides an excellent starting point for these new developments.

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Total Phosphorus Trends in the Greater Everglades Headwaters: Upper Kissimmee Chain-of-Lakes

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Changes in total phosphorus concentration were studied in the Upper Kissimmee Chain-of-Lakes in order to address the mandates of the Lake Okeechobee Protection Act. Twenty years of monthly total phosphorus data stored in the South Florida Water Management District database were analyzed for East Lake Tohopekaliga, Lake Tohopekaliga, Cypress Lake, Lake Hatchineha, and Lake Kissimmee.

Lake wide annual means reveal a monotonic decrease in total phosphorus concentration in these lakes, except in East Lake Tohopekaliga where total phosphorus concentration fluctuated around 0.020 mg/l. Lake wide annual mean total phosphorus concentrations decreased from 0.500 – 0.040 mg/l, 0.160-0.040 mg/l, 0.100-0.030 mg/l, and 0.065-0.040 mg/l in Lake Tohopekaliga, Cypress Lake, Lake Hatchineha, and Lake Kissimmee, respectively. This decrease appears to be related to the removal of sewage treatment plant effluents from tributaries to the lakes and from decreases in farmland around the lakes.

In addition, lake wide annual means revealed an approximate four-year cycle in total phosphorus concentration superimposed on the monotonic decrease. This cycling is most evident in East Lake Tohopekaliga, which was not affected by sewage discharges and, therefore, did not show the decreasing trend in total phosphorus concentration observed in the other KUB lakes. Total phosphorus peaks in these cycles were observed in 1984, 1987, 1990-92, and 1998 during the sampling period. The cycles appear to be intrinsic to the ecology of the lakes, probably related to some climatic variability expressed at the local scale, and not man-made. Cyclic climatic variability with a frequency of about 4-years could be linked to El Niño/La Niña events. During El Niño years, lake wide annual mean total phosphorus concentrations tend to be higher, whereas, during extreme La Niña years they tend to be lower. The cycling tendencies in lake wide annual mean total phosphorus concentrations seem to persist in spite of different activities in the lakes such as sewage diversions, drawdowns, muck removals, and chemical treatments of aquatic vegetation.

Lake wide monthly means, combined for the period of record, reveal a seasonal trend in total phosphorus concentration in these lakes. Higher monthly mean total phosphorus concentrations occur during the summer and lower concentrations occur during the winter. The onset of the increasing trend occurs in March. This increase could be associated to in-lake treatment of aquatic vegetation or indirectly to increases in temperature. The end of the increasing trend could be associated with increases in precipitation during the summer, perhaps due to dilution. This seasonal trend in lake wide monthly mean total phosphorus concentration in the Upper Kissimmee Chain-of-lakes indicates that increases in total phosphorus concentrations during the wet season is not created by precipitation runoff alone, as is commonly believed.

The results of the current study indicate that natural ecological cycles influence total phosphorus patterns in the Greater Everglades headwater lakes and that these cycles need to be taken into consideration when developing restoration evaluation criteria and ecosystem health indicators for the Everglades.

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Groundwater Monitoring and Modeling in an Agricultural Area Adjacent to the ENP

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The Comprehensive Everglades Restoration Project (CERP) introduces many changes in water management practices to the South Florida region. Decisions for water management are mainly based on large scale modeling. However, to assess the local effects of regional water management and understand hydrological processes, research at a local and field scale is necessary.

Therefore, an intensive groundwater monitoring and modeling program was established in the Frog Pond Area, a non flood protected agricultural area adjacent to the ENP. In the northern part of this area, a new pumping station and detention pond area of the South Florida Water Management district have been taken in operation in 2002.

Goals of the project are: 1. Modeling of groundwater flow and heads under current and possible future CERP management scenarios in this area. 2. Investigation of the impact of agriculture on groundwater quality and simulation of transport of agrichemicals in this area. 3. Determination of flood endangered areas and areas with groundwater heads in the root zone under the changing management conditions. 4. Extension of this information to the growers and other stakeholders in the area

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Quantifying Internal Canal Flows in South Florida

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The need to determine future surface-water flow requirements in the interior canal system of south Florida is being met with the successful implementation of strategic placed stream-flow and water-quality gaging sites in the interior of southern Florida. The multi-agency effort involves four entities that collect, analyze, and distribute information for water managers. In 1995 the U.S. Geological Survey (USGS) established three monitoring sites south of Lake Okeechobee in an effort to accurately gage flows in canals entering and exiting Tribal lands, the Big Cypress National Preserve, and Water Conservation Area 3A in southern Florida. These flows are also being monitored to calculate nutrient loads in the canals that cross or border Tribal lands. Two of the gaging sites, L-28U and L-28IN, are located on the southern border of the Seminole Tribal lands along the L-28 canal and the L-28 Interceptor canal, respectively, west of Water Conservation Area 3A in Hendry County (fig. 1). The third gaging site, L-28IS, is located along the L-28 Interceptor canal where flows enter the western lands of the Miccosukee Indian Tribe from the Big Cypress National Preserve in Collier County and has been discontinued.

Acoustic instrumentation, in lieu of standard methods for field data collection and flow computations, is used to quantify flows in the canals. Using the acoustic velocity meter (AVM), Acoustic Doppler Velocity meter (ADV), and the Acoustic Doppler Current Profiler (ADCP), it is possible to more accurately gage flows in this type of environment because of new capabilities to quickly measure low or rapidly changing water velocities. Construction, instrumentation, and calibration of the flow gaging sites were completed by the USGS during 1996 and 1997. The South Florida Water Management District (SFWMD) installed flow-weighted samplers at the gaging sites for nutrient analysis in conjunction with the stream flow monitoring; the Seminole and Miccosukee Indian Tribes have serviced the flow-weighted samplers. Real-time telemetry instrumentation and programming assistance along with phosphorus and nitrogen load calculations have been provided by the SFWMD. ADCP calibration of the installed acoustic velocity meter indexes is ongoing and development of the "sum of least squares regression" has been provided for data processing at all sites and continues to be refined. Velocity data collected during the dry season has displayed a phenomenon known as acoustic refraction or ray bending produced by thermal stratification in the water column during extended periods of very slow vertical flow. Various installed electromagnetic and new Doppler mean velocity-indexing techniques have been tested and proven largely successful.

The L-28U site along the L-28 canal is used to monitor freshwater flows from the lands of the Seminole Tribe and to provide nutrient data load summaries. Average annual runoff of 63,930 acre-feet for the period from 1997 to 2001, represents about twice the inflow amount determined by the SFWMD at their upstream U.S. Sugar Outflow (USSO) site located on the northwestern border of the Seminole Tribal lands. The L-28IN site along the L-28 Interceptor canal is used to monitor flows from the lands of the Seminole Indian Tribe to the Big Cypress National Preserve and ultimately to Miccosukee Tribal lands as well as providing nutrient data for water-resources planning and management. Annual runoff averaged 53,140 acre-feet from 1997 through 2001. The L-28IS site along the L-28 Interceptor canal, discontinued September 1999, was used to monitor flows from the lands of the Seminole Indian Tribe and the Big Cypress National Preserve to the lands of the Miccosukee Indian Tribe. For the three years of operation this site also provided flows and associated nutrient load data for water managers, and was instrumental in bracketing and quality assuring the flow calibration conditions for the upstream L-28IN site. Average annual runoff at the site for the 1997-1999 periods was calculated to be 49,070 acre-feet.

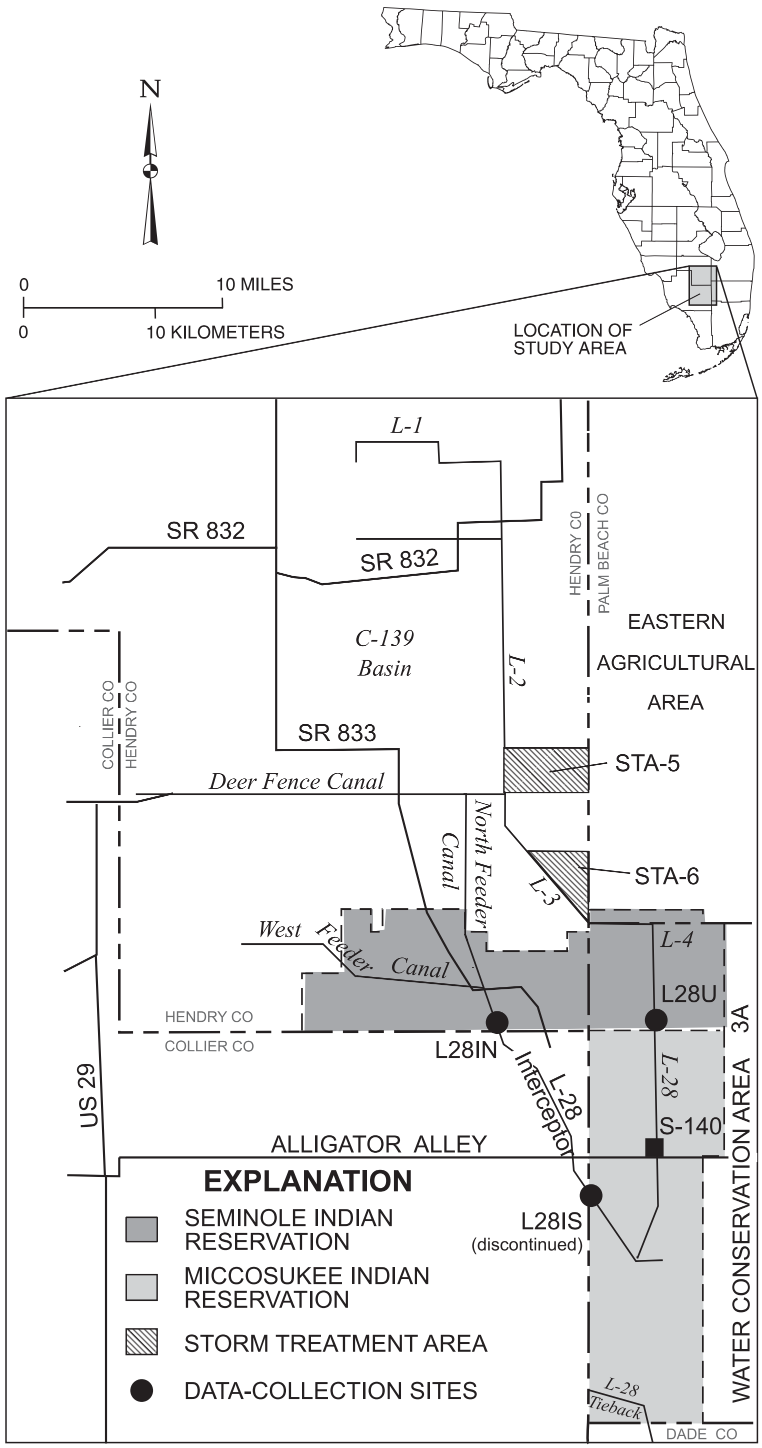

Figure 1. Study area showing location of Tribal lands, data-collection sites, and major canals and levees.

Measuring flow-weighted nutrient loads requires extremely accurate flow-data collection combined with a highly coordinated nutrient collection and analysis procedure. A collaborative product that meets this need is provided as part of current efforts and has been documented in seven semi-annual progress reports presented to the SFWMD/Seminole Working Group. An ancillary report was produced from funding sources outside of the USGS Placed Based Studies (PBS) program budget during the 2002 water year (Lietz, 2002). The report examines the feasibility of estimating concentrations and loads based both on USGS acoustic backscatter data and Seminole Tribe nutrient water quality data.

Reference:

Lietz, A.C. 2002 (in press), Feasibility of estimating constituent concentrations and loads based on data recorded by acoustic instrumentation: U.S. Geological Survey Open File Report 02-285, 10 p.

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Characterization of Microtopography in the Everglades

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As concerns over how to restore the Everglades intensify, the need to improve capabilities of surface-water flow models becomes increasingly important. One of the physical factors not often considered in surface flow modeling is the micro-topography of the wetland surface. At the local scale (1-m horizontal), the elevation of the wetland surface undulates between hummocks associated with macrophytes and the depressions between them. At a larger spatial scale (100 m), topography varies between the tops of ridges and the bottom of nearby sloughs. We refer to all of these topographic variations as "microtopography."

Microtopography affects the cross-sectional area of a wetland that is available for surface-water flow. As water levels decline seasonally, the tops of ridges and hummocks become exposed, making flow paths more sinuous, and therefore, increasing the resistance to surface flow. Microtopography also plays a role in the water exchange between wetland surface water and porewater of sediments.

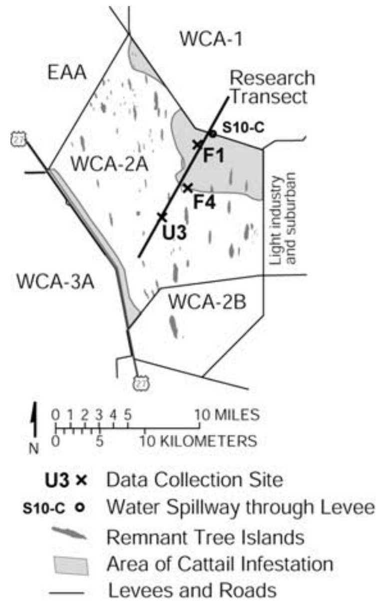

FIGURE 1: Location of data-collection sites in WCA-2A, central Everglades, south Florida.

To characterize microtopography, elevations of the top of the peat surface and the top of the layer of flocculent organic material, or "floc," were estimated in Water Conservation Area 2A (WCA-2A) at sites F1 and U3 (figure 1). These two sites are located along a research transect where water generally flows toward the southwest.

Two types of measurement tools were used to determine the microtopography at different vertical and horizontal scales. Schematic diagrams of the measurement tools are shown in figure 2. The type I tool generally did not penetrate the floc, and estimated the elevation of the top of the floc layer. Due to its more open footprint, the type II tool penetrated the floc and was used to measure the elevation of the peat surface, which is considerably firmer than the floc. Field measurements of microtopography were made in different vegetative conditions near sites F1 and U3 (fig. 3), and the measurements were distributed so that the variability of the wetland surface could be characterized for 100-meter and 1-meter spatial scales. Measurements show that the elevation of the peat surface varies 3-4 times more at the 100-m scale compared with the 1-m scale (table 1, and fig. 4).

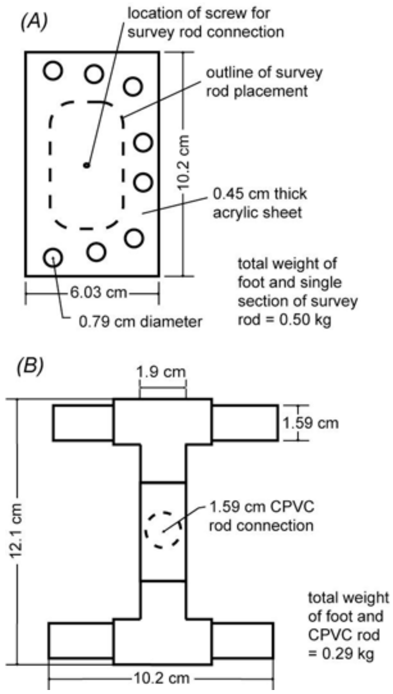

FIGURE 2: Top view schematics of type I *(A)* and type II *(B)* measuring tools.

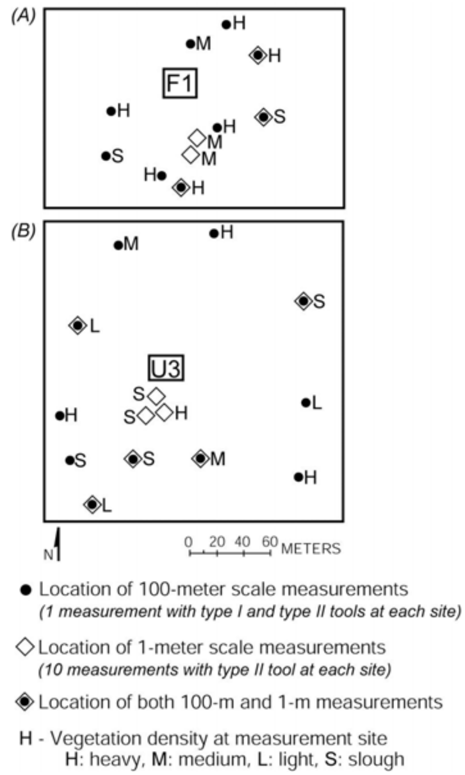

FIGURE 3: Location of microtopography measurements at site F1 *(A)* and site U3 *(B)*, WCA-2A, central Everglades, south Florida.

Microtopography data for sites F1 and U3 are summarized in figure 5 by plotting an inverse distribution function, i.e. elevation of the peat or floc surface versus the probability of occurrence when sampling at the 100-m scale. The x-axes in figure 5 can be interpreted as the fraction of wetland cross-section that has an elevation equal to or less than a given elevation. Using this function allows estimation of the average wetland cross-section available for surface flow at a given surface-water level.

Our ongoing work focuses on using the microtopography distributions in a surface- water flow model. In addition to using microtopography data to compute the cross-sectional area of surface flow over a period of fluctuating water levels, these data are being used to quantify the water exchange fluxes that occur between the surface water and the porewater of sediments that become exposed at low water levels. The microtopography measurements are also being used to identify critical surface-water levels below which the microtopography becomes a dominant factor in flow resistance.

Horizontal Scale of Measurement	**2 Standard Deviations of the Peat Surface Elevation**	
	F1	*U3*
1-meter	0.20 ft	0.14 ft
100-meter	0.76 ft	0.48 ft

TABLE 1: Microtopographic variability of peat surface elevation (type II tool).

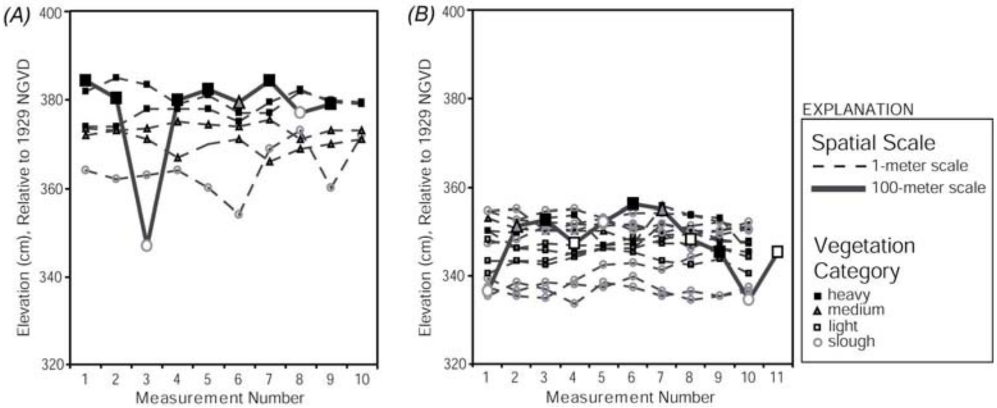

FIGURE 4: Variability of peat surface elevation (type II tool) at 1-meter and 100-meter measurement scale. Site F1 *(A)* and site U3 *(B)*, WCA-2A, central Everglades, south Florida.

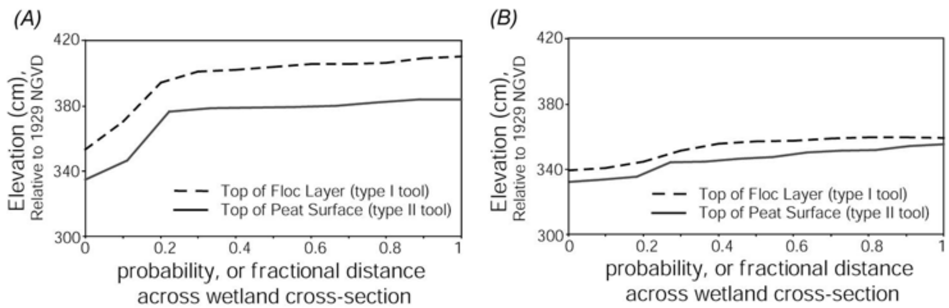

FIGURE 5: Inverse cumulative distribution function of elevation measurements at site F1 *(A)* and site U3 *(B)*, WCA-2A, central Everglades, south Florida.

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Large Scale Treatment Wetlands for Everglades Restoration: Baseline Comparisons and First Year of Operation of STAs 5 and 6

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There has been a tremendous increase in agricultural and urban development in South Florida following congressional approval of the Central and South Florida (C&SF) Flood Control project in 1949. The C&SF project created a system of canals and levees, designed to drain the landscape and prevent future flooding in an effort to promote agricultural and urban growth in south Florida, but has also resulted in the loss of more than half of the original 1.17 million ha that comprised the oligotrophic Everglades ecosystem. The remaining Everglades ecosystem is being negatively impacted by hydrologic changes and nutrient-rich runoff generated from increasing urban and agricultural sources (Light & Dineen, 1997). It has been determined through extensive research that the primary nutrient of concern for the Everglades is phosphorus (McCormick et al., 2002).

In response to the concern over the integrity of the remaining Everglades due to changes in both hydropattern and nutrient concentrations, the Florida Legislature enacted the Everglades Forever Act (EFA) (Section 373.4592, Florida Statues. The EFA mandated the construction of a series of large treatment wetlands, referred to as Stormwater Treatment (STAs), to reduce the phosphorus loading in stormwater being discharged into the remaining Everglades system to an interim target of 50 ug-P/L.

The overall performance of a treatment wetland depends on a number of features, such as size, seasonal effects, soil characteristics, predominant vegetation type, previous land use, and nutrient loading. Therefore, some treatment wetlands function efficiently as nutrient sinks, while others may become a source or less effective sinks. STAs 5 and 6 are both located in Hendry County, Florida but have different soils, nutrient loads, prior land use and operational regimes.

STA-5 encompasses an area of 1,975 ha, with an effective treatment area of 1,663 ha, and is divided into parallel north and south flow-ways, with the front 156 ha of each flow-way of higher elevation and not routinely flooded. Construction of STA-5 was completed in December 1998, and routine flow-through operation of the southern flow-way commenced on June 2000 and in August 2000 at the north site.

STA-6 is located due south of STA-5 in the southwestern corner of the Everglades Agricultural Area (EAA), is divided into two parallel treatment cells with a total effective treatment area of 352 ha. Inflow into STA-6 is via a pump station (G-600) that is owned by U.S. Sugar Corporation (USSC), and is operated based on the irrigation needs of the upstream basin (4,209-ha; USSC owned and operated). STA-6 began flow-through operations in 1998.

Dominant soil types were determined using the 1990 soil survey of Hendry County Florida. Due to the complex mosaic of soil types in STA-5 and STA-6, soils were divided into three categories (muck soils, sandy soils, and intermediate soils) based on the presence or absence of organics and analyzed for percent cover using ArcView 32a. Both STA-5 and STA-6 contained about 55% of the intermediate soil type, indicating a muck surface layer with a sandy layer abutting the shellrock. However, STA-6 historically had more area composed of all sand (29%) than STA-5 (8%).

Additionally, the District obtained ten (10) soil cores from STAs 5 and 6 – Cell 5 each. Soil cores were taken using an aluminum-coring device with a 10-cm internal diameter, 40 cm long and divided into two sections: 0-10 cm and 10-30 cm below the surface, and were analyzed for total carbon (TC), total phosphorus (TP), total nitrogen (TN), and bulk density. Soil nutrient concentrations were similar for both the 0-10 cm and 10-30 cm intervals among all cores. When soil concentrations were corrected for bulk density, which was higher in STA-6 due to the greater percentage of sandy soils, the nutrient concentrations for STA-5 were consistently higher than those calculated for STA-6. However, mean concentration values in upper sediment layer (0-10 cm) of STAs 5 and 6 were closer in value, while values in the deeper sediment layer (10-30 cm) were more disparate, with STA-5 TP, TC, and TN nutrient concentrations 34%, 99%, and 99% greater, respectively, than in STA-6.

During the first District Water Year of operation (30 April 1998 to 1 May 1999 for STA-6 and 30 April 2001 to 1 May 2002 for STA-5) STA-5 mean TP inflow concentrations were double that of STA-6, with concentrations of 0.105 mg/L and 0.052 mg/L, respectively (Table 1). However, mean TP areal mass loading rates during this time were about the same, with rates of 1.103 $g/m^2/yr$ and 1.129 $g/m^2/yr$ for STA-5 and STA-6, respectively. While mean outflow TP concentrations from STA-5 were 0.128 mg/L, which exceeded inflow concentrations, the system removed 62.6% percent of the phosphorus mass entering the system. However, this was less than the 76.8% phosphorus mass removed by STA-6 during the first operational year.

Despite the geographic proximity of both STAs, the prior land use, nutrient inflow concentrations, dominant vegetation type, and antecedent soil nutrient concentrations all differ between STAs 5 and 6 and may be contributing factors to the different phosphorus removal performance exhibited by the two systems. STA-5 antecedent soil was primarily high nutrient concentration organic material that was uniform throughout the entire 0-30 cm soil section, while STA-6 exhibited a clear stratification of nutrients between the upper and lower soil sections and had a high mineral content throughout. Additionally, cattail is the predominant vegetation in STA-5, whereas a dense community of mixed grasses and sawgrass dominates STA-6, which could be the result of low antecedent nutrient concentrations and low mean TP inflow concentrations.

Table 1. Geometric mean and mean area mass inflow and outflow TP values for STAs 5 and 6 for the first year operation of each STA. The operational period for extends from 30 April 1998 to 1 May 1999 for STA-6 and 30 April 2001 to 1 May 2002 for STA-5.

Geometric Means TP (mg/L)				**TP Mass (g/m^2/ year)**			
STA-5		**STA-6**		**STA-5**		**STA-6**	
Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
0.105	0.128	0.052	0.021	1.103	0.412	1.129	0.262

References:

Light, S.S. & Dineen, J.W. (1997). Water Control in the Everglades: a historical perspective. *In* Everglades. The ecosystem and its restoration (eds. S.M. Davis & J.C. Ogden), pp. 826. St. Lucie Press, Boca Raton, FL.

McCormick, P.V., Newman, S., Miao, S., Gawlick, D.E., Marley, D., Reddy, K.R., & Fontaine, T.D. (2002). Chapter 3. Effects of anthropogenic phosphorus inputs on the Everglades. *In* The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. An Ecosystem Source Book (eds. J.W. Porter & K.G. Porter), pp. 83-142. CRC Press, Boca Raton, FL.

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Stormwater Treatment Area Optimization Research: The Result of Pulsed Loading and Depth Changes on Half-acre Research Treatment Wetlands in South Florida

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The Everglades ecosystem is known to be extremely sensitive to phosphorus (P) loading, and excess P has had negative impacts on Everglades flora and fauna. The Everglades Forever Act (EFA) requires the South Florida Water Management District (District) to construct a series of large treatment wetlands (ca. 17,000 ha) called Stormwater Treatment Areas (STAs) to reduce nutrients in runoff to levels that will have no negative impact on the Everglades. The STA Optimization research and monitoring program is mandated by the EFA to assist the District in developing an operational strategy that maximizes performance of the STAs. One part of this program involves conducting hydrologic research in the STA-1W test cells that are located at the inflow and outflow regions of the treatment wetland. This research examined how hydrologic conditions would influence STA performance; i.e., what water management scenarios would promote maximum TP removal efficiency in these systems and conversely, under what hydrologic conditions would TP removal efficiency fail to meet mandated requirements.

The test cells are shallow, fully lined wetlands, about 0.2 ha in size, located within the boundaries of the ENRP, a prototype STA built and operated by the District. Six test cells located at the northern end of STA-1W are dedicated to STA Optimization experiments. Two test cells are being used as controls and operated at a mean hydraulic loading rate (HLR) of 2.65-cm/d and nominal depth of 0.6 m, which approximates the average design conditions for the STAs. Two of the remaining four test cells (NTC-7 and NTC-8) were used to document the effect that depth has on nutrient removal, while two test cells were operated at a constant depth (NTC-6 and NTC-9) but with widely varied inflow volumes (pulsed).

During the depth experiments, the HLR was held constant while the depth was reduced from 0.6 m to 0.15 m for 180 days, and then increased to 1.2 m for the following 180 days. This effectively decreased the nominal hydraulic residence time (HRT) in these systems from about 20 days to 5.5 days during the low-depth experiments, while the HRT increased to 45.7 days during the high-depth study. The pulsing scheme consisted of changing the HLR biweekly, ranging between 0.05 to 15.27 cm/d, while the depth was held at 0.6 m. Holding the depth constant while pulsing the HLR results in varied HRTs, which, in part, simulated operation of an STA. The pulsed inflow pattern developed for this experiment was based on a 10-year period of record (1978 to 1988) for the STA-2 basin. The pulsing experiments were conducted for one calendar year that extended from October 2000 through September 2001 to include both wet and dry seasons.

Lowering water depth to a nominal 0.15 m resulted in a slight improvement in TP removal at the north site, but resulted in markedly poorer TP removal performance in the south site compared to the respective controls. The median outflow TP concentrations at the north control and low-depth test cells (20 versus 15 µg/L, respectively) were significantly different (Fig. 1). In the south, median outflow TP concentration for the low-depth cell (32 µg/L) was significantly greater than for the control cells (18 µg/L).

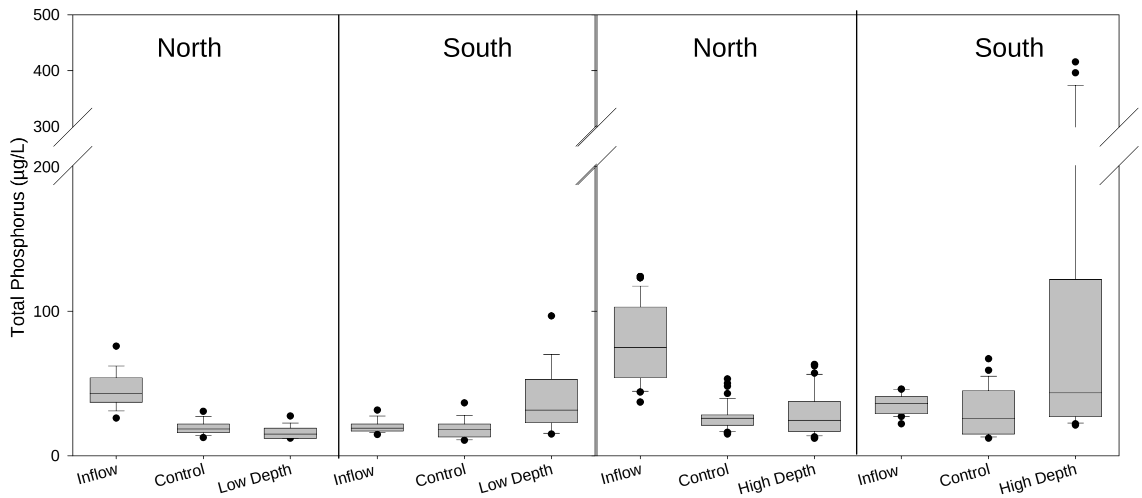

Fig. 1 Total Phosphorus Outflow Concentrations during low and high depth studies for North and South Sites

Increasing water depth in the north site had no significant effect on TP reduction; median outflow TP concentrations were 26 and 25 µg/L for the control and high-depth test cells, respectively. At the south site, the median outflow TP concentration from the control test cells (31 µg/L) was significantly less than outflow from the high-depth test cells (49 µg/L). Outflow TP concentrations from the controls and high depth cells often exceeded inflow concentrations during this experiment.

During the pulsed experiment, differences between median outflow TP concentrations for the control and pulsed-HLR cells were significant for both the dry season (20 vs. 29 µg/L, respectively) and the wet season (32 vs. 39 µg/L, respectively) in the north. At the south site, mean outflow TP concentration from the pulsed cell was 20 µg/L; slightly lower than the control cell mean (26 µg/L). As at the north site, the mean outflow TP concentration was higher during the wet season than the dry season although the percent reduction increased due to increased inflow TP concentrations.

Decreasing the depth of the system, while maintaining the HLR had a slight positive effect on the TP removal performance in the wetlands at the north site, while increasing the depth had no significant effect. Additionally, at the south site, both alterations in depth had negative effects, with increased depths having the greater effect. However, even at the constant depth the emergent systems showed little or no TP removal capabilities, probably due to extremely low inflow TP concentrations at the south site.
While pulsing in both the north and south site wetland systems during the dry season resulted in slightly higher degradation of TP removal compared to controls during the wet season, overall pulsing did not have a significant negative effect on TP removal performance from these wetland systems.

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Litter Quality Versus Environmental Conditions: What Regulates Decomposition?

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Over the last six years, surface water sampling along transects within 4 km of the A.R.M Loxahatchee National Wildlife Refuge (Refuge) perimeter have shown extensive pulses in alkalinity and conductivity, likely due to increased penetration of canal water into the marsh interior. Changes in water chemistry have resulted in significant changes in the microbial community, which in turn may influence wetland function. We hypothesized that decomposition rates in the Refuge would increase with increased conductivity due to increased productivity of the microbial community and improved substrate quality.

We conducted a reciprocal transplant experiment between interior sites in the Refuge (X4) and WCA-2A (U3) to assess whether litter decomposition was greater under softwater versus hardwater conditions and which factors dominated, environmental conditions or litter quality. Decomposition rates, assessed as loss of dry matter, were determined using litterbags and leaf packs of sawgrass and cattail. We examined mechanisms controlling decomposition by measuring the activity of enzymes responsible for C, N and P acquisition (β-glucosidase, leucine aminopeptidase and phosphatase), and lignin breakdown (phenol oxidase and peroxidase) of the litter material. Litterbags and leaf packs were deployed Sept 2002 and retrieved after 1, 3 and 6 months. Preliminary analysis of the first three months data indicates significant differences in enzyme rates. In general, phosphatase activity of the leaf litter increased by > 150% from the first to the third month of deployment, while the activity of other enzymes decreased. After one month, phosphatase activity was 44-81 % higher in litterbags deployed in the Refuge compared to WCA-2A, however this difference was lost during the second sampling event. These data, along with data obtained from the 6-month retrieval in March 2003, will be used to highlight the use of extracellular enzyme assays as a measure of decomposition responses in the Everglades.

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Changes in the Fish Fauna of the Kissimmee River Basin, Peninsular Florida: Non-Native Additions

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Recent decades have seen substantial changes in fish communities in rivers of peninsular Florida. The most striking change has involved the addition of non-native fishes, including taxa from Asia, Africa, and Central and South America. I review recent and historical records of fishes occurring in the Kissimmee River Basin (7,800 km^2), a low-gradient drainage with 47 extant native fishes (one possibly the result of an early transplant), at least 7 foreign fishes (most of which are widely established), and a stocked hybrid. Kissimmee assemblages include fewer marine fishes than the nearby Peace and Caloosahatchee rivers, and fewer introduced foreign fishes than south Florida canals. Fish communities of the Kissimmee and other subtropical Florida rivers are dynamic, due to new introductions, range expansions of non-native fishes already present, and periodic declines in non-native fish populations during occasional harsh winters. The addition, dispersal, and abundance of non-native fishes in the basin is linked to many factors, including habitat disturbance, a subtropical climate, and the fact that the basin is centrally located in a region where drainage boundaries are blurred and introductions of foreign fishes commonplace.

The first appearance of foreign fishes in the basin coincided with the complete channelization of the Kissimmee River in the 1970s. Although not a causal factor, artificial waterways connecting the upper lakes and channelization of the Kissimmee River have facilitated dispersal. With one possible exception, there have been no basin-wide losses of native fishes. When assessing change in peninsular Florida waters, extinction or extirpation of fishes appears to be a poor measure of impact. No endemic species are known from peninsular Florida (although some endemic subspecies have been noted). Most native freshwater fishes are themselves descended from recent invaders that reached the peninsula from the main continent. These invasions likely were associated with major fluctuations in sea level since the original mid-Oligocene emergence of the Florida Platform. As opportunistic invaders, most native freshwater fishes in peninsular Florida are resilient, widespread, and common.

Foreign non-native fishes first appeared in the Kissimmee in the 1970s; most are much more recent. At this early stage, it is not possible to predict the long-term consequences caused by these introductions. We know a few details about the unusual trophic roles and other aspects of the life histories of certain non-natives. Still, the ecological outcome may take decades to unfold, shaped by a complex interplay between established foreign fishes and their new environment.

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Whole-Ecosystem Phosphorus Budgets for Freshwater Everglades Wetlands

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We are currently developing synthetic, whole-ecosystem phosphorus (P) budgets for freshwater Everglades wetlands. The development of P budgets will aid attempts to understand the impact of P enrichment on oligotrophic Everglades wetland ecosystems and prioritize future research by identifying knowledge gaps. Preliminary P budgets were developed for oligotrophic wet prairie (slough; Figure 1), oligotrophic *Cladium*, mixed *Cladium*/*Typha*, and *Typha* marsh ecosystem types. Mean P standing stocks (g P m^{-2}) for each component were quantified by reviewing published and unpublished literature on biomass and P concentrations in the Everglades. Fluxes (g P m^{-2} yr^{-1}) were determined by a variety of methods, including estimates of C turnover (assuming fixed C: P), water velocity, ^{32}P cycling, and long-term soil accretion rates. No reasonable estimate could be independently derived for many flux rates, in which case flux was determined by mass balance. As a first approximation, the P budgets assume steady-state conditions, 12-month hydroperiod, no mega-consumers, and no consumption of macrophyte detritus by consumers. In addition, nutrient turnover rates of periphyton, floc, and consumers in *Cladium* marsh were assumed to be equivalent to wet prairie marsh.

Mean total ecosystem P standing stocks ranged from 3.46 in wet prairie, 3.65 in *Cladium*, 7.29 in *Cladium*/*Typha*, to 10.44 g P m^{-2} in *Typha* marsh. In wet prairie, soils (0-10 cm) held the most P in the ecosystem (72%), followed by floc (22%), live macrophyte rhizomes and roots (2.3%), aquatic consumers (1.5%), periphyton (1.2%), live aboveground macrophytes (1.1%), dead aboveground macrophytes (0.4%), and the water column (0.2%). Phosphorus partitioning, the percentage of total ecosystem standing stock, differed in oligotrophic *Cladium* and P-enriched *Cladium*/*Typha* and *Typha* marshes. In *Cladium* marsh, P partitioning is 4x and 6x greater in live and dead aboveground macrophytes, respectively, and 5x less in periphyton compared to the same components in wet prairie. As Everglades wetlands receive additional P loading and shifts in macrophyte species occur, live and dead aboveground macrophytes store increasingly larger proportions of whole-ecosystem P standing stock. Live aboveground macrophyte tissues store 3x and 9x larger proportions of ecosystem P in *Cladium*/*Typha* and *Typha* marsh, respectively, than in oligotrophic wet prairie. Similarly, dead aboveground macrophyte tissues increase P partitioning 11x in *Cladium*/*Typha* and 7x in *Typha* marsh. Periphyton partitioning increases slightly in the P-enriched ecosystems. Finally, floc stores 2x smaller proportions of P in the ecosystem as it enriches with P.

Long-term, steady state P dynamics in oligotrophic Everglades marshes are limited by average inputs (atmospheric deposition, 0.03 g P m^{-2} yr^{-1}) and outputs (soil burial, 0.09 g P m^{-2} yr^{-1}). Very large quantities of P flow in and out of a given area of oligotrophic marsh (~ 800 g P m^{-2} yr^{-1}), but net ecosystem uptake from the water column (0.06 g P m^{-2} yr^{-1}) is constrained by atmospheric input and soil burial. In wet prairie marsh, slow turnover of macrophyte stems and low P standing stocks result in relatively low net annual P flux from macrophytes compared to periphyton, floc, and consumers. For example, periphyton net annual through-flux is estimated to be 1.33 g P m^{-2} yr^{-1}, while live aboveground macrophyte tissues cycle 0.04 g P m^{-2} yr^{-1}. The smaller periphyton and greater macrophyte biomass in *Cladium* marsh relative to wet prairie are paralleled in less periphyton (0.27 g P m^{-2} yr^{-1}) and more macrophyte (0.23 g P m^{-2} yr^{-1}) throughput. Phosphorus enrichment, and the invasion of *Typha*, greatly increases the importance of macrophytes (both P standing stocks and throughput) to the ecosystem P budget. Macrophyte senescence results in the annual net movement of 1.59 g P m^{-2} yr^{-1} in *Typha* marsh.

Although data on biomass and P concentrations, and hence P standing stocks, are plentiful, few measurements of P fluxes exist. Relative to fluxes involving soils and macrophytes, fluxes between the water column, floc, periphyton, and consumers are less well quantified. In addition, most P flux rates have been measured in wet prairie and few rate measurements exist for *Cladium* or *Typha* marsh. Furthermore, most P cycling occurs in the water column between water, periphyton, floc, and consumers, while soil stores the largest amount of P in the ecosystem. Finally, P enrichment in the Everglades results in an increased importance of macrophytes to P cycling.

As part of the Florida Coastal Everglades LTER, these nutrient budgets will be expanded in the future to include site-specific data and nitrogen and carbon dynamics. In addition, nutrient budgets can serve as an integrative and synthetic tool for comparing freshwater marsh, mangrove, and seagrass ecosystems, and the impacts of nutrient enrichment on ecosystems.

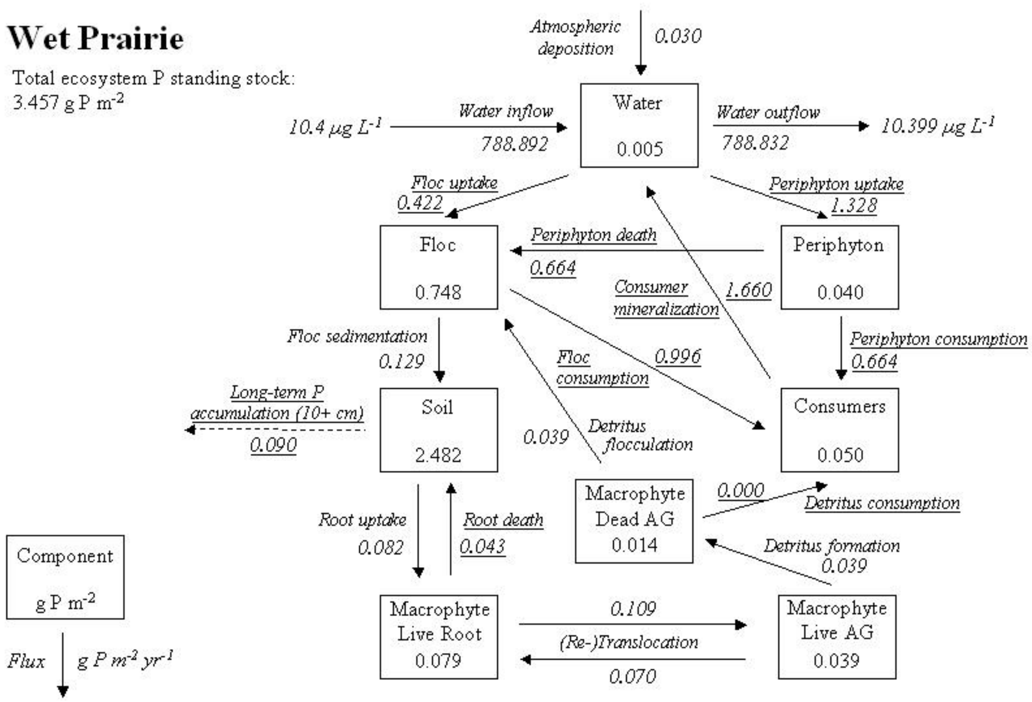

Figure 1. The P budget for oligotrophic wet-prairie marsh. Boxes represent the P standing stock (both organic and inorganic) of the different ecosystem components (g P m^{-2}) and arrows indicate net annual P fluxes between components (g P m^{-2} yr^{-1}). Underlined fluxes have high uncertainty.

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Can Stormwater Treatment Areas be Managed to Optimize Total Phosphorus Concentration Reductions for Everglades Restoration?

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For the last eight years, the South Florida Water Management District has been required to meet a 12-month rolling average total phosphorus (TP) outflow concentration of 50 ppb from the Stormwater Treatment Areas (STAs). The prototype STA, originally called the Everglades Nutrient Removal Project (ENRP), has succeeded in meeting this standard throughout its period of record (1994 through 2002). A stricter TP outflow concentration, expected to be 10 ppb, requires determination of whether and how these wetlands can be managed to further reduce TP concentrations to this new standard.

The ENRP consists of four treatment wetlands. Cells 1 and 3 form one flow path, and cells 2 and 4 form the second. Inflow, outflow, and internal hydrologic and water quality parameters have been collected for the ENRP and for the internal cells for eight years, allowing performance tracking for TP reduction. After operating as the ENRP for four years, an additional large treatment cell was added in 1999, but monitoring continued largely uninterrupted. These data provide a unique opportunity to analyze the performance of an STA under two management regimes, one as a prototype experimental wetland and the other as a fully operational stormwater treatment area. Inflow and outflow concentrations of TP have varied over time, as have various biotic and abiotic factors. Reducing outflow TP concentrations is a major objective of the STAs, and identifying management options to minimize TP concentrations is a significant goal.

During the 4-year period the STA was operated as the ENRP, the project reduced flow-weighted TP inflow concentrations from a mean of 89 ppb to 25 ppb at the outflow. For the four-year period during and following construction of the STA, mean inflow flow-weighted concentrations of 125 ppb were reduced to a mean outflow of 40 ppb.

To identify factors that can be manipulated to produce lower outflow concentrations of total phosphorus, monthly flow-weighted concentrations were calculated using measured TP concentrations and flows. Monthly means or sums of water and total phosphorus concentrations, hydraulic retention time, water depth, vegetation types and cover, wind, net radiation, air temperature, and other biotic and abiotic variables were analyzed. The entire ENRP and each internal treatment cell (1 through 4) were analyzed separately. Correlations between outflow TP flow-weighted concentrations and inflow TP flow-weighted concentrations, flow rates, depths, residence time, vegetation type and extent, and climatic variables identified possible linear relationships between each of these variables and outflow concentrations. Stepwise multiple regressions were used to identify combinations of variables that could lead to operational strategies that would consistently reduce outflow TP concentrations.

No statistically significant relationships were identified between operational variables and outflow flow-weighted TP concentrations for either the ENRP and STA periods, nor for treatment cells 1, 2, or 4. Only treatment cell 3, a mixed emergent marsh, showed a significant positive relationship between inflow and outflow TP concentrations. Treatment cell 4, managed for submerged aquatic vegetation, achieved very low outflow concentrations for a two-year period in the late 1990's. While no significant relationships have been discerned between cell 4 operational parameters and outflow TP concentrations for this period, relationships to vegetation and seasonality were noted.

Except for cell 3, there were no clear relationships between operational factors and outflow TP flow-weighted concentrations for these treatment wetlands. These results suggest that managing operational variables alone may not achieve flow-weighted TP concentrations of 10 ppb. Possible explanations include 1) that relevant processes involve feedbacks or processes that do not show up in linear representations; 2) that the responsible processes reside in vegetation and sediments and cannot be readily measured or controlled operationally; or 3) that the system is working optimally and has not been pushed hard enough to reveal controlling factors.

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Quantifying the Current Landscape Patterns of the Everglades Ridge and Slough

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Everglades restoration is partly intended to restore wetlands to their original, pre-drainage condition. Much of the original Everglades system was a landscape dominated by ridges, wooded islands, and open sloughs arranged in a linear pattern oriented parallel to the pre-drainage flow direction. The ridges were elevated bands of peat supporting a predominantly sawgrass (*Cladium jamaicense*) community. The sloughs were open water expanses with vegetative cover usually consisting of floating and sparse emergent vegetation. Tree islands provide a notable raised feature of the Everglades elevated above the ridges and dominated by woody vegetation.

A substantial portion of the originally patterned Everglades has changed as a result of drainage and water management. With efforts to restore the ecosystem to a more natural condition, baseline information characterizing existing landscape patterns, both degraded and better preserved, is needed. While the differences are apparent visually, a quantitative approach facilitates discussion of existing conditions and restoration goals for the ridge and slough landscape.

To achieve this comparison, eighteen quadrants 4 km by 6 km in size were selected to represent the range of patterning seen from above in the remnant Everglades landscapes. Using a Thematic Mapper satellite image, all polygons in these quadrants representing ridges, strand and other tree island types were digitized, totaling nearly 1900 polygons. The quadrants contained from 28 to 240 polygons, averaging 105.

Within the quadrants, orientations of most polygons were highly non-random and parallel to the likely pre-drainage flow directions. Parallel directionality of the larger structures within a quadrant was expressed even in quadrants having lost much of their original ridge and slough microtopography. Polygon lengths ranged from 55 to 4300 m, with the majority under 400 m. Even the smaller polygons (under 200 m long) averaged three times longer than their widths. Length-width ratios, a measure of linearity, varied from 1.6 to 35, revealing that all detectable features expressed linearity throughout the quadrants.

In the four quadrants expressing patterns thought to most closely resemble pre-drainage patterning, ridge and tree island polygons together occupied roughly 30% to 40% of the quadrants, leaving 60% to 70% as open water sloughs. In these same quadrants, the longest polygons averaged 12 to 16 for length-width ratios and included those with the highest length-width ratios (15 to 35). In contrast, the quadrant with the least patterning (11% polygons) contained shapes of remnant tree islands but was dominated by sawgrass. In this quadrant, the historic ridge and slough patterning has largely disappeared, resulting in few polygons distinct from the sawgrass cover.

We found that a combination of metrics (number, cover, length-width ratio, and directionality) was needed to differentiate the better preserved from the highly degraded quadrants. These quantitative measures facilitate discussion of the characteristics of patterning in the ridge and slough landscape of the Everglades.

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Picturing Pre-Drainage Everglades Hydrology: How Fuzzy Is It?

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Previous research efforts have amassed an extensive collection of historical information regarding pre- and early post-drainage conditions in the Everglades. Synthesis of this information has yielded maps of pre-drainage landscape extents and semi-quantitative descriptions of soils, vegetation and hydrology. While the collections of specific pre-drainage observations such as water depths or flow directions are helpful, perhaps even more important is the overall "picture" or conceptual model that emerges from synthesis of the full body of information. This picture provides a sense of the pre-drainage hydrology of the Everglades in its entirety, including inflows and outflows across borders. Some aspects of this picture which can help guide more quantitative modeling of pre-drainage hydrology include uniformity/nonuniformity of the landscape, seasonality of outflows, location of outflows, and seasonality of inflows.

The research presented here used this previous historical work to guide sensitivity analyses of the Natural System Model. These analyses focussed on pre-drainage topography and conveyance capacities of the cuts through the coastal ridge. It is well known that the topography of the Everglades has a major influence on the hydropatterns of the natural system. All available information was used to derive plausible estimates of pre-drainage topography. Similarly, a range of plausible estimates of eastern outflow capacity were considered. Sensitivity analyses were conducted using a combination of these different estimates of model inputs.

As a complement to the sensitivity analyses, a water budget approach was taken to improve understanding of pre-drainage hydrology. In the 1940s, Parker *et a.l* (1955) conducted comprehensive hydrologic and environmental studies of the Everglades region. This data, although they characterize a drained system, has been used to compute water budgets, rainfall-runoff relationships, and inflows and outflows in subregions of the Everglades. The purpose of this effort was to determine if inferences regarding the predrainage system can be made from the data collected in the 1940s.

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Gladesmen Cultural Landscapes and Community Engagement: A Case Study

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In this paper, I introduce the idea of "cultural landscapes" as a conceptual tool for facilitating constructive dialogue between resource managers and local communities. In particular, I present a case study detailing the process by which one local community, South Florida gladesmen, constructs the Everglades of southern Florida into a cultural landscape. The focus of my research has been to determine how gladesmen invest the Everglades landscape with historic, economic, and community values. In other words, I am interested in finding out what the Everglades actually "means" to this local community. In this paper, I specifically discuss the relationship of gladesmen cultural landscapes to contemporary ecological models of the Everglades. Research for this paper stems from ethnographic interviews I conducted with gladesmen in several locations throughout the southern Everglades, from 1998 to 2001, and was supported, in part, by the U.S. EPA's STAR Environmental Fellowship.

This research builds upon the emerging "landscape approach" within anthropology, a theoretical orientation that treats geophysical environments as culturally significant topographies. Feld and Basso (1996) suggest that variables which inform the cultural significance of landscapes include: economic value (subsistence and exchange values), historic use, stories associated with the landscape, cosmology, as well as contestations of struggle (over fishing rights for example). Furthermore, anthropologists have demonstrated in a variety of cross-cultural case studies (Aboriginal "dreaming" being the most recognized example) that local people tend to experience landscapes as locations which evoke narratives of community identity (Selwyn 1995, Myers 1986, Fairhead and Leach 1996).

Gladesmen, white settlers who first moved into the region in the mid-1800s, supported themselves through commercial and subsistence hunting and fishing, particularly the alligator hide trade. Not surprisingly, their understandings of the Everglades are shaped by their experiences in the backcountry while hunting. For instance, gladesmen understand the Everglades as a landscape charged with use and exchange values, and as topography whose geophysical features and place names evoke shared community history. These features of the gladesmen's cultural landscape are certainly unique to their historic tradition and practices.

At the same time, gladesmen cultural landscapes exhibit several points of intersection with contemporary ecological representations of the Everglades. Here I will outline two of these commonalities. In the most obvious sense, gladesmen "ecological thinking" compares with contemporary ecosystem approaches. Both emphasize, at the macro level, the ecological distinctions of and relationships between landscape components. Gladesmen narratives also reveal keen appreciation of ecological complexity at smaller scales—with gladesmen attributing ecological purpose to "habitats" such as alligator holes or tree islands. Second, gladesmen "maps" of the landscape correspond with contemporary ecological models of ecosystem process. For instance, gladesmen skiff routes follow hydrologic courses (sloughs, etc.); camp locations punctuate the landscape on the very tree hammocks and higher topographic ridges that are considered "characteristic" of the greater Everglades ecosystem.

Part of the challenge managers face involves integrating social, cultural, and economic concerns into the ecosystem model. While the ecosystem model offers a comprehensive, holistic approach for conceptualizing the inter-relationships of different ecological systems, variables that are difficult to systemize (such as cultural values, environmental justice issues, etc.) are often left out of the planning process. Instead, human systems often are characterized as static or solely in terms of their "impacts" on natural systems (Moran 1990). For anthropologists, "culture" is understood to include not only human behavior (such as "impacts"), but also the way people make sense of the world (their knowledge, beliefs, taxonomies, etc.). Though culture may be a difficult category to include within the ecosystem framework, culture decidedly plays a role in the decisions make about their local environments and their support for environmental protection (or lack of support).

The literature on community engagement suggests that an active acknowledgement and utilization of local knowledge can build the necessary self-confidence of local people to participate in social action (White 1999, McCall 1987). In this paper, I argue that cultural landscape research can be used to shape public engagement strategies. Recognizing the commonalities between ecological and local landscape discourses represents a potential catalyst for creating dialogue between natural resource managers and locals. Emphasizing the importance of local environmental knowledge shifts the dynamic away from a top-down approach to decision-making, a power dynamic particularly unsuccessful in communities traditionally marginalized by past land management decisions.

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Microbial Trophic Levels within the Carbon Cycle in Oligotrophic and Nutrient Impacted Regions of Water Conservation Area 2-A

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We are interested in the impact of nutrient enrichments on the pathways by which carbon is mineralized, and linkages between microbial species and carbon mineralization in Water Conservation Area 2-A (WCA-2A) of the northern Everglades. Information on the specific pathways followed by the carbon cycle will provide important insight into the impacts of nutrient enrichment on biogeochemical cycling and may be used in development of sensitive indicators of nutrient impact and ecosystem restoration.

Carbon is transferred through a series of trophic levels composed of different species of microorganisms in anaerobic systems, such as those found in wetlands soils. Cellulolytic microorganisms initially attack plant material, and primary fermentative organisms metabolize smaller molecules. A variety of fermentation products, potentially including propionate, butyrate, H_2, CO_2, acetate, and lactate, are subsequently used by a lower trophic groups, including methanogens, homoacetogens, and sulfate reducing bacteria. The specific pathway followed and the species composition of individual trophic levels depends to a large extent on a variety of environmental factors, including the nutrient status of the environment.

We have been studying relationships between lower trophic groups and position along phosphate gradients in WCA-2A, and similar studies on cellulolytic and fermentative bacteria were recently initiated. Included in the lower trophic groups we are currently investigating are syntrophic fatty acid oxidizing bacteria ("syntrophs"), methanogens, and sulfate reducing bacteria (SRB). The compositions of lower trophic levels are less likely to be significantly impacted by daily fluctuations in environmental conditions than are higher trophic groups because they are generally deeper in soil profiles and have very narrow substrate utilization ranges. In addition, lower trophic groups will likely provide indicators of structures and compositions of higher trophic groups because the quality and quantity of carbon and electron donors produced by fermentors will control the composition and structures of the lower groups.

SRB have largely been ignored in the Everglades and other fresh water systems, but are sensitive to eutrophication due to increased concentrations of sulfate (their preferred terminal electron acceptor) and potential changes in electron donors resulting from changes in fermentation patterns. SRB can be divided into two broad subdivisions that belie physiological and ecological roles of the two groups: complete and incomplete oxidizers. Complete oxidizers typically utilize a broader range of substrates than do incomplete oxidizers, and may be considered as generalists compared with the more specialist incomplete oxidizers. A dominance of complete oxidizers may suggest the availability of a broader range of substrates compared with those environments where incomplete oxidizers dominate. We have found that, for at least one genus of SRB (*Desulfotomaculum*), complete oxidizers dominate incomplete oxidizers in eutrophic regions of WCA-2A, and that incomplete oxidizers dominate in oligotrophic regions of the marsh.

We have studied the distribution of *Desulfotomaculum* species associated with complete and incomplete oxidization at two sampling times (Spring and Summer, 2001) in oligotrophic (U3) and eutrophic (F1) regions of WCA-2A. A clear relationship was observed between the distribution of complete and incomplete oxidizers and the region of the marsh. Complete oxidizers are almost exclusively found in U3, whereas incomplete oxidizers clearly dominate F1. Laboratory enrichments on various substrates support the observation that SRB in F1 utilize a greater diversity of fermentation products than do those in U3.

Studies on methanogens and syntrophs reflect a similar dependence of composition and physiological group on nutrient status, although somewhat less clear cut than for SRB. Like SRB, methanogens may be divided into two functional groups that represent different physiologies, and hence, different ecologies: the acetotrophs and the hydrogenotrophs. Most acetotrophs are limited to use of acetate for electrons and carbon, whereas the hydrogenotrophs exhibit a broader carbon substrate range, and can use H_2 as an electron donor. Hydrogenotrophic methanogens are the most numerous methanogens in F1, F4 (an area of transition between the eutrophic F1 and oligotrophic U3), and U3. Significantly, most probable numbers of hydrogenotrophs in F1 outnumber acetotrophs by a factor of 100,000, but only by a factor of 100 in F4 and U3. This may be due to higher concentrations of H_2 in F1 resulting from greater activities of fermentative bacteria. In addition, most probable numbers of syntrophic bacteria capable of oxidizing propionate and butyrate are ten to one hundred times higher in F1 than U3, respectively. Syntrophs work together with hydrogenotrophic methanogens to oxidize propionate and butyrate, such that hydrogenotrophic methanogens are required to remove H_2 in order to make the oxidation thermodynamically feasible. The higher numbers of syntrophs in U3 likely led to higher numbers of hydrogenotrophic methanogens. These trends are supported by molecular characterization of DNA from enrichments, and significantly more propionate and butyrate oxidation are observed in microcosms constructed from F1 than either F4 or U3. Finally, acetotrophs are also regarded as specialists, approximately analogous to the SRB complete oxidizers, and hydrogenotrophs are regarded as generalists, like the SRB incomplete oxidizers.

It is likely that the composition of lower trophic levels of prokaryotes and the specific pathways by which carbon is cycled in wetlands is controlled largely by the diversity and quantity of fermentation products, and hence by the activities of primary fermenters in these environments. Our data on SRB, syntrophs, and methanogens suggest that a broader range of fermentation substrates is produced in nutrient impacted areas than in oligotrophic areas of the marsh. A greater diversity of fermentation products may be due to the presence of different species of fermenters in the different regions, or that similar fermenters are present and respond to different environmental conditions that may affect the fermentation pathways of these strains. We are currently investigating the activities of fermentative bacteria in F1, F4 and U3 to answer these questions.

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Sulfur Contamination and Geochemistry of the Everglades

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Sulfur is an important water quality issue in the Everglades because of its role in microbial sulfate reduction and the methylation of mercury. Microbial sulfate reduction produces toxic hydrogen sulfide (H_2S) as an endproduct, and accumulation of H_2S in sediment porewater may change sediment redox chemistry and the ability of aquatic macrophytes and other marsh plants to maintain necessary oxygen levels in root systems. Microbial sulfate reduction also produces methylmercury (MeHg), a neurotoxin that is bioaccumulated. MeHg has been found in high concentrations in freshwater fish from the Everglades, and poses a potential threat to fish-eating wildlife and to human health (especially pregnant women) through fish consumption. Based on USGS results, sulfur appears to play a key role in regulating both the magnitude and distribution of MeHg within the ecosystem.

Freshwater wetlands typically have low sulfur concentrations, but we discovered high concentrations of sulfate sulfur in surface water of the northern Everglades. Independent studies conducted by the U.S. EPA and the South Florida Water Management District have also documented high concentrations of sulfate in large parts of the northern Everglades. Marshes in portions of the Water Conservation Areas (WCA's) have surface water sulfate concentrations that average nearly 60 mg/l, compared to concentrations of ≤1 mg/l in pristine areas of the Everglades. Areas with high surface water sulfate concentrations are concentrated in the northern WCA's, and especially near sites of canal discharge and along canal levees. Even higher concentrations of sulfate (average >70 mg/l and sometimes approaching 200 mg/l) were found in canal water draining from the Everglades Agricultural Area (EAA). This canal water appears to be the major source of excess sulfate entering the Everglades. The high loads of sulfate entering the ecosystem stimulate microbial sulfate reduction, and areas with high concentrations of sulfate in surface water also have very high levels of toxic H_2S in sediment porewaters. Porewater sulfide concentrations range from 5,000 ppb at marsh sites near canal discharge, to <0.05 ppb at pristine sites. Porewater sulfide concentrations were highly correlated with surface water sulfate concentrations.

We used sulfate concentration data and the sulfur ($\delta^{34}S$) and oxygen ($\delta^{18}O$) isotopic composition of sulfate in marsh surface water, canal water, rainwater, and groundwater to trace the source(s) of the excess sulfate entering the Everglades. Although the canals originate in Lake Okeechobee, the lake on average contributes only about 20% of the sulfate observed in the canals. Rainwater has too little sulfate to account for the high sulfate concentrations observed in the canals and in large portions of the Everglades. Groundwater beneath the Everglades has either too low a sulfate concentration or a $\delta^{34}S$ signature that is inconsistent with that of surface water in the Everglades. Both sulfate concentration data and the $\delta^{34}S$ values of sulfate in surface water from the Everglades and canal water confirm that canals in the EAA are the major source of excess sulfate entering the ecosystem. Furthermore, results showed that canal water with the highest sulfate concentrations had $\delta^{34}S$ values of +16 per mil, which is consistent with the $\delta^{34}S$ signature of agricultural sulfur (a soil amendment used in the EAA). Sulfate extracted from the upper 10 cm of soil in a sugarcane field in the EAA also had a $\delta^{34}S$ value of about +16 per mil. These data suggest that agricultural sulfur is the principal source (but not the only source) of excess sulfate entering the canals and Everglades wetlands.

The high levels of sulfate entering the Everglades from canal discharge have had important effects on the ecosystem. The H_2S buildup in sediment porewater at sites in the northern Everglades has significantly lowered redox potentials in the sediments. The lower redox conditions and high levels of H_2S in the sediments may have an impact on vascular plant growth in the Everglades by limiting oxygen penetration to roots. It is noteworthy that cattails have replaced sawgrass as the dominant macrophyte at sites heavily impacted by sulfur, although factors other than sulfur (e.g. eutrophication and high water levels) may also be influencing this change. Similarly, tree islands have disappeared mostly from the northern Everglades, in areas heavily impacted by sulfur.

The effect of excess sulfur load on MeHg production in the Everglades is complex. Sulfur appears to stimulate MeHg production through increased microbial sulfate reduction, but buildup of sulfide in sediment porewater inhibits MeHg production. The balance between these two effects of sulfur influences both the magnitude and location of MeHg production in the Everglades, and produces the interesting effect that the zone of maximum MeHg production occurs in areas with sulfur loads only moderately higher than natural. This MeHg "Goldilocks" zone (where sulfur levels are just right) occurs in the central portion of WCA 3A, at the front end of the northern Everglades sulfur contamination plume. The complex relationship between sulfur geochemistry and MeHg production in the Everglades was first hypothesized from field studies at various sites in the ecosystem. This hypothesis has been further solidified from experimental studies in the Everglades using mesocosms. These mesocosm studies show that increasing sulfate concentrations increases MeHg production up to sulfate concentrations of about 10 mg/l. At sulfate concentrations >10 mg/l buildup of sulfide from microbial sulfate reduction inhibits the methylation of Hg.

The principal sink for sulfur entering the Everglades ecosystem is long-term storage in sediments. Sequestration of sulfur in sediments typically results from microbial reduction of sulfate to sulfide, and subsequent reaction of sulfide with either organic matter, to form organic sulfur compounds, or metals, to form insoluble metal mono- and disulfides. The dominant sulfur species in Everglades sediments is organic sulfur. Sulfur accumulation rates (g m^{-2} day^{-1}) in Everglades sediments ranges from 9.0×10^{-3} to 0.38×10^{-3}, a difference of more than 20 fold. The highest sulfur accumulation rates occur in brackish water mangrove (average of 6.0×10^{-3}), and sulfur-contaminated freshwater marsh areas (average of 4.5×10^{-3}). Sulfur accumulation rates average about 1.6×10^{-3} at pristine sites.

Sulfur in sediments represents a reservoir of reduced sulfur that may be reoxidized and remobilized during drought/fire and subsequent rewetting. Because drought and fire are frequent occurrences in the Everglades ecosystem, the remobilization of sulfur from sediments is an important factor influencing sulfur and mercury geochemistry. Studies of sulfur remobilization were conducted in northern WCA 3A following a burn and subsequent rewetting in that area during 1999. The average sulfate concentration in surface water at 14 sites was 58.6 mg/l immediately after the burn and rewetting of this area, compared to an average sulfate concentration of 5.10 mg/l before and over a year after the burn. The sulfate remobilized after the burn and rewet stimulated sulfate reduction and extreme levels of MeHg production (see abstract by Krabbenhoft et al., this volume). Cores from burned and control (e.g. unburned) sites in northern WCA 3A showed that burned sites had significantly lower total sulfur contents in sediments. A simulated laboratory experiment was conducted in which mini-cores were dried under simulated natural sunlight in controlled laboratory conditions for a specified period of time and then rewetted to further examine the effects of fire/drought on S geochemistry and MeHg production. Results verified the remobilization of sulfate and stimulation of MeHg production following fire/drought events. Ecosystem and water managers must consider the effect of drying and rewetting portions of the Everglades in order to avoid exacerbating the already extensive MeHg problem in the Everglades.

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Spatial and Temporal Patterns of Surface Water Quality on the Big Cypress Seminole Indian Reservation

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The Seminole Tribe of Florida is implementing a designated Critical Project, the Water Conservation Plan (WCP), as part of the Comprehensive Everglades Restoration Plan on the Big Cypress Seminole Indian Reservation. The WCP will deliver water from canals on the northeastern side of the Reservation into a system of impounded wetlands on the northwestern side. A portion of the water released from these impounded wetlands will flow into the relatively intact riparian slough system that occupies the southwestern portion of the Reservation. In conjunction with the WCP, we are conducting a series of studies that will provide baseline information on water quality on the Big Cypress Seminole Indian Reservation.

Like much of southern Florida, high levels of phosphorus greatly impact water quality in surface water and canals traversing the Reservation. Prior to major anthropogenic influences levels are believed to have been in the range of 10-30 ppb total phosphorus, yet today many canals on the Reservation often attain substantially higher levels.

Within the Big Cypress region, measurements of surface water quality have been taken for more than 10 years, but nevertheless there remains a substantial gap in our knowledge with regard to comprehensive water quality studies. As a consequence, the 10 ppb standard for [P] is based largely on water quality studies conducted within the sawgrass marsh Everglades while the forested Big Cypress region of the Greater Everglades ecosystem has been largely ignored.

The objective of our studies has been to examine the spatial and temporal patterns of surface water quality on the Big Cypress Seminole Indian Reservation. As a first step, we conducted time series analyses of an extensive database of biweekly surface water quality sampled at 10 sites across the Reservation. A predictive model of TP concentrations in surface water leaving the Reservation was developed through multiple regression analysis of inflow and outflow TP concentrations. Rainfall patterns were investigated using daily rain data recorded at seven stations located on or near the Reservation within the regional watershed. The relationship between rainfall and surface water parameters was explored by time series and multiple regression analysis using rainfall trend models. These analyses showed that TP concentrations entering the Reservation are significantly higher than at outflow points. TP concentrations are positively correlated with rainfall trend models and correlations are significantly improved when the rainfall time series is lagged by three to four weeks. These findings point to mobilization of phosphorus by rainfall as a primary source of phosphorus in surface water entering the Reservation.

We have also examined surface water quality within an impounded forested wetland receiving high-nutrient point-source input from agricultural effluents. Mean TP levels at interior sites and the outflow site were significantly lower than inflow levels. Comparison of relative changes in total phosphorus and chloride ion concentrations provided evidence that biological or chemical processes were the primary mechanism of phosphorus reduction within the impoundment. In parallel with this high-nutrient point-source study, we studied water quality in a relatively low-nutrient nonpoint-source, the Kissimmee Billie Slough, a semi-pristine forested slough located on the southwestern boundary of the Reservation. Overall nutrient levels were found to be generally low across its entire north-south expanse, with mean total Keldjahl nitrogen (TKN) and total phosphorus (TP) concentrations of 1.027±0.08 mg l^{-1} and 0.024±0.003 mg l^{-1}, respectively. Preliminary results from this study suggest that potassium, rather than phosphorus, may act as the limiting nutrient within this system. Mean K concentrations within the study basin were extremely low, (0.843±0.103 mg l^{-1}), approximately seven times lower than concentrations typically found in other open-water oligotrophic sloughs in the sawgrass marsh Everglades.

We are currently conducting a forest stand-level study within the Kissimmee Billie Slough to determine whether potassium is more limiting to plant growth than phosphorus in this system. Data collected from this study will assist us in determining the fate of surface water nutrients within the Reservation and improving the quality of surface water as it traverses the Reservation and is discharged into the Everglades.

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The Role of Fire in the Restoration of Everglades Wetland Communities

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Hydrological modification and nutrient loading from surface water inputs have led to alterations in the community structure of northern Everglades plant communities, where southern cattail (*Typha domingensis*) has been rapidly expanding into the natural mosaic of slough, sawgrass (*Cladium jamaicense*) marsh and tree island communities. We are investigating if community type and extent of soil nutrient enrichment influence whether fire can be used to control *Typha* expansion. Managed cover burns (surface water is present to prevent root or peat burn) encompassing three plant community types of interest - *Cladium*-dominated and *Cladium*-*Typha* mixed marshes, and *Cephalanthus*-*Salix* shrub communities fringing hardwood tree islands - were conducted by the Florida Fish and Wildlife Conservation Commission from March to October 2002 in Water Conservation Area 3a (WCA3a). The soils of WCA3a are generally considered to have a background soil nutrient status (< 500 mg P/kg dry weight). We established sites in these three community types in both burned and non-burned communities, and sampled for water, soil, and vegetation both before and after fire events. Surface and interstitial water chemistry response was highly variable both temporally and spatially between and within community type. We did observe short-term increases in interstitial phosphorus and both increased and decreased ammonium-nitrogen following burns. Preliminary analysis of vegetation response suggests that fire had mixed success in removing *Typha* from the community structure of mixed-species marshes while maintaining structure in non-*Typha* communities. We will present soil chemistry data to illustrate fire-induced changes in the peat matrix and relate that data to vegetation response.

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Comparison of Benthic Cover Trend Between Satellite and *In Situ* Datasets (1996-2002) for Reef Ecosystems of the Florida Keys National Marine Sanctuary

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The primary operational method to gather percent coral cover for coral reefs is to gather *in situ* data for the specific site. The Florida Marine Research Institute (FMRI), under the Coral Reef Monitoring Project (CRMP), has been gathering such data for 40 sites in the Florida Keys National Marine Sanctuary (FKNMS) since 1996, with the introduction of three more sites in the Dry Tortugas in 1999. This dataset is the largest of its kind and has provided for the basis of a change detection study to be made. The CRMP uses eight permanently placed stakes per reef site to construct four 20m x 2m transects. This provides approximately $160m^2$ of coverage for each reef site. Video transects are analyzed with PointCount® software to provide percent cover. The results of these yearly studies provide live coral percent cover, by species, as well as the percent cover of broader benthic categories (e.g., substrate, sponges macroalgae, octocorallia). Unfortunately *in situ* methods allow for only the study of a small part of the coral reef system, as the time and cost required to cover all would be immense.

Recent advances in satellite remote sensing technology and methodology have allowed for long-term change detection studies to be performed on benthic habitats. The Landsat series of satellites carrying the Thematic Mapper (TM, Landsats 4 and 5) and the enhanced Thematic Mapper Plus (ETM+, Landsat 7) sensors are the longest running continuous satellites that can be used for coral reef studies. Landsat provides 16-day repetitive coverage for sites at a 30m spatial resolution. Although the resolution is too coarse to yield specific coral species coverage, TM and ETM+ data allow for the study of overall benthic cover at the community level. This synoptic view of a reef system allows the researcher to study all sections of a reef, not just a small part, at various places in time over the past 20 years.

CRMP and Landsat datasets for 1996, 1998, 2000 and 2002 for six sites in the FKNMS and one site in the Dry Tortugas for 2000 and 2002, are used in this study. The sites were chosen for their location (two sites for each of the upper, middle and lower keys), their designation as a Sanctuary Preservation Area (SPA), and their depth (less than 12m). The sites are: Carysfort Reef Shallow and Molasses Reef Shallow (Upper), Alligator Reef Shallow and Sombrero Reef Shallow (Middle), Looe Key Reef Shallow and Sand Key Shallow (Lower), and White Shoal Reef (Dry Tortugas, non-SPA) (figure 1). Because of the difference in spatial resolutions, e.g. species level versus community level; the trend in the change in benthic cover becomes a paramount concern. Not only is the percent coral cover the most comparable between the two datasets, but also is of the most importance to local policy makers.

Preliminary results (1994-2000) show an excellent fit between the two datasets (figure 2). In one case for Carysfort Reef Shallow the values are nearly identical (2000). Other sites show more variance between the datasets. These positive results between remote sensing data and data gathered *in situ* highlight the fact that remote sensing can provide information about a reef that *in situ* data cannot, i.e., a view of the entire reef community, whereas satellite data cannot provide information on the species level. There will unlikely ever be a time when there is no need to visit a reef for either species information (unable to gather using current remote sensing technology) or to gather ground-truthing information (to provide quality control for satellite data). However, it is hoped that the positive results of this study might help push the use of satellite remote sensing into a more operational phase for coral reef monitoring.

Figure 1. Satellite image displaying the locations of the seven study sites.

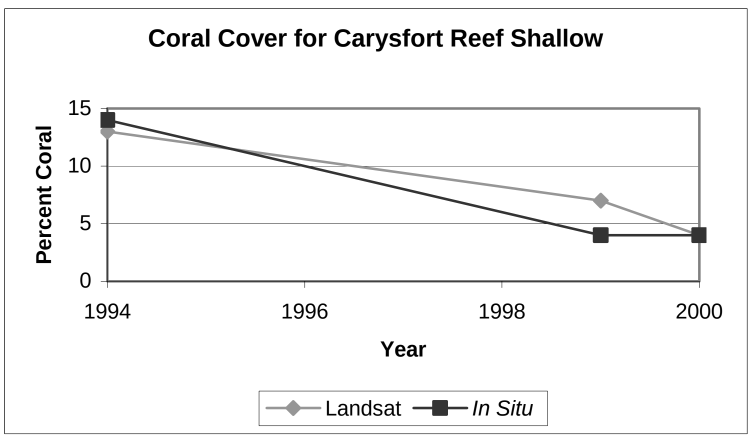

Figure 2. Percent live coral cover for Carysfort Reef Shallow derived from both CRMP *in situ* data and Landsat satellite data.

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Hydrologic Information for Tidal Rivers along the Southwest Coast of Everglades National Park

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The health of estuaries and bays along the mangrove zone of southwest coast of Everglades National Park (ENP) is dependent on the amount and quality of fresh water the area receives. For decades this area has been affected by management practices that control freshwater flows across Tamiami Trail and determine water budgets of ENP. Until recent years however, limited hydrologic information has been collected in the area, making it difficult to understand and describe the magnitude of the effects along the mangrove zone.

From 1960 to 1969, the U.S. Geological Survey (USGS) conducted a study of tides and flow in coastal rivers (fig. 1) along the Shark River Slough system to aid in the calculation of water budgets for ENP. In 1996, the USGS initiated a second hydrologic study to determine the flow and nutrient characteristics of some of the same tidal rivers of the Shark River Slough system, and in 2001 the study was expanded to cover the area from Whitewater Bay to Everglades City (fig. 2). USGS hydrologic data from these stations and others in nearby coastal marshes, along with hydrologic data from the Marine Monitoring Network of ENP, can now be used to describe the flow and water-quality characteristics of estuaries along the southwest coast of ENP.

Figure 1. Photograph of the Harney River monitoring station in 1960.

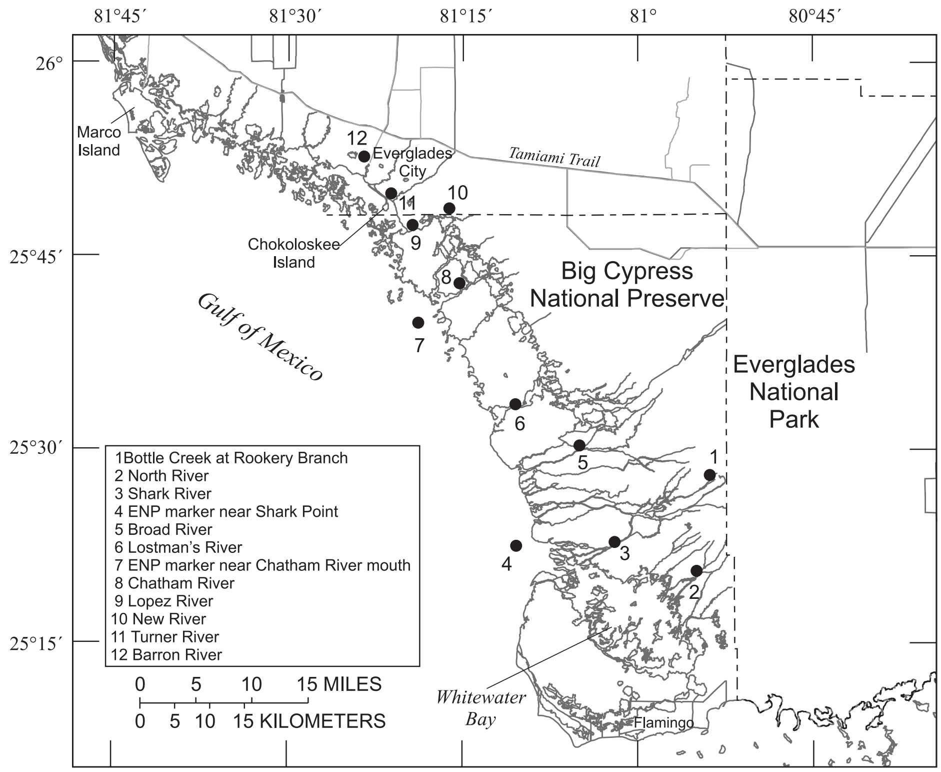

Figure 2. Location of monitoring stations for coastal rivers along the southwest coast of Everglades National Park.

The primary goals of the current study are to describe the salinity patterns along the southwest coast of ENP in relation to freshwater inflows to the estuaries and tidal exchange with the Gulf of Mexico, provide support to the USGS Tides and Inflows in the Mangroves of the Everglades model (TIME), and to aid programs such as Everglades Long Term Ecological Research (LTER).

Continuous salinity data from the main rivers and along transects from freshwater wetlands to the Gulf of Mexico (fig. 3) will be useful for describing both spatial and seasonal variation of salinity throughout the study area. The data also will help scientists and managers determine how salinity patterns may change in response to restoration efforts affecting freshwater deliveries to ENP and Big Cypress National Preserve.

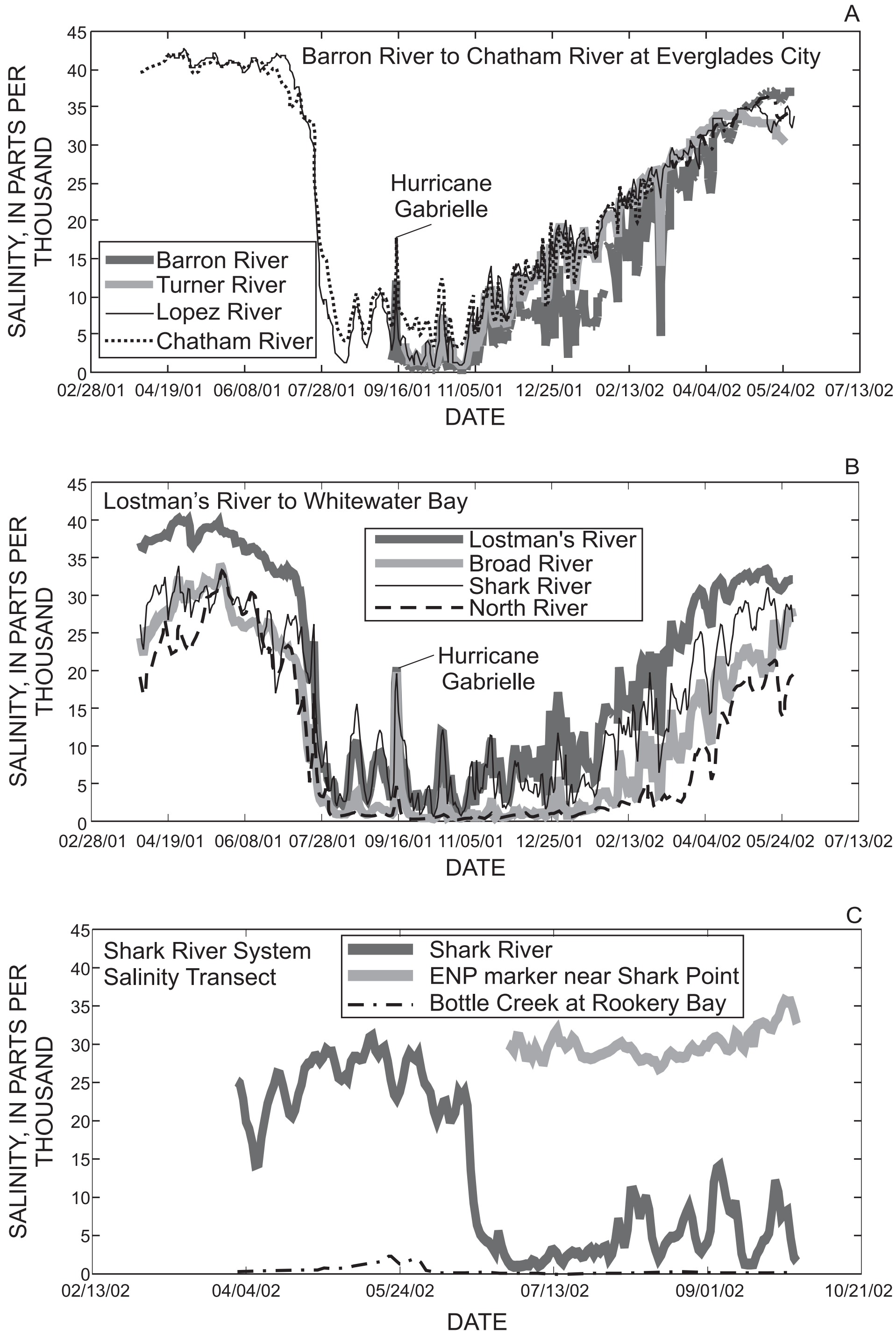

Figure 3. (A and B) Daily salinity values for rivers along the southwest coast of Everglades National Park, and (C) for a transect along the Shark River System.

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Wading Birds, Shorebirds and Waterfowl in Rice Fields of the Everglades Agricultural Area

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Wetland reclamation and development have resulted in wildlife habitat loss and poor quality habitat in south Florida. In response to these changes, waterbird populations have declined or moved into modified or artificial habitats. Rice, a well-known artificial habitat for waterbirds in many rice-growing regions, is cultivated in the Everglades Agricultural Area and may provide habitat to south Florida's waterbirds. Throughout the 1998 rice-growing season, 300 surveys were conducted in 14 representative rice fields. Objectives were to assess the number and species of waterbirds using rice fields and their activity and microhabitat use. Abundance and richness were compared to temporal and spatial field conditions. Forty-one species of waterbirds were observed in rice fields; species richness and overall abundance fluctuated in response to changes in field conditions. Species richness at survey sites ranged from 12-39 and abundance ranged from 4.6 to 72.6 birds/m/100 ha. Crop cultivation phase significantly affected overall bird abundance, while cloud cover was negatively correlated to waterfowl abundance, and water depth and rice height were negatively correlated to shorebird abundance (ANOVA, $P \leq 0.05$). Primary activity of all birds was foraging (62.8%), followed by lounging (33.3%), locomoting (3.7%), and nesting (<1%). Based on area available, the preferred microhabitat was edge followed by open water. Over 8,000 ha of rice in the EAA provide foraging and nesting grounds for large numbers of waterbirds. Increasing the number of ratooned fields and total land area devoted to rice cultivation may increase abundance and richness of waterbirds in the EAA. However, prior to increasing rice production for waterbirds, additional research must be conducted, particularly regarding the effects of farming practices on waterbirds in the EAA.

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Spatial Decision Support Systems for Ecological Restoration and Management

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Decision support systems (DSS) are broadly defined as computer-based systems used to aid decision makers using data and models to solve unstructured problems (Sprague and Carlson 1982). Support methodologies that help authorities involved in ecological restoration sort out all the decision variables and parameters, categorize problem solving heuristics, and appreciate the impacts of potential policy actions are critical to successful planning and management (Kersten et al. 2000). DSS supports adaptive management initiatives by facilitating the planning process in goal formation, selection of alternative strategies for implementation, and targeting monitoring.

A complete spatial DSS requires more than just the provision of a simple interface for viewing spatial data. Components of a DSS may include: (1) knowledge acquisition and representation, (2) goals and issues identification and conflict resolution, (3) alternatives evaluation, and (4) group negotiation support. Establishing a modular design and evaluating the need for these components as DSS development progresses can seamlessly integrate them as necessary and as funding and time permits.

Knowledge acquisition and representation is principally the ability to bring in and update spatial data layers used to portray landscape and habitat variables, the decision rules for how these data layers interact, and easy to navigate viewers for display of the data. A preliminary list of available spatially explicit data layers from modeled output that may be a part of the decision process in south Florida includes: (1) Vegetation Classification and Modeling; (2) Wildlife Species Habitats; (3) Hydrology; (4) Urban Growth and Socioeconomic; and Sealevel Rise Models.

Defining a goal or multiple goals establishes endpoints. The DSS helps the user evaluate compatibility of the goals, resolve conflicts in the proposed goal set, and estimate how successful a particular alternative will be in achieving a set of goals (Nute et al 2000).

A DSS should provide tools for priority setting and for measuring changes in the landscape with indices of landscape pattern, linkages and fragmentation, diversity, ecological integrity that match published success criteria such those prepared for the Working Group of the South Florida Ecosystem Restoration Taskforce (Science Subgroup 1997).

It is also in alternative evaluation that we need to deal explicitly with the limitations of our data and models. There is uncertainty in all science to varying degrees, but that is not a reason to discard that information; that is the reason for uncertainty analyses and sensitivity analyses as an integral part of DSS.

Group negotiation management helps the decision makers organize their ideas, formulate relationships surrounding issues and arguments, and refine their understanding of the problem and their own value systems (Holsapple and Whinston 1996).

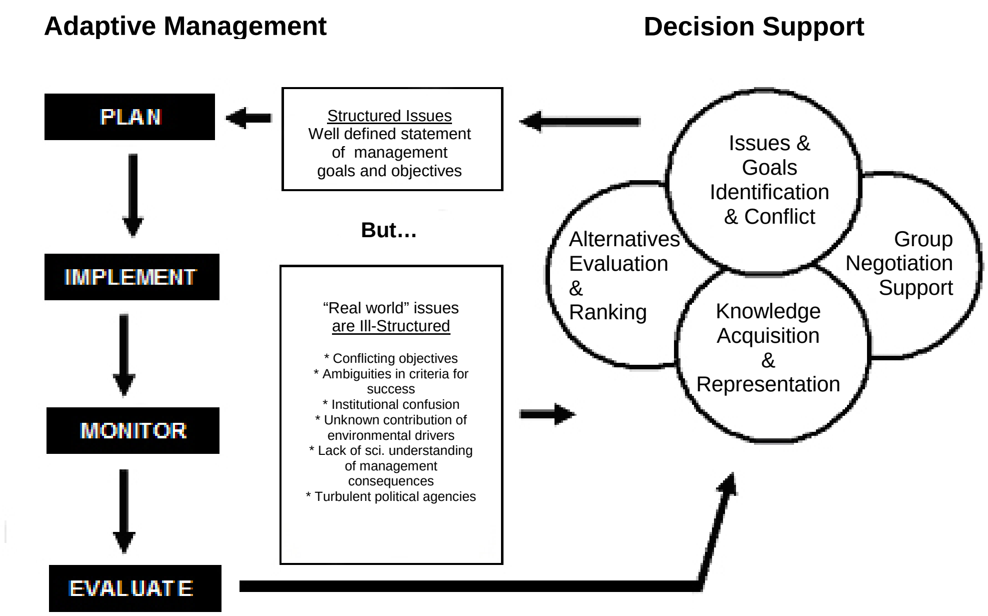

Figure 1. Implementation of decision support systems within the adaptive management structure.

Evolutionary prototyping Sprague and Carlson (1982) is a development cycle of prototype DSS development, evaluation, and refinement, repeated continually until (and beyond) its implementation. Verification, validation, and extensive user involvement are vital parts of the evaluation cycle (D'Erchia et al. 2001). Any successful support system will be characterized by concise and succinct presentation of the issue and consistency of internal data and procedures (Hill 1982).

None of this works without knowing the culture and legal requirements of the agencies that will be using the DSS. Development must include the user. The collaboration of key agency individuals, their interaction with other agencies, and their knowledge of other agencies' needs helps to ensure that this effort will be focused on the needs and objectives of on-the-ground natural resource planners and managers. A DSS will only be successful if it contributes to the implementation of agency objectives and is valued by the decision-makers.

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Florida Keys Carrying Capacity Study--Process and Lessons Learned

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The Florida Keys have long been recognized at local, state and national levels as ecologically rich, culturally significant and environmentally sensitive. The Florida Keys were designated as an Area of State Critical Concern in 1974. Legal challenges to the Monroe County Comprehensive Plan resulted in Florida Administration Commission (FAC) Rule 28-20.100, which included the completion of the Florida Keys Carrying Capacity Study (FKCCS). The goal of the FKCCS, excerpted from FAC 28-20.100, is "to determine the ability of the Florida Keys ecosystem, and the various segments thereof, to withstand all impacts of additional land development activities." The FAC Rule further stated: "The carrying capacity analysis shall consider aesthetic, socioeconomic (including sustainable tourism), quality of life and community character issues, including the concentration of population, the amount of open space, diversity of habitats, and species richness."

The purpose of the FKCCS was to provide an information database and an analysis of consequences (a tool) that could be used to determine the level of land development activities that would avoid further adverse impacts to the Florida Keys. The local governments would use the tool to determine if and how their Comprehensive Plans should be amended. The Carrying Capacity Impact Assessment Model (CCIAM) was developed to be that tool. The CCIAM is a spatially explicit, Geographic Information Systems based, automated computer model that evaluates end-state effects of land development, redevelopment and/or restoration activities on the Florida Keys ecosystem, including impacts on socio-economics, fiscal and human infrastructure.

Carrying capacity studies are on the cutting-edge of ecological and environmental science. Including analyses of socio-economics, fiscal and human infrastructure further complicates an already complex, cutting-edge study. The CCIAM was coded specifically for the Florida Keys ecosystem, however, the process used to develop the FKCCS and the CCIAM could be applicable to other areas, considering each unique environmental, socio-economic, fiscal, infrastructure and spatially explicit condition of the specific study area.

Many lessons were learned during the development of the FKCCS and CCIAM, which are valuable for others that may undertake development of a carrying capacity impact assessment study or model, as well as any other type of study or modeling effort. Some of the lessons learned include adaptation and incorporation of datasets and databases developed for other studies or projects, melodramatic press coverage, stakeholder involvement and input, public outreach, and expectation management.

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Habitat Selection and Home Range of American Alligators in the Greater Everglades

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Regional development and water management practices have drastically altered the spatial extent and traditional hydropatterns of the Greater Everglades. Proposed restoration plans will dramatically affect the Everglades ecosystem. Alligators are a keystone species that have an important role in the trophic dynamics of the Everglades by engineering trails, "gator" holes and caves that are important refugia for many species of plants and animals (especially fish and amphibians) during the dry season. Canals (one focus of restoration plans) serve as refugia for alligators throughout the Everglades. Alligator life history patterns (including movement and habitat selection) are expected to change in response to restoration efforts.

For this study, the American alligator was selected (*Alligator mississippiensis*) as an indicator of the success of restoration efforts. The objective was to collect information that can be used in ecological models for predicting and evaluating alternatives of the Comprehensive Everglades Restoration Plan (CERP). The success of restoration efforts will rely on models such as the Across-Trophic Level System Simulation that require valid estimates of alligator response to habitat restoration.

Radio telemetry was used to examine habitat selection and home range of alligators in the Greater Everglades. The size and shape of home ranges as well as selection of cover types within home ranges reflect the quality and condition of available resources. As canals are removed and alligators move back into adjacent marsh habitat, we anticipate that resource selection (and ultimately demography) will depend on where the alligator is located in the Greater Everglades. Therefore, alligators were observed in 3 contrasting Everglades habitats: marsh in Water Conservation Area 3A North (WCA), marsh in the Everglades National Park (ENP), and canals in both the WCA and ENP (Canal). Weekly locations for 66 alligators (WCA = 11, ENP = 22, Canal = 33 alligators) and intensive daily locations for 31 alligators (WCA = 6, ENP = 7, Canal = 18 alligators) were recorded in the 3 habitats. Weekly locations were recorded using aerial telemetry, while the daily locations were recorded using ground-based telemetry.

Home range for all alligators was estimated using a 95% adaptive kernel model, which is a more robust and conservative estimate of home range size. However, we used a 100% Minimum Convex Polygon (MCP) to estimate the proportion of habitat available to alligators in our examination of habitat selection. A 100% MCP included all cover types used by each alligator. We used compositional analysis to examine the selection of cover types with the 100% MCP. We examined 7 cover types for the daily locations. The number of cover types was restricted by sample size. Cover types for daily locations included: 1) sawgrass (*Cladium jamaicense*), 2) emergent vegetation - including spikerush (*Eleocharis cellulosa*) and cattails (*Typha* spp.), 3) uplands - tree islands and shrub islands, 4) floating vegetation - mainly water lilies (*Nuphar* spp., and *Nymphaea* spp.), 5) open water - areas with little or no vegetation, 6) "gator" hole, and 7) canal. For weekly locations the same 7 cover types included in the daily locations were examined, but levee break, gator trail and airboat trail were added.

Mean home range was larger for alligators in canals (111.2 ± 27.1 ha, $\bar{x}$ ± SE) than either WCA (55.5 ± 17.7 ha) or ENP (79.7 ± 25.2 ha) marshes. There was no difference in home ranges for alligators in the marsh of WCA and ENP. Mean male home range (144.34 ± 22.3 ha) was larger than female home range (35.91 ± 16.76 ha).

Alligators frequently selected deeper water marsh in WCA (table 1) for both daily ($P < 0.05$) and weekly locations ($P < 0.001$). Floating vegetation was selected more than any other cover type for both daily and weekly locations. Weekly location data also indicated selection for emergent vegetation, levee breaks and airboat trails that was greater than other cover types.

Alligators were frequently located in gator holes (table 1) in ENP during both daily ($P < 0.01$) and weekly locations ($P < 0.0001$). Daily locations also indicated a selection for emergent vegetation not observed for weekly locations. Spikerush and cattails often surround gator holes in ENP. More intensive daily locations were more likely to record locations in the surrounding emergent vegetation while alligators were using holes.

As expected, canal alligators strongly selected canals over all other cover types (table 1) for both daily ($P < 0.0001$) and weekly locations ($P < 0.0001$). The creation of canals in the Greater Everglades has influenced alligator movement and habitat selection. Canal alligators spend most of their time in canals and move greater distances (i.e., have larger, more linear home ranges) than alligators in WCA or ENP marshes. The response of alligators to the proposed removal of canals may depend on adjacent habitat. Alligators are able to restore abandoned alligator holes or create new holes in the peat dominated slough of ENP, but they may be drawn to deeper water marsh, such as found around floating vegetation or in levee breaks in the WCAs.

Table 1: Selection ratios (i.e., the ratio of the proportion of cover types used to the proportion of cover types available) for American alligators radiotracked in the Greater Everglades from November 1996 to August 1999.

A. Daily Locations (n = 31 alligators)

	sawgrass	emergent	upland	floating	open water	gator hole	canal
WCA	0.42	3.36	0.002	13.47	0.41	0.08	NA
ENP	0.27	9.57	1.17	0.001	0.01	7.41	NA
Canal	0.003	0.03	0.005	0.17	0.07	0.11	4.99

B. Weekly Locations (n = 66 alligators)

	sawgrass	emerge	upland	floating	open water	gator hole	levee break	gator trail	Air-Boat trail	canal
WCA	0.21	3.24	0.001	3.47	1.20	0.07	2.58	0.63	2.33	NA
ENP	0.03	0.02	0.32	0.003	16.40	17.79	1.00	0.11	0.33	NA
Canal	0.03	0.98	0.01	0.02	0.20	0.35	0.20	0.05	0.09	3.90

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Conceptualizing *Melaleuca quinquenervia* Invasion: A Feedback System between the Plant and its Soil Biota

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There are several leading theories to explain the extraordinary success of invasive plants but most focus on mechanisms associated with plants themselves (e.g., life history traits, physiological properties, or diversity of invaded plant communities). Other theories suggest that disturbance, release from natural enemies, and alteration of the soil chemistry intensify the invasion process. Soil biota are rarely suggested to have an important role in the plant invasion process.

Aboveground and belowground components of ecosystems are implicitly dependent on each other as plants provide sources of carbon and nitrogen for soil biota and soil biota provide plants with simple nutrients. Soil organisms are involved in processes of decomposition and nutrient mineralization, and the composition, abundance, and activity of decomposer communities are crucial in regulating these processes. Composition and density of the soil community can vary markedly with different plant species. It is likely, therefore that soil community structure and their activity change following invasion. Alternatively, soil organisms associated with plant communities have profound effects on plant performance. It is possible, therefore that soil biota have a significant role in structuring plant communities and in promoting or preventing plant invasions.

We model plants-soil biota interactions in the form of a feedback system, where plant species affect the composition and abundance of soil biota (alteration of soil community) and the soil biota in turn feeds back to the plant community (alteration of aboveground diversity and productivity). I propose this feedback system as a mechanism explaining the success of *M. quinquenervia* in the Florida Everglades ecosystems. If true, soil biota have a potential in indicating the status and extent of plant invasions and therefore could be crucial in establishing successful management and restoration programs.

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Screening Level Probabilistic Aquatic Ecological Risk Assessment of Canal C-111 and Adjacent Coastal Areas

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The first phase of an ecological risk assessment is underway to evaluate the potential risks of organic pesticides found in the water and sediment in the lower Canal 111 (C-111) Basin and adjacent tidal zones in South Florida. The goal is to develop a perspective on chemical stressors present in an area undergoing large-scale hydrologic restoration, as recommended by interagency evaluations of contaminant issues in Everglades restoration. It is the first phase in development of a retrospective ecological risk assessment, and it focuses on an area where a critical Everglades restoration project is underway (C-111 Project).

The results of the study are expected to identify areas with data gaps and information needs, that if met, will provide risk information detailed enough to support water quality management planning and increase the probability of success of Everglades restoration. Results are intended to be used by the appropriate state and federal jurisdictions for interpretation, evaluation, and application of appropriate remedial actions for protection of fishery and wildlife resources.

This risk assessment was conducted under the U.S. EPA ecological risk framework and focuses only on potential effects of water exposure concentrations to the herbicides atrazine and metolachlor and to the insecticides chlorpyrifos, endosulfan, and malathion. It did not take into account the potential additional effects of exposure of organisms to other contaminants present, such as heavy metals, or other types of exposure, such as through sediment or bioaccumulation from consuming food items that have also been exposed.

Results from initial evaluations of risk of acute effects in fresh- and estuarine –waters from pesticide exposure show:

- Highest risk was associated with endosulfan effects on estuarine arthropods, followed by endosulfan on freshwater arthropods.
- Highest risk of acute effects from joint toxicity of the compounds considered was to estuarine invertebrates.
- Highest risk of acute effects in fresh water are associated at sites near water control structure S-178 and canal C-111e, a branch of canal C-111. The highest risk of acute effects for saltwater organisms is in Joe Bay, which receives water discharges from canal C-111.

Results from initial evaluations of risk of chronic effects from pesticide exposure show:

- Highest risk is associated with endosulfan at S-178 in freshwater.

Probability-based statistical models of joint pesticide interactions (probabilistic risk assessment) showed risk increased from single to multiple exposures.

Information needs to reduce uncertainty include:

- Ecotoxicity testing with indigenous, native indicator species exposed to metals and/or organics in water and sediment
- Improved chemical monitoring in water, sediment, and organism body burdens

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Inventory and Review of Aquifer Storage and Recovery in Southern Florida

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Aquifer storage and recovery (ASR) in southern Florida has been proposed on an unprecedented scale as part of the Comprehensive Everglades Restoration Plan (CERP). ASR wells were constructed or are under construction at 27 sites in southern Florida, mostly by local municipalities or counties in coastal areas. The Upper Floridan aquifer, the principal storage zone of interest to the Restoration Plan, is the aquifer being used at 22 of the sites. The aquifer is brackish to saline in southern Florida, which can greatly affect the recovery of the freshwater recharged and stored.

The purpose of this study is to inventory and compile data for existing ASR sites in southern Florida and identify various hydrogeologic, design, and management factors that control the recovery of freshwater injected (recharged) into ASR wells. Data for all wells at most of the 27 sites were compiled into four main categories: (1) well identification, location, and construction data; (2) hydraulic test data; (3) ambient formation water-quality data; and (4) cycle testing data. Each cycle during testing or operation includes periods of recharge of freshwater, storage, and recovery that each last days or months. Cycle testing data include calculations of recovery efficiency, which is the percentage of potable recharged water recovered for each cycle.

Potable water recovery efficiencies for 16 of the 27 sites were calculated and, generally, recovery efficiency improves with the number of cycles. Except for two sites, the highest number of cycles was five. Only nine sites had a recovery efficiency above 10 percent for the first cycle or two. However, at two out of the other seven sites, low recharge volumes per cycle of less than 10 million gallons (Mgal) could explain the poor recovery. Ten sites achieved a recovery efficiency above 30 percent during at least one cycle. The highest recovery efficiency achieved per cycle was 84 percent for cycle 16 at the Boynton Beach site (fig. 1). Recharge volume per cycle averaged 95 Mgal, ranging from 0.6 to 714 Mgal, for 55 cycles at 14 Upper Floridan aquifer sites. Recharge volume for cycle 3 at the West Well Field site in Miami-Dade County was 714 Mgal and included simultaneous recharge into 3 ASR wells. All cycles were conducted in a single well, except for two cycles at the West Well Field site.

Factors that could affect recovery of freshwater varied widely among sites. The thickness of the open storage zone at all sites ranged from 45 to 452 feet. For Upper Floridan aquifer sites, transmissivity based on tests of the storage zones ranged from 800 to 108,000 ft2/d (feet squared per day), chloride concentration of ambient water ranged from 500 to 11,000 mg/L (milligrams per liter), and leakance values indicated that confinement between the storage zone and lower zones may be limited in some areas. High transmissivity can adversely affect recovery, because it may equate to high dispersive mixing in a limestone aquifer. Additionally, depending on the ambient salinity of the storage zone, the probability of buoyancy stratification increases as transmissivity increases. At three sites that have transmissivities above 70,000 ft2/d with 3 to 5 cycles at each, recovery efficiencies over 10 percent per cycle were not obtained.

Based on review of four case studies and data from other sites, several hydrogeologic and design factors appear to be important to the performance of ASR in the Floridan aquifer system. Performance is maximized when the storage zone is thin and located at the top of the Upper

Floridan aquifer (fig. 2), and transmissivity and ambient salinity of the storage zone are moderate (less than 30,000 ft2/d and 3,000 mg/L of chloride concentration, respectively). The structural setting at a site could also be important because of the potential for updip migration of a recharged freshwater bubble due to density contrast or loss of overlying confinement due to deformation.

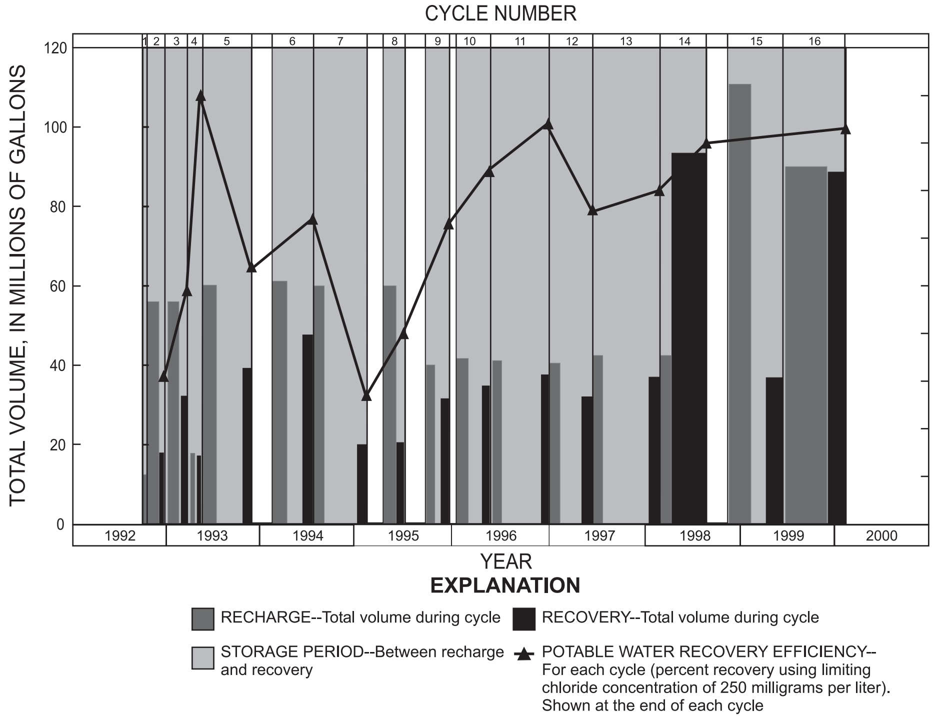

Figure 1. Operational cycles at the Boynton Beach East Water Treatment Plant site in Palm Beach County and relations of volumes recharged and recovered, time, and percent recovery for each cycle. Recovery for cycle 15 was 34 percent for and ending chloride concentration of 146 milligrams per liter.

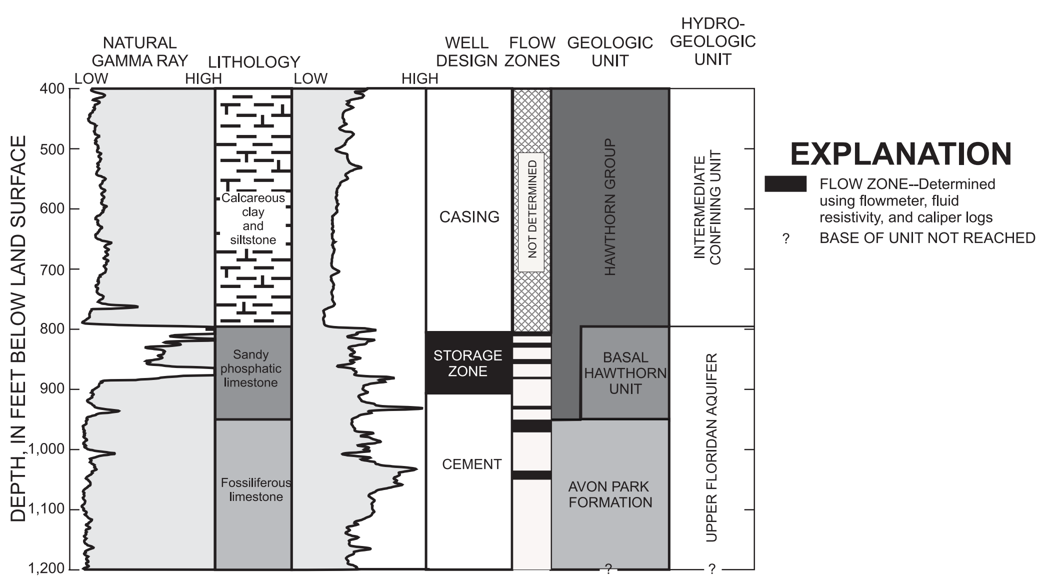

Figure 2. Location of storage zone in relation to geophysical logs, lithology, flow zones, and geologic and hydrogeologic units for the aquifer storage and recovery well at the Boynton Beach East Water Treatment Plant site in Palm Beach County.

This five-year study is divided into two phases, the first of which lasted two years. The first phase laid the groundwork for data inventory, review, and analysis. The second phase will allow for collection of additional data as it becomes available, expand the hydrogeologic framework, and perform a more complete comparative analysis of ASR sites. Results from the first phase are provided in Reese (2001); results from the current phase also will be published.

References:

Reese, R.S., 2001, Inventory and review of aquifer storage and recovery in southern Florida: U.S. Geological Survey Water Resources Investigation Report 02-4036, 56 p.

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Movements and Habitat Requirements of Radio Tagged Manatees in Southwest Florida; Implications for Restoration Assessment

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A study on West Indian manatees (*Trichechus manatus*) in southwestern Florida is being conducted to determine the relative abundance, distribution, movements, and habitat use of manatees associated with coastal waters and rivers. As part of the study, an individual-based ATLSS model is being developed to predict manatee response to changes in hydrology caused by the Comprehensive Everglades Restoration Plan (CERP). A large proportion of the southwest Florida manatee population occurs throughout the Everglades National Park (ENP) and northwest into the Ten Thousand Islands (TTI). On-going research in this region shows that manatees make frequent movements up tidal creeks to obtain freshwater for drinking and to find thermal refugia during cold weather. Alteration of the freshwater and estuarine ecosystems associated with restoration of the Everglades and Southern Golden Gate Estates (SGGE) is likely to affect this manatee population. We hypothesize that manatee distribution, relative abundance, habitat use, and movement patterns will change because of altered water management regimes and resulting changes in near shore salinity. Aerial surveys and radio tracking tagged manatees provide valuable means of documenting the response of manatees to natural and human-induced fluctuations in freshwater inflow. This information, combined with water-quality data obtained from monitoring stations, is being incorporated into the manatee ATLSS model, which will be used to better understand and predict manatee response to different restoration scenarios. This project also fills a significant void in our knowledge of manatee ecology, as there is very little existing information on manatee population biology and habitat use in southwestern Florida. Recent advances in tracking technology have made this project logistically feasible and cost-effective.

Data from manatees radio tagged in the TTI documented the pre-restoration use of habitat by manatees within the region affected by the SGGE restoration. During the initial phase of this study, three captive, rehabilitated adult manatees were tagged and released in July 2000. Eight more wild manatees were captured and radio-tagged at Port of the Islands in February and March 2001. Two others tagged by Mote Marine Lab near Charlotte Harbor moved into the Ten Thousand Islands during summer 2001. During January 2002, five more manatees were captured and radio-tagged at Port of the Islands, bringing the total number of manatees tagged and tracked in this study to 20 individuals.

We relied on several technologies to acquire geographic locations from tagged manatees. Most manatees were fitted with satellite-based Argos transmitters, which have a serviceable battery life of six months and provide locations along with data on temperature and transmitter activity. A location class (LC) designating the accuracy of each position is also recorded; quality locations include LC 1 <1000m, LC 2 <350m, and LC 3 <150m. Tagged manatees relayed an average of six quality locations per day, with a frequency of approximately two per day from each location class. In addition to the Argos satellite-monitored tags, we opportunistically attached a datalogging GPS tag to six manatees. The GPS tag provides locations which are much more accurate than the Argos data (approx. 30 m vs. ≥150 m) every 15-30 minutes, but the battery life expectancy is much shorter (8 weeks vs. 6 months). In combination, the Argos data provided region-wide, long-term coverage suitable for revealing general patterns of habitat use, while the GPS data showed fine details of travel pathways and time spent in specific areas.

Newly developed Argos-linked GPS tags were recently deployed on individuals. This tag relays GPS locations as sensor data through the Argos satellite link, enabling detailed tracking data to be acquired remotely. All tagged manatees were periodically located and observed in the field using standard VHF tracking techniques. All location data were formatted using the SAS statistical software for error checking, analyses, and display in ArcView. Databases were correlated with temperature, salinity, and tidal data collected throughout the region.

From 2000 through July 2002, a total of 4,563 tracking days were recorded from 36 tag deployments on the 20 manatees. Two of the males traveled to areas more than 100 km north of the Ten Thousand Islands. Most remained within the study area, however, providing the first detailed movement data collected across seasons from wild manatees in the region. Warm season use areas for some individuals included seagrass beds off Cape Romano and the canals of Marco Island. Other manatees moved southeast into the northwest region of Everglades National Park, relying on inland creeks for fresh water. These data provide the first details on manatee use patterns in the TTI/ENP region.

Movement patterns for all individuals suggest a preference for foraging on seagrass beds in marine areas with brief trips to inland creeks and canals, which provide a source of fresh water. These inland trips, undertaken approximately four to eight times per month, reveal the reliance of these marine animals on accessible freshwater. Individual movements were linked to a network of travel corridors connecting seagrass beds and sources of freshwater, identified by manatee locations during GPS tag deployments. Movements were often rapid and direct. The deep canals at Port of the Islands provide access to freshwater at the spillway, as well as a passive thermal refuge for manatees during brief cold winter weather. Individual site fidelity for some manatees varied with season and calving events.

Feeding areas were documented within *Thalassia*, *Syringodium*, and *Halodule* seagrass beds along the outer islands. Spatial distribution of submerged aquatic vegetation, temporal fluctuations in freshwater areas, and bathymetry influenced movement and use patterns of manatees within the region. Salinity of inshore waters fluctuated with winter dry periods and summer rains. Abundance and species composition of submerged vegetation within inland bays may vary with these seasonal changes, thus influencing manatee feeding patterns. Additional studies are planned to assess manatee habitats including characterizing and mapping the distribution of submerged aquatic vegetation in areas used by tagged manatees for foraging.

Tracking data and field observations of tagged manatees revealed that the spatial distribution of submerged aquatic vegetation, availability of freshwater, and bathymetry influenced manatee movements and use patterns within the TTI and northern Everglades. Manatees routinely traveled from offshore seagrass beds to inland freshwater areas. We expect that altered water management regimes and resulting environmental changes may affect manatee habitat use and movement patterns within the region. These data are being integrated into the ATLSS model that will attempt to predict manatee responses to management actions.

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Consensus Building for Defining and Prioritizing Restoration Science and Restoration Project Needs in Southwest Florida

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Consensus building is a decision-making process that arose in response to problems in the areas of business, government, labor, and the environment. In contrast to the "one party wins, one party loses" theory of litigation, consensus building brings parties together to define issues in terms that require joint problem solving, by sharing information and responsibility. Parties combine resources to solve problems that may be intractable individually. When consensus is successful, the parties have reached solutions by clarifying their core values, sharing information, and establishing trust.

The use of consensus building in environmental planning and management has increased over recent years in Southwest Florida. Agencies and multi-agency groups like the Watershed Council, Lee County Smart Growth Management, and Charlotte Harbor NEP, have incorporated consensus-based decision-making into their mission statements. The Southwest Florida Regional Restoration Coordination Team, a regionally approved multi-agency group reporting to the South Florida Ecosystem Restoration Task Force Working Group, employs consensus-building techniques at their meetings and in their science and restoration plans.

The incorporation of consensus building was instrumental in the review and completion of the Big Cypress Basin – Estero Bay Regional Science Plan. A draft of the science plan has existed in various forms since 1997. Six workshops were held between 1997 and 2000 to develop science plan projects that would identify, through consensus, priority research, monitoring, and coordination needs for the region. In November 2001 when the Big Cypress Basin - Estero Bay RCT began its operation, one of the principal objectives of the RCT was to finalize the Regional Science Plan. This required editing the projects contained within the Plan; prioritizing those projects; and finally seeking peer review of the plan's contents by the Working Group's Science Coordination Team. A draft regional science plan for the Big Cypress Basin - Estero Bay region was recently completed following a three-year collaborative partnership of local agencies and organizations. The plan identifies specific recommendations for regional restoration research and monitoring activities, and promotes the concept of a long-term, sustainable research coordination effort linked to restoration within the Basin. Due to the success of this effort the Charlotte Harbor - Caloosahatchee RCT has undertaken a similar effort, using the Big Cypress Basin – Estero Bay's RCT process as a guideline for the development of their plan.

Similar efforts are now underway by both the Big Cypress Basin – Estero Bay and Charlotte Harbor – Caloosahatchee Restoration Coordination Teams to identify and prioritize restoration project needs within their respective subregions. These efforts are being used to garner support for restoration problems of more regional significance from local agencies or are being recommended for Working Group endorsement when the restoration problem is of system-wide significance.

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Impact of Water Management on Coastal Hydrology in Southeastern Florida

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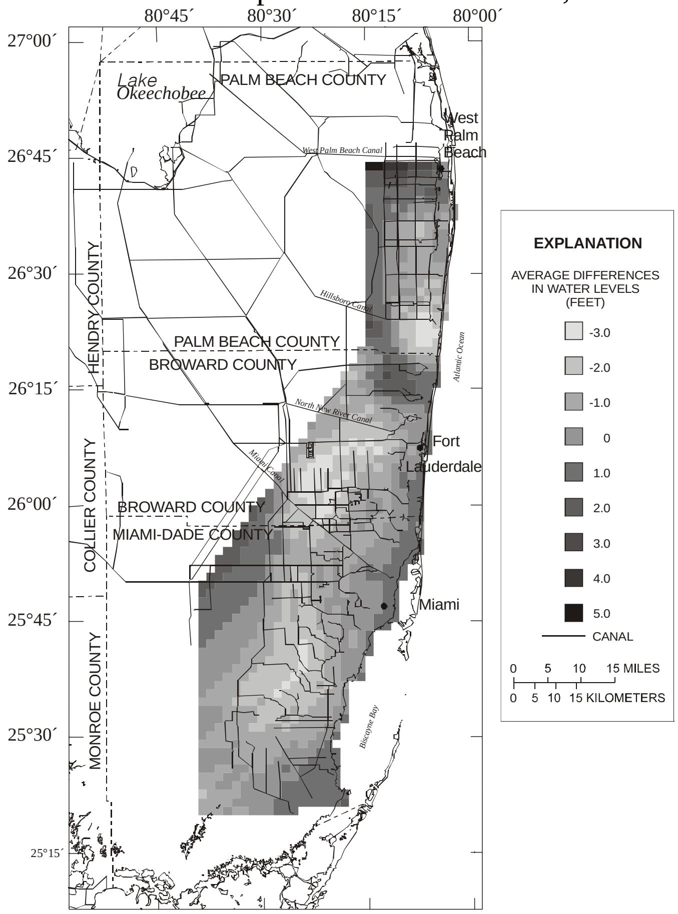
Surface and ground water hydrology and natural ecosystems of southeastern Florida have been subjected to conflicting anthropogenic stresses, which are attributed to the development of a highly controlled water-management system designed to reclaim land for urban and agricultural development. During the first half of the 20th century, Everglades wetlands and coastal estuaries were viewed as a wasteland suitable only for drainage and development. Predevelopment surface- and ground-water systems were intensely transformed by construction of a complex system of canals, impoundments, control structures, levee systems, and many large well fields. These features were collectively designed to manage the competing needs of agriculture, urban users, and natural ecosystem areas. Water-management systems were used to control floods, sustain ecosystems, prevent overland flow from moving eastward and flooding urban and agricultural areas, maintain water levels to prevent saltwater intrusion, and provide an adequate water supply.

Miami-Dade, Broward, and Palm Beach Counties have experienced explosive population growth, increasing from less than 4,000 inhabitants in 1900 to more than 3.8 million in 2000. The use of ground water, the principal source of municipal supply, has increased considerably, from 3 well fields producing 65 Mgal/d (million gallons per day) in 1930 to more than 770 Mgal/d from 79 operating well fields in 1995. Agricultural water use increased from 505 Mgal/d in 1953 to almost 1,150 Mgal/d in 1988, but has since declined to 764 Mgal/d in 1995. This decline is partly due to the displacement of agriculture by urban growth. Present-day agricultural supplies are obtained largely from surface-water sources in Palm Beach County and ground-water sources in Miami-Dade County, whereas agricultural growers in Broward County have been largely displaced.

Before 1948, surface-water conveyance canals provided unregulated flow and were incapable of effectively transporting floodwaters. A lack of canal control structures exacerbated overdrainage of the aquifer during periods of low rainfall and drought. The Central and Southern Florida Flood Control project restructured the existing conveyance system through canal expansion, construction of protective levees and control structures, and greater management of ground-water levels within the surficial aquifer. Currently, gated canal control structures discharge excess surface water during the wet season and remain closed during the dry season to induce recharge.

Managed surface-water conveyance has been used successfully to increase ground-water levels near the coast to impede saltwater intrusion, minimize urban and agricultural flooding, and maintain lower inland ground-water levels. Measured canal stage at the coastal reaches increased during the latter half of the 20th century, whereas surface-water discharge to coastal bays and the Atlantic Ocean declined. Stage increase is presumably the result of efforts to prevent saltwater intrusion into major canals and aquifers. The decline in coastal surface-water discharge is attributed to municipal ground-water withdrawals that induce recharge from the canal to the aquifer. The rerouting of surface water in major canals to secondary canals to elevate coastal ground-water levels also may have contributed to these declines. In contrast to coastal areas, long-term canal flow near the western margin of the urban area has remained relatively consistent (without a general increase or decrease in flow). Consistent long-term surface water flow along the western edge of urban areas and a decline in flow near the coast further supports municipal well withdrawals as a causative agent of declining coastal discharge.



Average difference in water levels between October 1940-44 and October 1990-94

Ground-water levels within the surficial aquifer respond quickly to rainfall; annual wet- to dry-season fluctuations within the aquifer can range from 2 to 8 ft. Wide seasonal variability in water levels can tend to obfuscate longer-term patterns. To better illustrate the effect of canal drainage on the water table, long-term "average condition" analyses were used to dampen storm and drought climatic events. During 1990-94, wet-season (October) and dry-season (April) inland water levels within the surficial aquifer averaged 1 to 4 ft lower than the "average" water levels experienced during 1940-44. However, coastal ground-water levels averaged 1 to 2 ft higher, thus reflecting efforts to minimize coastal saltwater intrusion as previously described.

A broad zone of diffusion defines the saltwater interface, and its position is largely a function of lateral movement of seawater from the ocean, seepage from tidal canals, and upconing of relict seawater. The predevelopment balance between freshwater and saltwater was altered considerably following construction of conveyance and drainage canals and municipal supply wells. Saltwater intrusion has been an issue of concern in southeastern Florida since the early 1930s; its effects were most prominent in Miami-Dade and Broward Counties during the 1940s and 1950s, respectively. Canal drainage seems to have had the most widespread impact on saltwater intrusion, lowering water levels within the surficial aquifer and contributing to landward movement of the interface

The pre-1900 Biscayne Bay coastal ecosystem and salinity was different than it is today as recorded in sediment cores. Salinity increased in the early 1900s, remained stable until the early 1940s, and then increased above levels recorded in the early 1900s. The marine fossil record shows that coastal vegetation changes that have occurred. Sea grass became more abundant during the past century in the central bay and in the coastal Manatee Bay region. Increasing epiphytal and macro-algal habitat dwelling organisms indicate a change in substrate conditions. From the late 1980's to present time, salinity has decreased slightly in Manatee Bay, and field observations in this region suggest the health of sea grasses is deteriorating.

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The ATLSS American Alligator Population Model: Results from Restoration Alternatives

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The American alligator (*Alligator mississippiensis*) is a top consumer in South Florida that also physically influences the Everglades landscape through construction and maintenance of alligator holes and trails (Mazzotti and Brandt 1994). The existence of this species is important to the faunal and floral character of the Everglades as it has evolved. The U.S. Geological Survey (USGS) and its cooperators are using empirical data collection and model simulations to apply information on wildlife community patterns to the Everglades restoration process. The ATLSS (Across Trophic Levels System Simulation) project is a large-scale spatially explicit system of interacting landscape models of hydrologic processes, and plant and animal responses. ATLSS is designed to evaluate the effects of alternative water management plans on plant and animal abundance across the greater Everglades Ecosystem. ATLSS requires an alligator population model to simulate the South Florida ecosystem under varying management strategies. The current project provides estimates of population parameters and modeling frameworks for an ATLSS American alligator population model (APM).

Current water management practices have resulted in a high and unpredictable rate of nest flooding. The natural predictability of the system has been lost (Kushlan and Jacobsen 1990). Historically, alligators were abundant in prairie habitats of the eastern floodplain. Pre-drainage occupancy of deep- water central sloughs was relatively low. Marsh alligator densities are now highest in the central sloughs and canals (Kushlan and Jacobsen 1990) and relatively low in the edge habitats. Modified hydrologic conditions might be expected to increase nesting effort, nesting success, and abundance of alligators in the aforementioned edge habitats. There may also be a corresponding increase in the number and occupancy of alligator holes that serve as drought refugia.

The Everglades is believed to be a harsh environment for alligators. Everglades alligators weigh less than alligators of the same length from other parts of their range (Jacobson and Kushlan 1989, Barr 1997). In addition, maximum length is decreased, and sexual maturity is delayed (Kushlan and Jacobsen 1990, Dalrymple 1996). Jacobsen and Kushlan's (1989) model for growth in the Everglades of South Florida suggests alligators reach a mere 1.26 meters in 10 years and require at least 18 years to reach sexual maturity. It is currently suspected that the reason for this reduced condition is a combination of low food availability and high temperatures (Jacobson and Kushlan 1989, Dalrymple 1996, Barr 1997). Through the development of the APM, restoration alternatives will be evaluated and restoration performance measures will be assessed. By applying the APM to proposed restoration alternatives and predicting population responses, alternatives can be chosen that result in biotic characteristics that approximate historical conditions, and future research needs can be identified.

The APM uses water data from historical measurements, and alternatively simulated water data from the various restoration alternatives. Daily water levels were modeled by the South Florida Water Management District. The APM also obtains input from the ATLSS American alligator production index (API). Finally, the API model uses the water data in combination with the underlying topography and vegetation distribution to predict the probability that (1) a female alligator in a model cell will breed and construct a nest that year, (2) that the nest will not flood, and (3) that the habitat is favorable for nesting.

The core model component is a 3-D matrix that records the density of each stage of alligator in each 500x500m spatial location. The density matrix interacts with survival and condition matrices calculated for each time step based on water level, crowding, etc. To disperse alligators, a discrete spatial convolution method is used. The effect is similar to a "blur filter" used by many image-processing computer programs, and is a process that takes the contents of a cell and redistributes it according to a mathematical dispersal kernel. Dispersal kernels are sized according to the average dispersal distance of each alligator stage determined by field studies.

Output of the model is a 3-D alligator density matrix, with space along two axes (x and y), and the stage classes along the third axis (z). Also included in the matrix is a "running average" of the historical health and survival rates of each stage in each cell. This construct can easily be summed to obtain the total alligator population, or subsampled to verify agreement with field data. Instantaneous densities and local rates-of-change can be calculated from this model.

Using the historical calibration water dataset, which simulates actual hydropatterns from 1979-1995, the model output was compared to historical counts of alligators conducted along various airboat trails at night with a spotlight. Preliminary model results of overall alligator abundance along the airboat trails are within the maximum and minimum estimates derived from the surveys. Preliminary comparisons of base conditions (1995 and 2050) to alternatives (ALT D13R) suggest that conditions would improve, and populations of alligators would be reestablished in short hydroperiod wetlands such as the Rocky Glades in Everglades National Park (ENP). Habitats such as Shark River Slough in ENP that are projected to have increased water depths under proposed restoration alternatives are expected to maintain populations or experience slight declines. The results of these simulations agree with observations of crocodilian biologists working in the Everglades. Full model simulations and comparisons of base vs. alternative scenarios are available for comment.

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Using Proportion of Area Occupied to Estimate Abundance of Amphibians in Everglades National Park and Big Cypress National Preserve

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Declines in amphibian populations have been documented for many regions and habitat types worldwide (Alford and Richards 1999). No single cause for declines has been determined, and it seems likely that several factors interact to threaten populations (Carey and Bryant 1995). In response to concerns about amphibian population declines, the Department of Interior (DOI) received funding from Congress to institute long-term surveys of the status and trends of amphibians on DOI lands. The U.S. Geological Survey has been conducting inventories of amphibian species in Everglades National Park (ENP) and Big Cypress National Preserve (BCNP) from 2000 to present.

Together ENP and BCNP comprise a contiguous protected area of more than 890,000 ha. This landscape, unique in the United States, contains a diverse array of different wetland and upland habitats. The amphibian fauna of the Everglades and Big Cypress region comprises 15 native species, all derived from temperate zone fauna, and three non-indigenous species from the tropics. Although historical and recent survey and inventory work on amphibians has been done on DOI lands in South Florida (Duellman and Schwartz 1958, Meshaka et al. 2000), there is a need for a current inventory and estimate of the abundances of the amphibians of ENP and BCNP. This project uses data on detection of amphibian species after repeated sampling at a site to estimate the occupancy rate of various amphibian species (MacKenzie et al. 2002).

Sampling locations were chosen randomly throughout ENP and BCNP using a Geographic Information System (GIS), and all sampling was stratified by major habitat type. We divided the parks into six natural habitats: pineland, rocky glades, tropical hardwood hammock, mangrove forest, cypress dome, and freshwater slough. These habitat designations were based loosely on the vegetation classification scheme of Madden et al. (1999), and their map was used as the basis for site selection. We selected points at random within each of the major habitat types. Six of these sites in each habitat type at each park were used as monthly sampling locations. These were visited once within each calendar month for one year. Other random locations were sampled at least twice during times when they were accessible. A total of 118 sites in ENP and more than 75 sites in BCNP were sampled.

The primary method of sampling was a standard visual encounter survey (VES) technique combined with a 10-minute auditory survey for calling anurans (Heyer et al. 1994). Each sampling event lasted 30 minutes and all were conducted after dark. Each area searched was a 20-m radius circle (1256 m^2 area) around the randomly chosen point. Each individual found was identified to species, sex, age, and snout-to-vent length. We measured the air temperature and relative humidity using a digital thermohygrometer. Cloud cover, wind speed, whether the plot was inundated with water, and water temperature (if applicable) were also noted.

Data were organized into capture history matrices where detection of species was denoted by a "1" for a given site and month. Non-detection of a species was denoted with a "0", and a "-" was used in cases where a site was not visited during a particular month. These data were analyzed using the program PRESENCE to calculate a proportion of sites occupied (PAO) by each species within each habitat (MacKenzie et al. 2002).

We observed 1788 individual amphibians in ENP and more than 2000 in BCNP during VES surveys. Not all of the anurans were observed a sufficient number of times to allow calculation of proportion of sites occupied in ENP. Data collection and analysis for BCNP is still underway. For some of the more abundant anurans it was possible to estimate the site occupancy by habitat (table 1).

The results obtained for site occupancy may serve as a baseline for long term monitoring of amphibians in the national parks of South Florida. Estimating the total abundance of any of these species is practically impossible due to the large area involved and complicating variables like weather and phenology of amphibian behavior. However, by estimating the site occupancy rate of each species at randomly chosen sites within each habitat, it is possible to produce an estimate of the proportion of that habitat in which a species occurs. This number does not indicate the abundance of individuals, but it does permit estimates of the abundance of populations. This can serve as the basis for tracking changes in population abundance over time.

The sampling protocol developed here for these parks is considered appropriate for future monitoring of amphibians in the Everglades ecosystem. The methods are relatively inexpensive, and replication should be straightforward. Tracking changes in site occupancy over time will help identify trends in amphibian populations and serve as an early warning if any amphibian populations are truly declining in South Florida. Plans for future work include using PAO with hydrologic models of the Everglades ecosystem to predict how populations of species might react to hydrologic change. With estimates of the proportion of sites occupied by each species in amphibian assemblages in areas with different hydrology, it will be possible to predict how the assemblage will change during restoration. This will assist managers in assessment of proposed hydrological changes and restoration success.

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Table 1: Proportion of sites occupied by amphibian species by habitat in ENP.

Habitat	*Acris gryllus*	*Bufo quercicus*	*Bufo terrestris*	*Gastrophryne carolinensis*	*Hyla cinerea*	*Hyla squirrella*	*Rana grylio*	*Rana sphenocephala*
Pineland	0.63	1.00	1.00	0.64	0.95	0.94	0.33	0.38
Rocky Glades	0.84	0.60	0.21	0.46	0.99	0.61	0.90	1.00
Hammock	0.85	0.00	0.49	0.67	0.96	0.39	0.91	0.76
Cypress	0.84	0.00	0.00	0.66	0.90	0.97	0.78	0.68
Mangrove	0.00	0.00	0.47	0.40	0.49	0.53	0.27	0.35
Slough	1.00	0.00	0.39	0.28	1.00	0.24	1.00	0.76

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Everglades Plant Community Invasibility and Facilitation of Invasion by Native Plant Species

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Invasibility, which describes a community's ability to resist invasion by exotic species, is an ecosystem property that emerges from the strength of interactions among species in the ecosystem and between species and the abiotic environment. W.M. Lonsdale (1999) proposed that the number of exotic species in a region (*E*) is a product of the number of exotic species introduced (*I*) and the survival rate (*S*) of these species in their new habitat. Given the large number of exotic species already in south Florida, understanding the invisibility of native plant communities requires understanding *S*. Lonsdale breaks *S* down into S_v (survival after competition with native species), S_h (survival after herbivory and pathogens), S_c (survival after chance events at establishment), and S_m (survival after extinctions due to maladaptations). S_v is especially affected by disturbance, which alters the competitive regime of native species. Propagule pressure, or the number of propagules arriving at a site, is also important in invasion dynamics of natural areas. Because native species are already adapted to extant S_h, S_c, and S_m, and because they are pre-dispersed in the landscape, they have an increased probability of invading under conditions of environmental disturbance. Such invasions cause additional disturbance. I propose here that exotic invasions can be facilitated by invasions by native species (Figure 1) and present 2 examples of community change caused by invasions by natives in south Florida.

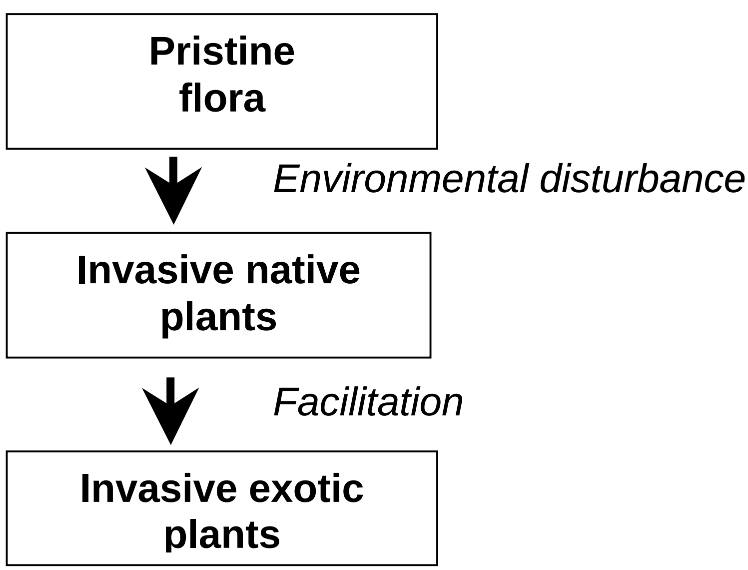

Figure 1. Model for facilitation of exotic species invasions by native invasive plant species.

In its undisturbed state South Florida is an oligotrophic ecosystem that has both aquatic and terrestrial communities. South Florida's aquatic communities should be among the least invasible community types, because plants living in these environments have to adapt first to the aquatic habitat, then to a nutrient-poor environment. Plants living in short- and many long-hydroperiod marshes have the additional requirement of being able to withstand more or less extended periods of dry-down. Native plants are able to out-compete invasive plants in this environment. Thus, the dominant Everglades macrophyte, sawgrass (*Cladium jamaicense*), has a high tissue N: P molar ratio (56 ± 12 for samples collected at 30 sites across the Everglades), indicating that it can build biomass for less P per g dry weight than most other plants. Thus, S_v for exotics is very low in pristine environments, and the natives that grow in these environments have special adaptations that enable them to succeed.

In 1999, as part of their REMAP study, the US Environmental Protection Agency surveyed plant species presence and abundance across the Everglades ecosystem from Loxahatchee National Wildlife Refuge to the landward margin of Florida Bay. One hundred and twenty sites were sampled in May 1999 and an additional 120 in September/October 1999; a stratified sampling scheme was used. Soil and water samples were collected for nutrient analysis from the same sites within 2 weeks of the plant sampling. Plant species presence and relative abundance was recorded for 1 or 2 10 M transects per site; 418 transects were sampled.

A total of 161 plant species were recorded from these transects; of these 128 samples were identified to species and 8 to genus, for a total of 136 identified taxa. Five exotic species, *Alternanthera philoxeroides, Ludwigia peruviana*, *Lygodium japonicum*, *Melaleuca quinquinervia* and *Panicum repens* (3% of the species sampled), were found along the transects. All but *L. peruviana* are Category I or II invasives on the Florida Exotic Pest Plant Council's 1999 list of invasive species. They occurred at 1 to 3 sites each and were found in single ¼ m^2 quadrates in all cases except for *Alternanthera. Alternanthera* occurred at a single site where 2 transects were sampled; it was present in all 20 ¼ m^2 quadrates of 1 transect but only 1 ¼ m^2 quadrate of the other transect.

In contrast to these invasive exotics, the invasive native cattail, *Typha domingensis,* was abundant in parts of the Everglades ecosystem. Cattails occurred in 55 transects (13%). This species occurred at frequencies greater than 15/20 ¼ m^2 quadrates in 22% of these transects. Cattail invasions are associated with increased P levels in the soil and, often, with deeper water and/or longer hydroperiod. Thus cattails, which are preadapted to native herbivores and pathogens (S_h), natural random disturbances (S_c), and the natural environmental conditions (S_m), and have extant, predispersed seed sources to provide propagule pressure (I), succeed when environmental disturbance such as soil P enrichment or increases in water level favor them in competition with sawgrass.

Similarly, native periphyton mats that are common in pristine south Florida marshes have a characteristic flora of algae and cyanobacteria that are adapted to oligotrophic, P-poor conditions. A long-term P dosing experiment in Everglades National Park has shown that levels of P addition as low as 5 μg above ambient cause a change in mat flora to species that are present in low abundance in the native mat but are not dominant. These new species create populations with very different structural and functional characterisitics. Essentially, the calcareous mat disintegrates, creating new habitat through increased light levels throughout the water column. This new habitat is open to invasion by exotic species.

Exotic plant invasions are successful when the invaders either create new habitat or effect ecological processes in existing habitat (Schmitz *et al.*1997). Invasion of new habitats by native species is an indicator of an environmental change that favors the invasive species. These species continue to alter the environment. Cattail populations can reduce oxygen levels in the water, increase soil nutrient levels through increased detritus, and reduce light levels in dense stands. Such environmental alterations create new conditions that may, in turn, facilitate invasions by exotic species. In the case of the periphyton mat, a completely new habitat with high light levels throughout the water column is created when the old habitat (the calcareous mat) is destroyed.

Dramatic increases in populations of native invasive species are thus indicators of environmental disturbance and can create conditions that facilitate invasion by exotic species. Because of their preadaptation to existing environmental regimes and predispersion through the landscape, they provide an early warning of environmental disturbance that will favor invasive exotics.

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Experimental Phosphorus Enrichment in Everglades National Park: II. Results

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This presentation describes the results to date of phosphorus (P) dosing research at the experimental flume facilities established in Everglades National Park by the Southeast Environmental Research Center, Florida International University. The experimental design, dosing protocols, and central hypotheses were described in the previous talk.

Phosphorus dosing began in October 1998 and has continued until the present time as long as flow exceeded the minimum rate necessary for downstream movement of P (2 mm sec^{-1}). Each year of dosing has included a no-dose phase during the dry season when flows dropped below the criterion.

Overall, the estimated patterns of cumulative load at the flumes (dosage rate weighted by actual water flow through each flume) matched the relative differences established by the experimental P concentrations. There is natural variation in the volume of water flowing through the sloughs where our flumes are located; this and slight deviations of flume orientation relative to local water flow have produced inter-flume variation in P load administered at the same dosing rates. Comparison among flumes provides insight into the effects of load when dosing concentrations are relatively constant.

Dose added as SRP is taken up into biotic components rapidly and efficiently. Water sample analyses rarely show elevated TP at any location within the flumes at any treatment (Figure 1A). Similarly, soil TP has remained the same over time (Figure 2). Instead, elevated TP levels have been found in the detrital flocculent material sampled at the soil surface (Figure 2) and in the floating periphyton mats at the water surface (Figure 1B). At all doses the macrophyte *Utricularia purpurea*, which forms part of the periphyton mat, rapidly responds with abnormal growth. Flocculent detrital sediment displays increased TP and microbial respiration at all concentrations of P dosing, while the soil below displays no response. The difference in these parameters between control and P-supplemented channels increased over time, and was most marked in the upstream portion of the flumes (1-3 m). We have observed no significant change in soil parameters below the detritus, including pH, ash-free dry weight, bulk density, TP, TN, TC and microbial parameters.

Our most striking result comes from periphyton analyses, which have revealed biologically important and statistically significant P-dosing effects at ALL treatment levels (including the 5 $\mu g\ l^{-1}$ above ambient treatment). Treatment effects were noted in increased periphyton-tissue TP concentration, in decreased periphyton biomass per m^2, and in mat species composition. Periphyton uptake of P was not related to P concentration in the water but instead was related to P load (Figure 1B). Other periphyton responses were noted at tissue TP concentrations above 300 $\mu g\ g^{-1}$, a level reached quickly even at our lowest dosing rate. This initial change in the periphyton community affects the entire ecosystem independently of additional responses to P levels through effects on other ecosystem parameters, such as light availability.

After one year of dosing, spikerush (*Eleocharis cellulosa*), the dominant vascular plant, displayed increased biomass in the upstream portion (20-m from the point of P addition) of the high-dose channel relative to the control. Analysis of standardized photographs showed that P dosing decreased the cover of periphyton and increased the cover of vascular plants in the upstream end of the high-dose flumes (near the dosing additions) but not in the downstream ends.

Nutrient treatment effects were noted in fish and some invertebrate groups, primarily at the upstream end (approximately 10 meters from the nutrient additions) of the flume channels. Biomass of consumers was enumerated separately for fish, amphibians, crayfish, grass shrimp, snails, and aquatic insects. Nutrient additions led to increases in the biomass of fish, grass shrimp, and snails, but not amphibians, crayfish, or aquatic insects sampled by the throw-trap technique. The pattern of estimated biomass of fish and grass shrimp across dose levels suggests a non-linear response with a marked increase between the medium and high dose level. Such non-linearity in the dose-response effects needs to be considered in future statistical modeling. The absence of treatment response in biomass of aquatic insects, amphibians, and crayfish may reflect a trophic cascade where increased abundance of fish and grass shrimp consume any increased production by aquatic insects.

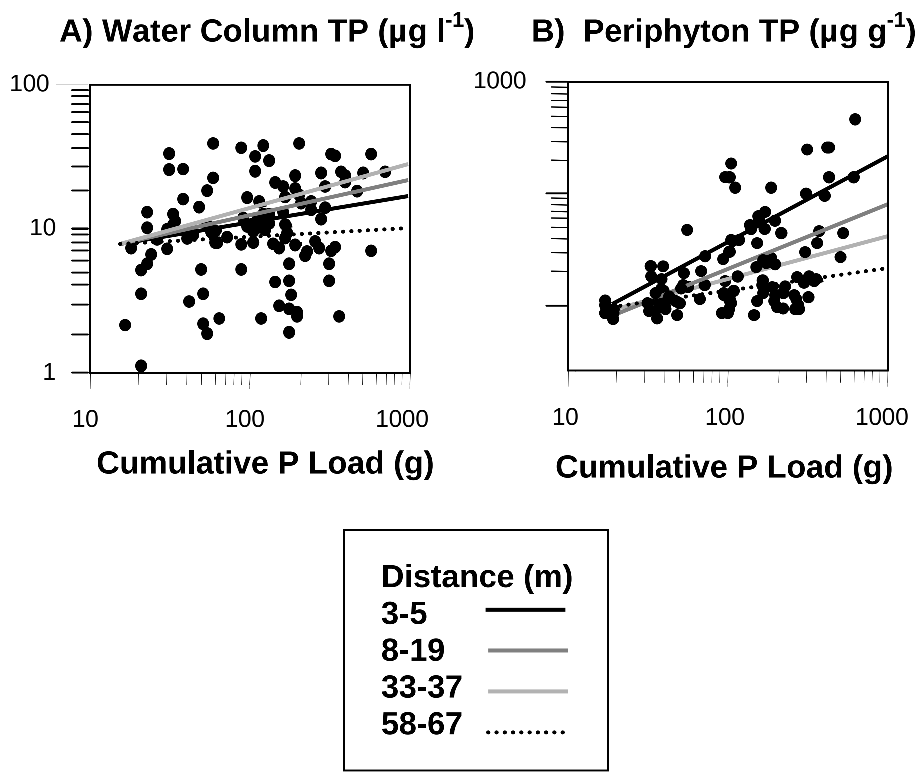

Figure 1. Water column (A) and periphyton (B) total phosphorus vs. cumulative P load.

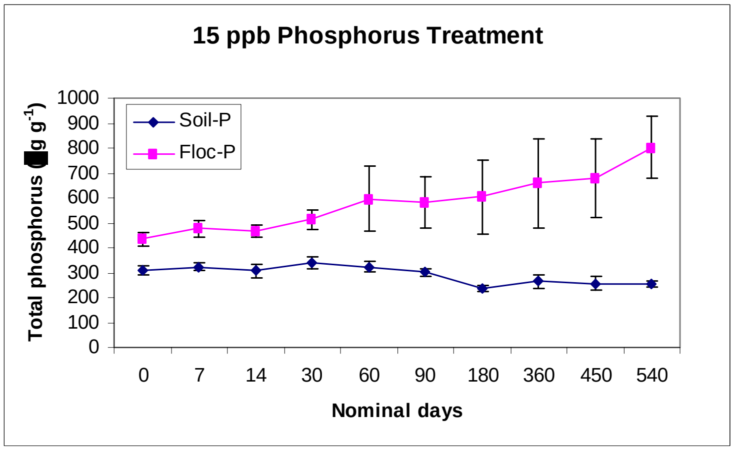

Figure 2. Soil and floc total phosphorus accumulation over time in 15 ppb P dose channels.

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Predicting Trophic Level Responses to Phosphorus Concentrations in the Everglades

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The Everglades are one of the most P limited wetlands in the world. The effects of varying levels of P additions are often debated but an understanding of the process that control P cycling and concentrations are essential to our being able to properly assess the P concentrations that will allow for the restoration of the structure and function of the Everglades. We present results from a 6 year phosphorus (P) dosing experiment in the Everglades and long-term gradient studies that suggest that the 10 ppb (μg/L) P threshold often given for average annual concentrations in oligotrophic waters ("natural pristine lakes") is not appropriate for defining oligotrophic wetland status in the Glades due to differences in ecosystem structure (periphyton versus phytoplankton) seasonal water depth affects on P concentrations, and natural nutrient gradients (i.e., higher exterior nutrient concentrations in wetlands gradate to lower interior nutrient levels) that exist in wetlands versus lakes. We show that biotic responses to water column concentrations for the Everglades is highly predictable across trophic levels but estimates of uncertainty and confidence intervals must be utilized to accurately bound biotic P thresholds responses, which change with water depths and across seasons. Bayesian change point analyses indicate that long-term water column phosphorus concentrations above 15.6 ppb (μg/L) P results in an ecological imbalance for both flora and fauna attributes.

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Water Pricing as a Conservation Tool: An Economic Analysis of the Lower East Coast of South Florida Water Utilities

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The Lower East Coast (LEC) of South Florida is characterized by fast population growth, high-income levels, urban development, and rising per-capita water demand. The supply of water is greatly controlled by the aggregate influence of population and economic activities. In order to keep the growth in water demand under control, the South Florida Water Management District has been promoting water conservation measures at the utility and consumers' levels.

These measures range from educational programs to more direct practices such as water pricing. Water utilities often tend not to opt efficient pricing as a water conservation tool. At the time of implementing effective price levels and structures, Florida's water utilities are mandated by their respective County Board of Commissioners. These Boards impose controls and regulations that affect the implementation of water pricing methods.

Despite the recent efforts from water management agencies, county governments have allowed water utilities to adopt no-profit-no-loss policies (revenue-neutral pricing) in fixing prices (not depending on volumetric amounts), which normally end up in lower price levels and less efficient price structures than the *true* cost of water. The *true* cost of water is a concept that attempts to incorporate not just the costs of treatment and delivery of water but also includes the costs of extraction, the effects on the environment of this extraction and use (environmental externalities), and the forgone uses of water (user cost).

The purposes of this research are (a) to review the current water pricing policies of selected water utilities in the LEC region, and (b) to estimate the gaps between the water prices under the revenue-neutral pricing structure and the 'true-cost' prices under the alternative scenarios of population growth, income growth, technology improvement, and the ongoing Comprehensive Everglades Restoration Plan (CERP). It is claimed that the successful implementation of CERP projects (related to water supply and delivery) would reduce the problems of water scarcity in the future. This research also attempts to evaluate whether the new water supply to be generated by the Everglades restoration projects will have any impact on the water prices.

The study involves two phases. First, we carry out an analysis of the current regional situation for a period of five years in terms of economic and demographic patterns and water demand behavior. Second, a partial equilibrium model of the water market is designed and simulated using data collected from selected water utilities, South Florida Water Management Districts, demographic information from the CENSUS and other sources. The model is simulated for 30 years to compute the market prices and demand for residential and industrial water users.

The initial analysis reveals that per capita water demand depends not just on price but also on income and information provided by water utilities as far as conservation needs. Further, water utilities incorporate water conservation pricing structures only after the required regulations by the water management agencies. Per capita water demand has continued to grow over time, but at lower rates. However, prices are also increasing but the rates of increment and the structures do not reflect the *true* cost of water. The simulated efficient water prices under with- and without-CERP scenarios are found to be much higher than the estimated water prices under the current pricing structures. The above analysis is made under the assumption that the future CERP-enhanced water supply will be distributed between the environment and urban needs at 80 percent and 20 percent, respectively. If water is distributed strictly accordingly to this administrative decision, the CERP may not alleviate the water scarcity problem completely. An efficient water pricing structure is, therefore, recommended for LEC water utilities even with the new CERP-generated water sources. This water pricing structure will have to be flexible enough to represent the needs of the region and to account for the environmental externalities.

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The Utility of Mangrove Unit Models (FORMAN and HYMAN) in Support of the Comprehensive Everglades Restoration Plan

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The FORMAN (mangrove structure) and HYMAN (hydrology) models are used to link community development and biogeochemistry of mangrove ecosystems in the South Florida region. These models are applied to project the response of mangrove stands to changes in quantity and quality of discharge in Taylor River (TR) and Shark River (SR) as part of the Everglades Restoration Program. The SR and TR regions are characterized by significant differences in soil TP concentrations and hydroperiod. The HYMAN model simulates soil salinity and was calibrated using long term water level and salinity data from 1995-2002 for 3 sites in both regions. The FORMAN model was also calibrated to simulate mangrove structural changes as a function of salinity and Total Phosphorous (TP). Models were run to evaluate different scenarios of freshwater diversion as a part of the 2 x 2 South Florida Water Management model. Model simulations indicate the critical importance of TP and elevation in controlling mangrove species composition and productivity.

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The Response of Everglades Tree Species to Simulated Hydrologic Regimes: An Experimental Study

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Tree islands appear in many forms in the Everglades landscape, each with a characteristic regional distribution, physiography, shape, and plant species assemblage. Surface elevation at the center of most southern Everglades tree island types is higher than the surrounding marsh. Consequently, a gradient between well-lit, frequently flooded edge locations and shaded, better-drained interior positions can usually be identified, with individual species arranged in a predictable sequence along it. However, the responses of Everglades tree species to this environmental gradient have rarely been tested under controlled conditions. In this presentation we describe the response of twelve tree species to three realistic hydrologic regimes that were applied while holding other variables (e.g., light, nutrients) constant across treatments. Seven species (*Annona glabra, Magnolia virginiana, Myrica cerifera, Persea borbonia, Ilex cassine, Chrysobalanus icaco, and Salix caroliniana*) were characteristic of Shark Slough Bayhead and Bayhead Swamp forests, while five (*Coccoloba diversifolia, Mastichodendron foetidissimum, Eugenia axillaris, Bursera simarouba*, and *Simarouba glauca*) were common in Hardwood Hammocks in the region.

Recently emerged seedlings of all species were collected from Everglades tree islands in May-June 2001, and planted in standard potting soil in small peat pots. After several months in greenhouse conditions, healthy seedlings of each species were transferred to larger pots and an organic soil medium, where they were maintained in a shadehouse (50% full sunlight) erected on the FIU campus. All plant individuals were treated with a systemic insecticide and slow-release fertilizer three weeks before the experiment commenced in April 2002. The experimental design was randomized complete block, with 36 Species x Treatment combinations represented twice in each of four blocks. The blocks were plastic-lined tubs in which water levels were managed to mimic variation among weekly means from the years 1990-1999 at a single Shark Slough water level recorder. Treatments representing Hammock, Bayhead, and Bayhead Swamp hydrologic regimes were maintained in each tub by supporting the three sets of pots on stages (plastic pots and wastebins) established at the appropriate relative heights (Hammock at 57 cm, Bayhead at 27 cm, and Bayhead Swamp at 0 cm) indicated by topographic surveys in Shark Slough tree islands. Plant structural and physiological responses were monitored at 1-6 week intervals throughout the experiment, which was continued for 30 weeks.

Upland species showed signs of stress from inundation by Week 12, though most remained alive through the end of the experiment. Some species typically found in Bayhead and Bayhead Swamp sites appeared to be better adapted to rising water levels than others. Our data suggested that *A. glabra, M. cerifera, M. virginiana,* and *S. caroliniana* responded most positively to flooding, while *P. borbonia, C. icaco,* and *I. cassine* were less flood-tolerant. The arrangement of species according to their response to the flooding treatment were for the most part established within the first 12 weeks of the experiment, and these rankings roughly paralleled their spatial distribution in the marsh landscape. Tracking hydrologic responses directly in the shadehouse may allow us to isolate the mechanism and timing of species' morphological and physiological responses. Results from such experimental treatments may eventually allow early warning of flooding stress in tree islands, and modification of water distribution – information that may be useful Everglades water management.

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Spatial and Temporal Patterns of Fish Population Dynamics in the Everglades

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We examined population dynamics of five abundant fishes in the Florida Everglades. Fishes were collected with 1-m^2 throw traps at 17 sites five times per year between 1996 and 2001. Our sites were located throughout three water-management units (Water Conservation Area 3A, Shark River Slough, and Taylor Slough), and sampling events corresponded with important transitional phases of the wet-dry season (i.e., February, April, July, October, and December). We found significant patterns in fish density across space and time for all species. Variation in fish density among sites within water-management units was greater than among water-management units, and intra-annual variation was greater than among years for most species. These patterns in fish density were affected by local hydrology. We found significant relationships between fish density and time since the most recent drought, although the strength of these relationships varied among sites. *Heterandria formosa*, *Lucania goodei*, *Fundulus chrysotus*, and *Jordanella floridae* were most strongly affected by drought, whereas the response of *Gambusia holbrooki* was weak and variable. Densities of *Heterandria formosa*, *Lucania goodei*, and *Fundulus chrysotus* usually increased gradually following a drought. In contrast, densities of *Jordanella floridae* recovered quickly following a dry-down event and then usually declined. Our results suggest that local hydrology is an important factor shaping patterns of fish population dynamics across the Everglades landscape.

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Fuel Loads in the Understory of Florida Keys Pine Forests along a Chronosequence of Time Since Last Fire

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The pine rocklands of South Florida are globally endangered ecosystems containing a rich herbaceous flora with many narrowly endemic taxa. Pine rockland forests occupy uplands in Everglades National Park (ENP), Big Cypress National Preserve (BCNP), and the Key Deer National Wildlife Refuge (KDNWR). In the pine rocklands, fire plays an important part in shaping the structure and function of ecosystems. Many rare and endemic species are found in pine rocklands and depend on conditions resulting from frequent fires. In the absence of fire, a closed hardwood canopy develops and the characteristic pineland herb flora is lost. In fact, it is the requirement of these endemic herbaceous species for fire that led to the prescribed burning program in pine rockland forests in ENP and other areas. Here we characterize fuel loads before and after prescribed fires at six separate sites in the KDNWR during a four year period (1998-2001). The sites represented a chronosequence of 30+ years since previous fire, and we take advantage of this range in stand histories to assess how rapidly fuels accumulate over a decadal scale.

Experimental burns were carried out at two times of the year: in June/July (wet season), and in December/January (dry season). Two types of pineland were treated: those with a relatively sparse shrub layer and a well-developed herb layer and those with a dense shrub layer and poorly developed herb layer. In each type of pineland, three blocks of at least 4 ha were established, each containing three plots of 1 ha each and a buffer area. Altogether there were 18 plots scattered in six blocks (2 types of pineland x 3 blocks x 3 treatments), namely Buttonwood, Dogwood, Iris, Locust Berry, Orchid and Poisonwood.

Fuel loads were measured before and after the burns to estimate fuel consumption. Shrub fuel was measured in 20 circular 50 m^2 sub-plots within each 1 ha burn unit. Pre-burn low vegetation and woody fuels were collected from two 50 cm x 50 cm quadrats nested within the shrub sub-plot, and were defined as all live plant material less than 0.5 cm in diameter and all dead plant material < 2.5 cm up to 1 m above ground level. After burning the remaining low vegetation and woody fuels were collected from adjoining quadrats. Materials were sorted into live and dead fuels, and further into the following categories: forbs, ferns, grasses (including sedges and grass-like forbs), woody plants, palms, litter less than 0.5 cm, and litter greater than 0.5 cm but less than 2.5 cm, and dried at 70^o C.

Significant among-block differences were detected for both shrub ($p = 0.0003$) and total low vegetation fuels ($p < 0.0001$) before fire. Shrub biomass and low vegetation fuels increased in a sigmoid pattern with time since previous fire. The three longest unburned sites, Buttonwood, Poisonwood and Dogwood, did not differ in total shrub biomass, suggesting that shrub biomass stabilized after about 11 years. Pre-burn low vegetation fuels reached highest after 12 years since last fire. Low vegetation fuel consumption ranged between 40% in Locust berry and 73% in Dogwood, but was not correlated with time since last fire. Post burn recovery of shrub and low vegetation biomass also varied among sites depending on their micro-climatic conditions. The present results suggest that fuel loads were the function of time since last fire in pine rockland forests.

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The Next Generation South Florida Water Management Model – Moving into the 21st Century with Version 5.0

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As we move into the 21st century, the next generation South Florida Water Management Model (SFWMM), released as version 5.0, will be the primary tool for regional hydrologic modeling and an essential element in supporting the objectives of the Comprehensive Everglades Restoration Plan (CERP). The Plan, approved in the Water Resources Development Act of 2000, provides a framework and guide to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades. It includes more than 60 elements, will take more than 30 years to construct, and will cost an estimated $7.8 billion. Extensive use of the SFWMM is documented and enhancements to the SFWMM presented.

The SFWMM has been used extensively as the primary regional modeling tool in evaluating the effects of different water management alternatives in regional and operational planning efforts in South Florida. The SFWMM has been applied to the following projects:

- Development of the Draft Lower East Coast Regional Water Supply Plan
- Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement (Restudy)
- Modified Water Deliveries Project (MWD)
- Lower East Coast Regional Water Supply Plan
- Water Preserve Area (WPA) Feasibility Study
- Interim Structural and Operational Plan (ISOP) and Interim Operational Plan (IOP)
- Everglades Construction Project (ECP)
- Operational Planning
- Drought Management
- Preliminary Water Reservation sensitivity analysis

The next generation SFWMM incorporates significant updates with respect to previous versions, such as:

- Extension of climatic record by 5 additional years to include data through December 2000 (period of simulation is now 36 yrs from 1965 to 2000)
- Topography using latest USGS data for Everglades National Park and Water Conservation Area 3
- Land cover data using the latest satellite images (1995) and areal photographs (2000)
- Updated demands and runoff for the Caloosahatchee and St. Lucie Basins
- Updated Public Water Supply and Irrigation demands
- Restructured code and documentation of input files

- Additional code to simulate daily variation in canal water surface slope for selected major canals
- Additional code to simulate reservoirs, whose areas are significantly less than the resolution of the grid network, as separate entities
- Additional code to simulate drought features, such as backpumping of Everglades Agricultural Area (EAA) runoff to Lake Okeechobee (LOK), forepumping of LOK water for water supply purposes, and delivery of LOK water to the EAA and the Lower East Coast (LEC) on specified days of the week in order to minimize competition for use of conveyance for water supply
- Additional code, applied to selected structures, in order to deviate from normal operations during simulation according to certain conditions such as heavy rainfall, or conditions associated with operation of the IOP
- Calibration/Verification through December 2000
- New and improved post processing and performance measure utilities that incorporate additional flexibility and ease of use
- Creation of new performance measure graphics which meet the requirements of the Regional Evaluation Team (RET), which is critical in the Restoration Coordination and Verification (RECOVER) process

These enhancements enable the SFWMM to continue to play a key central role in regional hydrologic evaluation of different water management alternatives for short-term and long-term planning efforts in South Florida. Further evolution of the SFWMM will occur as new requirements arise from future projects. Additional information on SFWMM v5.0 and calibration/verification results can be found at:

http://www.sfwmd.gov/org/pld/hsm/models/sfwmm/index.html

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USDA-Everglades Agro-Hydrology Computer Model (EAHM)

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The agricultural area of south Miami-Dade County, Florida, is bounded by urban development to the north, Biscayne National Park to the east, Everglades National Park to the west, and Biscayne Bay and Florida Bay to the south. Agricultural goods are worth about $538 million annually in Miami-Dade. Over 23,000 people are directly involved in the county's highly efficient agriculture. The climate is maritime subtropical with a yearly mean of 23 °C and an annual rainfall of 165 cm. The warm climate, high humidity, and ample rainfall allow for the production of tropical and subtropical crops year round and traditional vegetable crops for eight months of the year. The long-term plan by the Comprehensive Everglades Restoration Plan (CERP) to increase water flow to the ENP and Florida Bay may elevate the water table in parts of Miami-Dade and the resulting spatial and temporal flooding will have an adverse effect on the agricultural production. During the dry season (October - May) crops may face a shortage of water as the porous limestone soils have a very low water holding capacity and frequent irrigation is needed to maintain crop production. The quality of water seeping into the aquifer is another cause of environmental concern. The nutrient loading from agricultural and urban areas had significantly increased nutrient concentrations, particularly phosphorus at the ENP (EPA, 1996). Considering the three national parks (Everglades, Biscayne and Big Cypress) in south Florida, major challenge in agricultural production is the development of satisfactory techniques that combine optimum crop production with environmental protection.

Model Description

Hydrology Component-The EAH model (Fig. 1) maintains a continuous daily water balance using the following equation (Savabi et al., 2001):

$$SW_d = SW_{d-1} + (P_d \pm (S)) - (RO_d + D_d + Qd_d + ET_d) \qquad (1)$$

Where, *SW* is root zone water content (*m*), *d* is day of simulation, *P* is daily precipitation (*m*), *S* is snow water content (m) ((+) for snowmelt and it equals daily snowmelt, (-) snow accumulation), *RO* is daily surface runoff (m), *D* is daily deep seepage (*m*), Q_d is daily subsurface drainage or subsurface lateral flow (*m*), and *ET* is daily evapotranspiration (*m*).

The subsurface lateral flow is calculated using the mass continuity equation (Sloan and Moore, 1984):

$$\frac{S_2 - S_1}{d_2 - d_1} = PE - (D + ET) - \frac{q_1 + q_2}{2} \qquad (2)$$

Where *S* is the drainable water (*m*), d is day of simulation, *PE* is percolated water to the drainable layer ($m\ day^{-1}$), *D* is seepage out of the drainable layer ($m\ day^{-1}$), ET is actual evapotranspiration from drainable layer ($m\ day^{-1}$) and q is discharge from the hillslope per unit width (*m*) (Sloan and Moore, 1984). Calculation of subsurface lateral flow is done on a daily basis:

$$q = 86400\ H_o\ K_{e\,(a)}\ Sin\ \%\qquad (3)$$

Where, K_e is the horizontal hydraulic conductivity ($m\ sec^{-1}$) at moisture content *a* and % is average slope angle.

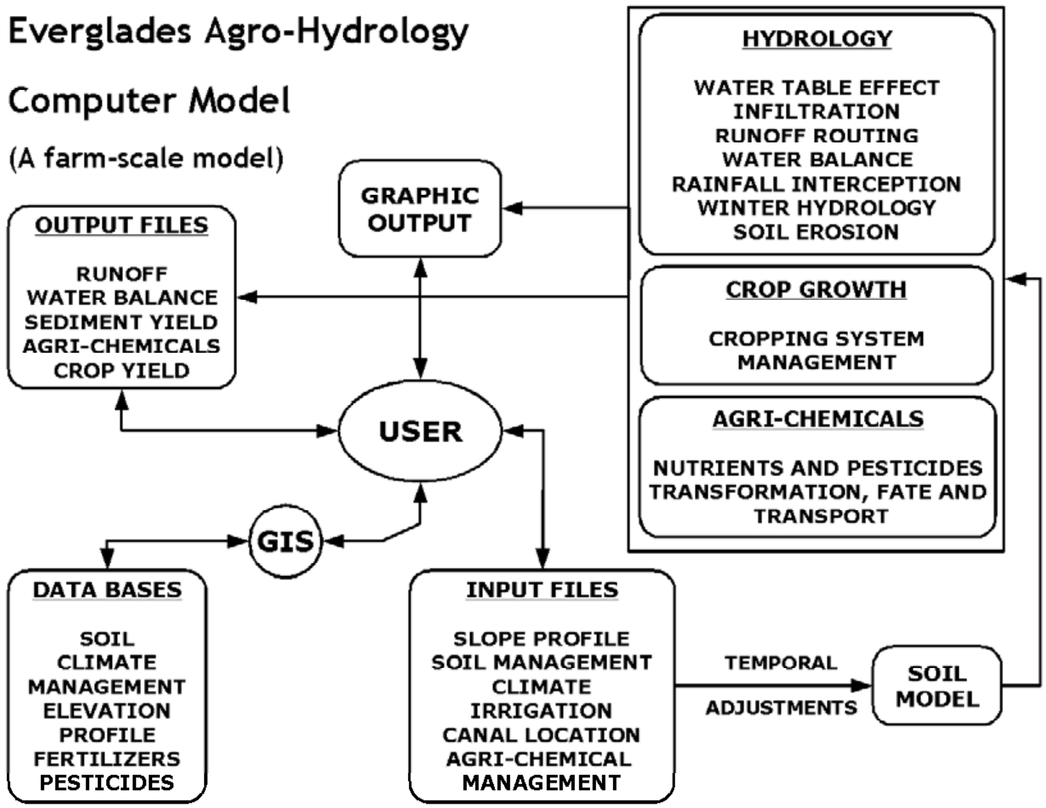

Figure 1. *The schematic representation of the USDA-Everglades Agro-Hydrology Model.*

Agro-Chemical Transport Component - The surface runoff and sediment losses of nutrients and pesticides and leaching losses are considered in the model. An approach similar to GLEAMS model (Leonard, et al., 1987) has been adapted to simulate the chemical transport. In order to represent the daily nutrient state of the system, relatively complete nitrogen and phosphorus cycling are included. The two nutrient elements are treated as nearly alike as possible, that is mineralization from crop residue, from soil organic matter, and from animal waste, immobilization to crop residue, solution and adsorbed phases for transport and routing, and crop uptake. There are some obvious differences considered such as nitrogen fixation by legumes, denitrification, nitrogen in rainfall, ammonia volatilization from animal waste, and two-stage mineralization of nitrate–ammonification and nitrification.

Conclusions

A computer model, Everglades- Agro-Hydrology Model (EAHM), has been developed. The Everglades Agro-Hydrology model will be linked with the regional computer model via GIS.

The model then will be used to evaluate the possible impact of the agricultural practices in the water quantity and quality of South Florida while considering the implementation of the CERP.

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Oyster Physiology and Ecological Distribution as an Indication of Environmental Health and as a Performance Measure of Restoration Effectiveness of Southwest Florida's Estuaries

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Oyster reefs make excellent sentinels for estuarine health in Southwest Florida. Oyster reef development is critical to estuarine ecology and to the geomorphologic structure of the region. The development of mangrove islands that differentiate the inner and outer bays and passages along the coast is founded upon oyster reefs. Additionally, because the eastern oyster, *Crassostrea virginica*, is the principal suspension feeder within these estuarine waters, oyster reefs are critical to pelagic – benthic coupling. Reefs remove the carbon fixed by these waters' principal primary producers, the phytoplankton, and transfer that carbon to the benthos. This filter feeding ability also serves to improve water quality and clarity for benthic primary production. Lastly, oyster reefs are "essential fish habitat" and provide substrate for many other fin- and shellfish species. Because many of Southwest Florida's estuaries lack prolific sea grass beds, oyster reefs are therefore the most "valued ecosystem component" of our estuarine system. Consequently, oysters and their reefs are ideal measures of estuarine health and can be used to monitor management and restoration practices.

Our research investigates the response of oyster growth, standing stock, mortality, larval recruitment, disease prevalence (to DERMO, caused by the protozoan parasite *Perkinsus marinus*), and living density on reefs, and upon oyster reef distribution and aerial extent to water management within altered and pristine estuaries in Southwest Florida. Studies have been completed or are presently underway in the Ten Thousand Islands, Henderson Creek (within waters of Rookery Bay NERR), Estero Bay, and the Caloosahatchee River.

The results presented herein concern three estuaries within the Ten Thousand Islands that are germane to a pending CERP restoration project: South Golden Gate Estates. South Golden Gate Estates (SGGE) is a 94 square mile tract of drained wetland that was originally altered for a large housing development in the 1960s. The developer, Gulf America Corporation, had planned and subdivided the area, but went out of business before homes were built. Development, however, was not halted before networks of drainage canals and roads were constructed. These canals and roadways have disrupted sheet flow into the estuaries of the central Ten Thousand Islands and have generated a freshwater pollution point source, through the main Faka Union trunk canal, to Faka Union Bay. Estuarine ecology has been drastically altered as a result. SGGE has been targeted for restoration since the 1970s as the impacts of excessive drainage became apparent. Since that time, SGGE restoration was designated a South Florida Critical Ecosystems Restoration Project under the Water Resources Development Act of 1996 and is presently a proposed project of CERP. The expected engineering improvements to SGGE include the disassembly of the canals feeding the Faka Union canal, the possible use of spreader canals, and the removal of roads.

Three estuaries were considered: (1) Faka Union, the estuary most impacted by present-day water management and the one to be monitored most carefully during and after SGGE restoration; (2) Henderson Creek, located south of the city of Naples, outside the influence of SGGE management but also an estuary under restoration; and (3) Blackwater River, a relatively pristine estuary within the Ten Thousand Islands west of Faka Union. Some of the measures concerning oyster physiology and ecological distribution outlined above were made seasonally (wet versus dry season); others were made monthly; and oyster reef distribution was mapped once at the study's initiation. Measurements were compared using a "spatial homologue" approach. Because the three estuarine systems have a comparable geomorphology (i.e., similar bay distributions and sizes, watershed areas, and drainage lengths), this suggests that prior to human alteration they had similar hydrologies. Consequently, it is appropriate to assume that spatially homologous points along the onshore-offshore estuarine axis (i.e., those located at equal distances upstream from the outermost marine coastline) had similar water quality characteristics (e.g., salinity) and that oyster ecology and physiology were comparable when the estuaries were in their natural state. Aspects of water quality and oyster physiology and ecology were compared among 5 spatially homologous points within the 3 estuaries. Any deviation in conditions from those measured in Blackwater suggests a human-effected change in Faka Union.

Results clearly demonstrate that water management practices, specifically the impacts of freshwater inundation from the uncontrolled draining and channeling of the wetlands within SGGE, have adversely affected oysters and the development of reefs. In Faka Union, an estuary that receives excessive freshwater during the rainy season because its watershed has been enlarged, reef distribution, regions of maximum living density, recruitment, and standing stock are displaced seaward along the estuarine axis relative to the pristine estuary. Henderson Creek, an estuary receiving pulses of nutrient-rich freshwater because of a crude weir design, has populations with higher standing stocks and densities. Two demographic patterns in standing stock are consistently discernable: one of greater variance, indicating a wider age distribution and a second skewed toward smaller individuals, indicating greater juvenile mortality. The first pattern persists where pulsed release or protracted inundation of freshwater occurs. The alternative pattern dominates in natural settings. The persistence of small oysters with few older individuals, seen in the latter, is related to the net effect of recruitment, growth rate, and susceptibility to the disease-causing parasite *Perkinsus marinus*. Higher salinity and temperature increase *P. marinus* prevalence in adult oysters within all estuaries. Ironically, excessive freshwater input or freshwater pulsing favors disease resistance. However, despite the lower disease prevalence among adult oysters at upstream locations, juveniles in these water-managed estuaries experience heavy mortality due to freshwater releases. Similar patterns are seen in recruitment. Although spat recruit effectively to upstream locations within the managed estuaries, few of those individuals survive to reach adulthood.

The location and aerial coverage of reefs best exemplify the effect of water management. Of the 3 estuaries, Faka Union has the lowest area of reef occurrence (24,300 m^2; 1.0 % coverage) compared to 35,400 m^2 (1.7%) in Blackwater and 47,700 m^2 (1.6%) in Henderson. Additionally, the area of densest reef coverage in Faka Union is positioned downstream relative to Blackwater and Henderson and is now located in a region of the estuary where the accommodation space for reef growth is most limited. There is greater intertidal wetted area for reef development further upstream in and around the inner bays in the region that historically had the best water quality for reef development.

These results have great implications for hydrologic restoration. Because of the above effects, oyster physiology and distribution is proposed as a performance measure of restoration effectiveness. Target salinities to generate normal oyster distribution and physiological state are obtained by comparing altered to pristine estuaries using the spatial homologue approach or by comparison against hypothetically modeled conditions. Such approaches have been applied to restoration of SGGE and the Ten Thousand Islands. Performance measure targets have been established for the western Ten Thousand Islands by comparing these estuaries with spatial homologues in Fakahatchee Bay, a pristine estuary just east of the effected region. We predict that the restoration of sheet flow should improve oyster health, physiology, and ecologic distribution. The decrease in freshwater point-source discharge into Faka Union Bay that would accompany improvements in sheet flow should shift the foci of oyster growth, recruitment, standing stock, and reef distribution back to the middle regions of the estuary. Consequently, any restoration strategy that augments sheet flow and decreases freshwater point-source discharge should improve oyster physiology and reef development. The closer a strategy restores the natural pre-alteration sheet flow conditions, the better the predicted improvement in estuarine health.

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Applications of a Numerical Model for Simulation of Flow and Transport in Connected Freshwater-Wetland and Coastal-Marine Ecosystems of the Southern Everglades

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Water-management agencies responsible for implementing the Comprehensive Everglades Restoration Plan (CERP) need to insure that hydrologic conditions are maintained in land-margin ecosystems of Everglades National Park (ENP) that satisfy habitat requirements of endangered freshwater and estuarine species. The U.S. Geological Survey has developed a hydrodynamic/transport model uniquely suited to simulate flow and salt flux through these coupled surface- and ground-water ecosystems. A numerical algorithm was developed to synchronize surface-water tidal-compatible time steps with ground-water stress periods and to assure mass conservation of simulated flux quantities across the surface-/ground-water interface and land-surface boundary in the model (Swain and others, 2002). Hydraulic expressions, derived from hydrologic process studies in the Everglades, have been formulated to link flow resistance (Lee and others, 2002), wind stress (Jenter and Duff, 1999), and evapotranspiration processes (German, 2000) to vegetation properties and shallow flows typical of these low-gradient wetlands.

Two applications of the coupled model have been made that are largely within the confines of ENP (fig. 1). The Southern Inland and Coastal Systems (SICS) model encompasses the Taylor Slough wetlands, part of the C-111 drainage basin, and sub-tidal embayments along the northern coastline of Florida Bay. The Tides and Inflows in the Mangrove Ecotone (TIME) model encompasses the SICS model domain, Shark River Slough, other western sloughs, and sub-tidal embayments and tidal creeks along the southwest Gulf coast. Measured surface-water flow discharges, water levels, and salt concentrations at tidal creeks (fig. 1) (Hittle and others, 2001); wetland water levels and flow velocities (Tillis, 2001; Riscassi and Schaffranek, 2002); and ground-water heads and salinities (Price, 2001) supplemented by sub-surface salinity maps (Fitterman and Deszcz-Pan, 1998) and peat thickness and hydraulic gradients (Harvey and others, 2000) were used for model calibration and verification. Tide levels and salt concentrations along the coast and discharges and water levels at hydraulic structures (fig. 1) and road culverts constitute the data used to drive the SICS and TIME simulations.

Flow exchanges between the surface- and ground-water systems simulated by the SICS model are presented in figure 2 to demonstrate its capability and illustrate typical model output. Positive exchanges, expressed as averages in cm/day for the 5-year simulation, indicate areas of recharge to the aquifer and negative values indicate areas of discharge to the wetlands. Similar output is available that identifies salt fluxes between the surface- and ground-water systems. Model output such as this is needed to fully evaluate the potential impact of restoration decisions for the greater Everglades on coastal land-margin ecosystems of ENP.

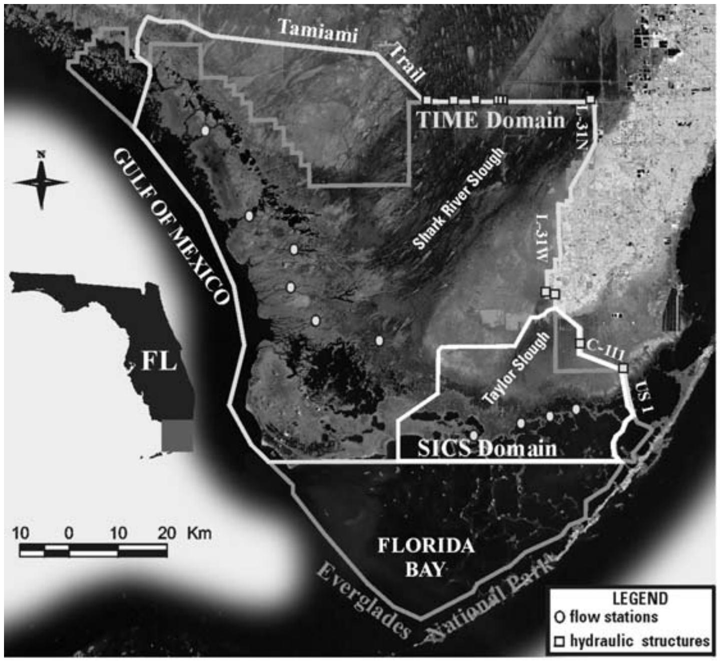

Figure 1. South Florida satellite image showing SICS and TIME model domains.

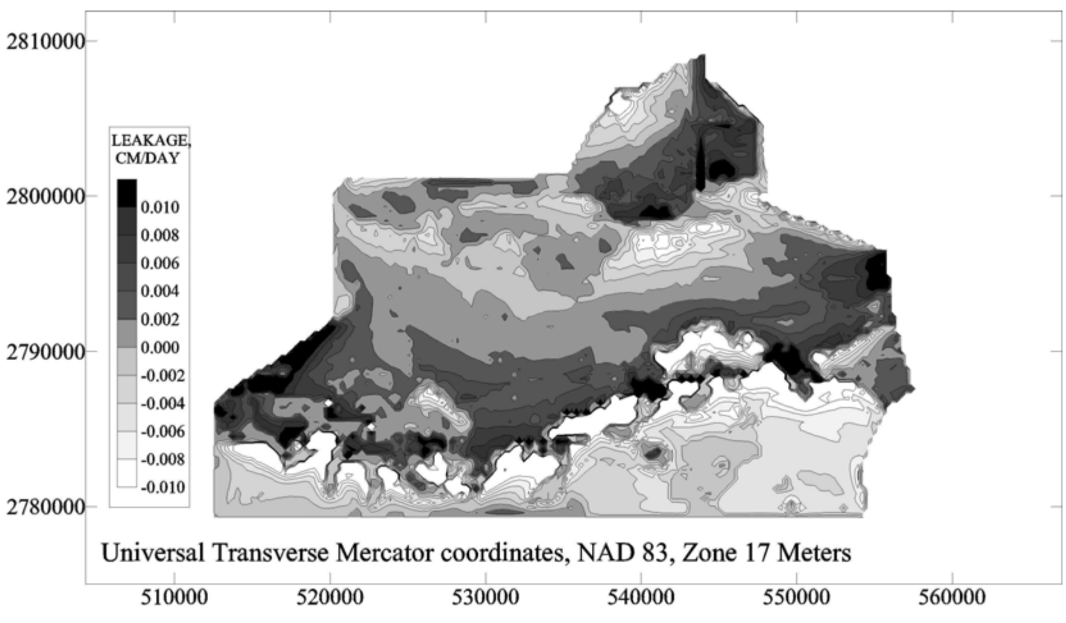

Figure 2. SICS model output showing surface-/ground-water exchange.

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Fire Effects on Flow in Vegetated Wetlands of the Everglades

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Fires are a critical, but not well-understood, dynamic occurrence that randomly and variously affect the Everglades ecosystem. However, fire impacts on subsequent surface-water (sheet) flow conditions have never been investigated. The nature of sheet flow in burned areas has not been documented and compared to adjacent unburned areas and any residual effects of fire on sheet flow behavior during vegetation recovery have not been assessed. The potential impacts of fire disturbances on vegetation and sheet flow behavior should be recognized and considered in the analyses of restoration scenarios being evaluated for the greater Everglades ecosystem.

In the late afternoon of June 2, 2001, lightning ignited a fire about 10 km west of Pa-hay-okee Lookout Tower in Everglades National Park (ENP). The fire was centered in a dense stand of sawgrass (*Cladium jamaicense*) at the headwaters of Squawk Creek, a narrow tributary of Tarpon Bay, approximately 5 km south of the ENP P35 water-level gage (fig. 1). On the afternoon of June 3, a rainstorm extinguished the fire but not before it burned approximately 202 hectares. Residual sawgrass plant stems, about 10 to 15 cm in length, remained above the top of the root zone. The location of the burn area afforded the opportunity to quantify the effects of fire on sheet flow conditions and to investigate flow behavior during vegetation recovery.

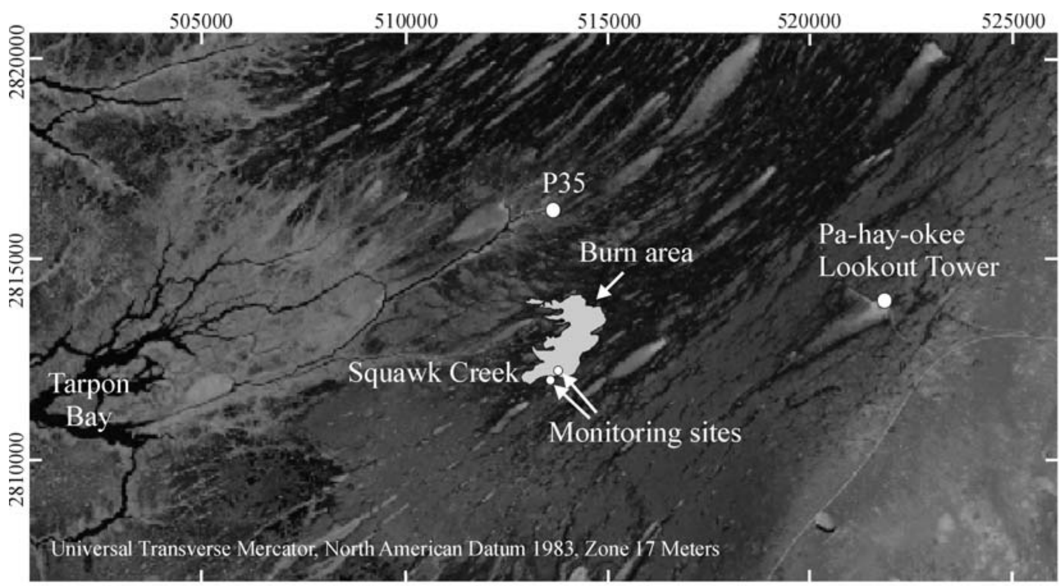

Figure 1. Satellite image of Squawk Creek burn area.

In August 2001, two flow-monitoring stations were established at the southern extent of the Squawk Creek burn area (fig.1). Located in burned and unburned vegetation approximately 280 m apart, each station consisted of a self-recording, point-sampling, acoustic Doppler velocity (ADV) meter. The ADV meters were set to record mean flow velocities simultaneously over two-minute sample intervals every 15 minutes. Analyses of initial continuous ADV data revealed periods during which flow velocities in the burn area were on the order of two times faster than in the unburned vegetation. During intermittent site visits, vertical velocity profiling was conducted at 3-cm depth intervals to document the water-column flow structure (fig. 2a) in conjunction with 10-cm incremental determination of vegetation volume (fig. 2b). Data from eight sets of vertical velocity profiles covering a depth range of 22 to 42 cm revealed similar two-fold velocity magnitude differences between the sites, particularly in the upper part of the water column (fig. 2a).

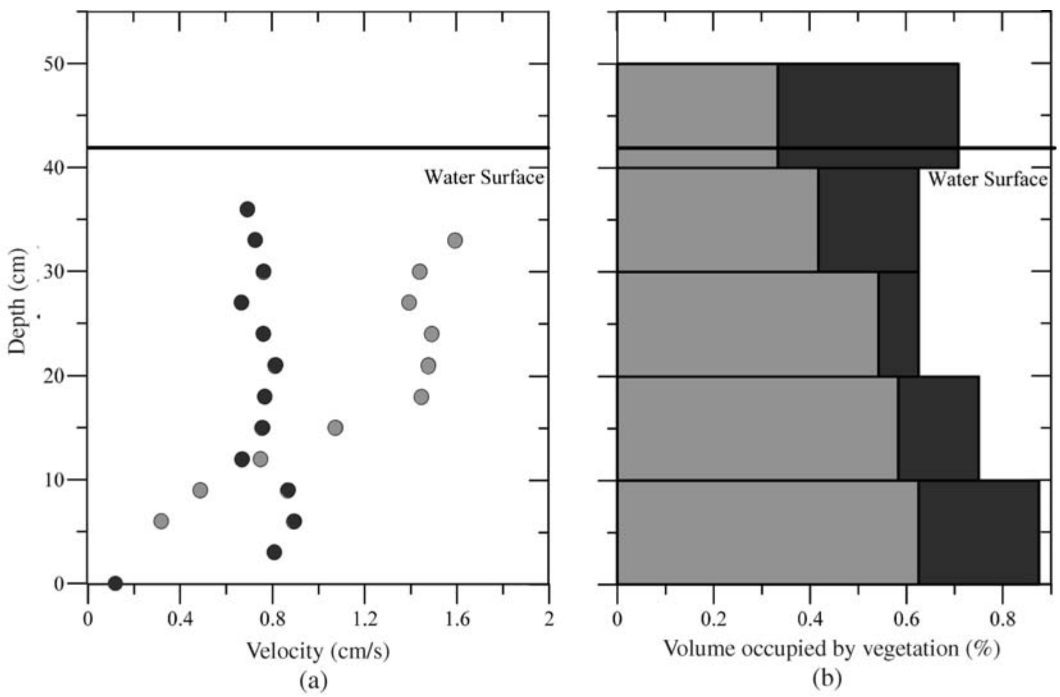

Figure 2. Velocity (a) and vegetation volume (b) measured at the burned (light gray) and unburned (dark gray) sites in June 2002.

During site visits, vegetation types and densities immediately upstream and within the flow paths to the ADV meters were assessed by measuring vegetation properties in selected areas of similar composition in the local vicinity of, but removed from interference with, the ADV probes. Initial vegetation differences, observed in August 2001, included lower plant heights and less biomass in the burn area as implied by the smaller number of leaves per sawgrass culm than in the unburned vegetation. During June and October 2002, emergent stem densities and vegetation volumes (expressed as a percentage of the water column volume) were measured at 10-cm depth intervals in three 0.04 m^2 quadrats at each site. Additionally, the diameters of all plant stems in the top 10 cm of the water column were measured to calculate stem spacing near the water surface. Plant heights were measured and qualitative observations of vegetation type and density also were recorded. In June 2002, the dominant plant species was sawgrass at both sites with lower plant heights measured in the quadrats and observed throughout the burn area. Vegetation volume within the 41-cm water column was less at the burn site (0.54 vs. 0.69 %) (fig. 2b) and stem spacing near the water surface was greater (3.4 vs. 2.5 cm). In October 2002, sawgrass remained the dominant plant species at both sites with lower plant heights again measured in the quadrats and observed throughout the burn area. However, significant quantities of periphyton and muskgrass (*Chara* sp.) also were found in the burn area. Both vegetation volume within the 32-cm water column, which included the periphyton and chara, (1.28 vs. 1.14 %) and stem spacing near the water surface (5.9 vs. 3.6 cm) were greater at the burn site.

Implications from measured, vertical velocity profiles (fig. 2a) are that remnant dead plant stems continue to impart equivalent, pre-fire shear-resistance effects on flow in the lower part of the water column. Although flow depths at the two monitoring stations were similar during all site visits, unit mass flux through the upper part of the water column at the burn site was computed to be equivalently greater than at the unburned site due to the greater flow velocities near the water surface. Reduced plant heights above the water surface as well as greater stem spacing just below the water surface appear to yield diminished sheltering effects from wind and reduced shear-resistance effects from vegetation thus contributing to the greater flow velocities in the upper part of the water column at the burn site.

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Sheet Flow in Vegetated Wetlands of the Everglades

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Little is known about the behavior of shallow surface-water (sheet) flows in and through the vegetated wetlands of the Everglades, including the nature and extent of the effects of water-management controls. This project focuses on quantifying flow velocities and investigating local and regional forces both internal and external that affect sheet flows in varied vegetative communities of the southern Everglades. The purpose of the project is to determine the magnitude, direction, and nature of flows in the wetlands of Everglades National Park (ENP). Insight into sheet flow behavior in wetlands is essential to the development and use of models to evaluate and compare restoration scenarios for the greater Everglades ecosystem.

Three stations were established in 1999 and 2000 to monitor flows and related hydrologic conditions in differing vegetative communities within Shark River Slough (fig. 1). Monitoring station SH1 was established in medium dense spikerush (*Eleocharis*) on the edge of a dense sawgrass (*Cladium jamaicense*) stand; GS-203 was located in medium dense sawgrass at the edge of dense sawgrass; and GS-33 was established in an area of patchy, medium dense spikerush with significant concentrations of submerged aquatic vegetation and periphyton. All three stations were co-located with hydrologic stations to provide water level and rainfall data for flow analyses. Additionally, GS-33 was located near a gage that provided meteorological data for use in flow analyses.

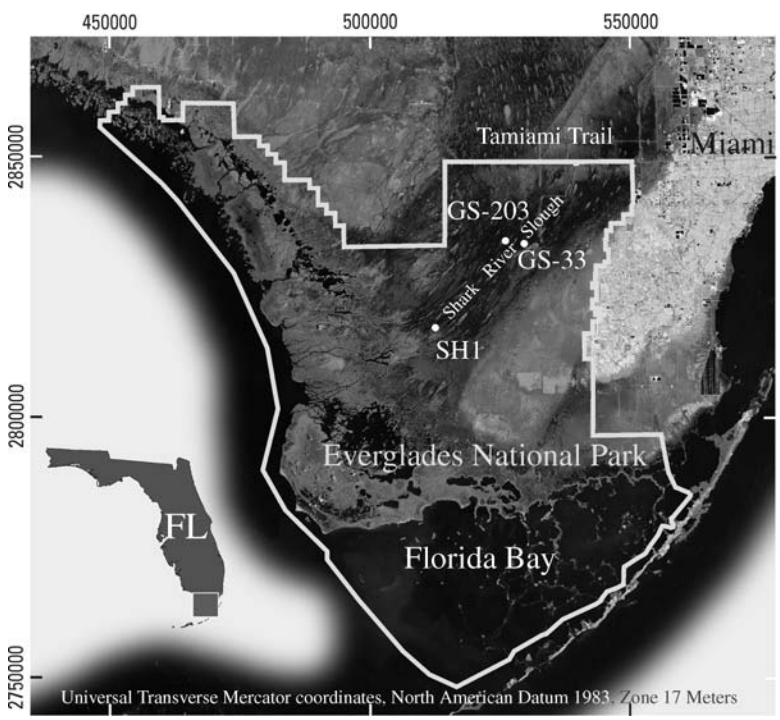

Figure 1. South Florida image showing stations GS-203, GS-33, and SH1.

Flow velocities, water and air temperatures, and specific conductances were monitored continuously, typically bi-hourly, at all sites. Flow velocities were measured at a fixed point in the water column using autonomous-recording, acoustic Doppler velocity (ADV) meters. The

ADV meter yields 3-D velocity components to a resolution of 0.1 mm/s with an accuracy of 1 % of measured velocity (Sontek, 2001). Water and air temperatures were monitored using thermistors spaced at 5-cm or 10-cm depth intervals above the plant litter layer. Specific conductances were sampled at a fixed point in the water column near the plant litter layer. All data were collected, edited, and filtered according to methods established and documented in Riscassi and Schaffranek (2002).

Vectors showing flow speeds and directions, in the horizontal plane relative to magnetic north, during the 2000-2001 wet season at GS-203 are shown in figure 2. Flow velocities were measured 10 cm above the plant litter layer throughout the wet season. Water depths at the ADV probe (fig. 2) were fairly constant at approximately 40 cm in late October through early November, but fell steadily in late November through mid-January (31 to 16 cm) except for one 4-cm increase on December 9th due to a rain event. Early in the wet season when water levels were relatively high, flow speed and direction averaged 0.62 cm/s and 235 degrees, respectively, with standard deviations of 0.06 cm/s and 7 degrees. As water levels declined in the later part of the wet season, the average flow velocity was slightly lower at 0.53 cm/s with an identical average direction. However, there was more than a threefold increase in the range of measured flow speeds and directions with standard deviations increasing to 0.19 cm/s and 22 degrees, respectively. Perturbations on the flow are considerably damped with increased flow depth as is clearly evidenced by both the quality and range of measured flow velocities. Implications are that during times of higher water levels more stable regional factors appear to drive flows more uniformly, however, as water levels fall, flow velocities at the sample depth decrease and become more susceptible to dynamic forces imposed by wind and rainfall at the water surface. Changes in the relationship between the water depth and vegetation composition as water levels fall also appear to alter the influences that vegetation has on vertical flow structure and, therefore, local sheet flow behavior.

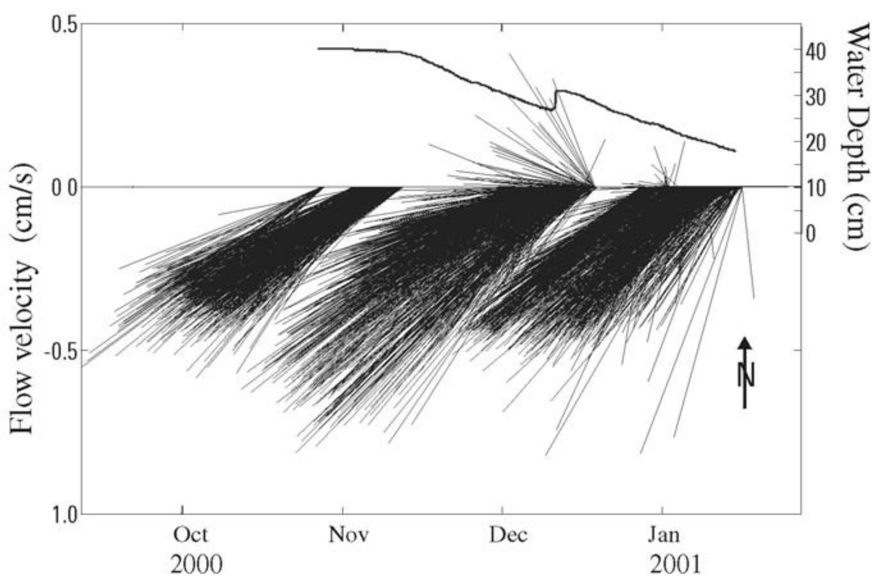

Figure 2. Water depths and flow velocities at station GS-203.

Data sets similar to that for GS-203 illustrated in figure 2, collected at the other sites, have yielded additional insight into the typical range of flow velocities found in particular vegetative communities and the dynamics of velocities and sheet flow conditions within and between sites. Findings from all data collected and analyzed to date at all sites indicate that dynamics in the magnitude, direction, and nature of sheet flows are attributed in varying degrees to both internal and external effects, both locally- and regionally-driven. Local conditions include the type, density, and physical attributes of vegetation in the area, as well as the presence and composition of submerged aquatic vegetation and (or) periphyton. Upstream vegetation, water levels, water-surface slopes, landscape gradients, proximity of airboat trails, presence of tree islands, and vegetative heterogeneity are regional factors that affect sheet flow conditions. Dynamic forces such as storm and rainfall events also have variable effects on sheet flow behavior.

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Salinity Tolerance of Introduced Swamp Eels: Implications for Range Expansion in South Florida

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Asian swamp eels (family Synbranchidae; genus *Monopterus*) are air breathing amphibious teleost fishes, typically inhabiting vegetated areas of streams, marshes, swamps, ditches, and temporary ponds. They are opportunistic predators and most species can survive out of water or in moist soils for extended periods. The native range for *Monopterus* includes tropical, subtropical, and temperate climates, not unlike the southeastern United States. This habitat similarity concerns natural resource managers since the lowland areas of the Coastal Plain could provide ideal conditions for its spread into natural or artificially created habitats. The biology of the swamp eel makes it well suited for a variety of habitats in Florida. This species has the potential to occupy natural aquatic and wetland habitats, including much of the Greater Everglades Ecosystem and other southeastern wetlands. If swamp eels successfully invade the Everglades, these fish could pose a major threat to native wildlife by reducing the abundance of small prey species, crayfish, fish, frogs, tadpoles, etc., that form the food base of larger fishes, wading birds, and other Everglades wildlife.

Salinity is one of the more important environmental factors that will determine potential range of swamp eels in South Florida and other parts of the United States. Because there is little information on the salinity tolerance ranges of swamp eels, potential range must be inferred from distribution within native ranges and anecdotal information on habitat in the scientific literature. The family Synbranchidae has a broad, native distribution, known to occur in fresh and occasionally brackish or estuarine waters. Although generally considered freshwater fishes, individuals of some species have been reported from brackish or estuarine waters (Rosen and Greenwood 1976) and one or more individuals of the Neotropical species *Ophisternon aenigmaticum* have been taken in hypersaline waters within a coastal mangrove (Tyler and Feller 1996).

We are currently aware of four populations of the Asian swamp eel (*Monopterus* sp.) in the southeastern United States. Three of the four populations are known from peninsular Florida. In 1997, populations of eels were discovered in north Miami (Dade County) and south of Tampa (Manatee County), Florida. In late 1999, an additional population was found near Homestead, in south Dade County, Florida. These populations are well established and reproducing. Initially, it was believed that all swamp eels introduced into the United States involved the species *Monopterus albus*, an eel with a very broad natural distribution in Asia and thought to represent a species complex. Recent genetic analysis (using mtDNA sequencing) of introduced and native swamp eels now indicates that the four introduced populations established in the southeastern United States represent as many as 3 distinct clades or species (Collins et al. 2002). In Florida, the North Miami and Manatee County populations are most similar, with the Homestead population being the most distinct genetically. Nevertheless, it is unclear how these genetically distinct lineages may vary with respect to ecological or life-history traits, and thus whether they represent different potential threats to the ecosystems they inhabit. The new information presents important implications concerning assessment and management of the different introduced populations. Depending on level of environmental tolerances, individuals from one of the established populations may be a more serious threat to the Everglades.

Swamp eels that inhabit the canal systems of South Florida may be exposed to varying levels of salinity based on their position within canals (e.g., distance from oceanic outlet) and water management practices. At this time, the salinity tolerance of swamp eels is largely unknown; however, genetic results indicate that some eels now in Florida were derived from (primarily) southern Chinese/southeast Asian stock. Thus, it is possible that they naturally inhabit estuarine areas. Consequently, determination of salinity tolerance of introduced swamp eels would aid in predicting their potential dispersal throughout the South Florida ecosystem, including potential dispersal into the Everglades National Park.

We determined acute (e.g., "plunge-type") salinity tolerance of swamp eels from the North Miami population, wherein swamp eels were transferred directly from freshwater (0.2 ppt) to a range of salinities (14, 16, 18, 20 & 22 ppt). Swamp eels tolerated transfer to 16 ppt for up to 6 d with no mortality. However, transfer to salinities $\leq$ 18 ppt were not well-tolerated by swamp eels. All swamp eels were dead by 24 h at 22 ppt and by 48 h at 20 ppt. Eel mass directly affected latency to death: Small eels expired more quickly than large swamp eels.

We are currently conducting a comparative study on the chronic salinity tolerance of swamp eels from each of the three known Florida populations: Homestead, North Miami and Manatee County areas. In this experiment, swamp eels are being held at 0.2 (freshwater control), 12, 14, 16 and 18 ppt. Although this experiment is currently ongoing, it is clear that the North Miami and Manatee County populations are less resilient to salinity stress than the Homestead population. The Manatee County and North Miami populations exhibited significant (>90%) mortality from salinity stress within 30 d at the highest salinity (18 ppt) and more than half of the swamp eels held at 16 and 14 ppt were dead within 60 d. Conversely, no swamp eels from the Homestead population died in the first 45 d of the experiment. Furthermore, swamp eels from Manatee County and North Miami were significantly less likely to feed during the experiment, while most Homestead swamp eels fed actively throughout the first 40 d of the experiment. Our study included a wide size-range of swamp eels (mean = 116.3 $\pm$ 130 SD; range 0.3 – 785.8 g), and thus we were able to determine that (similar to the acute experiment) smaller eels succumbed to salinity stress earlier than larger eels.

At present, all swamp eel populations in Florid are known only from freshwater habitats. However, additional sampling is needed to determine if they also occur in adjacent brackish-water areas. Based on our laboratory experiments on salinity tolerance, all three swamp eel populations in Florida are able to tolerate moderate levels of salinity. Individuals from the Homestead area exhibit the highest level of salinity tolerance. These preliminary results have important implications to South Florida. The Homestead population occupies the C-113/C-111, a canal system that flows south into Florida Bay and forms part of the eastern boundary of Everglades National Park. If not already present, it is likely that the population will eventually spread into southern parts of the Park and colonize brackish-water wetlands. Although our laboratory results suggest that the Homestead eels will continue feeding in such habitats, it is not yet known if the eels are capable of reproducing in these more saline habitats.

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Changes in Ecosystem Macronutrient Budgets, Microbial Characteristics and Vegetation Patterns along Phosphorus-Enrichment Gradients in Everglades Wetlands

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System changing perturbations, such as eutrophication processes, first affect those system components with short turnover times, rapid uptake and release kinetics, and short lifespan. Other system components with slower response kinetics subsequently show signs of change. Wetlands response to eutrophication tends to be more rapid and longer lasting in oligotrophic systems such as the Everglades. Thus ecosystem state change occurs as a cascade of response, first measurable in microbial and periphyton components, followed by sequential changes in soils, microinvertibrates, and finally in macroinvertibrates.

The original Everglades was an extensive (10 000 km2) oligotrophic wetland flowing from Lake Okeechobee south to the mangrove estuaries of Florida Bay. Approximately half the original Everglades have been developed for urban and agricultural use by filling and other hydrologic modifications including an extensive network of canals and water control structures. These hydrologic modifications have resulted in the compartmentalization of the once contiguous Everglades with water flows determined by placement and operation of water control structures rather than diffuse flow distributed across the landscape. Concurrent, to hydrologic modification was an increase in the nutrient load of the water entering the Everglades. For instance, canal water originating largely in the Everglades Agricultural Area (EAA) and discharging into northern Everglades marshes was shown to contain TP concentrations up to 30 times higher (100 – 300 $\mu g\ L^{-1}$) than typically found in unimpacted interior Everglades marsh water (<10 $\mu g\ L^{-1}$). These effects have been greatest in the northern Everglades and have led to a general north to south gradient in canal water nutrient concentrations. One characteristic response of wetlands to nutrient enrichment is an increase in soil nutrients and subsequent shifts in plant community composition. Well- documented gradients in soil TP and cattail (*Typha domingensis*) dominance have been observed in several areas of the Everglades.

In this project we sampled a total of 68 sites distributed among 5 transects throughout the Everglades. Transects were established perpendicular to inflow canals with sites located along suspected P-enrichment gradients. One transect was located in each of five areas: the Arthur R. Marshall Loxahatchee National Wildlife Refuge (a.k.a. WCA-1), WCA-2A, WCA-3A, and Shark River Slough (SRS) and Taylor Slough (TS) in Everglades National Park (ENP). At each site we examined patterns of P, N, and C, concentrations, standing stocks, and partitioning by sampling the surface water, periphyton, floc, soil, macrophytes and consumers. We positioned four of our transects (1999) in relation to transects that were originally sampled in 1989 to document changes in soil TP content and macrophyte species composition that has occurred over the past ten years.

Although water quality was shown to have improved throughout much of the Everglades in the 1990's we found that water quality impacts worsened during this time in the northern Everglades, WCA-1 and WCA-2A. Zones of high soil P (>700 mg kg^{-1} dry wt. soil) increased to more than 1 km from the western margin canal into the WCA-1 marsh and more than 4 km from the northern boundary canal into WCA-2A. An asymptotic, exponential decrease equation generally modeled P-enrichment gradients, when present, in soil and floc and allowed evaluation of differences in TP concentrations in enriched versus unimpacted areas. The expansion of high soil TP zones paralleled an expansion of cattail-dominated marsh in both regions. Where P-enrichment leads to a dominance of cattails it causes a state change in the ecosystem to P-rich components and an increase in the relative importance of macrophytes to the ecosystem P budget. This state change also decouples P accumulation from N and C storage. The proportion of total ecosystem P in the soil and floc compartments was approximately 95% of the ecosystem P and did not vary across the landscape. The TP concentrations in soil, floc, periphyton, and macrophytes were all positively correlated across the Everglades. Macrophyte species richness declined in WCA-1 and WCA-2A but not in the less-impacted southern Everglades (WCA-3A, SRS, TS). There was not an apparent change in plant community patterns at WCA-3A or in SRS over the period 1989-1999. Periphyton exhibited a shift from mat-forming oligotrophic assemblages to filamentous green algal assemblages with P-enrichment. Measures of microbial activity (enzyme activities and CO_2/CH_4 evolution) were correlated locally to Soil TP concentration but not across the entire Everglades Landscape.

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Photochemical and Microbial Transformation of Dissolved Organic Matter in the Florida Everglades

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In this study we quantified the role of photochemical and microbial processes in contributing to the transformation of DOM derived from various plants that dominate the Florida Everglades. Plant biomass leachates were exposed to photochemical and microbial treatments and the response of the organic matter characterized through optical, chemical and biological analyses. Optical parameters such as the synchronous fluorescence intensity between 270 and 290 nm (FnpeakI), a strong indicator of protein content, decreased exponentially for all biomass samples with microbial dark decay rates ranging from 1.0 day^{-1} for Seagrass to 0.11 day^{-1} for Sawgrass. Similar decreases in polyphenol content and dissolved organic carbon (DOC) concentration also occurred but bacterial numbers remained relatively constant. Molecular weight (Mw) analysis demonstrated that samples containing relatively large proportions of both high and low molecular weight structures were especially susceptible to microbial degradation processes. High and low Mw compounds decreased exponentially over the incubation period for most samples. Conversely medium and high Mw components increased during the incubation period for mangrove samples, which we attributed to a physical polymerization reaction. The initial Mw distribution of the samples seems to have strongly influenced the rate of FnpeakI decay. Biomass samples such as Seagrass with relatively large average Mw (>9000) had FnpeakI decay values an order of magnitude higher than samples with Mw values <8000. Exposure to simulated solar radiation had a strong negative effect on the polyphenol, DOC concentration and FnpeakI of sawgrass, mangrove leaves and seagrass leachates in natural waters. Low Mw components of the samples decreased whereas the medium and high Mw fractions remained the relatively unchanged. These data indicate that large protein structures and smaller polyphenol compounds, two major constituents of the plant biomass of the Everglades are consumed via different pathways. Recalcitrant polyphenol structures of plant material can undergo both photochemical and microbial degradation whereas the major sink for large Mw protein structures appears to be limited by physical and microbial processes.

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Southern Everglades Application of the Regional Simulation Model

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The Everglades, the only remaining subtropical wilderness in the continental USA, is the home to a number of threatened and endangered species. Although the pre-drainage Everglades covered an area of approximately 11,000 km^2, urbanization and farming have reduced its area by approximately 50%. The remaining Everglades has also changed as a result of drainage and compartmentalization by over 2,200 km of levees and canals. This area is also adversely affected by exotic species, nutrient enrichment, contaminants and altered freshwater flows. The $8 billion Comprehensive Everglades Restoration Plan provides a "framework and guide to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades" (www.evergladesplan.org). The success of this project, one of the largest eco-system restoration projects in the world, depends heavily on our understanding of the quantity, quality, timing and distribution of South Florida's pre-drainage freshwater flow. Consequently, accurate hydrologic modeling is crucial for the restoration of the greater Everglades ecosystem. Although, the South Florida Water Management Model (SFWMM) developed by the South Florida Water Management District (SFWMD) has been used in the past, its two-mile spatial resolution and fixed grid geometry prevents it from being used to obtain detailed hydrologic information at sub-regional scale. In addition, its limited spatial coverage restricts it from being employed to accurately capture the flow dynamics in areas adjacent to the Whitewater Bay and the Gulf of Mexico coastlines within the Everglades National Park.

The SFWMD is planning to apply its Regional Simulation Model (RSM) to gather detailed hydrologic information on a significant portion of the remaining Everglades. The boundary of this modeling domain encompasses the Water Conservation Area 3, the Everglades National Park and the Big Cypress National Preserve. Primarily, this RSM application will be used to investigate the sensitivity of de-compartmentalization on hydro-periods and stages, and to quantify the freshwater flows to the Florida Bay. The RSM is an implicit, finite-volume, continuous, distributed, integrated surface/ground-water model, capable of simulating one-dimensional canal flow and two-dimensional overland flow in arbitrarily shaped areas using a variable triangular mesh. It utilizes physically based formulae for the simulation of overland and groundwater flows, evapotranspiration, infiltration, levee seepage, and canal and structure flows. It is capable of simulating features that are unique to South Florida such as low-relief topography, high water table, saturation-excess runoff, depth-dependent roughness and very permeable soils. Since, one of the main objectives of applying the RSM to the southern Everglades area is to investigate the impact of compartmentalization on stage and flow, the accurate simulation of flow barriers within the model domain is crucial for the success of this project. To this end, a 52,817-element mesh has been constructed to conform to all major levees, highways and canals within the model domain and to simulate flows across all major bridges and culverts. The resultant numerical model uses a mesh with an average element size of 1.81 km^2, and a one-day time step. It employs recently updated land-use, elevation and soil data for the derivation of static model parameters. The RSM is calibrated using historical time-series data from 1988 to 1995. The preliminary calibration results of this modeling study will be presented for review and analysis.

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Multi-Disciplinary Research and Modeling to Support the Nature Conservancy's FLOW Initiative for the Kissimmee-Okeechobee Watershed

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One of the facts often lost in discussions on the restoration of the Kissimmee River and Lake Okeechobee watersheds is that within this largely rural 2.1 million acre watershed, over 400,000 acres of wetlands have been lost to drainage and conversion to improved pasture. The vast majority of this wetland loss has occurred on private ranch lands in areas of the watershed far removed from the river floodplain and lakes where most of the present restoration activity is now focused. As part of its FLOW (Florida Outstanding Lands and Waters) initiative, The Nature Conservancy (TNC) has identified some 337,000 acres of drained but potentially restorable wetlands on cattle grazing lands within the Kissimmee-Okechobee watershed, with less than five percent of this total occurring on existing public lands. Unlike the federal and state restoration projects in the basin, which have focused on large contiguous wetlands (e.g., the Kissimmee River floodplain), the restorable wetlands on private range lands are mostly small (average 10 acres), seasonally isolated depressions, flats and sloughs scattered throughout the watershed in varying densities and landscape positions within the larger drainage system. While it has long been suspected that such extensive loss of wetlands within the Kissimmee-Okeechobee basin could have profound impacts on the hydrology of the river and the transport of nutrients through the system, little technical analysis has been conducted to quantify these impacts. Similarly, little information is available to help with strategic planning of wetland restoration in locations and amounts that will maximize benefits to the watershed.

The Nature Conservancy is presently conducting a multi-disciplinary research and modeling effort to support implementation of the FLOW initiative and help quantify the costs and benefits of large-scale wetland restoration on cattle grazing lands within the Kissimmee-Okeechobee watershed. This work consists of a basinwide GIS analysis, a spatially-distributed hydrologic and water quality modeling study and a macroeconomic analysis of various configurations and total acreage of wetland restoration. The GIS analysis is now complete and provides reliable estimates of total potential for wetland restoration and the habitat benefits of restoration at scales of 50,000 to 250,000 acres. The macroeconomic analysis was completed by Hazen and Sawyer, Inc. in December 2002 and compares full costs (including costs of restoration and acquisition of easements) and benefits (phosphorus removal, water supply, habitat improvement, revenue generated) with ten other phosphorus control options and strategies that have been proposed by the South Florida Water Management District for restoring Lake Okeechobee. A strategy of wetland restoration on 100,000 acres of improved pasture and rangeland ranked third among the alternatives in terms of total phosphorus removed and fifth among alternatives for total cost-effectiveness.

The hydrologic modeling study, conducted jointly with the University of Florida, is still in progress and has initially focused on potential for wetland restoration in the Fisheating Creek (FEC) basin. The modeling approach uses GIS-based spatial information to quantify important hydrologic, topographic, soil and land cover parameters and spatially-distributed modeling of water storage, hydrologic fluxes and flow processes using the MikeSHE/Mike11 software developed by DHI, Inc. Rainfall response functions have been defined for four categories of wetlands common within the FEC basin as a means of determining the impacts of wetland restoration on seasonal runoff volumes and phosphorus loading. The model study is evaluating the relative benefits of different spatial configurations of wetland restoration in the basin, including restoration in headwaters versus downstream locations, clustering restoration on adjacent properties versus restoration widely distributed through the watershed and restoration of riparian or near-stream wetlands versus restoration of wetlands further removed from stream corridors. The results of this modeling will provide strategic direction to TNC for implementing its FLOW initiative and to government agencies involved in planning restoration and prioritizing funds for restoration and easement acquisition.

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An Integrated Modeling System for Forecasting the Response of Indian River Lagoon and Tampa Bay to Anthropogenic and Climatic Changes

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This paper describes the application of an integrated modeling system CH3D-IMS which is consisted of a hydrodynamic model, a wave model, a sediment transport model, a water quality model, a light attenuation model, and a seagrass model. The integrated modeling system has been used to forecast the response of two estuaries – Indian River Lagoon and Tampa Bay in Florida - to anthropogenic and climatic changes. Model simulations of the Indian River Lagoon in 1998 and Tampa Bay in the summer of 1991 are considered the baseline conditions. Model simulations with reduced nutrient loading and climatic change are then conducted to forecast the response of these estuaries. The forecast results are presented in terms of predicted changes in salinity, water quality, light, and seagrass.

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Modeling Circulation and Transport in Charlotte Harbor Estuarine System

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This paper describes the development and application of a three-dimensional modeling system for the Charlotte Harbor estuarine system in Southwest Florida. The modeling system includes a 3-D curvilinear-grid hydrodynamic model, a wave model, a 3-D sediment transport model, and a 3-D water quality model. Very fine model grid is used and a large offshore region is incorporated to allow accurate resolution throughout the model domain and interaction between the estuary and the Gulf of Mexico. Model simulations will be presented to show the different flow regimes during which different forcing functions (wind, freshwater discharge, and ocean tide) are dominant. Realistic simulations of salinity transport during 2000 and 2001 will be presented. Model results show good agreement with observed data, during both high and low freshwater discharges. Potential influence of dissolved organic matters from the Peace River and Caloosahatchee River on the water quality in Gulf of Mexico will be explored. Results of a model for the entire Gulf of Mexico will also be presented.

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Relative Importance of Tripton, Chlorophyll_a, and Dissolved Organic Matters in Affecting Light Attenuation in Florida Estuaries

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This paper examines the relative importance of various parameters in causing light attenuation in various Florida estuaries. Analysis of extensive field data from the Indian River Lagoon demonstrate the dominant influence of tripton (non-algal particulate matters) in causing attenuation of PAR (Photosynthetically Active Radiance), particularly during the high attenuation regime. Chlorophyll_a and color (dissolved organic matters) are shown to have noticeable influence on light attenuation during low attenuation regime. The overall relative importance for light attenuation is 78%, 5%, and 16% for tripton, color, and chlorophyll_a, respectively. These numbers, however, change when somewhat different analysis method is used. These numbers also change significantly for different estuaries in Florida. For example, color has a much stronger influence (22%) in Charlotte Harbor, while chlorophyll_a has a stronger influence (27%) in Tampa Bay. A review of available literatures is presented, and a method to more accurately determine the relative influence of these parameters on light attenuation is proposed.

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Habitat Related Growth in the Juvenile Florida Applesnail, *Pomacea paludosa*

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Much of the remnant Florida Everglades consists of a mosaic of dense stands of the emergent macrophyte sawgrass (*Cladium jamaicense*) interspersed with periphyton-dominated sloughs that provide a diverse resource base to aquatic consumers. This diversity is gradually being lost as macrophytes replace sloughs, apparently in response to nutrient enrichment and altered hydrology within this wetland.

Phosphorus-enriched runoff entering the northern Everglades has caused the conversion of sloughs to dense stands of cattail (*Typha domingensis*). On a broader scale, the impoundment of much of the system during the 1950s and 60s has altered water depths and flow regimes in ways that are believed to favor the growth of sawgrass in areas previously dominated by sloughs. The result has been a measurable decline in the areal extent of slough habitat in recent decades.

Slough habitats are characterized by high submerged primary productivity, high dissolved oxygen, and high invertebrate species richness and abundance, and are a preferred foraging area for wading birds compared with other native vegetation types. And, while few data exist with which to predict the consequences of these changes for most aquatic consumers other than wading birds, there is a scientific consensus that reductions in slough habitat will negatively affect key Everglades animal populations and food chain structure.

We examined the potential effect of habitat shift on the growth and survival of the Florida applesnail (*Pomacea paludosa*). *P. paludosa* is the largest gastropod in the Everglades and an important food for many species including the endangered Everglades snail kite (*Rostrhamus sociabilis*), wading birds such as the limpkin (*Aramus guarauna*), white ibis (*Eudocimus albus*), juvenile alligators, turtles, amphibians and fish.

Applesnails are non-selective periphyton grazers; thus, periphyton abundance may affect growth, survivorship, and fecundity. Periphyton is the dominant primary producer in slough habitats, but is sparse in sawgrass stands as a result of shading. Thus, replacement of slough habitat by sawgrass may reduce food availability to applesnail populations.

The objective of our study was to assess the relative quality of food available in sloughs (periphyton) and sawgrass stands (detritus) by: 1) evaluating the nutritional value of periphyton and sawgrass detritus based on chemical composition; and 2) directly measuring the capacity of these two food sources to support growth and survival of juvenile applesnails.

Growth of newly hatched snails was measured in microcosms containing food sources from either slough (primarily periphyton) or macrophyte (primarily sawgrass detritus) habitats. Samples of each food source were also analyzed for nutritional value (% ash, carbohydrate, protein, and lipid). Changes in aperture length, shell length and wet weight were measured after 30 days to calculate growth. Increases in aperture length and shell length were nearly 4-fold and 2-fold greater, respectively, for snails grown in periphyton as opposed to detrital microcosms.

Increases in wet weight also tended to be higher for periphyton-reared snails, although not significantly. Greater growth occurred in periphyton microcosms despite the apparently poor nutritional value of bulk periphyton (high ash content, low protein and lipid content). Growth in both treatments showed that young snails could assimilate detrital material when periphyton availability is limited. However, significantly higher growth in periphyton microcosms suggests that slough habitats are the preferred environment for juvenile apple snail development.

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Policy and Management Strategies for the Restoration of Lake Okeechobee

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The Lake Okeechobee Protection Program (Chapter 00-130, Laws of Florida) (LOPP) was passed by the 2000 Legislature. This program committed the State of Florida to restore and protect Lake Okeechobee. Restoration will be accomplished by achieving and maintaining compliance with water quality standards in Lake Okeechobee and its tributary waters, through a watershed-based, phased, comprehensive and innovative protection program designed to reduce phosphorus loads based upon the Lake's Phosphorus Total Maximum Daily Load (TMDL) that was adopted by the Florida Department of Environmental Protection (FDEP) in 2000. The program sets forth a series of activities and deliverables for the coordinating agencies (the South Florida Water Management District, the Florida Department of Environmental Protection, and the Florida Department of Agriculture and Consumer Services) to cooperatively complete to aid in the development of the Lake Okeechobee Protection Plan to be completed by January 1, 2004. Restoration will require the development and implementation of watershed phosphorus control strategies that range from local controls (on-farm best management practices) to large-scale regional treatment systems to achieve the lake's TMDL by 2015. Several different phosphorus reduction technologies are currently being implemented and tested within the watershed. A few of these efforts include the restoration of isolated wetlands, dairy best available technologies, best management practices, phosphorus filters, sediment traps and the construction of pilot stormwater treatment areas. The program also directs the responsible agencies to research options to address the internal phosphorus load coming from the in-lake sediments and invasive exotic species. The restoration of Lake Okeechobee has a strong foundation, however, the restoration will take unprecedented cooperation between the public and private sector in evaluating and implementing the various technologies.

Additionally, the Florida Department of Environmental Protection has been specifically directed to address non-agricultural nonpoint sources within the Okeechobee watershed. This includes developing appropriate nutrient application rates for non-agricultural soil amendments, implementing urban stormwater best management practices, improving wastewater management, and regulating the land application of wastewater residuals.

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Restoration of Lake Okeechobee through the Implementation of the Lake Okeechobee Protection Program

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The Lake Okeechobee Protection Program (Chapter 00-130, Laws of Florida) was passed by the 2000 Legislature. This Program committed the State of Florida to restore and protect Lake Okeechobee. This will be accomplished by achieving and maintaining compliance with water quality standards in Lake Okeechobee and its tributary waters, through a watershed-based, phased, comprehensive and innovative protection program designed to reduce phosphorus loads and implement long-term solutions, based upon the Lake's Phosphorus Total Maximum Daily Load (TMDL). The Program sets forth a series of activities and deliverables for the coordinating agencies (the South Florida Water Management District, the Florida Department of Environmental Protection, and the Florida Department of Agriculture and Consumer Services) to be completed to aid in the development of the Lake Okeechobee Protection Plan. Restoration will require the development and implementation of a range of watershed phosphorus control strategies from local controls (on-farm best management practices) to regional treatment systems. Several different phosphorus reduction technologies are currently being implemented and tested within the watershed. A few of these efforts include the restoration of isolated wetlands, dairy best available technologies, cow-calf best management practices, phosphorus filters and the construction of pilot stormwater treatment areas. The Program also directs the responsible agencies to research options to address the internal phosphorus load and invasive exotic species.

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Assessing the Consequence of Hurricane-Induced Conversion of Mangroves to Mudflats on Fish and Decapod Crustacean Assemblages in the Big Sable Creek Complex of Southwest Florida

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Hurricanes routinely cause damage to mangrove forests, generally by breaking and toppling trees. Normally forests recover through growth of new plants from seedling germination. For reasons that are not completely understood, the passage of two category 4-5 hurricanes across the Cape Sable peninsula in SW Florida (1935, 1960) resulted in permanent damage to some mangrove forests: adult trees were killed, sediments eroded, and no seedlings germinated. The net result was localized conversion of mangrove forests to unvegetated mudflats. Mangroves are generally considered to be critical nursery habitat to the juveniles of many species of estuarine transient fishes whose adults spawn offshore and whose young life history stages use mangrove environments. This project asks the question "What is the consequence of the conversion of mangrove to mudflat habitat on intertidal assemblages of fish and decapod crustaceans within the creeks in the Big Sable Creek complex?"

The Big Cape Sable Creek complex is located at the far downstream end of the Everglades restoration area, but is of interest because it naturally receives little freshwater inflow. The creek complex consists of six tidal creeks that are a mosaic of mangrove forest and mudflats (fig.1): both habitats are inundated at high tide. Intertidal rivulets, i.e., drainage features smaller than first order creeks, also drain both habitats. Rivulets are depressions in the substrate up to 1 m deeper than the forest floor or mudflat around them. Rivulets fill earlier on flood tides and retain water later on ebb tides. Rivulets are "hotspots" for the entry and egress of fish and decapod crustaceans (shrimp, crabs) from intertidal habitats, and are a convenient location for sampling these animals with block nets (fig. 2) to compare the fish and decapod fauna leaving replicate forest and mudflat habitats.

We hypothesize that forested sites will be dominated by small benthic forage fishes (e.g., gobies, killifishes) that experience a lower risk of predation within complex intertidal vegetation. Alternatively, we expect deeper mudflat sites lacking vegetation to be dominated by two groups of fishes: water column schooling fishes (e.g., anchovies, silversides), and large roving predators (e.g., subadult snappers, catfishes), both of whose movements will be unimpeded by the structural complexity of stems and roots of mangrove trees.

The statistical design is a repeated measures ANOVA. The dependent variable is catch per unit effort (CPUE), the independent variable is habitat type: catch will be quantified as both numbers and biomass. We are sampling 3 replicate creeks, each with a forested and a mudflat site. The rivulet sites are fixed and drain an unknown area that varies with both tidal height and with location. Sampling will occur every 2 months for 12-18 months. A major challenge is defining either the area drained by each net, or the volume of water flowing through each net to refine our measurement of catch.

Species composition will be compared between habitat types using an ordination technique, multidimensional scaling (MDS), followed by analysis of similarity (ANOSIM) to ascertain statistical significance of species groupings. Very preliminary analysis of the first data collected in fall 2002 indicates compositional differences in the fish faunas of the two types of intertidal habitats.

Figure 1. Big Sable Creek complex. Intertidal mudflats show up in B&W photo as light gray openings in an otherwise continuous dark forest.

Figure 2. Permanent end posts either side of a routinely sampled intertidal rivulet: posts accommodate block net for capturing fish and crustaceans leaving the mangrove forest on an ebb tide.

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TAME Melaleuca: The Areawide Management and Evaluation of Melaleuca

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Melaleuca quinquenervia (common name melaleuca) is a myrtaceous tree of Australian origin that has become a noxious weed in Florida, occupying approximately 200,000 ha of agricultural, riparian and wetland systems. This invasive tree is competitively superior to many native plants and rangeland grasses with infestation resulting in degradation of native wildlife habitat and of the limited grazing lands in south Florida. In addition, melaleuca degrades vital waterways that significantly contribute to fisheries productivity, act as nursery sites for fish and crustaceans, regulate run-off quantity and quality, mitigate flooding, and control erosion. Nearly $25 million has been spent over the past decade in managing melaleuca infestations, yet the weed continues to proliferate, particularly on private lands.

Control of invasive plants such as melaleuca is essential to the conservation and expansion of native species. Melaleuca control is therefore integral to the Comprehensive Everglades Restoration Plan (CERP) objective of achieving restoration and sustainability of south Florida's natural ecosystem. The Melaleuca Management Plan, developed by the interagency Melaleuca Task Force in accordance with CERP, recommends the integration of multiple control approaches, with an emphasis on biological control, as the most effective method for long-term, sustainable management of melaleuca.

The Areawide Management and Evaluation of Melaleuca, or TAME Melaleuca, is a collaborative project recently established to demonstrate and promote the practical, integrated weed management strategies outlined in the Melaleuca Management Plan, including the emphasis on biological control. In the course of this five-year project, research and demonstration sites will be set up in varied habitats in south Florida where public and private landowners are highly motivated to manage melaleuca. Project activities include assessing melaleuca's geographic distribution, the impacts of control tactics and the socio-economic factors associated with current and proposed control tactics; researching impacts of control tactics on the weed, interactions among biological control agents, and non-target effects of tactics; and technology transfer. By partnering with federal, state, local and private land managers on these goals, TAME Melaleuca intends to develop a sustainable and integrated melaleuca control program for the long-term control of this invasive weed.

TAME Melaleuca is funded by the USDA Agricultural Research Service's Areawide Pest Management Initiative. Cooperators include the USDA ARS and APHIS, the South Florida Water Management District, the University of Florida, Florida State University, and the Florida Department of Environmental Protection.

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The Effects of Water Velocity on Phosphorus Uptake by Periphyton: Implications for Improving Phosphorus Capture by Stormwater Treatment Areas

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Artificial wetlands are increasingly being used as filters of wastewater with high nutrient loads. This is especially true in Florida, where Everglades restoration includes construction of six Stormwater Treatment Areas (STA's) totaling 16,000 hectares. These filter marshes, composed largely of submerged aquatic vegetation and periphyton communities, are designed to remove excess phosphorus from agricultural runoff and urban wastewater before it reaches the Everglades. Numerous studies over the last forty years have demonstrated the positive effects of water movement on phosphorus uptake by periphyton communities. However, research on phosphorus uptake in freshwater systems has focused primarily on rates of flow appropriate to lotic systems. In the Everglades, water velocity has not been extensively studied for its potential to reduce water phosphorus concentrations. Optimizing flow through constructed wetlands may prove to be important in increasing the efficiency of nutrient removal by periphyton and achieving a lower outflow phosphorus concentration.

The primary objective of this research was to investigate the effects of water movement on phosphorus uptake by periphyton communities. Our hypothesis was that removal of phosphorus within a periphyton-dominated system would correlate positively with increased water flow. We tested this hypothesis within constructed mesocosms. The unique design of the constructed mesocosms allowed for us to solely test the effect of flow rate, while other factors, such as hydraulic retention time and hydraulic loading rate were kept equal across treatments. Treatment water velocities were approximately 0.22 cm $s^{-1}$and 2.0 cm s^{-1}, which are levels achievable within an STA. The first study, presented here, was conducted for 12 weeks in spring 2002. The mesocosms, which were installed at the outlet (south) end of the Everglades Nutrient Removal Project (ENRP) within STA-1W, received water that had already been filtered by the STA. Therefore, much of the biologically available phosphorus had already been assimilated by the STA. After twelve weeks of treatments we found a significant 20% greater increase in biomass in the fast compared to the slow treatment. Plant tissue phosphorus analysis showed no statistically significant differences in tissue phosphorus accumulation between the two treatments, thus the greater biomass accrual in the fast treatment represents a greater phosphorus removal.

Optimizing water movement within STA’s may lead to greater operational efficiencies and a final discharge concentration of phosphorus that is more compatible with the natural plant community of the traditional Everglades system. The information obtained from this study is relevant to current ecosystem restoration timetables, and can assist in augmenting critical decisions of both supplemental and current water quality treatment applications.

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Land-Use Planners and Regulators and the Multi-Species Recovery Plan: Exposure, Awareness, and Motivations

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The South Florida ecosystem has been considerably damaged by development of natural lands in response to rapid population growth, and the result has been a growing number of animal and plant species listed as threatened or endangered. The government has taken action to restore the Everglades and the species that live in this ecosystem; in 1993 the Federal government began the South Florida Ecosystem Restoration Initiative, and in 1998 the U.S. Fish and Wildlife Service completed the South Florida Multi-Species Recovery Plan (MSRP) to address the Restoration Initiative's goals concerning biodiversity and threatened and endangered species. The MSRP identifies recovery and restoration needs of threatened and endangered species along with their habitats in the South Florida ecosystem. Success of these efforts, however, may depend on land-use decisions made at the local level and the motivation of local officials to consider the impact of their decisions on threatened and endangered species.

In Florida land-use decisions are accomplished at the regional level by Regional Planning Councils and at the local level by county and municipal governments. While regional and local planners are, in all likelihood, willing to participate in the Restoration Initiative, they operate with limited time and resources and may not be actively seeking scientific input into their decision making process, and they may not be aware of documents such as the MSRP.

The purpose of this study was to (1) examine the quantity and type of information land-use decision makers have been exposed to regarding threatened and endangered species, (2) assess awareness and perceptions of the MSRP, and (3) identify factors that influence land-use decision makers' motivations to seek information about threatened and endangered species. The theory of planned behavior (TOPB) was employed to accomplish the third objective. The TOPB is a social psychological theory that predicts motivation to engage in a particular behavior and models psychological processes that mediate the relationship between attitudes and behavior. According to the theory, the proximal cause of behavior is behavior intention, or one's psychological propensity to engage in the behavior. Behavior intention is a function of (1) attitude toward personally engaging in the behavior (attitude toward the act), (2) beliefs about how significant other people would evaluate one's engaging in the behavior (social norms), and (3) perceptions of one's ability to perform the behavior (perceived behavioral control). Research has also found past behavior to be a significant predictor of motives to engage in environmental behavior.

A survey ($\underline{N} = 59$) was administered to employees in offices relating to land-use planning or regulation in the nineteen counties of South Florida as defined as the boundary of the MSRP. The names and structure of these offices are not uniform throughout the counties, so county web sites and phone calls were used to identify relevant offices and personnel in these offices. The first wave of data was collected through the mail and the second wave was by telephone. The overall response rate was 28.5%. Respondents were asked how much threatened and endangered species information they had heard lately from five sources on a five-point scale ranging from "absolutely none" to "a great deal." The means for all sources were relatively low. The mean for non-profit organizations (M = 3.00, SD = 1.17) was significantly greater than the other sources at alpha of .05. There were no statistical differences among the other means: media (M = 2.53, SD = 1.06), state government (M = 2.47, SD = 1.04), U.S. Fish and Wildlife Service (M = 2.47, SD = 1.19), Federal government (M = 2.34, SD = 1.17).

When asked whether they had heard of the MSRP, most respondents answered no (n = 34, 45.9%), while 25 (33.8%) answered yes. Respondents answering yes were asked to write in how they had heard about the MSRP. The most common answers were through one's colleagues or job or through personally having a copy of the MSRP. Other answers were through conferences and a U.S. Fish and Wildlife Service meeting and notice. Awareness of the contents of the MSRP was also low. Respondents rated their awareness that the MSRP contained information about five topics on a five-point scale ranging from "not at all aware" to "very much aware." Awareness was significantly higher that the MSRP contained information about threatened and endangered animal (M= 2.36, SD = 1.73) and plant species (M = 2.33, SD = 1.74) than restoration goals for these species (M = 2.24, SD = 1.64), habitat requirements for these species (M = 2.23, SD = 1.64), and ecological communities of South Florida (M = 2.12, SD = 1.58).

The remaining questions assessed the variables of the TOPB; all were measured with five-point response scales. Behavior intention was assessed by averaging three items, including "I intend to seek out information about threatened and endangered species in my region" (scale mean = 3.88, SD = 1.01). Three items measured attitude toward the act ("In your profession, working to protect threatened and endangered species is useful/useless;" scale mean = 4.35, SD = .72). Two items measured social norms, including "My colleagues believe that good stewardship of threatened and endangered species is very important" (scale mean = 3.86, SD = .86). Internal and external perceived behavior control (PBC) were each measured with two items. For internal PBC respondents indicated whether obtaining information about threatened and endangered species in their region would be easy/difficult (scale mean = 3.27, SD = .84). For external PBC questions focused on the degree to which external sources would make it difficult to protect threatened and endangered species (scale mean = 2.49, SD = 1.16). Finally, past behavior was measured with a single item, "How much effort would you say you've made in the last 12 months to look for information on threatened or endangered species in your region" (M = 2.69, SD = 1.30). A step-wise regression indicated that past behavior, attitude toward the act, and social norms predicted 42% of the variance in intention to seek information about threatened and endangered species.

Maximum Predictive Stepwise Regression Model

Model & variables	R^2	Standardized beta	Partial correlations
1. Past behavior	.17	.53	.56
2. 1 + attitude toward act	.38	.34	.38
3. 2 + social norms	.42	.26	.29

The results provide direction for communicating with land-use decision makers, who are not currently receiving a great deal of information about threatened or endangered species and who are mostly unaware of the MSRP. Motivation to seek information about threatened and endangered species depended on past behavior, attitude toward the act, and social norms. Means for these variables were relatively high. To increase motivation, however, communications should be designed to provide some experience in accessing relevant data and to support and build favorable attitudes towards protecting threatened and endangered species among land-use planners and regulators and their colleagues.

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What We Know and Should Know about Tree Islands

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Tree islands are a feature of many large, flat wetlands. They develop in these wetlands around some point of formation. Points of formation can include topographic highs in the bedrock, blocks of floating peat and depressions in the bedrock. Their point of formation can even be the result of human activities. Tree islands are important to the Everglades because:

- They are a major spatial feature of the landscape and provide much of its biocomplexity,
- They enable many terrestrial plant and animal species to live in the Everglades ecosystem,
- They are essential for many groups of wetland animals and birds during part of their life cycle, especially for nesting,
- They concentrate nutrients and may play an important role in the overall nutrient dynamics of the Everglades ecosystem, and
- They preserve important archaeological and cultural features of South Florida.

Basic information about the hydrology, geology, and ecology of tree islands is still rudimentary. Most studies have focused on their geological origin or on their plant communities. Both, however, are still not well understood, and most aspects of tree island ecology (vertebrate and invertebrate population dynamics, primary production, peat accumulation rates and patterns, etc.) have received very limited or no attention. Recent landscape studies have indicated that there were significant losses of tree islands during the second half of the Twentieth Century. Studies of their archaeology indicate that larger tree islands have been used for thousands of years in a variety of ways and that many tree islands have been significantly altered as a result. This presentation provides a framework for understanding the current status of tree islands, including a consideration of their location and significance in the Everglade's landscape, theories about their origin and development, historic trends in their abundance, and restoration goals within the Comprehensive Everglades Restoration Plan.

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Spatial Pattern and Scale of Everglades Macroinvertebrate Communities along Nutrient and Hydroperiod Gradients

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The periphyton mat and its associated invertebrate community are an integral part of the Everglades food web, so it is important to understand their distribution and response to variation in the physical environment. While several groups have described macroinvertebrate community dynamics across a nutrient gradient, the consistency of these patterns across a range of hydroperiods has not been addressed. In this study we sought to determine the spatial scale and distribution of the floating periphyton mat and its associated macroinvertebrate community. We used this information to design a sampling study that sought to describe the response of the community to both enrichment and variation in hydroperiod. A deeper understanding of these community dynamics will enable researchers to better identify trophic interactions and determine the impact of environmental stressors on this system.

Fig 1: Floating periphyton mat in wet prairie *Eleocharis sp.* slough.

In the wet-season of 2000 we conducted an intensive sampling survey in northern Shark River Slough, ENP to describe the densities of macroinvertebrates in the floating mat and to detect any spatial patterns that may exist between 0.5 and 90 m. Four sites were established approximately 1 km apart along a transect parallel to slough flow. At each site, approximately 100 6-cm diameter cores were taken from the periphyton mat in a nested-L pattern (Fig. 2) in both July and November 2000. Epiphytic algae in the water column was sampled in the absence of a floating periphyton mat. All animals greater than 1 mm in length were removed and identified to lowest feasible taxonomic resolution. Epiphytic algae samples differed from periphyton samples in both physical structure and community composition. We found that periphyton from the floating mat contained more inorganic $CaCO_3$ than epiphytic algae from the water column (P=0.054), while it contained 350-550% more amphipods and 50-175% more *Dasyhelia spp*. Epiphytic algae, however, contained 25-50% more chironomids than surface periphyton. From July to November we saw an increase in water depth, periphyton percent cover, and abundance of all major invertebrate groups (P<0.01). While we saw more spatial variation in July when abundances were lower, a nested ANOVA revealed no general patterns in spatial variation at any scale. Analysis of semivariance also failed to detect significant spatial patterns at a scale smaller than 25 m.

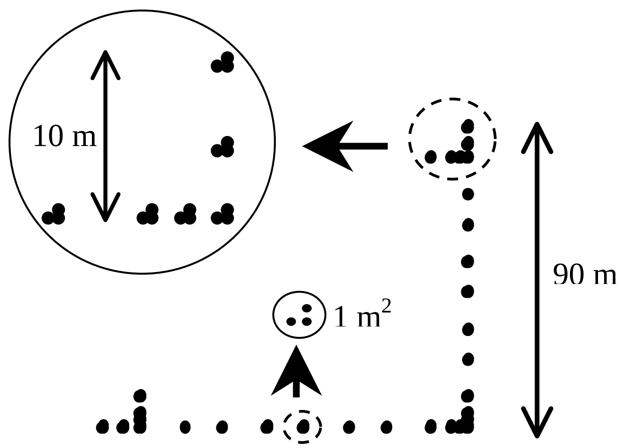

Fig 2: Nested-L sampling design for each site (each dot represents 1 sample)

In December 2002 we sampled sites at two levels of phosphorus enrichment (enriched and unenriched) and three hydroperiods (short: <200 days since last dry-down; long: >400 days since last dry-down; and very long: >4000 days since last dry-down) in a factorial design. This was replicated in WCA-3A and Shark River Slough, ENP, although no 'very long' sites were available in Shark River Slough. At each site, 15 6-cm diameter periphyton mat cores and 15 6-cm diameter benthic floc cores were taken within a 10 x 10 m area. Soil, floc, and periphyton were also collected and analyzed for total phosphorus. We failed to find any significant differences in the total number of invertebrates from the two areas, or consistent patterns in the total number of invertebrates in sites with different hydroperiods. It was clear, however, that enrichment caused almost a three-fold increase in the total number of invertebrates in each sample (P<0.001). We also saw a significant interaction between hydroperiod and enrichment. We found that when short hydroperiod sites were enriched, they experienced almost a six-fold increase in the total number of invertebrates (P<0.001), with more than twice as many invertebrates as any other enriched sites (Fig. 3). Similar results were found when most taxonomic groups were treated individually.

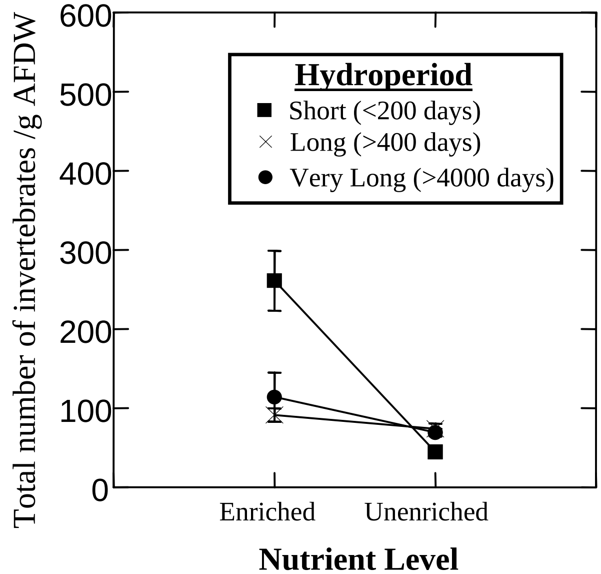

Fig 3: Effect of the interaction of enrichment and hydroperiod on the density of macro-invertebrates in the periphyton mat

This research was funded in part by the NSF Florida Coastal Everglades Long-Term Ecological Research Program and a US EPA STAR Fellowship.

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A Decade of Mangrove Forest Change Following Hurricane Andrew

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Hurricane Andrew crossed the southern Florida peninsula on the morning of August 24, 1992. Following the storm, the National Park Service conducted an "Environmental Damage Assessment" to gauge its' impacts on the natural resources of south Florida Park Service holdings. Although hurricanes had impacted Park's lands, such as the Everglades, in the past, no systematic, permanent sampling scheme had ever been established to monitor long-term recovery (or lack of recovery) following catastrophic disturbance.

In October 1992 six large plots were established in the heavily damaged areas of mangrove forest on the southwest coast of the Everglades, along the Lostmans and Broad Rivers. The plot network was expanded during the next 24 months and now encompasses more than 20 permanent plots. Each plot is circular. For each stem > 1.4 m in height, the distance and bearing from the stem to a permanent center stake was measured. The stem was identified to species and its diameter at breast height measured. The condition of each stem was recorded (alive, killed by Andrew). Each living stem was marked with an aluminum tree tag for future identification. Since establishment, each plot has been sampled from 6-9 times. During a resampling, all tagged stems were located and their dbh and condition recorded. Recruits (previously untagged stems now having grown to 1.4m in height) were identified, measured and mapped. Changes in condition of all stems were noted (e.g. mortality from various causes). Increases or decreases in biomass were calculated for individual stems based on allometric equations relating biomass to dbh. Total biomass was determined by summing individual changes and changes due to addition of recruits and losses from mortality. Co-incident with the establishment of the permanent vegetation plot network, researchers from the USGS were constructing a network of hydrological monitoring stations in the southwest coastal Everglades. Each hydrology monitoring station has one or more vegetation plots nearby (but not all vegetation plots have an adjacent hydrology station).

The trajectory of vegetation change, growth, mortality and recruitment has been highly variable among plots. Indeed, most plots have followed unique patterns. The only overall pattern was the increase in stem density observed in all plots. The species that dominated recruitment varied, sometimes being *Rhizophora*, often *Laguncularia*, but never *Avicennia*. The rate of stem density increase varied among plots. After 10 years, Second Onion Bay had >1,900 stems, whereas Johnson Mound Creek had 325, about an order of magnitude difference. Individuals are continuing to recruit into the population at all plots except at Lostmans Ranger Station and Broad River Mid. The 10th year survey at both of these showed slight declines in stem density (Fig. 1).

Mortality is occurring at all sites. Sources of stem death have included: continuing mortality from damage initially induced by Hurricane Andrew, stems being killed by falling debris, lightning, wind-throw during winter cold fronts, freeze, fire and several smaller hurricanes since Andrew such as George, Harvey, Irene and Mitch. Stems in the smaller size classes are beginning to perish due to suppression (that is, being overtopped and heavily shaded by larger neighbors).

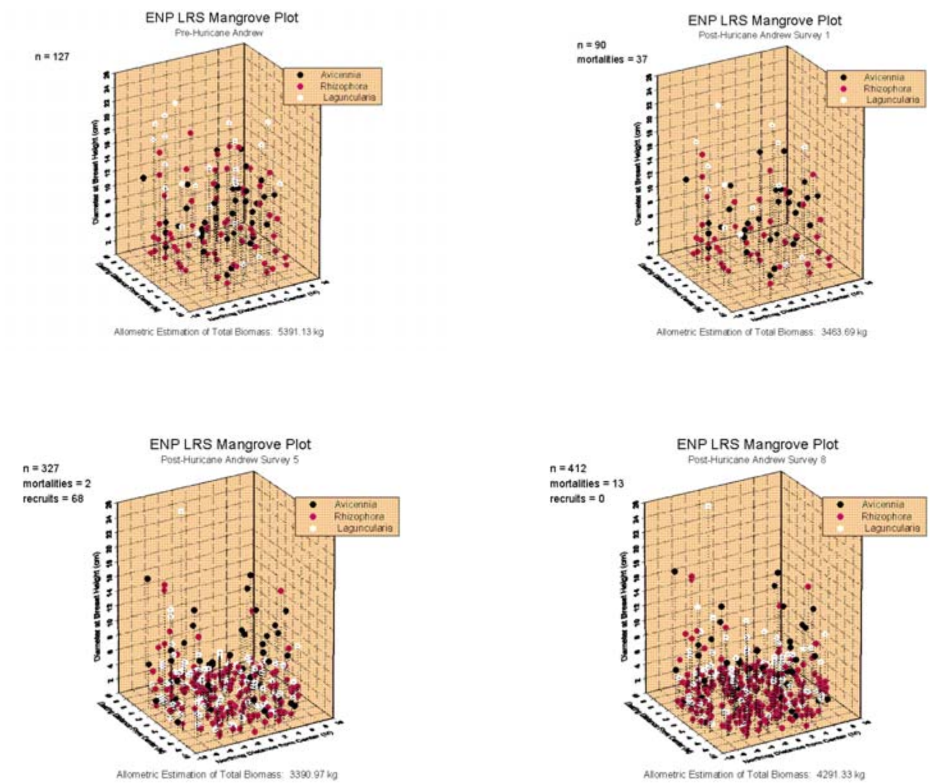

Figure 1. Illustrative data for the Lostmans Ranger Station plot. Results from four surveys are shown. The upper left figure depicts the plot as it appeared prior to Hurricane Andrew and is based on a “reconstruction” from the initial sampling in October 1992. The upper right figure is the “actual” state at the initial sampling. The situation in Jan 1995 is shown in the lower left. Recruitment is well underway and consists of an even mix of *Rhizophora* and *Laguncularia*. The bottom right figure shows 10 years after the hurricane, October 2002. *Rhizophora* has now come to dominate the pool of recruits and total biomass is beginning to exhibit an increasing trend.

Growth by stems that survived Andrew or which have since recruited into the plots is difficult to explain. Productivity cannot be explained simply by sediment porewater nutrient concentrations, which are highly variable. Salinity and hydrologic parameters seem most promising to explain patterns of biomass increase following the catastrophic disturbance from Hurricane Andrew. Sampling of these plots will continue in order to monitor the effect of increasing freshwater inflow that will occur as a major component of the Everglades restoration.

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Development of Digital Aerial Photography Archives for the Greater Everglades of South Florida

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Currently a restoration effort, guided by the Comprehensive Everglades Restoration Plan (CERP), is underway in central and southern Florida. A basis for the restoration must be a clear understanding of pre-management wetland characteristics in order to establish a gauge for future performance and impacts of CERP. An increase in studies related to pre-management wetland characteristics has resulted in an increased demand for historical data from the Greater Everglades region. Aerial photographs provide one form of historical data documenting past effects of flood protection and water supply management measures on south Florida ecosystems.

More than 25,000 historical aerial photographs of the Everglades and South Florida, some flown as early as the mid 1920's, are known to currently exist in print or negative form at various locations. This estimate only includes photographs whose physical location is known and accessible, many of which are temporarily situated at the USGS Gainesville facility. The USGS Florida Integrated Science Center (FISC), in collaboration with USGS Eastern Region Geography, processed some of these photographs in 2001 and 2002 (see fig.1). The primary goals of this project were to 1) catalog available photographs in a database 2) convert these print and negatives to digital form 3) make the digital files readily accessible via publication and 4) orthorectify the files for future spatial data analyses.

To date this effort has produced one USGS Open-File Report on CD-ROM with rectified 1927 topographic sheets (t-sheets). Other Open-File Reports containing digital files of 1940 and 1987 aerial photography are currently in review. Another report with 1964 aerial photography is being prepared. Over 8,000 entries have been added to the database, documenting quality and quantity of available photographs. More than 2,000 photographs have been scanned at 800 dots per inch (dpi) or close to 31.75 microns. Thousands more photos have been scanned at 300 dpi to generate mosaics that establish flight information. The mosaics and flight lines will also facilitate future orthorectification and are used for publication purposes.

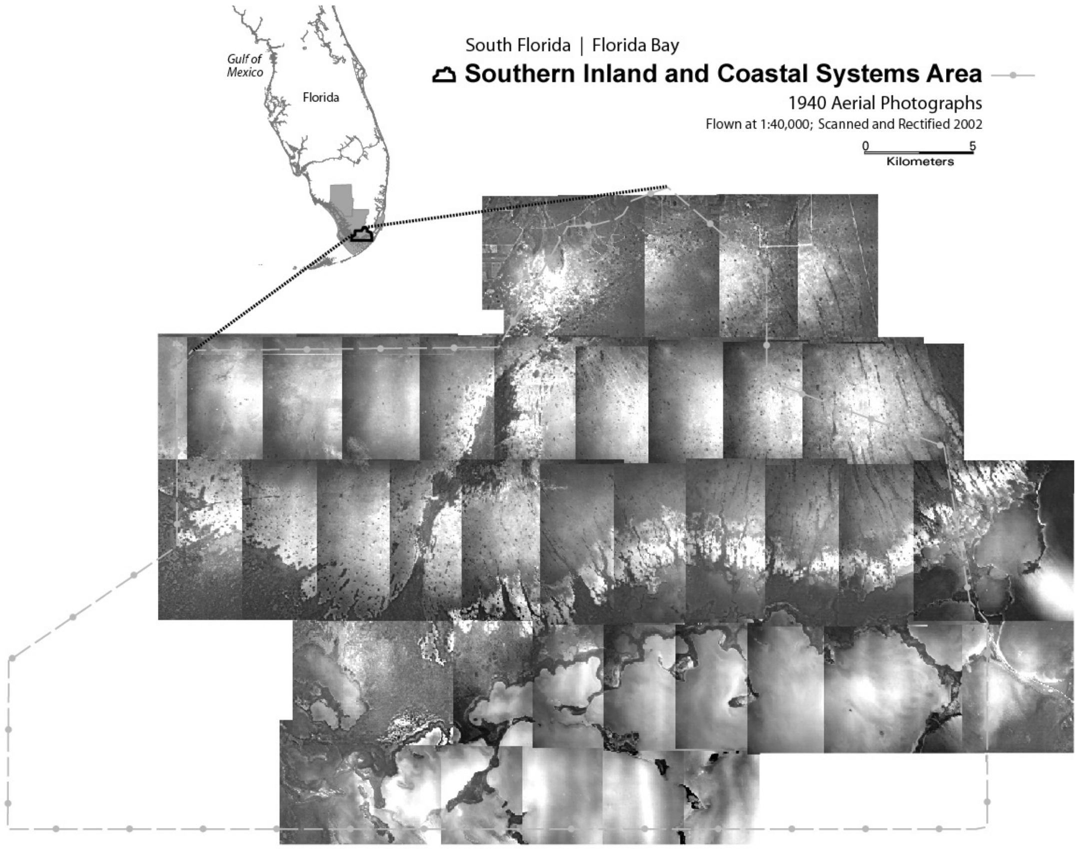

Figure 1. Example of 1940 Rectified Imagery, South Florida and Florida Bay

Another related product resulted from the conversion of 820 digital ortho quarter quads (DOQQs) to 54 south Florida basemaps extending from Lake Okeechobee to Florida Bay. These basemaps are 2-meter resolution mosaics in contrast to the 1-meter DOQQs. Using 2m basemaps makes storage and retrieval more efficient compared to the DOQQs, and thus reduces the time necessary for orthorectification. Each basemap is a mosaic of 8-16 DOQQs derived from aerial photography flown in 1994.

The aerial photographs converted to digital files and published so far represent a segment of the existing prints and negatives available. Many aerial flights covered portions of the south Florida area and these photographs remain in analog form. A small technical staff of 1-3 may require 4-12 years of full-time effort to convert the remaining photographs to orthorectified and published form given current available hardware and software capabilities. This assumes future storage needs will be accounted for. An associated project will make all the digital images and linked attribute databases available via the internet.

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Do Surface and Groundwater Fluctuations Influence Sediment Surface Elevation in the Coastal Everglades Wetlands?

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The Greater Everglades ecosystem stretches for over 360km, from Lake Kissimee in the north to Florida Bay in the south. At its widest point it covers more than 100km from west to east. The vast flow way has been dissected by a network of canals and levees over the recent past to control flooding, provide water storage for human consumption and protect croplands. Natural surface water flows into Everglades National Park have been seriously disrupted, in terms of quantity, quality and timing of flow. Presently federal, state and local agencies have established a $7.8 billion ecosystem restoration program for the Everglades, known as the Comprehensive Everglades Restoration Plan (CERP). Many science questions remain unanswered as the restoration begins. Major questions exist concerning rates of soil formation in the various wetland plant communities and about factors regulating surface elevation in these wetlands.

This report provides data from a network of Surface Elevation Tables (SETs) in the southwest coastal wetlands of Everglades National Park. At each of eight sites, three SETs were established. Three study locations were along each of the Shark and Lostmans Rivers, the two major coastal drainages of the southwest Everglades. On each river one site is in an upstream freshwater wetland, a second site is in the middle reach of the river in a brackish marsh – mangrove forest community, and the third site is downstream near the river's mouth in a pure stand of mangrove forest. The two freshwater sites are non-tidal and highly seasonal with respect to surface water flows and depths (both highest in summer and negligible in the winter dry season). Tides are measurable, but small, at the brackish waters sites and there is a noticeable variation in surface water. Tidal activity dominates the hydrological signature at the saline, downstream, mangrove forest sites. The seventh and eighth sites are located at Big Sable Creek, a marine dominated region on northwest Cape Sable. The cape was devastated by the 1935 Labor Day Hurricane and again by Hurricane Donna in 1960. At this location three SETs are in mangrove forest and three are in open, unvegetated, intertidal mudflat. Ground-water and surface-water sampling wells are present at all sites and are instrumented to record elevation and conductivity at hourly intervals. SETs have been sampled at 3-6 month intervals for more than three years (fig.1). For each of the eight sites we calculated the rate of change in relative wetland surface elevation (only one site is currently surveyed to MSL) between sampling intervals. We also calculated the rate of change in daily ground and surface water elevation for the same intervals. Average surface and groundwater stage was determined for the day of SET sampling, and for the 15 and 30 days prior to sampling. Simple linear regression was used to test for differences between surface elevation change and the water level parameters and to calculate the slope of that relationship for each site.

Sediment surface elevation at all sites showed apparent annual cycles that differed between sites. Surface elevation appeared to be greatest during the dry season at upstream freshwater locations (fig.1) and lowest during the dry season at downstream saline locations. The two brackish water, middle river, sites showed little variation in sediment surface elevation. Surface-water stage, over the 15 days prior to sediment sampling, was strongly related to the change in sediment elevation between samplings (fig. 2). Most importantly, this relationship was the opposite between sites. At freshwater sites, as average stage **increased,** sediment change **decreased**, whereas at saltwater sites, **increasing** surface-water stages led to **increasing** sediment elevation between sampling periods. The pattern at the two brackish sites was intermediate.

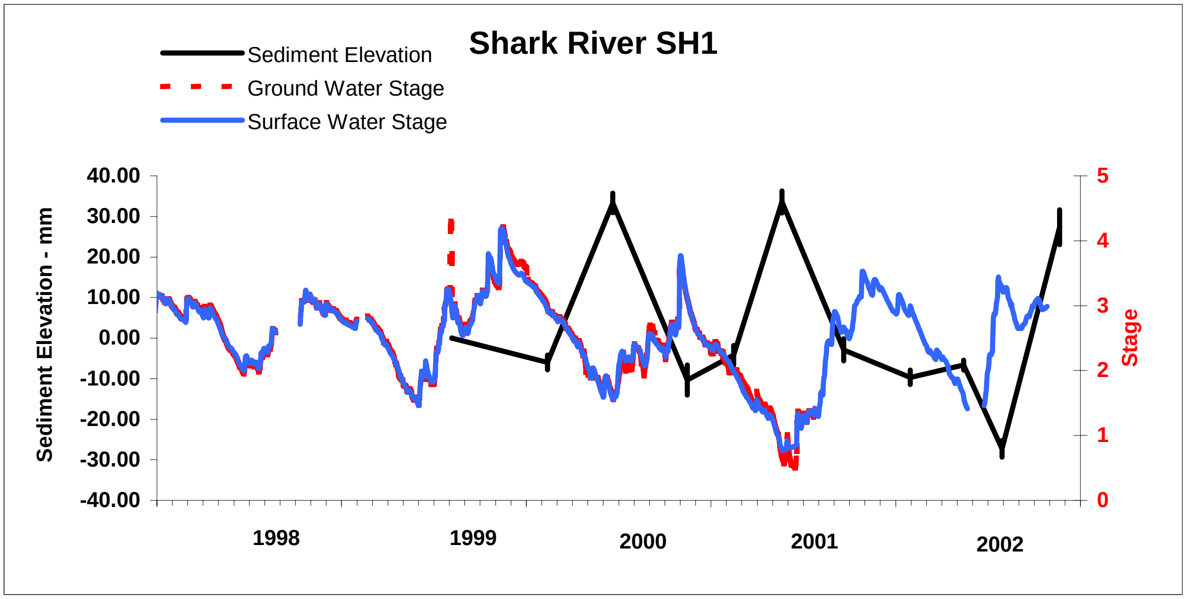

Figure 1. Representative data showing the time series of surface & groundwater stage and sediment surface elevation at the upstream freshwater site on the Shark River (SH1).

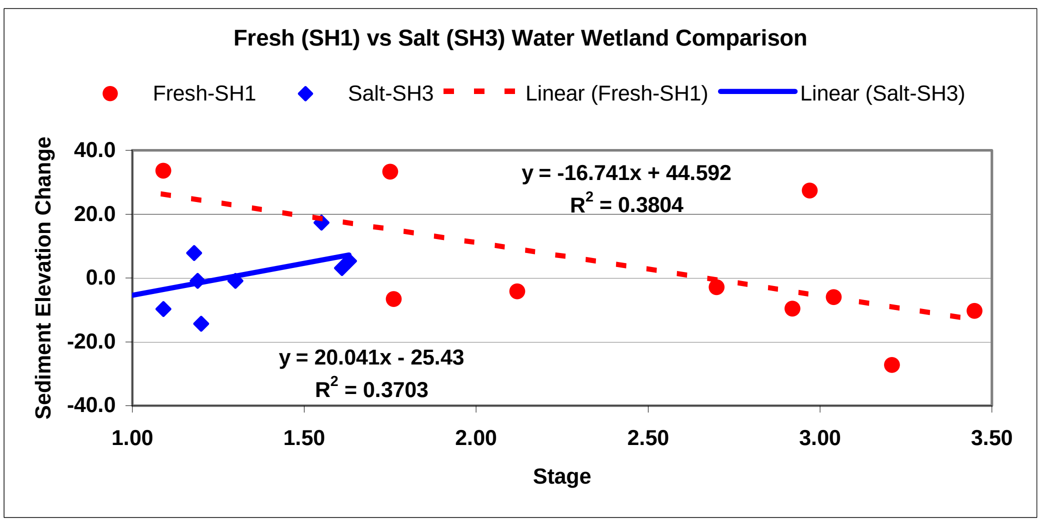

Figure 2. Sediment elevation change versus average surface water stage for a freshwater marsh (SH1) and a salt water mangrove forest (SH3).

Why these two wetland systems behave in an opposite manner is unclear at this time. One hypothesis is that in the freshwater systems, a sedimentation – re-suspension process is occurring whereby, as the dry season progresses, flocculent material in the water column sediments out, and as the wet season sets in and water levels (and current velocities) go up, this material becomes re-suspended and lost from the site. This hypothesis will be tested in coming months.

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Invasive Exotic Plant Management at the Arthur R. Marshall Loxahatchee National Wildlife Refuge, an Integrated Approach

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Invasive exotic plants pose a severe threat to natural ecosystems worldwide including South Florida's unique and imperiled Everglades ecosystem. The sub-tropical climate, international commerce, and ornamental plant trade industry are factors, which significantly increase the susceptibility of Florida's habitats to invasion. The Everglades are already threatened by human encroachment, rampant development, and fragmentation of adjacent buffer lands. The Arthur R. Marshall Loxahatchee National Wildlife Refuge (the refuge) represents a unique remnant of the northern Everglades ecosystem, whose native species and ecological integrity are slowly yielding to the influx of invasive exotic plants. Old World climbing fern (*Lygodium microphyllum)* is decimating tree islands by smothering native vegetation, toppling trees, altering fire ecology, creating tangled mats capable of ensnaring wildlife, and preventing native species establishment. *Melaleuca quinquenervia* forms dense stands that are impenetrable to wildlife, alter hydrologic patterns, fire ecology, and native plant communities. In addition, other Florida Exotic Pest Plant Council Category I and II plant species occur with associated detrimental impacts to native plant communities and wildlife. In response to this threat, the refuge has developed a multi-faceted program incorporating detection, control, monitoring, and research, while working closely with other government and private organizations; a truly integrated pest plant management approach. The primary goals of this program are to reduce invasive plant populations to controllable levels where impacts to native plant communities and wildlife are minimized and to further understand the underlying causes and consequences of exotic plant invasions to native plant communities and wildlife.

To address the increasing populations of invasive exotic plants, a detection and treatment program was implemented. The refuge conducts Surveillance and Reconnaissance Flights (SRF) as the primary mode of detecting visible infestations of invasive exotic plants. These surveys are coordinated with the South Florida Water Management District (SFWMD) and the National Park Service (NPS) to ensure a consistent data set, providing complete coverage of invasive exotic plant infestations on the refuge as well as infestations on a regional level for all of South Florida. These SRF results are used to direct field operations by both private contractors who concentrate on heavier infestations over large acreages and refuge crews who concentrate on isolated populations and outliers. The preferred management strategy is to contain and treat small and/or outlier populations. The most effective method to date for the most problematic species remains herbicides, which are applied using a variety of techniques. Refuge crews and volunteers deal with ancillary exotics on an individual basis. Along with conventional control methods, refuge staff are also active on the biological control front, working closely with the United States Department of Agriculture (USDA) to coordinate the release of insects such as the *Melaleuca* psyllid, a potential biocontrol agent for *Melaleuca quinquenervia,* and by implementing vegetation studies on *L. microphyllum* infested tree islands in collaboration with private parties such as the Institute for Regional Conservation (IRC) to provide baseline information on the impacts of *L. microphyllum* for future biological control releases. To combat aquatic invasive plants such as water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*), the refuge collaborates with the SFWMD to ensure waterways are clear and navigable to maintain effective water flow and drainage and to ensure public recreational activities such as fishing and canoeing are not adversely impacted.

Areas that have undergone eradication efforts are monitored to document impact to and re-growth of the targeted invasive plant species and of surrounding native vegetation. These two parameters are then used to gauge the effectiveness of the treatment programs, improve efficiency, and provide modifications for future treatment protocols. This monitoring program includes establishing plots on islands where *Melaleuca* and *Lygodium* have been treated via ground-based herbicide applications. Though ground applications appear to be effective when performed correctly, they may not be cost efficient due to the severe infestations now occurring within all refuge habitats. To evaluate an alternative control technique refuge staff, in cooperation with the SFWMD and University of Florida (UF) scientists, are also examining the effectiveness of aerial application of two herbicides at two concentrations on two strand tree islands severely infested with *L. microphyllum*. In addition to monitoring post-treatment efforts, the refuge supports and facilitates several research projects on invasive plant species through cooperative efforts as well as through the issuance of Special Use Permits. Keeping with one of the primary functions of the National Wildlife Refuge system, refuge staff are examining an often-overlooked impact of invasive plant species; the toll these plants take on the wildlife. By studying the relationship between *L. microphyllum* infestations and vegetation and wildlife diversity, biologists hope to provide insight into the interactions between invasive exotic plants, native plant communities, and wildlife populations.

Research is also underway to develop tools to aid land managers in effective detection of invasive plant species as an alternative to the SRF. The SFWMD is conducting research to determine the feasibility of using IKONOS (satellite) data to detect infestations of *L. microphyllum*. Another crucial question for effective management is the ability to determine those areas at high risk of invasion as a result of exposure to an invasive seed/spore source. To address this concern, refuge staff are collaborating on yet another project to examine the distance *L. microphyllum* spores can be dispersed from existing infestations. By determining areas of highest spore deposition, refuge staff can concentrate their detection, control, and eradication efforts in areas most prone to invasion. This data set will have a dual function, also being integrated into a larger project conducted by USGS and the University of Tennessee (UT). This venture will incorporate current distribution maps, life history attributes of *L. microphyllum*, dispersal data, control mechanisms, and hydrology to develop a computer simulation model. This program will allow land managers to input parameters (current infestation coverage, funding for control, control method, and hydrological limitations) and view the potential outcome of different scenarios, thereby facilitating managerial decisions on the appropriate resources needed for efficient treatment and the type and location of treatments needed to achieve the most effective control to limit spread and invasion to new areas.

Early detection, treatment, and monitoring are critical components of a successful exotic plant management program. The refuge is aggressively addressing this problem, and is taking the necessary steps to monitor and reduce populations of invasive plants on the refuge while strengthening its efforts by collaborating with other private, local, and federal and state agencies including the SFWMD, USDA, Florida Department of Environmental Protection, UF, UT, USGS, Florida Atlantic University, and the IRC. Collaboration is essential; a variety of agencies throughout South Florida are battling invasive plants on a landscape level, encompassing a plethora of federal, state, local, and private buffer lands. By working together and with the help of volunteers, refuge staff are helping ensure the reduction of current exotic plant populations across South Florida.

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Clipping as a Substitute for Fire to Study Seasonal Fire Effects on Muhly Grass (*Muhlenbergia capillaris* var. *filipes*)

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The Cape Sable seaside sparrow is a Federally listed endangered species whose range is almost entirely within Everglades National Park and Big Cypress National Preserve. Its preferred nesting habitat is the short-hydroperiod grassland known as marl or muhly (for *Muhlenbergia capillaris* var. *filipes*) prairie found on either side of the Shark River and Taylor Sloughs. Muhly is a perennial bunch grass with needle-like leaves generally less than one meter in height. Recent concerns about the survival of the Cape Sable seaside sparrow result from population declines attributed to prolonged flooding in the sparrow range west of Shark River Slough during the 1990's.

Muhly prairies can burn almost any time of the year. The area burned by wildfire is greatest during April, May, and June (Snyder 1991), which is the peak of the Cape Sable seaside sparrow breeding season (Nott et al. 1998). Prescribed burning is recommended to prevent large wildfires from denuding significant portions of the critical habitat. It is often done during the cooler winter months because of more predictable and favorable burning conditions. Prescribed burning during the transition from dry to wet season, when fires normally burn the greatest area, is generally avoided because of potential control problems and because sparrows are nesting. While fire is a natural and necessary phenomenon in muhly prairies, the interaction of fire and flooding can have profound effects on vegetation structure and composition. Fire followed by flooding can result in high mortality of plants that normally resprout vigorously (Herndon et al. 1991).

We have proposed to address two related questions relevant to fire management and the endangered Cape Sable seaside sparrow: 1. How does season of burning effect the rate of recovery of muhly? and 2. How does season of fire effect the ability of muhly to tolerate flooding? These questions will be addressed through two experiments, one in the field and one under more controlled conditions. Because experimental prescribed burns are relatively expensive to conduct and are difficult to apply consistently over time, the clipping of muhly plants was proposed as a substitute for fire. There is ample evidence that clipping and removal of litter can result in responses similar to those observed following fire (Hulbert 1988). The results of a preliminary experiment intended to compare the response of muhly to clipping and burning are reported here.

The experiment was conducted in an area of muhly prairie burned by a wildfire that occurred on May 7, 2001, along U.S. 41 in Big Cypress National Preserve. On May 22, 20 burned muhly clumps were marked, about 50 m south of the road and within 20 m of the fire edge. The plants had resprouted about 10 cm since the fire. In the adjoining unburned area to the east 80 unburned muhly clumps were marked. Ten randomly selected clumps were clipped about 2 cm above the ground, matching the amount of grass that remained after burning. Although 15 days had passed since the burn, it was assumed that the response from the clipped plants would be similar to that of the burned plants. Groups of 10 randomly selected plants were clipped on 5 additional dates through July 12 to see if the seasonal timing of top removal affected plant response. Twenty marked plants were not clipped and served as controls. The heights of the tallest leaves in the marked muhly clumps in the burned area were recorded each time plants were clipped. By the latter part of June, there had been substantial rainfall and the ground was wet. At the last clipping date on July 12 there was standing water in low spots. The heights of a few plants clipped at different times were measured to compare rates of regrowth after clipping and burning.

Figures 1 and 2 show regrowth of the burned and clipped plants, respectively. The figures cannot be compared directly because the growth of plants burned on May 7 was followed for up to 66 days; whereas, plants were clipped at various times up to 51 days before July 12. Therefore, the period during which leaf growth was observed differed in the two situations. The closest comparison is between plants clipped 15 days after the fire, which were slightly under 60 cm tall 50 days after clipping, to burned plants, which were slightly over 60 cm tall 50 days after burning. It therefore appears that growth is similar, but that burned plants may resprout more vigorously than clipped plants. It is possible that the ash fertilizes the grass after burning and enhances regrowth.

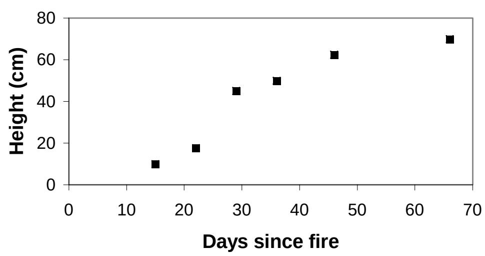

Figure 1. Approximate heights of tallest leaves resprouting from muhly clumps burned on May 7, 2001.

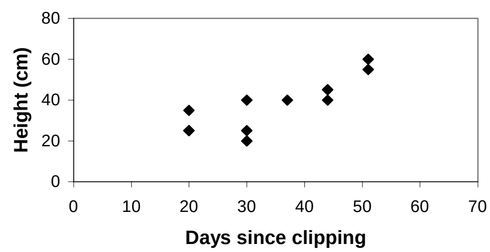

Figure 2. Heights (on July12, 2001) of tallest resprouting leaves from several clipped plants.

In October, the number of flowering culms in each clump was counted. In the unburned area, the 20 unclipped plants had no flowering culms. This was considered likely because flowering is seldom observed in muhly that has not recently burned. In the burned area the plants showed substantial flowering. Only 17 of the 20 plants originally marked in the burned area were relocated and they had a mean of 6.5 flowering culms per plant, with a range of 0 (2 plants) to 15 culms per plant. In contrast, a single flowering culm was found on a plant clipped on June 22; the other 59 clipped plants had no flowers. Therefore, the conclusion drawn is that clipping as done in this experiment is not an adequate substitute for fire, even though vegetative regrowth was similar between burned and clipped plants.

A few possible reasons that flowering is not stimulated by clipping include the lack of a nutrient pulse, excess residual litter, or a lack of stimulation to belowground parts by heat. Even though a 2 cm stubble is left after a fire, the tissues above ground are undoubtedly dead. This is not the case with clipped plants.

As a consequence of this preliminary study, a method to burn individual muhly clumps in the field relatively easily and safely has been developed. Experimental burning treatments addressing the issue of season of burning and the response of muhly in will begin in January 2003 and continue through the early part of the wet season.

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The Pollination Ecology of Everglades Sawgrass, *Cladium jamaicense* (Cyperaceae)

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Sawgrass, *Cladium jamaicense,* is the dominant macrophyte in the Florida Everglades. Changes in Everglades sawgrass populations as a result of anthropogenic inputs and restoration activities are thus of major concern. Sawgrass growth in relation to abiotic processes such as fire, hydrology, and nutrients have been studied, but research has only recently begun to address sawgrass's population structure. In a survey across the Everglades ecosystem sawgrass genotypic diversity has been found at the m^2 scale. Thus, despite abundant clonal reproduction, sexual reproduction is important to sawgrass population structure. To date, little is known about *C. jamaicense*'s breeding system. This study reports some of the basic biological parameters of sexual reproduction in sawgrass. The main objectives are to determine the compatibility reaction and to estimate the efficiency of pollen capture of sawgrass.

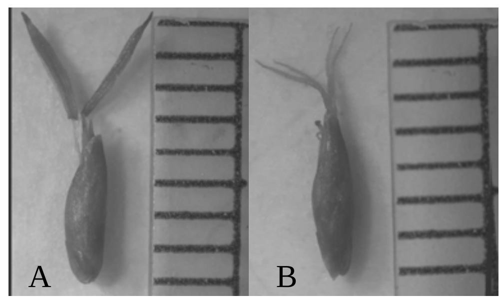

Figure 1. Sawgrass spikelets with (A) anthers of male flower and (B) stigmas of female flower

Sawgrass is a monecious, wind pollinated sedge that flowers from late April to early June in south Florida. Its inflorescence has a main axis that bears multiple lateral clusters containing branches of spikelets, which are the reproductive unit in sedges (Figure 1, 2). Each spikelet consists of two developmentally bisexual flowers. These typically function successively as a male flower and bisexual flower, for the ovary of the first flower in the spikelet aborts. Sex expression within a flower is temporally segregated, and the female style and stigma emerge, capture pollen and senesce prior to anther expansion. Members of the sedge family (Cyperaceae) can be self incompatible, but there is no report of whether sawgrass is self-incompatible or utilizes the temporal sex separation to prevent self-pollination.

Figure 2. Lateral clusters of Sawgrass inflorescence

Compatibility studies were preformed in both *ex situ* and *in situ* sawgrass populations. Seven plants from a 4-year old *ex situ* population at Henington Pond, Florida International University and 5 plants from F.I.U.'s Singletary restoration site in south Florida were used in controlled pollinations. On each plant, 5 treatments were used to test the compatibility response: autogamy, self-pollination, cross-pollination, an open pollination control, and a manipulation control. The manipulation control tested the effect of pollination manipulations; in this treatment previously-bagged flowers were exposed for the same period of time as the self and cross treatments were exposed to perform pollinations. Each treatment was performed on spikelets within the second and fourth lateral clusters (Figure 2), with the exception of the open treatment, which was also done on the fifth lateral cluster. Self treatment branches were enclosed in foil after anther dehiscence of the first flower was completed; once stigmas emerged, pollen from the same individual was placed on the stigmas via hand-pollination. Cross treatment branches were treated as above, but pollen from another population was placed on the stigmas. While self and cross treatments were hand-pollinated, open-pollinated treatment branches were covered in foil. Following pollinations, foil was removed and open treatment branches were left exposed. Autogamy (self-fertilization within the flower) treatment branches were enclosed with aluminum foil. For both the autogamy and manipulation control treatments the foil enclosures were permanently removed following initiation of cluster seed set.

The timing and efficiency of pollen capture by stigmas was experimentally determined in a population at the Singletary property. Four 6 m^2 plots > 3m apart were established. From each plot 8 plants were sampled. On each plant the second, fourth, and sixth lateral flower clusters were bagged in foil, then exposed at time 0 on the day the female flowers emerge and become receptive. Stigmas from these clusters were collected hourly until a majority of them had dried out and were fixed in 3:1 95 % ethanol: glacial acetic acid. The effects of humidity and temperature on pollen dispersal were measured throughout the exposure period using a HOBO Pro RH/Temp/Light H08-004-02 sensor. Stigmas were rehydrated in distilled water, mounted on slides and stained with Alexander's stain. The number of grains on collected stigmas was counted under a compound light microscope.

Results from compatibility treatments are summarized in Table 1. In both populations seed set on autogamy and manipulation control treatments was low. Sawgrass was found to be self-compatible, as self- and cross-pollination treatments did not differ significantly in all populations. Open seed set in the Singletary population was significantly lower than in self- and cross-pollination treatments, producing only 27 % of seeds, but at Henington Pond open pollinations produced seed set similar to self- and cross-pollinations. This is possibly due to end of season pollen limitation, as Singletary populations were sampled in late May-early June, while Henington Pond populations were sampled in mid-May.

Table 1. Seed set proportions (SE) across compatability treatments from May-June 2002 .

Treatment*	Henington Pond	Singletary Property	Pooled Sites
O	0.75 (0.16)	0.21 (0.22)	0.57 (0.15)
C	0.82 (0.19)	0.45 (0.25)	0.64 (0.17)
S	0.72 (0.22)	0.50 (0.22)	0.60 (0.16)
A	0.17 (0.17)	0.02 (0.06)	0.10 (0.10)
X	0.44 (0.29)	0.01 (0.05)	0.19 (0.14)

*Treatments: O = Open, C = Cross, S = Self, A = Autogamy, X = Manipulation control

Pollen release in a natural sawgrass population begins largely between 06:15 and 07:15 and appears to be largely dependant on temperature and humidity; stigmas dried out by approximately 10:30 to 11:00. Stigmas captured an average of 4.4 pollen grains ranging from 0 to 56.5. Across all plots, stigmatic pollen capture variation was high along the inflorescence and between plots. There was a trend, however, for increased pollen capture over longer exposure times. Additionally, pollen capture was positively correlated to ambient temperature and negatively correlated to relative humidity.

These results show that sawgrass is self-compatible, setting the same amount of seed with cross-pollination as with self-pollination. Thus, outbreeding is dependent on the timing of spikelet expansion in other inflorescences within a clone and other individuals within a population. Because sawgrass flowering is relatively synchronous within an inflorescence, isolated inflorescences should not set seed because of the temporal separation of sexual function. Flowering between inflorescences on the same clone can be asynchronous, however, so individuals can set selfed seed by pollination between inflorescences in the same clone. In addition, pollen capture, and thus seed set, is dependent on both temperature and humidity. Within the context of the Florida Everglades, understanding sawgrass reproduction, both sexual and asexual, is of particular importance in modeling distribution patterns and optimizing conditions for revegetation and transplantation in wetland restoration areas. Single plants can establish populations that will set seed, but populations established from multiple genotypes would promote outbreeding. The m^2 scale of genotypic variation in natural sawgrass populations would allow for outcrossing, but establishing this variation requires the dry-down conditions that promote seed germination and seedling establishment.

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South Florida Information Access System (SOFIA)

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The South Florida Information Access (SOFIA) system was created by the U.S. Geological Survey (USGS) in 1995. Its mission is to provide easy access to information about research projects and products generated as part of the USGS South Florida Placed-Based Studies (PBS) and other Federal, state, and local science providers. SOFIA provides this service by integrating information systems and tools enabling efficient storage, organization, and search and retrieval of scientific information about the South Florida ecosystem.

A principal objective of the USGS South Florida PBS is to assist resource managers who require an improved scientific information base to resolve or prevent complex resource conflicts or environmental problems in southern Florida. SOFIA is an integral element of this program and is a primary resource for providing the USGS scientific information to resource managers and scientists working to preserve and restore the South Florida ecosystem. SOFIA was designed to benefit three major user groups: USGS program managers and scientists working with the South Florida PBS, managers and scientists working for other organizations involved with Everglades restoration, and members of the public interested in USGS research and/or the science behind the Everglades restoration effort. Program managers and scientists working within the South Florida PBS use the SOFIA website in various ways: (1) coordination and sharing of scientific research information; (2) access to announcements and registration links for upcoming workshops, conferences, and seminars; (3) monitoring of current ecosystem conditions through the real-time data pages; and (4) access to synthesis of topic-specific research results to benefit from lessons learned and avoid duplication of effort.

The users of the SOFIA site have a variety of interests and informational needs. Information is provided at many levels of detail, catering to users from a wide range of technical understanding. The general public uses the site to understand the problems and research behind Everglades restoration. The site provides information for children and adults, including summaries already adapted for use in classroom, museum, and other public venues, as wells as for journalists, government, and non-government organizations. SOFIA is used by stakeholders who follow USGS activities in the community and outdoorsmen to track research as well as monitor real-time conditions in planning activities.

SOFIA is an evolving and dynamic system that builds on the ever-increasing sophistication of new information technology. The current architecture consists of three tiers. The top tier is the web browser; the middle tier is the web server with business logic, and static web pages and data files; and the bottom tier is the SOFIA database. A map server using geographic information system (GIS) technology is being developed to provide a map-based interface to the database and the website.

Data is served by three mechanisms on the SOFIA website. The Data Exchange (URL http://sofia.usgs.gov/exchange/) provides access to files organized by project. The projects are further organized using six primary themes: biology, chemistry, ecology, geology, hydrology, and mapping. Data are stored in various file formats, such as ASCII text files, spreadsheets, and databases. For each data set, additional information is provided, including a description of the method of data-collection, an explanation of the data file format, and a listing and a map of the data collection locations. The Data Exchange provides an efficient means of providing data to users who are familiar with a project and would like to obtain the project data sets.

The second mechanism of serving data is through a web interface (URL http://www.envirobase.usgs.gov) to an SQL-based database. The SOFIA database is currently being developed using PostgeSQL 7.2 as the database engine. The web interface is being developed using PHP, a server-side scripting language developed for the web. The database consists of over 50 tables, providing a means of storing the data and associated metadata. Included in the tables are the data values as well as information about methods of data collection, data-collection locations, and associated projects, publications, and photographs. Many of the database objects provide links to related information on the SOFIA website.

The third mechanism of serving data is through a web-based map server. The map server, which is being developed using ArcIMS software, will provide a means of accessing information stored in the SOFIA database and the SOFIA data exchange website through a geospatial query. The spatial data will be served using the ArcSDE software, which provides a mechanism for storing spatial data in a relational database. The spatial database will contain point data sets showing data-collection locations presented on the SOFIA website, published maps, such as bathymetric contours, geologic surfaces, and vegetation grids, as well as background data sets, such as political boundaries, hydrography, and roads. The map server will provide access to related information stored on the SOFIA website and in the SOFIA database.

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Metadata for the U.S. Geological Survey Greater Everglades Place-Based Studies

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The South Florida ecosystem, encompassing Everglades National Park, urban areas on the coast, intensely developed agricultural areas, rangelands, and wetlands, has been altered greatly over the last 100 years. In 1995, the U.S. Geological Survey (USGS) began a research program in support of the restoration of the Everglades and South Florida ecosystem. Early in the program, the need for information to document the projects and later the resulting datasets was recognized. Metadata allow for the documentation and discovery of data. They also provide lasting information about the data in the event the data producer is no longer available. Use of standardized terminology facilitates searches for data by all users.

In 1994, Executive Order 12906 was issued, which mandated that digital data produced by a Federal agency be documented with metadata specified by the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata. Members of the South Florida Information Access (SOFIA) metadata team conducted a survey of the project chiefs on the usefulness of metadata and their willingness to provide FGDC-compliant metadata for their projects and datasets. The overwhelming majority of the respondents agreed that metadata were very important, but that they had no funds or personnel to create the metadata. Furthermore, most of them felt that the FGDC standard was too confusing and cumbersome to use. The survey results led to the decision to create a metadata team for generating the required metadata. This would result in more consistent metadata, and the scientists would not have to become familiar with the FGDC standard to document only one or two projects or datasets a year.

The initial metadata records were created by interviewing the project chiefs and using their project proposals to fill in the elements in the FGDC standard. The project chiefs then reviewed the resulting records and the team made the indicated changes or corrections. The records were then posted on the SOFIA web site and indexed for searching on the FGDC National Spatial Data Infrastructure (NSDI) node as the South Florida Ecosystem database.

Several methods have been used to create the FGDC metadata records. Initially, a template was created using a word processing program. The required FGDC elements were populated, and the file was output in ASCII text format. For the last several years, the commercial software program Spatial Metadata Management System (SMMS) has been used. SMMS is currently a product of the Intergraph Corporation. This program is not perfect but is a great improvement over the word processing template. Output from this program is also in ASCII text for input to the USGS program “mp,” which is used to parse the metadata records for conformance with the correct parent-child relationships for FGDC metadata. This program also allows output of the records in various formats, such as the outline or standard FGDC format, a question and answer format that uses “plain English” statements for the metadata information, SGML to index the records for the FGDC NSDI node, ASCII text, XML, and several other formats not used on SOFIA. Other options for creating metadata include USGS in-house software XTME for UNIX-based systems and TKME for Windows-based systems. Metadata created from a word processing template must be run through preparser software “cns,” also from the USGS. This program formats ASCII text files into the outline format for input to mp.

Current work on the metadata involves updating the project records and creating records for all the datasets available on the Data Exchange pages on SOFIA. Information to update the metadata is being gleaned from project annual summaries, proposals, work plans, and published reports, such as USGS Open-File Reports, Water Resources Investigations Reports, fact sheets, conference abstracts, and journal papers. The updated records are sent to the project chiefs for review. Recently, the SOFIA program manager decided to document types of data rather than individual datasets. This necessitates combining records already on SOFIA into one record for each type of data collected by a project chief. It also will reduce the number of metadata records to be maintained. The plan is to have all fiscal year (FY) 2003 projects documented with FGDC-compliant metadata by the GEER conference in April 2003. By the end of the fiscal year, the data sets for FY03 will also have current FGDC metadata records. Metadata for projects and datasets that have been completed will also be updated but at a lower priority. Another lower priority goal is to document relevant historical datasets with metadata to enhance the ability to do time-series studies for the Everglades area. Links will be provided to other organizations' metadata applicable to the Everglades restoration effort.

Undocumented data are of little use other than to the collector. Information about the data must be available to ensure its future use. The FGDC metadata standard provides standardized element names and information. This allows potential users to search for and evaluate the data for their use. It also preserves the usefulness of the data if the original data collector leaves the organization. Data generated by the USGS as part of the research into the Everglades restoration effort need to be available to other researchers in the future and will enhance data collection efficiency. Documenting projects and datasets with proper metadata can help prevent duplication in data collection.

Information on XTME, TKME, cns, and mp can be found at:
http://geology.usgs.gov/tools/metadata/.

An explanation of Metadata in plain language can be found at:
http://geology.usgs.gov/tools/metadata/tools/doc/ctc/.

The FGDC metadata standard is available at: **http://www.fgdc.gov/metadata/contstan.html**.

Information on SMMS is available at: **http://www.intergraph.com/gis/smms/**.

The metadata for the USGS Place-Based Studies research in South Florida are on the SOFIA Web site at: **http://sofia.usgs.gov/**.

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Modeling Manatee Response to Restoration in the Everglades and Ten Thousand Islands

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The coastal waters of southwest Florida harbor nearly a third of Florida's population of the Federally listed West Indian manatee (*Trichechus manatus*). A large proportion of this population occurs within the Everglades National Park (ENP) and the Ten Thousand Islands (TTI), yet only limited information is available from this remote region. Aerial surveys conducted by ENP personnel in the early 1990s revealed heavy use of both inshore and offshore areas during most of the year. Manatees feed almost exclusively on submerged aquatic vegetation (SAV), and most individuals show a strong preference for marine seagrasses. Because manatees lack the ability to drink saltwater (mariposia), they need to drink freshwater periodically. Thus, manatees depend on resources in marine, estuarine, and freshwater zones, making them excellent indicators of the health and restoration success across all of these zones.

A primary goal of this research is to develop an individual-based ATLSS model to simulate manatee response to changes in hydrology caused by the Comprehensive Everglades Restoration Plan (CERP). In support of this goal we have analyzed manatee telemetry data from the study area to parameterize and calibrate the model. We have also conducted aerial surveys in the TTI region to provide information on the distribution and abundance of manatees that could be used to validate the model.

Analysis of telemetry data

Data was analyzed from 20 tagged animals between June 2000 and July 2002, representing 4,563 manatee tracking days. The attached Argos transmitters were programmed to fix at least 1 location during 4 time-windows each day, when satellite overpass geometry was optimal. The actual number and accuracy of fixes obtained varied due to animal behavior or equipment performance. Filtering out all points with poor spatial accuracy resulted in 12,600 fixes, a decrease of 31% over what could be obtained under optimal conditions. We also deployed GPS tags for 104 manatee days; these tags were programmed to obtain fixes at 15- or 20-minute intervals.

The Argos telemetry data provided valuable information on coarse-scale patterns of manatee behavior that were incorporated into the ATLSS model. We classified the landscape into 4 simple aquatic zones: offshore, travel corridors, inshore bays, and inland riverine systems or canals. We used a GIS overlay analysis to determine the aquatic zone for each telemetry point. Most manatees showed a consistent pattern of feeding on marine seagrass beds in offshore zones for a period of several days, followed by large movements of 5 to 20 km or more up rivers and canals, presumably to obtain freshwater. Several animals also made heavy use of inshore bays where they could feed on a suite of SAV different from the offshore areas. The home ranges of all animals incorporated one or more inland sites which supply freshwater, as well as offshore areas that provide food resources.

Comparison of the number of inland forays made during wet versus dry season showed a slightly higher number during the dry season, but the difference was not significant. Manatees made inland forays in the wet season, even when freshwater was available at the mouth of rivers or canals. During periods of significant cold weather, manatees greatly decreased their use of offshore areas and increased their use of inshore locations with favorable thermal buffering (typically deeper sections of canals, rivers, and inshore holes).

GPS data provided valuable fine-scale information on manatee behavior, which could not be obtained from the Argos data. Distribution of movement rates between GPS points fitted an inverse distribution, with a mean and mode well below 1 km/hour, and maximum speeds approaching 3 km/hour. Directionality of movement was highly biased towards small turn angles, and the GPS data provided precise movement pathways through the complex aquatic landscape in TTI and ENP.

The telemetry data provided valuable information needed to parameterize and structure the ATLSS model. The broad movement patterns provided by the Argos data were nicely complemented by the detailed data provided by the GPS tags.

Model structure

The manatee ATLSS model is being developed in C++ using object-oriented techniques. The model is individual-based, spatially-explicit, and simulates the movements of individuals on a raster image (20 m cell size) of southwest Florida. A network data structure of arcs and nodes is used to direct the movement of manatees in an efficient manner. This network structure was developed from telemetry locations and aerial survey data, and consists of nodes representing primary drinking areas, feeding areas, and thermal sheltering areas, connected by travel paths represented as arcs. Standard algorithms from graph theory are used to access and query this network structure.

Home range allocation – Each manatee is allocated a portion of the total network that includes one or more freshwater sites and offshore seagrass beds. The initial network portion allocated to each manatee at the start of a simulation is drawn from a distribution of home range sizes and geographic positions along the coast as determined from telemetry data. Manatees born after the creation of the initial cohort inherit their mother's network, to reflect maternal transmission of home range.

Movement rules - Manatees move on a network of nodes representing destination sites for feeding, drinking, and thermal sheltering, all connected by arcs representing travel corridors. Low water depths limit the movement of manatees along some portions of the network. Manatees can shift their home range to different parts of the total network if freshwater or seagrass becomes unavailable within their subset of the network.

Incorporation of environmental variables - Salinities, temperature, and water depth are modeled only along this network, rather than across the entire grid, to increase computational efficiency. Until linkages exist to hydrologic models such as TIME, we are relying on simple surrogate models that simulate observed patterns and possible restoration scenarios.

Manatee behavioral state switching - A Markov Chain approach is used to simulate the transition of manatees into different behavioral states that drive the movement patterns of each individual. Only a few, simple behavioral states (feeding, drinking, traveling, resting) inferred from the telemetry data are modeled. Transition probabilities were developed from the telemetry data and from previous research on manatee time budgets in other areas.

Manatee learning – Several simple learning modules simulate freshwater site switching by manatees. These modules determine how quickly manatees shift their use of different parts of the network in response to positive or negative reinforcement in the availability of freshwater at sites within the home range of each manatee. The simplest algorithm, the real-time linear operator model, assumes that animals maintain an estimate of resource availability at time *t*, which is incremented or decremented during each time step, depending on whether the resource was found or not.

Key assumptions – A key component of the model is the manatee-learning module, which determines how quickly manatees shift their use of different parts of the network in response to positive or negative reinforcement in the availability of a critical resource. Sensitivity analyses will be used to evaluate the importance of different assumptions and uncertainty associated with poorly understood parameters. As additional telemetry data are collected, the model will be refined to incorporate new insights from these data. Radiotracking and aerial surveys will provide an important means of monitoring manatee response to natural environmental fluctuations and human-induced alterations associated with restoration activities.

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Wading Bird Use of Managed Wetland Habitats for Foraging in the Northern Indian River Lagoon System

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Continuous long-term ecological monitoring of wading bird populations in the northern Indian River lagoon system has been underway since 1987. Some wading bird species appear to have benefited from changes in habitat resulting from salt marsh impounding. However, use of habitat by wading birds varies greatly between seemingly similar impoundments. The myriad conditions present in this region and the ongoing efforts to reconnect impoundments to the estuary provide a unique opportunity to investigate factors influencing wading bird habitat use under different management scenarios. This talk explores patterns of wading bird habitat use within managed impounded wetland habitat in a subtropical estuary, and the mechanisms controlling those patterns.

Study Site - The Kennedy Space Center/Merritt Island National Wildlife Refuge (KSC/MINWR) is located on the Atlantic coast of Florida, and encompasses a large portion of the northern part of the Indian River Lagoon System (IRLS). Stretching for ca. 250 km the IRLS is a sub-tropical estuary with an unusually high level of biodiversity due to its location at the junction of the warm-temperate Carolinian Province and the Tropical Caribbean Province. Historically the eastern shore of the IRLS was extensively vegetated with irregularly flood salt marsh habitat. However, almost all salt marsh in the northern part of the IRLS was impounded for mosquito control by the 1970's. There is growing concern that isolation of wetland habitat from the IRLS has reduced ecological benefits of the system. Currently, efforts are underway which will reconnect over three-quarters of all impounded wetlands in the IRL, including the majority of impoundments at KSC/MINWR. The IRLS is an important site for wading birds on the southeastern Atlantic coast of North America. KSC/MINWR supports a large wading bird population that utilizes freshwater and salt marsh habitats for feeding, roosting, and nesting.

Methods - Wading bird habitat surveys included in this analysis were conducted between April 1987 and April 2002. Surveys were conducted by helicopter flying at an altitude of approximately 60 m, and a speed of 60 kn. The sampling schedule for surveys was one per month, although some months were missed due to constraints on use of the NASA helicopter. Roughly 20 % of the nearly 11,000 ha of impounded marsh habitat and 16% of the estuarine/river boundary occurring on KSC/MINWR was surveyed. Impoundments were flown systematically such that all area within was observed, and all individuals visible within the impoundment were counted. Estuarine edge was surveyed by flying approximately 300 m from the shore and included observations within this 300 m strip.

Between April and June 2000, nesting Great Egrets and Snowy Egrets were followed by helicopter from their nests to their foraging locations between sunrise and five hours after sunrise. The helicopter was hovered near the colony until a bird was observed leaving the colony. Then the bird was followed until it landed at a foraging location. Once a bird landed, a GPS position was recorded at the location, and the habitat type was noted. If the subject was part of a group, an attempt was made to note the landing position of all members of the group, but often this was not possible because the subject bird would continue flying. In these cases, only information about the subject bird was recorded.

Results –Sixty-one percent of wading birds followed from nesting colonies landed at foraging sites within impoundments, 15 % landed in estuarine edge habitat and 24% landed in unimpounded freshwater wetland habitat. (N=79). The average number of wading birds foraging within impoundments and along estuarine shoreline was estimated to be approximately 7000 individuals; the number of birds using the northern IRLS system is certainly greater than this, since number of birds using unimpounded freshwater wetlands was not included in this estimate. Ten of the sixteen species of wading birds known to occur in the northern IRLS were observed regularly during aerial surveys (Figure 1).

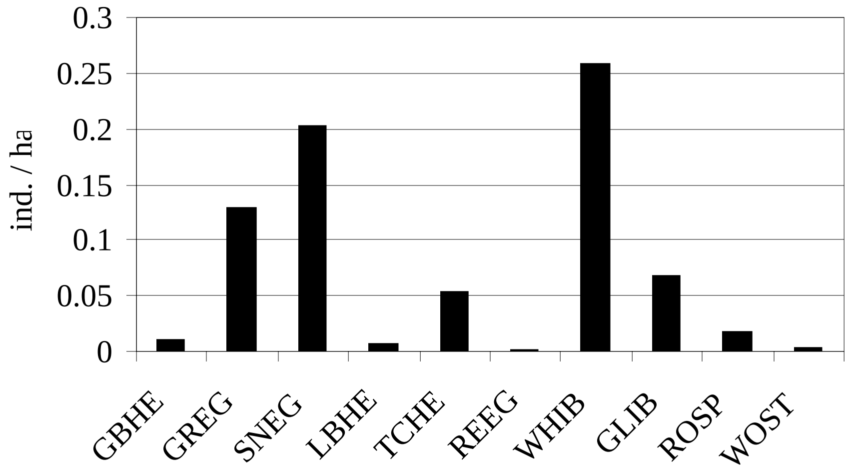

Figure 1. Density of wading birds observed foraging within impounded wetland habitat in the northern Indian River Lagoon System. Species are: Great Blue Heron (GBHE), Great Egret (GREG), Snowy Egret (SNEG), Little Blue Heron (LBHE), Tricolored Heron, TCHE), Reddish Egret (REEG), White Ibis (WHIB), Glossy Ibis (GLIB), Roseate Spoonbill, (ROSP), and Wood Stork (WOST).

There were distinct temporal and spatial habitat use patterns within individual wading bird species foraging in impounded wetlands. Most species showed a preference for foraging within open water habitat, but use of vegetated habitats increased in fall and winter. These changes in habitat use corresponded with hydrological changes within the system. Density of wading birds within impoundments varied greatly across the landscape; the ratio of marsh to open water habitat within the impoundment explained some of this variation (Figure 2).

Current research efforts focusing on linking wading bird habitat use patterns to prey availability will also be discussed. Models of the relationship between hydrological and habitat changes and bird use of foraging habitat will be presented.

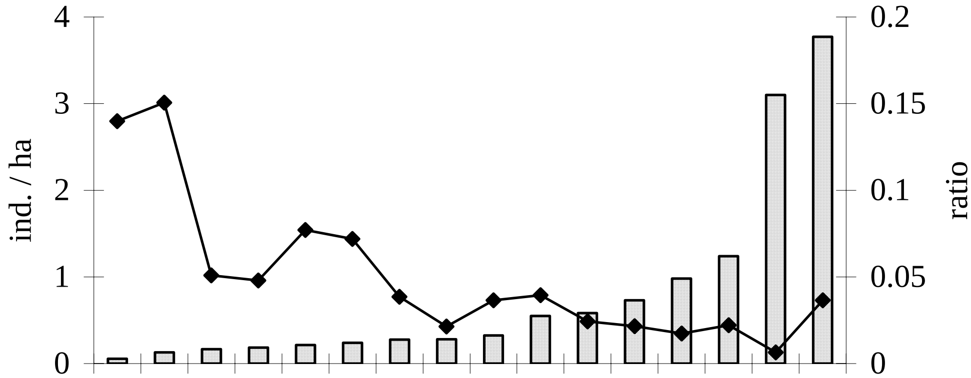

Figure 2. The density of foraging wading birds within impoundments (bars) increases as the ratio of open water to marsh habitat (line) decreases. Ratio calculated as arcsine (ha open water / ha marsh). Individual impoundment names not shown on figure.

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Diverse Organic Sediments and Stratigraphy in Large Tree-Islands of Shark River Slough, Everglades National Park

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The tree-islands ("hammocks") of Shark River Slough in the southwestern Everglades form one of the main assemblages of tree-islands in the regional peatland. There they are seemingly the least disturbed among the large mineral-mound-focused major type of tree-island in the peatland. Their importance as emerged to partially emerged sites in adding vegetational and habitat diversity in the encompassing marshland is obvious; additionally they have had a notable archeological and historical role. Important in their own right in the national park, they additionally likely represent lost landscape features of the eastern middle Everglades (CA2B southward) where mounds of sand or limestone also focused the upstream ends of large elongated tree-islands in wide marshes underlain by peat up to a meter or so thick. Related tree-islands lie to the north in CA3.

The numerous prominent large tree-islands are elongated roughly N–S, clearly aligned with the direction of sluggish overland flow in the marshes. The exact mechanism for this elongation remains unknown, but has been much speculated. Most of the large elongated ("teardrop" shaped) tree-islands here are two-component, with a rounded stand or "head" of more-tropical evergreen trees (true hammock) on the northern end and a long downflow (downstream) "tail" of bayhead forest. The hammock lies above a slight mound in the underlying limestone bedrock and is further raised above flooding by a cap of organic-rich (to peaty) granular sediment. One hammock had an intervening distinct layer of granular carbonate-rich marine sediment of pre-Everglades origin (perhaps a residuum of limestone erosion or perhaps a younger stratum). The bayhead tail lies upon a slight ridge of peat (and muck) and is seemingly unrelated to the topography of the directly underlying limestone, but clearly related somehow to the low mound just upflow. The tail floods in highwater season, though less so than the surrounding marshes. A dense sawgrass marsh can extend this distinct elongation still farther downstream (S) as well as slightly laterally of the tail (E–W) by contrast with the sparser or lower sawgrass or wet-prairie vegetation of the surrounding marshes. Certain large tree-islands lack the hammock head and by their uniform bayhead stand resemble the large tree-islands on deeper peats of the northeastern Everglades. Lacking the mineral mound, their origin and reasons for their location are even more obscure. The rock-mound focus of the more typical tree-islands existed before, during, and after the development of the early Everglades rock and marl marshes and then the peat marshes that now surround the tree-islands. The unfocused tree-islands and the typical tails of all tree-islands seem to have formed only later, during the peatland era.

Sediment cores in the head and tail of representative tree-islands, plus a few sites at the periphery and in nearby marshes, reveal an assortment of sediments (some unanticipated) in a fairly complex stratigraphy. Peat or peat-dominated sediment basically prevails (as expected) in the bayhead tails, while peat and a granular forest humus predominates in the hammock heads. But muck—being fine-grained organic- and mineral-rich sediment—is extremely common. It is found intermixed with peat in midlevel zones beneath the tails. Muck even dominates some strata, but their upper and lowers boundaries are usually more transitional rather than distinct. Parts of some muck zones have apparently burned to ash. A much different sediment, a granular organic-rich debris, and a sediment modification, incipient cementation, occur in places beneath the hammock heads and their edges (both are probably archeologically related).

The abundant muck was unexpected. It is not marly peat, enriched merely with carbonate silt precipitated by periphyton in the marshes. The origin of the silicate-rich muck is yet unknown. The source and mode of transport of the fine mineral matter is the most puzzling, but those of the fine organic matter are unknown too. The muck predominates at midlevels, with purer peat found toward the present surface and in places underlying the mucky sediment. The muck formation and transport possibly relate to a hydrologic and perhaps climatic stage. The emplacement of the muck materials by physical transport very plausibly is related to the process of elongation and alignment of the tails, important components in the widespread "sweep" of Everglades vegetation. Muck in any visible importance was not encountered in the two marsh cores, further adding to the mystery of its origin.

Apparent ash layers are found in the peat-and-muck sediment zone beneath two tree-island tails and cover an extensive area in one (occur in two cores 200+ m apart). No other origin seems plausible for this fine, organic-deficient (light-colored) sediment that contains a little carbonate but is mostly of insoluble mineral (i.e., siliceous). These relict layers are very thick (2.5B22 cm in three cores) compared to wetted ash from typical Everglades peat fires and must result from the burning of a muck or muck-rich organic layer instead. Typical peat would have had much lower mineral content. Such mucky source sediment underlies or overlies the ash layers, forming an obvious source. Very dry conditions with a severe fire is indicated in each case and these are possible contemporaneous in the two tree-islands (precise ^{14}C dating of this shallow-lying layer is problematic).

The pre-peatland era of Everglades wetland evolution is well represented in areas of thicker sediment beneath the tails. Thick marsh marl lies beneath peat in some local solution depressions and in places shows obvious, though subdued, internal stratigraphy, implying environmental changes.

These sediment profiles represent the long-term environmental records of the tree-islands, including at the top those of recent times. Questions under investigation using paleoecological methods to examine specifics of the floristic and, by proxy, vegetational and hydrological succession, include the following: Are drainage-era shifts evidenced? If so, what were their natures and directions? Prior to that, what was the long-term evolution of these tree-islands? What was the environment of formation of the muck? Additionally, the origin and emplacement of the muck and the shaping and elongation of the tails have strong implication to the whole question of flow and physical transport of solids in the Everglades.

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Peat Stratigraphy and Long-Term Succession of Bayhead Tree-Islands in the Northeastern Everglades

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Tree-islands are distinct patches of forest surrounded by low-stature vegetation. Though common worldwide, tree-islands in the Everglades are among the best known. The northeastern Everglades hosts one of the main vast assemblages, though it is now substantially diminished. Nearly all that remain are in the A.R. Marshall Loxahatchee National Wildlife Refuge (CA1) where they are a dominant landscape feature. Others, formerly extant in Conservation Area 2A (CA2A), are now destroyed, mainly by impounded flooding. Here, we deal with those found on relatively thick peat that seem unrelated to any local surface features on the buried mineral substrate. These include seemingly all those in Loxahatchee NWR and most those formerly in CA2A. (In CA2B and possibly southernmost CA2A, the mineral-mound-focused tree-island predominated, similar to most tree-islands in the middle and southern Everglades, excluding mainly the so-called SE "saline" Everglades.)

This northeastern portion of the Everglades is characterized by an abundance of marshes dominated or codominated by waterlilys, i.e., deeper marshes. Waterlily-rich peats in profiles below the marshes attest to the long prevalence of this general conditionXsince the Everglades peatland began, almost 5000 ^{14}C years in the oldest areas. Sawgrass too is and has been common, occurring now in large elongated strands down to small patches. Small patches of other shallower-marsh marsh plants are common as well. Two main types of tree-island occur(red): (1) roughly 100 large (to 1.5+ km long) elongated ("cigar" shaped in map outline) forests principally of dahoon holly occupying low, seasonally flooded, peat ridges, and (2) thousands of small (to a few 10s of meters in diameter) more-rounded clumps of trees with redbay usually codominant, on distinct mounds of peat (ca. 1 meter high in surveyed examples).

Complete peat profiles obtained by coring were examined for peat-type stratigraphy (main parent plant, shown anatomically in microscope thin section) and for pollen stratigraphy. Pollen and several peat profiles are newly presented here. All nine tree-islands (5 large, 4 small) had forest peat only as an uppermost layer, with marsh peats below. All had initiated upon marsh surfaces somehow, after 3000+ ^{14}C years of marsh existence at their sites. Most showed a stage of emergent marsh at their sites between the era of waterlily prominence and the formation of the eventual tree-island. Sawgrass was most common as this intermediate, but arrowhead occurred prior to two tree-islands (1 large, 1 small).

At the sites of present large tree-islands, spores (in the pollen analysis) show that the later marsh stages were rich in ferns, which if they represent growth at the immediate sites suggest shallower examples of sawgrass marsh (the sawgrass shown by peat type). Waxmyrtle first prevailed as a woody colonist, only later surpassed by the dahoon holly. It seems quite likely that the large tree-islands colonized large individual sawgrass strands already growing on low ridges, whereby the shaping and elongation occurred mainly in a previous stage. Some distinct sawgrass strands in the western fringe area closely resemble the tree-islands in size and outline. Either a shift to a less-wet condition (say, climatically controlled) or a relative rise in local elevation (presumably by faster peat accretion in the sawgrass strands) or even plausibly just a reduction in fire frequency may have induced the replacement of sawgrass by bushes and then trees. Curiously, one site showed a much earlier trend to woody vegetation (by presence of waxmyrtle pollen), but this later reverted back to marsh dominance before finally succeeding to a tree-island.

Most small tree-islands showed an intermediate stage of emergent marsh peat (sawgrass or arrowhead). But one may have formed directly upon waterlily marsh peat. Colonization of a floating peat island is a way this could have been accomplished, but resinking of such peat mats very possibly explains the origin of the more common shallow marsh stages of the other small tree-islands as well. Pollen stratigraphy of one small tree-island showed a prominence first of waterlily, then of arrowhead, then ferns, then waxmyrtle, then holly. It is difficult to say whether the arrowhead and ferns were themselves instrumental or even diagnostic of conditions instrumental to the later transition to bushes and forest here. The peak of arrowhead pollen lay substantially below the beginnings of waxmyrtle importance (ca. 230 cm vs ca. 170 cm, in a ca. 320 cm deep peat profile). A small peak of buttonbush pollen at ca. 155 cm depth, the same depth as the onset of holly pollen, may be significant. Buttonbush is a common colonist on new floating peat islands.

The small tree-island is apparently the older type. To 1.5 meter thickness of forest peat occurs, with several dated basal peats ranging roughly 800B1300 ^{14}C years old. Only thin forest peat is found in the large low tree-islands (ca. ¼ m), too thin to reliably date by ^{14}C methods (another dating method should be undertaken).

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Modeling Changes in Flow Induced by Anisotropy of Vegetation Patches and Topographic Features

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Surface-water flow in the Greater Everglades has historically been modeled using an isotropic Manning's n, implying that resistance to flow is the same in all directions. This approximation may be reasonable when grid cells are much smaller than vegetation patches or topographic features such as tree islands or sawgrass ridges. However, in large-scale models such as the Everglades Natural System Model and the South Florida Water Management Model, grid cells may contain several sawgrass ridges or tree islands.

A groundwater and surface water flow model that includes several options for modeling vegetative resistance to flow is used to explore the importance of anisotropy of large scale resistance features. The impact of these features is examined by considering a fine-scale grid with explicit delineation of the topographic and vegetation features with corresponding distribution of resistance parameters and topography. By imposing gradients parallel and perpendicular to the features, the fine-scale model provides a mechanism to assess the effect of large-scale anisotropy in resistance and topography on the flow system.

The impact of the surface anisotropy on system behavior is found to be dependent on both flow depth and permeability of the underlying aquifer. When the underlying aquifer has low permeability, both surface-water and groundwater flow directions are significantly modified. On the other hand, when the underlying aquifer has high permeability and the surface water is shallow, the overall system is dominated by the groundwater component so that the system is insensitive to surface anisotropy. As the surface water deepens, the surface water system dominates the overall system flow and the surface water flow can be significantly changed by the surface anisotropy.

This result may have important implications for large scale flow models of the Florida Everglades. Failure to simulate large scale surface anisotropies could lead to erroneous predictions in flow directions and could also explain differences in the observed tree island distributions and modeled flow directions in the current version of the Natural System Model. Methods for including directional surface anisotropy in large scale models are tested.

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Design and Operation of a Remote Phosphorus Analyzer

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A remote phosphorus analyzer has been designed and optimized using on-line UV/thermal induced persulfate digestion of total phosphorus in water and ascorbic acid-phosphomolybdenum blue method for total phosphorus and total reactive phosphorus colorimetric determination. The analytical parameters (such as the digestor and cabinet temperatures, the responses of the standards and samples, and the level of reagents and waste in the bottles) were remotely monitored and the data were remotely processed. This remote phosphorus analyzer successfully provided the near real-time total phosphorus and total reactive phosphorus data of the water at the outlet of a Stormwater Treatment Area (STA) of the South Florida Water Management District. The phosphorus concentration results from this analyzer were comparable with the lab analysis and the method detection limit was also similar (4 μg/L) to the lab method. The diurnal fluctuation of total phosphorus and total reactive phosphorus concentrations with the maximum near midday and the minimum near midnight in the water at the STA was observed. Not only may this analyzer be very useful for optimizing the operation of the STA, but also has the potential application in surface water phosphorus TMDL calculation and monitoring.

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The Etiology of White Pox, a Lethal Disease of the Caribbean Elkhorn Coral, *Acropora palmata*

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Epizootics have been reported for several coral species and evidence is mounting of substantial declines in the biodiversity and abundance of reef-building corals. The greatest losses within the Caribbean are among the branching elkhorn and staghorn corals, *Acropora palmata* and *Acropora cervicornis*. White pox disease, which exclusively affects *A. palmata,* was first documented in 1996 on reefs off Key West, Florida and has since been reported on reefs throughout the Caribbean. In Florida, populations of *A. palmata* are being decimated by white pox. Between 1996 and 1999, the average loss of *A. palmata* at seven reef sites in the Florida Keys was 85% and at some reefs losses were as high as 98%. These severe population declines of the coral community's most important primary producer and shallow water framework builder are especially important given the longevity and slow recruitment of this species. We have identified a common fecal enterobacterium, *Serratia marcescens,* as the causal agent of white pox. This is the first time that a bacterial species associated with the human gut has been shown to be a marine invertebrate pathogen.

It is unlikely that the mid-1990's are the first time that *Serratia marcescens* entered the tropical marine environment. Additional factors that may contribute to this bacterium's increased virulence include elevated water temperatures and elevated nutrients, both of which have been documented in EPA's long-term water quality assessment program in the Florida Keys. In general, increased nutrients and temperatures favor microbial growth, and the disease prognosis for a warmer, more polluted ocean is worrisome.

Coral colonies affected by white pox are characterized by the presence of irregularly shaped distinct white blotches of recently dead coral skeleton surrounded by a necrotic front of normally pigmented living coral tissue. Lesions range in area from a few square centimeters to greater than 80 cm^2 and can develop simultaneously on all surfaces of the coral colony. White pox lesions exhibit tissue loss along the perimeter and increase in area as tissue is lost from the leading edge of the infection. The rate of tissue loss is rapid, averaging 2.5 cm^2 day^{-1}, and is greatest during periods of seasonally elevated temperature. White pox is highly contagious with nearest neighbors most susceptible to infection. The disease spread rapidly within and between reefs in the Florida Keys during the late 1990s.

Substantial population losses of acroporid corals are changing the composition, structure, and probably function of Caribbean coral reef ecosystems. *Acropora palmata*, is an important Caribbean shallow water species, providing elevated rates of calcium carbonate deposition and the highly complex three dimensional structure of the shallow water fore reef. Acroporids reproduce almost exclusively by fragmentation. While vegetative reproduction may be well adapted to recolonization following mechanical disturbances such as hurricanes, colony fragmentation is ineffectual following severe population declines due to disease, which frequently kills the entire coral colony. If colonies are too rare or too far apart for high fertilization success, then *A. palmata* may be experiencing an Allee effect, making rapid recovery of this species in the Florida Keys impossible.

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Data-Driven Web Application for Access and Review of CERP System-Wide Modeling

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A key feature in the development of the Comprehensive Everglades Restoration Plan (CERP) was the comparison of the performance of different water management alternatives, facilitated through the use of performance measures accessible on the Restudy Hydrologic Performance Measures Web Page (http://www.sfwmd.gov/org/pld/restudy/hpm). As implementation of CERP proceeds over the next 30 years it will be refined through more detailed design of each project and monitoring of the response of the system to projects as they are implemented. To facilitate system-wide plan evaluation, simulation models will produce thousands of performance measures and indicators, for each of hundreds of simulation runs. The new CERP System-Wide Modeling web application, (http://modeling.cerpzone.org/cerp_recover/index.jsp) presented herein, facilitates the regular posting of model results to the web making them accessible to multi-agency, multi-disciplinary teams and the general public.

Design Criteria. Design criteria for the web page came from experience with development, maintenance and extensive use of the Restudy web page. Key design criteria included: minimizing the number of clicks to get to a particular graphic, maximizing speed with which graphicsare displayed, minimizing reading (i.e. a more graphical/spatial interface rather than text based), use of default settings, and minimizing the maintenance of uploading multiple model simulations on a regular basis. Furthermore there was a need to provide a common interface and repository for input, output and source code and a means of reviewing performance measures for each of the different models used to support CERP System-Wide Modeling.

Functionality. Additional funtionality requirements in the CERP System-Wide Modeling web page included: sorting by model, by project, by spatial feature (e.g. graphics for canals distinct from graphics for gages and cells) or by topic (e.g. separate access to animations, water budgets, water supply graphics, etc.). Accessibility to model input, output and source code for each run was required, as well as both a hierarchical and graphical means of accessing geographic locations from any point in the page.

Architecture. The design criteria and required features of the web application dictated certain design decisions. The ability to store and search for information necessitated using a web accessible database comprising a database server, application server and web browser. Oracle was selected as the database server and Java as the 'open-source' application development environment in order to ensure cross-platform compatibility and scalability. The database server stores maps, graphics and tables and their associated spatial component information, model data sets, metadata, and descriptive text. The application server's servlet makes all database queries, delivers database driven dynamic menu information, and delivers spatial/map features for different graphic locations. It also retrieves the text and pdf (Portable Data Format) files from the database, based upon a user’s selection, and presents them directly in the browser or using Adobe Acrobat's browser plug-in, respectively. The web browser makes use of a thin client Java server protocol (jsp) application to allow user interaction with the servlet from dynamic menus and a spatial/map interface that presents information and graphics.

Data Loading. Graphics from model simulations are converted to pdf files and loaded to the database using a master control file and program that assigns the spatial relational information, text for display on the web application, and a unique database identifier for each graphic. This facilitates maintenance of the web page because only the master control file needs to be updated whenever new graphics are produced. The information provided in the application is dynamically created based upon content in the database. This means that if for a particular project or simulation certain graphics are not produced, then for that simulation there will not be any broken links (links that point to a missing graphic), as often happens with static web pages, because the link will not be produced in the database. Input, output and source-code are also loaded to the database using a control file and are associated to a particular model simulation.

Development. Development of the web application occurred over a period from February 2001 up to the first public release of the page in October 2002. The development included creation of an initial prototype, presented to CERP Restoration Coordination and Verification (RECOVER) teams in July 2001. A Beta release of the application was demonstrated to RECOVER in December 2001. Following comments from RECOVER significant design modifications were made to the application before release to the public in October 2001. Since then, the application has continued to evolve as a result of comments from the potential user audience. Regional hydrologic modeling, undertaken since the development of CERP has been loaded onto the application and production modeling, commencing with the Initial CERP update and subsequent modeling for CERP Project Delivery Teams, will be provided on the web application as it becomes available.

Acknowledgements. Many individuals contributed significantly to the development of this application including supervision by Marie Pietrucha and Pattie Fulton, development by Mathew Hinton, Cory Adams, Jeyanthi Selvarasu, Michael Warner, Joseph Rodrigues and Maryam Mashayekhi, graphical support by Jeffrey Sullivan and Jenifer Barnes, hardware configuration by Ram Jadvani and review by Brenda Mills, Carl Fitz, Freddie James and Michael Choate. All of these contributions are gratefully acknowledged and without them the application would not have been possible.

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Habitat Suitability Indices for Evaluating Alternative Water Management Strategies

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Habitat Suitability Indices (HSIs) have the potential to provide useful information in the evaluation of alternative water management strategies by helping to answer questions like: Did we get the water right? or, Are there opportunities to change the hydrology to improve ecology, and if so where? HSIs can also be used to evaluate "what if" scenarios and their modeled effect on habitat suitability.

The methodology to develop Habitat Suitability Indices from South Florida Water Management Model output is presented. These indices were developed for the Ridge and Slough Landscape, Tree Islands, Periphyton, Alligators, Fish and Wading Birds with considerable input from biologists and ecologists working on research in these fields. Several selected indices are used to illustrate the development methodology.

The utility of the HSIs is shown by: first comparing values of a specific index, both spatially and temporally, then making spatial and temporal comparisons between indices, and finally making comparisons of index values for different water management strategies. This demonstrates how suitability indices can be used to show trade-offs between ecological indicators. It also shows the usefullness of HSIs in highlighting areas and instances where a water management action, designed to achieve some degree of restoration (improving the quantity, quality, timing and distribution of water), may improve some ecological indicators while impacting other indicators. This allows for review of the action, or alternatively review of the suitability index.

Habitat Suitability Indices are shown to be simple, yet robust and useful indicators of ecological response to hydrologic variables. They provide a quantitative, relative, system-wide indication of ecological habitat response to alternative water management strategies. HSIs can be used in regional analysis to provide an indication of when and where more detailed ecological modeling is needed. They can be generated fairly quickly and can be automatically produced directly from hydrological model output.

Acknowledgements

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An Assessment of Public Engagement in the Everglades Restoration Projects

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Public involvement in planning and implementation is one of the major challenges and a key element of success for environmental projects. Comprehensive Everglades Restoration Plan (CERP) currently faces this challenge. This is the largest restoration project that has ever been done before; therefore there are many uncertainties that are being anticipated. Due to the uncertainties of this project and the new conflicts that may arise from them, and the growing, changing population it is critical that there is a successful public engagement plan in place. The improvements of this natural area is dependent on the agencies' ability to educate the public, get the public involved, and incorporate the people's opinions in the final policy. Public involvement can be broadly defined as increased public awareness of policy goals, and increased community involvement in restoration projects through design, implementation, and monitoring stages. The most significant benefits of a successful public participation project are: involving the community, helping to form mutual understanding, establishing trust, and reducing conflict.

There are many laws that require public participation initiatives. The two main laws in this case are: Water Resources Development Act of 2000, which authorized CERP, mandates the development of a public participation program in the South Florida Ecosystem Restoration. National Environmental Policy of 1969 requires extensive public involvement in all federally funded projects. Public engagement must go beyond the traditional mechanisms for public involvement--public meetings, public comment on documents, etc.--that are usually implemented in response to NEPA mandates. Case studies reveal that these procedures are rarely effective in generating substantial public participation. An effective public involvement program must provide a vehicle for combining all *local* priorities with scientific and technical knowledge and agendas. Also, to be successful, such program must provide for community oversight and sense of ownership over restoration projects.

The development phase of the CERP has passed and we are entering into the implementation and monitoring phase, which will last for 30 years. During the next 30 years there are many issues that could arise, especially due to the uncertain nature of the restoration. This emphasizes the importance of implementing an effective mode of engagement now. This research attempts to evaluate the successes and failures attempted thus far through CERP on the basis of public opinion. We will also evaluate the public's satisfaction levels with the different modes of participation to provide a better policy management insight for CERP implementation in the future.

The specific objectives of our research are threefold: (1) To identify basic criteria of success of public engagement strategies from the perspective of the South Florida public, agencies involved in CERP, and environmental and other interested groups. (2) To estimate the level of satisfaction of those involved with CERP with respect to the engagement procedures used and the final outcome of their involvement. (3) To identify reasons for public participation and public preference for different engagement methods under diverse educational, occupational and ethnic backgrounds.

Two sets of models will be estimated; success criteria and satisfaction towards a participation mode. Success and satisfaction are important aspects of an effective public engagement program. Satisfaction measures the specific logistics involved in a particular mode, for example, convenience, time spent, and distance. Success is the goals of an engagement program measured by, for example, conflict reduction, trust establishment, and environmental justice/equity. The participants' satisfaction with a specific a mode is the means to the success of public engagement.

There are three distinct phases of our research. Phase 1 entails a literature review to identify public engagement success criteria. Phase 2 involves a survey those who participated in different engagement modes. Our goal here is to determine to what extent the identified success criteria are met with CERP development, and what engagement modes were preferred. The survey instrument will ask them to rate if a particular attribute was represented in the CERP plan on a scale of 1 to 4, 4 being the highest. Further, the survey will gather information the different satisfaction criteria with the mode, for example: time and space, availability and access to mode, and organization. In the final phase, the data so collected is analyzed using simple sample summary statistics, and the ordered probit model in order to estimate the levels of achievement of success criteria and satisfaction toward various participation modes.

We have completed a survey of more than 125 participants. The data is being currently analyzed. The preliminary results indicate the public hearing is the most common method of public engagement mode adopted in the case of CERP development. With this mode, the most of the identified criteria (e.g., conflict resolution, trust establishment, and environmental justice/equity) have attained a success level of 2 to 3, which we consider a moderate level of achievement. We hope to complete rest of the data analysis and model estimation before the conference.

The results of these models will help us determine better modes of participation based on participant's interests, ethnic background, literacy, occupation, etc. The research also serves as an empirical test for engagement procedures that are currently being evaluated by a team of researchers at the Florida International University who base their work on literature and focus groups. Our research is based on direct public assessment of these methods. The success of the CERP is dependent on identifying the most effective ways to involve the public whose decisions directly impact the progress of the projects. Due to the long-term nature of the CERP, it is imperative that there is enduring support for the restoration, which will result from better outreach initiatives identified by this project.

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Evaluation of a Periphyton-Based Stormwater Treatment Area (PSTA) in the Margin of the C-111 Canal and the Everglades National Park (ENP): Results of a Two-Year Investigation (2001-2002)

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Introduction

The Everglades is a large subtropical peat-based wetland located in a limestone depression of the South Florida peninsula, USA. Originally, this oligotrophic hydrosystem naturally depleted in phosphorus (typically <0.32 µM TP) encompassed a large surface area (10,000 km^2) and was characterized by shallow, slow-moving water originating from Lake Okeechobee and flowing to the Gulf of Mexico. Specific hydropatterns of seasonal drying and inundation (rainfall-driven hydrology) linked to low rates of nutrients loads allowed paradoxically the development of tremendous biomass of emergent macrophytes interspaced with tree islands and open water sloughs containing abundant benthic/floating mats of periphyton, thus sustaining a flourishing secondary production. However, for more than a century, this fragile hydrosystem has gradually been modified by the construction of dikes and canals aimed to drain some portions of the Everglades for the development of agricultural and urban areas. The result is a profound change in hydropatterns and nutrient loads of this region: the canals channelizing water and concentrating diffuse agricultural/urban runoffs containing high rates of pollutants, which pour into the remaining natural marsh with negative impacts on the ecosystem. In particular, increasing amounts of TP pouring into the Everglades profoundly affects the periphyton community which switches from a thick, cohesive diatom-cyanobacteria dominated mat in the pristine parts of the hydrosystem to a scattered non-cohesive filamentous green algae community in the impacted hydrosystem with a lower biomass per unit of surface area. Thus, it appears important to limit TP loads into the natural ecosystem and to restore natural hydropatterns.

The high growth rates of Everglades periphyton linked to high TP affinity led to the development of Periphyton-based Stormwater Treatment Areas (PSTA). These are hydrology-controlled shallow constructed wetlands positioned in the margin of polluted and natural systems and aim to remove TP from the water before it enters into the natural marsh. One obvious advantage of the PSTA over other ecotechnologies involving algae such as phytoplankton is that TP is sequestered in the periphyton matrix and can be easily harvested with the periphyton or permanently sequestered in the soil (accretion).

At the Southeast Environmental Research Center, we are studying how periphyton reacts to various TP loads (flume experiments, transects studies along TP gradients and PSTA), but also how PSTA can be managed for better TP removal. In the study presented, we evaluate a PSTA resulting from the southern levee removal of the C-111 canal, which once bordered the northeast side of the Everglades National Park (ENP).

Problematic

The removal in 1997 of the Southern levee bordering the C-111 canal and the ENP allowed not only more freshwater intrusion into the ENP, but also provided a relatively flat limestone area promoting, when flooded 6 months a year from June to December, the growth of thick short-hydroperiod calcareous periphytic mats (epilithon). Thus, this site is potentially an opened PSTA, which hydrology can be moderately controlled through the C-111 water gates and pumps. The study aims to evaluate/manage this PSTA through different harvesting periodicity to promote the best TP removal per unit of surface area. In that time, hydrology was not considered or managed.

Methods

In March 2001, the southern edge of the C-111 canal was dried and covered by thick, calcareous periphytic crusts about three years old (3 kg m^{-2}), interspaced with scarce rooted macrophytes. Three sites interspaced about 1 km were chosen for their visual similarity and elevation. A grid with one side parallel and the other one perpendicular to the canal (20 by 40 m^2, square cells of 3 m of side) was selected for each site in an area containing mats of similar TP content (110 µg TP g^{-1}). Within each grid, 5 different harvesting treatments (three replicates for each treatment) were randomly selected among the cells:

* Treatment A- harvesting 0, 2, 3, 4, 6 months after inundation of the site
* Treatment B- harvesting 0, 2, 6 months after inundation of the site
* Treatment C- harvesting 0, 3, 6 months after inundation of the site
* Treatment D- harvesting 0, 6 months after inundation of the site
* Treatment E- never harvested

Harvesting is defined as removing through scraping the whole periphytic mat from the treatment cell and discarding the harvested periphyton, downstream in the C-111 canal. Every month and if applicable, before harvesting, a digital picture of each treatment cell was taken and cohesive periphyton was randomly cored within the cell and analyzed afterwards for TP content in the laboratory. TP sequestered per unit of surface area was then computed by taking into account of the surface area of the core and of the periphyton mat coverage in the cell as deducted from the digital picture. Number of stems, periphyton cohesiveness/thickness, the percentage of floating periphyton in the cell and water-level were also recorded.

Results and discussion

The southern edge of the C-111 canal was flooded for 6 months with about 10 cm of water from the end of July 2001 to the end of January 2002. Two months after inundation, two-month old mats found in treatments A to D were cohesive and sequestered the same amount of phosphorus (111 mg TP m^{-2}). These treatments contained significantly less TP ($P<0.05$) than treatment E with 3 years and 2 month old mat (157 mg TP m^{-2}). After three months of flooding, there was no difference among the treatments (A to E) in TP sequestration per unit of surface area. Three months after inundation was also the time when sloughing (floating mats appearing) just occurred in all treatments. This suggests that mats older than three-years sequester significantly less TP per surface area than newly established mats on a bare substratum flooded 3-months or less. After four months of inundation, a decrease in the cohesiveness of the mat, especially in the youngest mats was observed denoting a decline of the productive capacity of the mat. This phenomenon occurring at the end of the flooding season is observed elsewhere in the Everglades and is still poorly understood. The drying down of the sites occurring during the month of January led to an increase in both mat cohesiveness and TP sequestration per unit of surface area suggesting that drying contributes to increase TP retention.

From the harvesting treatments described above, 6 harvesting frequencies (HF), which can be used as PSTA management practices, can be deducted:

* HF1= harvesting every two months (335 mg TP m^{-2} y^{-1})
* HF2= harvesting 0, 2 and 6 months after inundation (262 mg TP m^{-2} y^{-1})
* HF3= harvesting every 3 months (354 mg TP m^{-2} y^{-1})
* HF4= harvesting 0, 4 and 6 months after inundation (222 mg TP m^{-2} y^{-1})
* HF5= harvesting every 6 months (208 mg TP m^{-2} y^{-1})
* HF6= no harvesting (78 mg TP m^{-2} y^{-1})

It appears that HF6 has the lower TP retention per year. Therefore periphyton harvesting as a PSTA management practice should be envisaged. HF3 mimicking the best the periphytic cycle is the best HF with the most TP sequestered per surface area per year.

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Statistical Tests for Effects of Introduced Fishes on Native Fish Communities Inhabiting Wet Prairie and Mangrove Habitats in South Florida

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In a recent paper, we noted that the abundance of non-native fish species was generally low in freshwater marshes of the Everglades at sites distant from canals, but was relatively high in some mangrove-dominated areas north of Florida Bay. Further, we reported a negative correlation over a 10-year period between the numbers and biomass of native fish and the same parameter for the non-native Mayan cichlid, *Cichlasoma uropthalmus* (Fig. 1, reprinted from Trexler et al. 2000). Here we report an update from our ongoing sampling in both the freshwater Everglades habitats and the mangroves north of Florida Bay. Also, we describe the results of an analysis of fish community data testing for evidence of impacts by introduced taxa on native ones in those habitats.

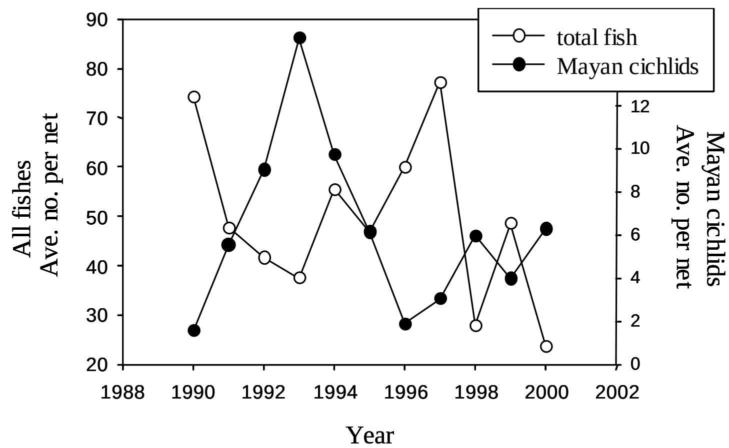

Fig. 1. Plot of catch per unit effort of all fish and Mayan cichlids from 1990 to 2000 from drop traps placed in the mangrove zone north of Florida Bay.

The density and relative abundance of non-native fish taxa have remained much greater in mangrove habitats compared to upstream freshwater marshes in Taylor and Shark River sloughs in Everglades National Park since the completion of our past analyses. In addition, we can identify no statistical evidence for effects from the non-native taxa on native fish communities in freshwater wet-prairie habitats. While no effect from non-native taxa is possible, we cannot exclude several factors that can be categorized as either technical limitations of the data (effects are weak or absent relative to statistical power to detect them) or as inherent in the temporal variation in the communities themselves. The abundance and standing stocks of non-native taxa, especially the Mayan cichlid, are elevated in wet prairie habitats bordering the mangrove zone in Shark River Slough.

The picture is clearly different in the mangrove zone on the northern fringe of Florida Bay. Mayan cichlids continue to be abundant in collections there. We have extended the correlation analysis reported in our earlier work to document the taxa of native species that appear to be adversely affected by Mayans. The native species sheepshead minnow (*Cyprinodon variegatus*) and marsh killifish (*Fundulus confluentus*) decline in abundance in periods when Mayan cichlids are common, and increase in periods of cold weather when Mayans relatively less abundant.

Two other small, abundant native fishes, sailfin molly (Poecilia latipinna) and rainwater killifish (*Lucania parva*), appear to be unaffected by the changing abundance of Mayan cichlids.

Our work indicates that non-native fish have altered the community structure and dynamics of native fishes in some habitats in southern Florida, but not others. There are probably multiple reasons for this, but the interaction of salinity and temperature tolerance of the introduced taxa currently present plays some role. Shafland has suggested that cold-temperature sensitivity has precluded some cichlids from expanding far from canals, where a permanent temperature refuge is provided by ground-water infusion. However, Mayan cichlids have no such refuges in the mangrove zone (the creeks there are not deep enough and their numbers do fluctuate with the severity of annual minimum temperature) and yet their abundance is much higher there than wet prairies. Thus, factors other than temperature tolerance may be involved in limiting their current expansion into wet prairies. The paucity of deep-water refuges during droughts, perhaps leading to local extirpation or severe reductions in population size may be a key factor in keeping cichlids out of the wet prairies.

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Refereence:

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Use of Long-Term Monitoring Data for Fishes and Macroinvertebrates in the Development of Performance Measures for the Modified Water-Delivery Project

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The Modified Waters Delivery Project (MOD Waters) is an on-going effort to improve hydrological management of the Everglades National Park (ENP). Starting in 1996, we initiated a monitoring program to assess the impacts of Test 7, an iteration of that effort, on ENP aquatic fauna. Our efforts focus on fishes and large invertebrates that can be sampled by 1-m^2 throw trap, as well as large fishes that could be sampled by airboat-mounted electrofisher. Seventeen long-term study sites were added to an existing set of three study sites in northern Shark River Slough to permit the establishment of a long-term database for use both to assess management impacts and serve as reference sites and to establish baseline ecosystem conditions. Eleven study sites are in WCA-3A and 3B, 6 are in Shark River Slough, and 3 are in Taylor Slough, reflecting the relatively different spatial areas of these regions. The sites encompass a range of hydroperiods and nutrient conditions. At this point, we have 6 complete years of information, with throw-trap samples collected in February, April, July, October, and December at all or most sites in each year. Systematic electrofishing was initiated in 1997 at a subset of the throw-trap sites, and is conducted in February, April, July, and October.

We have used these data to develop performance measures for assessing MOD Waters and Comprehensive Everglades Restoration Plan (CERP) activities. A key result is that fish and macroinvertebrate community composition is sensitive to the time since their local site was dried. For example, the density of bluefin killifish (*Lucania goodei*) and least killifish (*Heterandria formosa*) are diminished for as long as four years following a drying event. Eastern mosquitofish (*Gambusia holbrooki*) repopulate sites very rapidly following drying events, and are not good indicators of dry-down events. Recent water-management actions under the Interim Sparrow Operating Procedure (ISOP), have affected the rate and frequency of drying in the southern portion of the Everglades. Our monitoring data, coupled with statistical modeling, indicate that this operation may have affected the abundance of small fishes in some areas of ENP by altering the drying pattern and the area of drying. A recent series of dry years, possibly coupled with such water-management actions, have produced a marked affect on large fishes that we monitor by electrofishing. The invertivorous lake chubsucker (*Erimyzon sucetta*) was a dominant fish in the 8-cm and greater size classes in 1997 through 1999 in both Taylor and Shark River sloughs. However, its abundance has been dramatically lower since the dry season of 2000, and only one specimen was collected in Taylor Slough since that time. Dry-down events also appear to have altered the size distribution of lake chubsucker in Water Conservation Area 3A. Similar declines in the number and size of large-bodied fishes have been reported following other Everglades drying events in the 1980s and 1990s. Therefore, the relative abundance and size structure of lake chubsucker and the piscivorous gar (*Lepisosteus platyrhincus*) and largemouth bass (*Micropterus salmoides*) show promise as performance measures for hydrological management.

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Management of Large Inflow and High Water Levels in Lake Okeechobee

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WSE, which is short for Water Supply/Environmental, is a set of new operational guidelines for managing high water levels in Lake Okeechobee. This set of guidelines was put into operations in July 2000. The emphasis of these guidelines is to manage high water levels in a manner that would minimize the stresses on the Lake littoral zone without compromising the other major objectives of the Lake water management. Detailed analysis demonstrated that performance of the WSE operational guidelines are equal or better than the other proposed and past operational guidelines for meeting the objectives of flood protection, water supply, and environmental protection and enhancement, including benefits to the lake ecosystem and Everglades hydroperiod. The WSE guidelines incorporate tributary hydrologic conditions, regional seasonal and multi-seasonal climate forecasts for making operational decisions to discharge water to the Water Conservation areas and to tidewater. These guidelines also allow for operational flexibility for environmental enhancement and/or to minimize impacts to the natural ecosystems affecting by the operational decisions.

The purpose of this presentation is to:

1. Describe key features of the new WSE operational guidelines. Figure 1 illustrates the various high water zones that are defined within the WSE operational guidelines. Zone A, B and C are similar to the operational zones of the previous operational schedule known as ‘Run 25’. Zone D allows water discharges at Lake levels similar to operational practices prior to the year 1978. However, the new operational guidelines adjust the magnitude of the discharges based on hydrologic and climatological seasonal and multi-seasonal outlooks and the needs of the natural ecosystems affected by the discharges. Two decision trees based on extended period climate and hydrologic outlooks are part of the WSE operational guidelines. The first defines the range of discharges that may be made from the Lake to the Water Conservation Areas and the second defines the ranges of discharges that would be made to the estuaries.

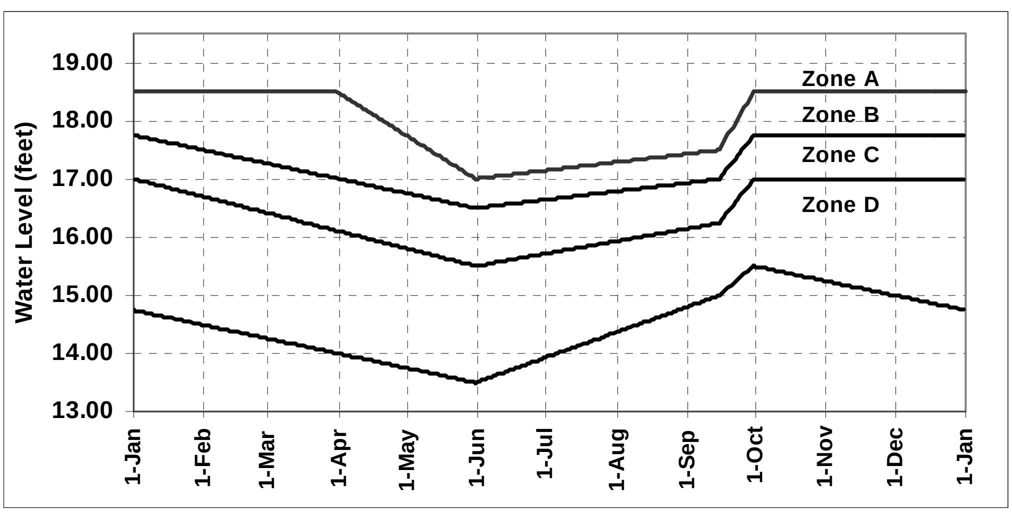
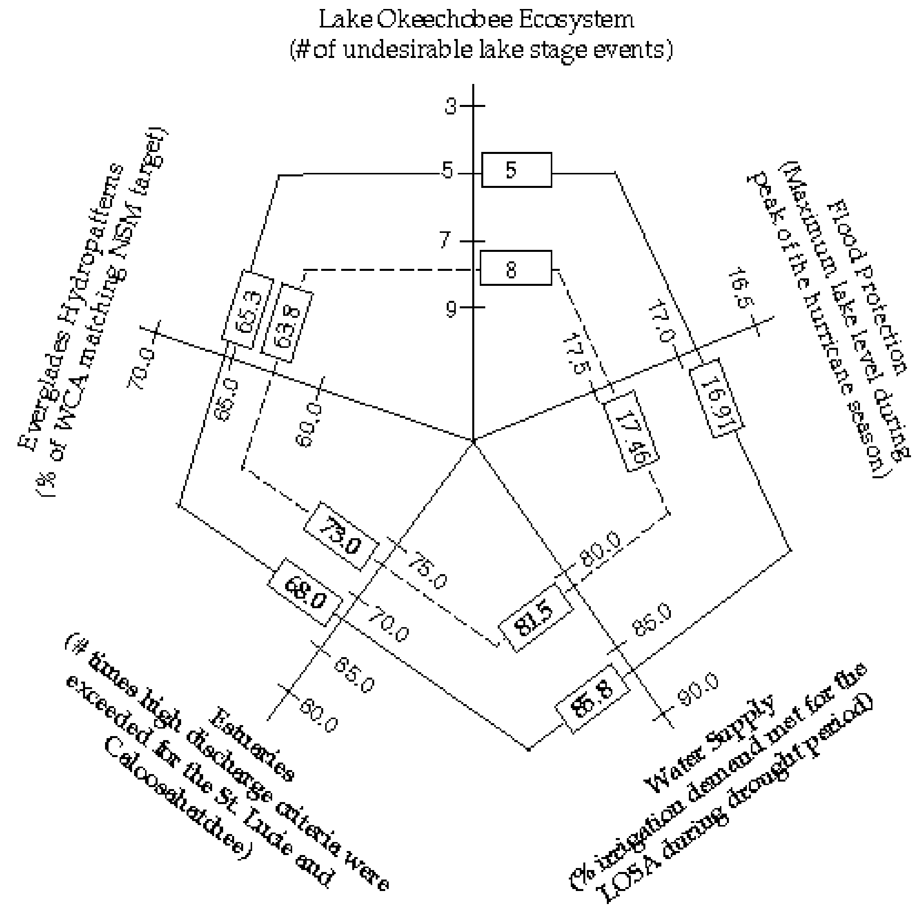


Figure 3. Lake Okeechobee High Water Operational Zones

2. Discuss the simulated overall performance benefits of the WSE operational guidelines compared to the previous operational guidelines known as 'Run 25'. Figure 2 gives an overall comparison of the performance of the new set of operational rules.



Operational Schedule 25 dashed format -------------
Operational Schedule WSE solid format _________

Axes are designed so that larger pentagon represents a better Performance

Figure 4. Performance Measure Summary

3. Explain the real time implementation process of the operational guidelines including monitoring: a) the health of the natural ecosystems that are affected by operational decisions, b) the state of the current climate and the seasonal and multi-seasonal climate outlook, and c) the current and projected states of the regional water levels and supplies.

4. Report on the initial performance of these guidelines. The water level for Lake Okeechobee as of January 7th, 2003 was 16.10 feet. Although this may be higher than desirable for the Lake littoral zone, it is nearly 1 foot lower than the water level would have been under the previous operational guidelines. Low volume regulatory discharges began during July of the year 2002 decreasing the magnitude of discharge that would be needed to tidewater through the estuaries during the 2002-2003 winter months.

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Recognition of Climate Variability within South Florida

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The increasing ability to understand and forecast regional climate anomalies is a valuable asset for water management authorities. To truly benefit from this increased understanding, it is necessary to have a global perspective of the ocean and atmospheric systems that may affect a given region. The statistical ties of south Florida's winter climate to the El Nino-Southern Oscillation (ENSO) process have already been well documented. The purpose of this presentation is to report on additional factors, including solar activity and the strength of Atlantic Multi-decadal Oscillation (AMO) that appear to significantly contribute to seasonal to decadal climate variability in south-central Florida. These various global factors are integrated and down scaled with the aid of artificial neural networks. While most previous studies have emphasized the statistical connection between Florida's climate and ENSO during the winter and spring months, this effort emphasis the climate variability that occurs during the months of May through October.

Solar Activity

Increasing statistical evidence of the relationship between the variability of solar output and the earth's climate fluctuations is becoming more evident (Labitzke and van Loon 1989, 1992, 1993). Willet (1987) has elaborated that solar eruptive activity such as solar flare activity may cause disturbances of the geomagnetic field and the temperature and wind fields of the upper atmosphere. This strong spot heating of the earth's atmosphere by such eruptive activity is believed to contribute to the breakdown the zonal weather circulation. The *aa* index of geomagnetic activity was taken by Willet to be the best indicator of solar eruptive phenomena. With the recent advent of high altitude space observatories and highly sophisticated measuring devices, the importance of phenomena such as coronal mass ejections, solar wind and cosmic rays on the terrestrial environment are now just beginning to be understood. Besides emitting a continuous stream of plasma called the solar wind, the sun periodically releases billions of tons of matter in what are called coronal mass ejections at speeds as high as 2000 km per second. These explosions of material from the Sun's upper atmosphere have been difficult to detect and monitor prior to the high altitude solar observatories due to their white light energy frequency being dimmed by the sun's brightness and the diffusive properties of the earth's atmosphere. Their consequences to terrestrial systems when emitted in the direction of earth are only now being recognized. Tinsley and Deen (1991), Tinsley and Heelis (1993) and Tinsley et al. (1994), documented a number of correlations between solar-wind and cosmic-ray variations and changes in various atmospheric parameters, such as Atlantic storm tracks, surface temperatures, and area-integrated storm intensity. Svensmark and Friis-Christensen (1997) found that the short term changes (days to weeks) in the cosmic ray intensity affects the global cloud cover and therefore may influence weather predictability.

In a more conventional approach to understanding the solar-climate connection, Haigh (1996) successfully simulated observed shifts of the subtropical westerly jets and changes in the tropical Hadley circulation that appear to fluctuate with the 11-year solar cycle. Photochemical reactions in the stratosphere are included in the model that enhances the effects of the variations of the solar irradiance energy. Even a small shift in the strength and positioning of these global scale climate systems would have significant effects on Florida's climate. Reid and Gage (1988), Reid (1989), and White and D.L. Cayenne (1996) reported on the similarities between secular variations of solar activity and that of the global sea surface temperature. In summary, solar activity affects the earth and it's atmosphere in many ways over different time scales. These may be broken down into the following categories: 1. Short duration sporadic events, 2. The 11 - and 22 - year sunspot cycle, 3. Longer secular solar cycles.

Atlantic Multi-decadal Oscillation

The Atlantic Ocean experiences large rearrangement of its ocean currents on a multi decadal time that has a significant effect on the Florida climate and hydrology (Enfield, Mestas-Nunez and Trimble, 2001). During one phase of the AMO the Atlantic thermohaline is enhanced which causes more stronger tropical activity and wetter conditions in Florida while during the other the Atlantic thermohaline current is weaker which generally causes drier conditions in Florida. The 20^{th} Century Lake Okeechobee inflow is analyzed to better grasp of how these climate steps affect the south Florida hydrology.

Lake Inflow versus Climate Indices

The wet season (May through October) inflows to Lake Okeechobee versus the geomagnetic index and the AMO are evaluated for the period from 1930 through 1996. The data is first separated into categories of weak and strong AMO. Each of these categories is then further categorized into terciles of low, medium and high geomagnetic activity (average Cp value for the nine months prior to the wet season). Quartiles of Lake inflow for the lowest and highest terciles of geomagnetic activity are illustrated in Figure 1. The various combinations of high or low geomagnetic activity are paired to either a strong or weak phase of the AMO as depicted. Inflows are reported in terms of equivalent depth by dividing the Lake inflow by the its surface area. Figure 1 illustrates a marked shift towards below normal inflow for the combination of low geomagnetic activity and the weak state of the AMO. Likewise, above normal inflows appear to be associated with high geomagnetic activity and the strong state of the AMO. A similar analysis was completed for Lake inflows (wet season only) versus the Nino 3 index with no such visible shifting in Lake inflows for warm events versus cold events. However, the importance of the El Nino Southern-Oscillation phenomena on Atlantic Basin tropical activity has already been documented, so that it has been included in this analysis.

Application of Artificial Neural Networks (ANNs)

ANNs is a computational method inspired by studies of the brain and nervous system of living organisms. Appealing aspects of ANNs are their applicability to complex non-linear problem sets, their adaptiveness to adjust to new information and their ability to make predictions from inputs in which the relationships between the predictors and the predicted are not completely understood. Among the variety of neural network paradigms, back-propagation is the most commonly used and has been successfully applied to a broad range of areas such as speech recognition, autonomous vehicle control, and pattern recognition and image classification. With the aide of artificial neural networks nearly half of the wet season variance in Lake inflow is explained with the following predictors: 1) solar activity, 2) the Atlantic Multi-decadal Oscillation (AMO), and the El Nino-Southern Oscillation.

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Big Cypress Basin-Estero Bay Regional Research Database/Web Site

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In 1996, at the request of Secretary of the Interior Bruce Babbitt and the South Florida Ecosystem Restoration Task Force, a Steering Committee was established to develop a regional science plan for the Big Cypress Basin of Southwest Florida. The Steering Committee was comprised of public land managers, regional planners, researchers, and agricultural landowners.

The Steering Committee was tasked with the following three specific objectives:

1. Identify a boundary for the Big Cypress Basin region that encompasses priority coastal estuaries and watersheds representing key land and water resources of the Big Cypress Basin.
2. Conduct an inventory of existing research and monitoring information within the Big Cypress Basin. This effort was intended to include input from local research programs ranging from federal and state to private interests.
3. Plan and conduct a series of workshops, targeting professionals involved in environmental research, management and land use planning.

The Big Cypress Basin research and monitoring database was designed to provide a comprehensive inventory of research and monitoring efforts within the basin. This database of past and current projects will not only prevent duplication of effort, but it will also enable users to identify potential gaps in the scientific research within this region.

In 1997, Florida Fish and Wildlife Conservation Commission's Florida Marine Research Institute (FMRI) began the process of assembling the Big Cypress Basin Regional Research and Monitoring Database by interviewing more than one hundred researchers from various agencies. FMRI staff held on-site meetings with each scientist, because mailed inventories and questionnaires generally have minimal response. This proved critical to the success of the database. Over time the database has improved significantly with the migration from inventory level entries to FGDC (Federal Geographic Data Committee) compliant records. In 2001, the project boundary was extended to include Estero Bay. Today, the database describes over 200 ongoing and historical research and monitoring projects. Currently, the database is stored in a Spatial Metadata Management System (SMMS) format.

A database-centric web site has been created to allow users easy access to the project database. This site is hosted by FMRI at http://ocean.fmri.usf.edu/bcb/. The web site's primary applications are the database and spatial query tools that allow users to interactively query the database and produce FGDC-compliant metadata reports for specific research projects. The web site allows users to access detailed information describing the scientific research occurring in the BCB-EB region.

The database query tool is a ColdFusion web application that allows users to query database records (research projects) based on database fields such as category, organization, theme keyword, place keyword, year started, and project status.

The spatial query tool is an Arc Internet Map Server (ArcIMS) application, which allows users to identify research projects that have been and are being conducted in specific areas. Background layers, such as imagery, roads, hydrology, and managed lands, are available to help guide these spatial queries. Key additional site components include the following: a project overview page, a BCB-EB links page, a calendar and a project documents page where meeting minutes can be posted.

The goal of this project is to develop a current and accurate database that contains documentation for all projects within the basin. Continued success of the database and web site development requires the on-going participation of scientists. Identifying new research and improving existing project descriptions will provide up-to-date information that will allow managers and researchers to track science at their desktop.

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Abundance and Diet of *Rana grylio* across South Florida Wetlands

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Federal and state agencies are attempting to project the impact of hydrologic restoration on the Everglades ecosystem. Current modeling efforts have focused on primary producers (e.g. macrophytes and periphyton) or organisms of higher trophic levels (e.g. panther, deer, birds). Amphibians are a vital intermediate link within the Everglades food web (ATLSS 1997, Ligas 1960). Even though amphibians are known to comprise a large portion of the faunal biomass within wetland systems, they remain underrepresented in restoration efforts (Burton and Likens 1975). The biphasic lifecycle of pigfrogs (*Rana grylio*) makes them extremely sensitive to hydrologic change. Unfortunately, little is known about their abundance, ecology and importance to the greater Everglades ecosystem. This study investigated temporal changes in *Rana grylio* abundance and diet in South Florida wetlands from August 2000 to September 2002. The goal of this study was to link changes in hydrology to the abundance and condition of this species throughout South Florida wetlands.

A total of 551 one kilometer transects were surveyed at night via airboat to compare the monthly abundance of *R. grylio* across large areas of Water Conservation Areas 3A, 3B, and Everglades National Park (ENP). Abundance estimates were calculated using a double-observer approach (Nichols et. al 2000). Capture-recapture techniques were used within three one-hectare plots at each site in order to estimate abundance and growth parameters on a smaller scale. We collected 684 frogs from throughout the study areas from 1999-2002 to examine stomach content among sites. A drought occurred during 2001, which allowed us to assess how this species responds to a severe prolonged dry-down.

Stomach contents were greatest during the mid to late dry season at all three sites (fig. 1). Frogs in 3A had less food in their stomachs than those in either 3B or ENP. Growth was highest from December to March. Frogs were most abundant from March through September (fig. 2). Recruitment of metamorphs appears to peak from July through September. It appears that as water levels decrease, food may become more available to the frogs, allowing them to grow or invest in reproduction during this time. The study sites in WCA 3A rarely dried down. These frogs rarely contained fat bodies or food in their stomachs; this may be due to prolonged flooding in this area. Frogs are both smaller and more abundant in WCA 3A than in ENP or WCA 3B. This is probably due to a combination of both frog harvesting and high water throughout the year. Final results including models of the effects of hydrology on this species will be available in Fall 2003.

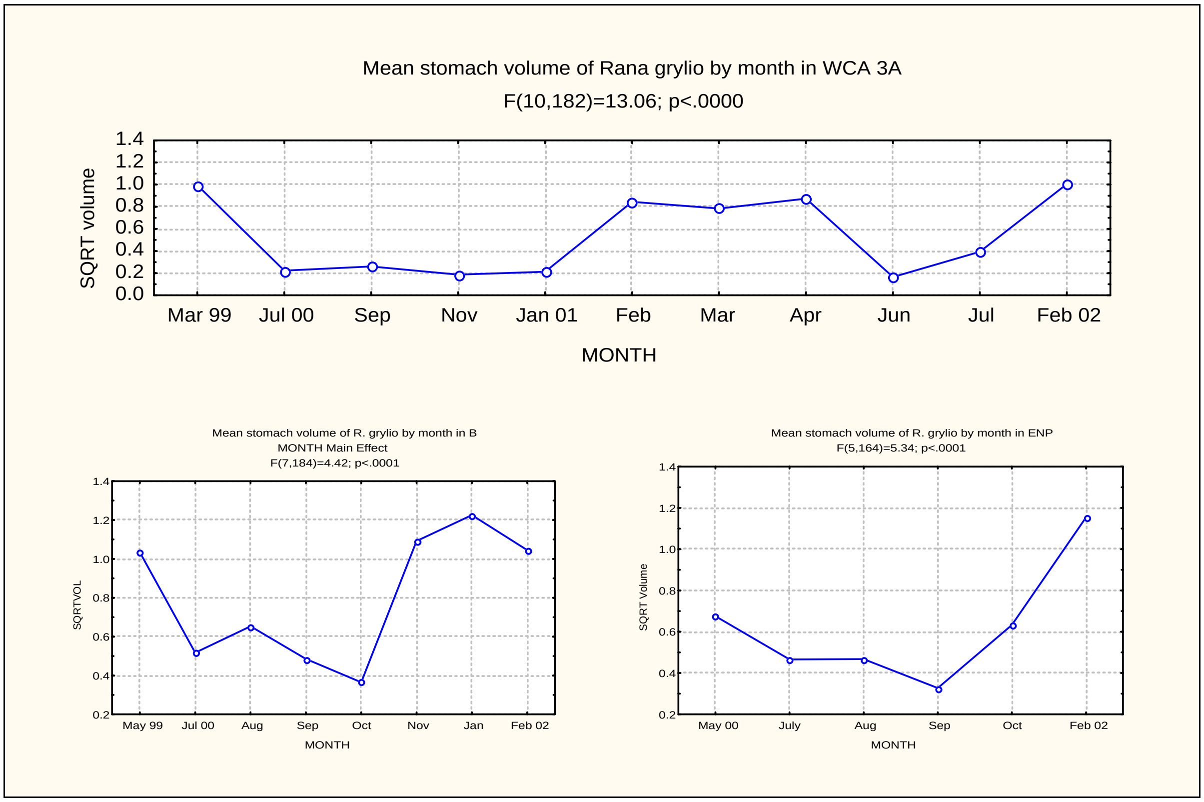

Figure 1. Mean total stomach volume of *Rana grylio* from 3 study sites in the Everglades during 2001-2002.

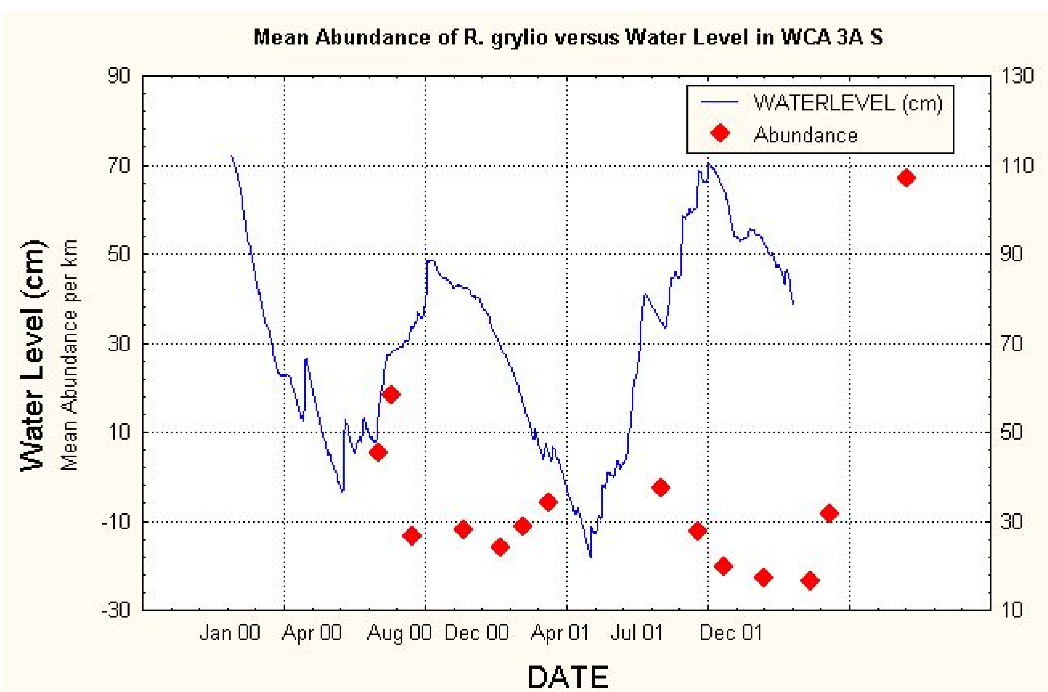

Figure 2. Mean abundance (animals/km) of *Rana grylio* from Water Conservation Area 3A

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Integration of Local Hydrology into a Regional Hydrologic Simulation Model

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South Florida hydrology is dominated by the Central and South Florida (C&SF) Project that is managed to provide flood protection, water supply and environmental protection. A complex network of levees canals and structures provide these services to the individual drainage basins. The landscape varies widely across the C&SF system, with corresponding differences in the way water is managed within each basin. The evaluation of planning, regulation and operational issues require a simulation model that captures the effects of both regional and local hydrology.

The Regional Simulation Model (RSM) uses a "pseudo-cell" approach to integrate local hydrology within the context of a regional hydrologic system. A 2-dimensional triangulated mesh is used to represent the regional surface and ground water systems and a 1-dimensional canal network is superimposed onto this mesh. The triangulated mesh forms cells, each of which have a pseudo-cell counterpart. Pseudo-cells are used to simulate the local hydrologic conditions within the cell. Protocols have been established to provide an interface between a cell and its pseudo-cell counterpart. A number of pseudo-cell types have been developed to deal with the undeveloped, agricultural and urban hydrologic conditions in South Florida.

This presentation will provide an overview of the overall RSM design, describe the relationship between cells and pseudo-cells, and illustrate how pseudo-cells are be used to simulate agriculture, urban and wetland hydrology.

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Biology and Ecology of Juvenile *Procambarus alleni* and *Procambarus fallax* from the Everglades

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Crayfish, fish, and mussels are important members of food webs in most freshwater aquatic ecosystems in North America, where crayfish often serve as keystone species, and may dominate energy and nutrient flow. Despite the wide-spread influences that crayfish have on all trophic levels, they are almost completely overlooked in conservation efforts. The roles of crayfish as herbivores and detritivores are well documented, but their importance as carnivorous predators has received little attention until recently. A growing list of crayfish prey includes leeches, tadpoles, newts, fish eggs and fry, and molluscs. As intermediates in food webs, crayfish form part of the diet of more than 36 species of vertebrates that inhabit the Everglades, including the keystone American alligator and wading birds. Crayfish burrows provide refugia for other organisms during times of drought and support an entire burrow ecosystem.

Two species of epigean crayfish, P*rocambarus alleni* (Everglades crayfish) and *P. fallax* (swamp crayfish) inhabit the Everglades. Some researchers have previously confused identification of these species and it was not until 2000 that *P. fallax* was officially documented in the southern Everglades. Field collections indicate that swamp crayfish have been present in the southern Everglades and in coastal Broward County since 1985. More recent studies suggest that although these two species occur in sympatric and occasionally syntopic distribution, *P. alleni* may prefer shallow water and short hydroperiod conditions, whereas *P. fallax* prefer more permanently flooded conditions. Elsewhere in Florida, where *P. fallax* was found within the range of *P. alleni*, *P. fallax* appeared to be the more successful competitor. Because of their critical roles in the trophic structure of Everglades wetlands, shifts in relative abundance of these two species may have significant effects on wetland communities and overall availability of crayfish as food for other organisms.

Researchers are now recognizing the critical importance of crayfish in Everglades wetlands, as bio-indicators to assess effects of hydrology, fire, and nutrient enrichment; as intermediates in food webs; and as ecosystem components in community sampling studies. More studies have been conducted on the biology and ecology of *P. alleni* than on *P. fallax* and *P. alleni* was proposed as an indicator species to monitor progress of Everglades restoration programs. Only two previous studies examined life history and ecology of both *P. alleni* and *P. fallax*. The two species appear to differ in reproductive strategies, growth and maturation rates, and migration and burrowing behavior patterns. The sparse information available centers on adults rather than juvenile crayfish.

Current Research. Three experiments were conducted on juvenile *P. alleni* and *P. fallax* under laboratory conditions that simulated conditions in South Florida wetlands. Adult crayfish of both species were obtained from various areas, including wetlands that were historically connected to the northern Everglades. Young crayfish were hatched from berried females captured in the field or bred in the laboratory. In the first experiment, growth, survival, and development of hatchlings were monitored to three months of age, under stable conditions. In the second experiment, effects of biotic and abiotic factors (water levels, food, density and competition) on growth and survival of hatchlings were examined during three months. In the third experiment, behavior patterns and substrate choice were observed in the presence of an adult arthropod predator.

Under stable conditions, juvenile *P. fallax* had significantly higher survival than *P. alleni*. *P. alleni* had significantly greater weight and total length than *P. fallax,* however, at a given length, *P. fallax* was heavier than *P. alleni.* More *P. fallax* than *P. alleni* developed gonopods 1 and 2 within three months. In conditions simulating different water levels, *P. alleni* survival was impacted most by low food levels, high density, all three water levels, and intraspecific competition. The highest survival occurred with high food levels, and low density. Lowest survival of *P. fallax* occurred in low food levels, high density, and low water levels, while high food levels, low density and drying conditions enhanced survival.

P. alleni grew larger than *P. fallax* in all conditions tested. Growth of *P. alleni* was most impacted by low food levels, drying conditions, high density, and intraspecific competition. The best conditions for growth of Everglades crayfish included high food levels, low water levels, low density, and interspecific competition with *P. fallax.* Growth of *P. fallax* young was most impacted by low food levels, high density, and high density interspecific competition. *P. fallax* grew largest in conditions of high food levels, low density, and low density interspecific competition. *P. fallax* grew to the same size in all three water levels.

With or without an arthropod predator present, both species spent the most time in *Utricularia foliosa* and *Panicum hemitomon,* and the least time in *Typha domingensis* and on sand. With a predator present, juvenile Everglades crayfish were exposed on sand more at night, and more than *P. fallax*. *P. fallax* spent significantly more time secluded in bladderwort than *P. alleni.* In the absence of an arthropod predator, feeding was the primary activity of both species during the day. *P. alleni* was more mobile at night, whereas *P. fallax* spent more time resting and less time feeding. In the presence of the predator, movement by both species was reduced and juveniles fed more during the day and rested more at night. *P. fallax* spent more time resting then *P. alleni* during day and night, but *P. alleni* wandered around twice as much as *P. fallax* at night. Both species exhibited diurnal behavior patterns.

Because of its larger size, *P. alleni* may have a competitive advantage in resource holding potential, and by producing more eggs. *P. fallax* grow more slowly, but compared to *P. alleni* are heavier at a given length, reach maturity at a smaller size, and may reproduce throughout the year. In Everglades wetlands, *P. alleni* are more abundant under fluctuating conditions and may survive better during dry periods. Juvenile *P. fallax* have higher survival under stable conditions. If survival and growth strategies of *P. fallax* are enhanced by long hydroperiods and appropriate depths, then *P. fallax* could have a considerable competitive advantage over *P. alleni* in survival, growth, and development.

Research Needs. A more holistic approach is needed to understand the role of crayfish populations in Everglades ecosystems that integrates laboratory, field and modeling studies. Detailed, long-term information is needed about most aspects of the life history and ecology of *P. alleni* and *P. fallax,* to determine nutritional needs, life span, reproductive strategies, and predator-prey cycles in Everglades environments. Studies of water depth, hydroperiod, and water quality are also needed, to understand how *P. alleni* and *P. fallax* can coexist, on a microhabitat level. Little is known about tolerances of either species to water quality factors such as oxygen, temperature, salinity, turbidity, or pH for different stages of the life cycle.

Water managers must consider that even small changes in hydrology may significantly alter crayfish populations and community structure over large areas and at multiple trophic levels in

Everglades ecosystems. Depth, delivery and timing of water may favor either species of crayfish, to the detriment of the other. Conservation strategies should consider the need to provide crayfish habitat that will allow balanced distributions of *P. alleni* and *P. fallax* populations that maintain floral and faunal biodiversity, and optimize the roles of crayfish as predators, prey, and habitat managers in southern Florida wetlands.

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Searching for Links Between Tree/Shrub Island Loss and Changes in Hydrology in the Everglades

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Water Conservation Area 3 (WCA3), a nearly 900 square mile impounded portion of the remnant Everglades, is a region composed of sawgrass ridges, deepwater sloughs, cattail marshes, and scattered tree/shrub islands. Everglades tree/shrub islands are one of the rarest communities in the ecosystem and serve as refugia for wildlife species, including a number of threatened or endangered animals. Hydrology appears to be a major factor affecting tree island spatial extent, vegetation distribution, composition, species richness, and zonation. The hydrology of WCA3 has been altered as a result of impoundment and compartmentalization by canals and levees that allow for the artificial control of depth, duration, distribution, and timing of water movement through the area.

A recent South Florida Water Management District (SFWMD) study tracking changes to tree/shrub island habitat in WCA3 using historic and recent aerial photography showed over a 60% decrease in areal coverage from 1940 to 1995. Numbers of individual islands over one hectare in size have been reduced from well over 1200 in the 1940s to less than 600 today. A direct cause and effect relationship between tree/shrub island habitat loss and hydrology seems probable but has yet to be confirmed. Due to tree islands' important role in the landscape and their relative sensitivity to changes in hydrology, tree islands can serve as useful indicators of the effects of hydrology on the Everglades' ecosystem.

Hydrologic models and historic water gage data will be used to explore possible correlations between tree island habitat loss and hydrologic change over time in WCA3. These correlations may prove to be useful in guiding future monitoring and management efforts in the area as part of the Comprehensive Everglades Restoration Plan.

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Landscape Mapping of Ridge and Slough Topography: Integration of Hydrology and Biological Processes

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We are developing a landscape vegetation model that is based on our hypothesis that spatially coupled positive and negative feedbacks among vegetation, peat accumulation, and hydrology, including flow, drive the self-assembly of the slough-ridge-tree island patterning of the Shark River Slough. A detailed understanding of these feedbacks is fundamental to any attempt to predict the ecological effects of proposed hydrological changes in the central Everglades – shifts in hydrology will not simply move vegetation zones up and down the existing microtopographic gradients, but alter those gradients as well, possibly quite rapidly. This project will quantify these landscape-level feedbacks for the first time, and incorporate them in a model to predict vegetation change and landform evolution under different hydrological regimes. Our preliminary work on the characterization of the current landscape patterning of vegetation in the northeast Shark River Slough and the southern sections of WCA 3A and 3B will be presented. We mapped vegetation based on remotely sensed data encompassing approximately 45,000 Ha using georectified false color infrared photography with a resolution of 1'/pixel. These aerial photographs were taken in February 2002, and approximately 60 km of transects have been conducted within the study area to develop the landscape map. On-screen digitizing of photointerpreted vegetation communities, classified according to several different community types with a minimum mapping unit of 300 m^2, has been developed. The detailed vegetation map will be utilized to develop a predictive quantitative model relating abiotic parameters to the composition of plant communities within the marsh and this model will be connected with a GIS landscape model that can be used to evaluate the effect of changes in various environmental parameters on landscape vegetation patterns.

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The Life History Patterns of the Invasive Fern, *Lygodium microphyllum*, at the Whole-Plant, Community and Landscape Scale

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One of the greatest threats to the integrity of native ecosystems is their invasion by non-indigenous species. Nowhere else in the continental United States is this threat more conspicuous than in Florida. In South Florida, *Lygodium microphyllum,* which is a relatively recent invader, is currently spreading throughout native ecosystems. Once established in a community, *L. microphyllum* displaces native species and alters local fire ecology, eventually leading to collapse of the natural community. We studied the life history of this highly invasive fern across different spatial scales. The results of our studies will be presented, including *L. microphyllum* reproductive biology and its growth and physiology at the whole-plant, community and landscape scale.

Examination of it's reproductive biology shows that *L. microphyllum* is capable of using all three mating systems: intragametophytic selfing, intergametophytic selfing, and outcrossing. This complex reproductive biology is highly unusual for the vast majority of fern species studied to date. The ability of *L. microphyllum* to utilize all three mating systems lends support to our hypothesis that its reproductive strategy partially explains its invasive spread across the landscape. Since spores are dispersed readily by wind, the ability of a single spore to form a sporophyte facilitates the rapid spread of *L. microphyllum* to new habitats. In addition, we found that its invasiveness is enhanced by the ability of a female gametophyte to determine the sex of nearby gametophytes, making them male and thus ensuring cross fertilization.

It appears likely that a higher growth rate confers a competitive advantage to *L. microphyllum* relative to many native species but to date this hypothesis has not been tested. To test this hypothesis, seedlings of *L. microphyllum, L. japonicum* and the native vines *Vitis rotundifolia* and *Parthenocissus quinquefolia* were grown under three different light levels for 180 days. Over this period, relative growth rate and its determinants were measured over two sequential harvests. Early results show that both Lygodium species, but particularly *L. microphyllum*, have a significant growth advantage in low light conditions compared to the two native vines. The mechanisms for this advantage in low light are currently being examined, although it appears to be a result of a significantly greater photosynthetic rate in low light-grown *L. microphyllum* seedlings compared to the other species.

The pattern of distribution of *L. microphyllum* was also examined at the community level in forested wetland sites within the Big Cypress Swamp. Species richness, abundance and distribution of herbs, shrubs and trees were characterized along with several physiographic and abiotic parameters. These parameters included elevation, substrate depth, substrate water content, substrate organic content, substrate texture and understory photosynthetically active radiation. The patterns of distribution of *L. microphyllum* indicated that presence of the fern was dependent on moderately hydric conditions, since relatively low elevation, deep substrate and high substrate water content were significantly related to *L. microphyllum* presence. This information was utilized in developing a landscape model of its spread throughout South Florida.

The *L. microphyllum* dispersal model utilizes a cellular automaton methodology. The model is calibrated using actual data from 1978 to 1993, then validated independently using actual data from 1993 through 1999. The projection to 2009 uses the actual 1999 flight survey data as a starting point and shows an alarming increase in *L. microphyllum* establishment across South Florida, in particular in the cypress-dominated wetlands of the Big Cypress Swamp.

These studies have been designed to increase our understanding of the ecology and physiology of this highly invasive species and to assist land managers in developing strategies to prevent and control its rapid spread.

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Interpreting Ecological Response to Changes in Freshwater Delivery by Periphyton Communities in the Biscayne Coastal Wetlands

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The coastal wetland communities of Biscayne National Park have been cut off from sheet flow for decades resulting in the current vegetation mosaic, which is considerably altered from the landscape present in the 1940's. Within this span of time (~60 years), the tall fringe forest adjacent to the coast has broadened, and the mixed graminoid-mangrove zone further inland has been replaced by a dense monoculture of dwarf mangroves extending to the base of the L-31E levee—a structure built in the mid 1960's to minimize the impact of storm tidal waters. This structure, along with several other canals, have effectively divided the area into coastal saltwater and interior freshwater ecosystems with no functional hydrological connection between the two. In an attempt to restore coastal wetlands and to mitigate the effects of canal point discharge into Biscayne Bay, the L-31E Freshwater Re-diversion Pilot Project was initiated in 1993 on a section of coastal Biscayne Bay (~25 ha) between the Mowry and the Military Canal. The treatment consisted of diverting water from the L-31E Canal into the mangrove swamp. At the same time, a monitoring program was initiated to track the treatment's effects. The results of the Pilot Project will help to guide proposed large-scale water re-diversions. Evaluation of the environmental consequences of such hydrologic alteration to coastal wetlands requires at least two elements: (1) recognition of biotic response to hydrologically-related parameters and (2) establishment of restoration success criteria in measurable abiotic or biotic units.

The research presented here focuses on periphyton in the Biscayne Coastal Wetlands, in particular, quantifying the relationship of periphyton community attributes to environmental gradients (ie., hydroperiod, salinity, nutrients). Periphyton communities are an important component of the Everglades coastal ecosystems and respond quickly in composition and function to changes in salinity regime. They can be useful in monitoring the pace and effects of saltwater intrusion associated with hydrologic manipulations, and developing quantitative performance measures as tools to evaluate the proposed water flow changes. In particular, diatoms are abundant in periphyton mats and, because they live in ornamented tests that remain taxonomically distinguishable in sediment deposits for decades to millennia, sequences of their sedimented remains can provide useful inferences about past fluctuations. These paleoecological data can aid in establishing a baseline on natural environmental variability that is essential in formulating realistic management goals. The goals of this ongoing study are to: (1) determine relationships between periphyton attributes (composition and function) and environmental gradients in the Biscayne Coastal Wetlands and (2) apply relationships in calibrating past environments (i.e., sea-level rise, saltwater encroachment) from fossil assemblages in sediment cores. The work presented here details the results of our efforts toward the primary goal of defining ecological relationships in this basin.

Periphyton was collected from three coastal wetland basins between the Mowry and Military canals near Biscayne National Park. Basin 1 is a treatment wetland, which receives freshwater from the L-31E during periods when canal stages are high . Basins 2 and 4 are control basins and are effectively blocked from freshwater inputs by the L-31E canal. Three sampling stations in each basin were distributed in the dwarf mangrove forest adjacent to the canal levee, the interior dwarf mangrove forest and between the dwarf and fringing mangrove forest. Periphyton production was measured bimonthly for 2 years by incubating replicate artificial substrates for 2 months at each station. Natural periphyton biomass was measured at each visit by sub-sampling a measured area of the periphyton mat. Periphyton biomass was measured by chlorophyll a, dry and ash-free dry mass; subsamples were removed for measurement of TC, TN and TP content; and diatom assemblage composition was assessed microscopically. At each bi-monthly visit, water depth, salinity, pH, water temperature and conductivity were measured at each station. Biomass accumulation rates exhibited similar temporal fluctuations among sites but no seasonal pattern was detected. Lack of pattern could be due to highly variable water inputs due to periodic flooding and ponding of tidal water. Variation in mat biomass was higher among sites than among dates. Biomass was highest in the western station of Basin 1 and decreased toward the easternmost sites, bordering on the taller fringing mangrove forests. Besides receiving freshwater pulses, western sites of basin 1 are more open and less shaded by mangrove canopy than the eastern sites. The same pattern is true for Basins 2 and 4, where shading from the mangrove canopy likely prohibits light from penetrating to the sediment layer, thereby stimulating periphyton growth.

Concentrations of nutrients in Everglades periphyton mat tissue often provide a highly sensitive index of the quantities of nutrients delivered to the marsh system. We found that distance to the canal had a significant effect on P accumulation in periphyton in Blocks 1 and 4, where TP was lowest in the western sites and increased eastward. This pattern has been observed in coastal mangrove wetlands elsewhere.

Over 200 diatom taxa representing 34 genera were identified from material collected from the L-31E wetlands. While there was significant compositional overlap among the 3 wetlands, based on taxon relative abundances, ordination revealed a unique community for each wetland. For instance, the westernmost community in Basin 1, which receives the most freshwater, was distinctly separable from other communities in the basin, as well as in Basins 2 and 4 (Figure 1).

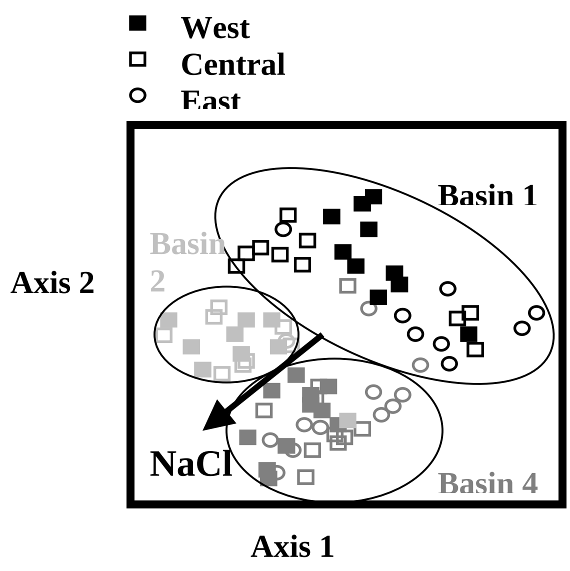

Figure 1. Ordination showing among and within-site differences in diatom species composition in periphyton mats in the 3 coastal basins.

In summary, we found periphyton production and species composition to be reliable indicators of ecological response to changes in freshwater delivery in the saline Everglades. If monitored on a regular basin, periphyton production should provide a good early indication of the ecological trajectory of implemented changes in water delivery to these areas. In addition, diatom indicators will be important not only in monitoring changes but also in paleoecological studies that retrospectively infer past environmental conditions, providing a natural-system ecological baseline for restoration targets.

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Impacts of Off-Road Vehicle Use on Wildlife in the Prairie Ecosystem of Big Cypress National Preserve

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The use of off-road vehicles (ORVs) has been a popular recreational activity in Big Cypress National Preserve (BCNP) for many years, and recently more than 2000 individuals per year have received ORV permits (National Park Service 2000). The repeated rutting of marl prairies due to ORV use has caused extensive damage to many areas within the preserve. A management plan has been implemented to mitigate this damage (National Park Service 2000).

Although the degree of ORV use is well documented in the marl prairies of BCNP, the impact of ORVs on wildlife species is not well known. However, human recreation may result in alterations in behavior and reduce survival (Swarthout and Steidl 2001) or fitness (Parent and Weatherhead 2000) of wildlife populations.

ORVs in the prairie habitats of BCNP may also have indirect effects on wildlife species. ORV use can impact the vegetation, hydrology, water quality, and soil structure of prairies (National Park Service 2000). Duever et al. (1981) documented changes in plant species composition and abundance in prairies with high ORV use. The extent to which these environmental changes affect wildlife populations in the prairies of BCNP is poorly understood.

Amphibians and small mammals may be affected directly and indirectly by ORV use in prairies. Further, these animals are particularly suited for this study on the impacts of ORV use on wildlife because they are likely to spend their entire lives completely within or near the same homogenous prairie habitat. Also, they are easily sampled with traps and should occur in great enough abundance to allow the estimation of a variety of population parameters like abundance and survival using mark-recapture analysis.

We will investigate the effects of ORVs on amphibians and small mammals by using mark-recapture techniques to estimate population parameters at sites with varying degrees of ORV use. The two most important population parameters used in this study will be survival and abundance. Our efforts will focus on two groups of species: treefrogs that will be captured in PVC pipe refugia and rodents that will be captured with Sherman live traps.

Grids of 3.5cm PVC pipes will be erected in prairie habitat in BCNP. These pipes are very effective at capturing treefrogs (Boughton et al. 2000). Approximately 50 pipes will be used per site at as many as nine locations. These locations will be classified as having light, moderate, or heavy ORV use. Three replicate sites will be used for each category of ORV use.

PVC pipes will be examined for treefrogs once every two weeks. Captured animals will be carefully removed from the pipe to avoid harm. They will also be identified to species, age, and sex whenever possible, measured snout-to-vent (SVL) and massed using a Pesola™ hanging scale. Frogs will be marked using a commonly accepted toe-clipping scheme (Donnelly et al. 1994). Toes will be removed quickly with a pair of sharp scissors. No more than two toes per limb will be removed, and the first toe on any limb will not be removed. Scissors and other equipment will be cleaned with alcohol to avoid disease transmission. All methods used have been approved by the American Society of Ichthyologists and Herpetologists and the Society for the Study of Amphibians and Reptiles (http://www.asih.org/pubs/herpcoll.html). Each frog will be released as soon as possible after capture to minimize stress on the animal.

Mammals will be trapped and handled in a similar manner. Grids of Sherman live traps will be baited with rolled oats to capture rodent species. The grid design will allow us to calculate a density of the animals (Jones et al. 1996). Trapping will be conducted one week each month at each site. Each captured rodent will be identified to species, sex, and approximate age. The body length, tail length, and the mass of each captured animal will also be noted. Finally, each captured rodent will be uniquely marked with an individually numbered ear tag.

In addition to providing important information about ORV impacts on key wildlife species of the prairie habitat, these data will be used with hydrologic data to determine how hydrology affects these species. Specifically, changes in abundance and survival across seasonal hydrological gradients will be observed on sites stratified by ORV use. The presence, abundance, and behavior of the amphibian and small mammal species changes with the transition from dry season to wet season in this habitat will also be examined. Collectively, this information will be valuable for evaluating hydrologic and human-use impacts during Everglades restoration.

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Use of Chloride Concentration to Assess Conservative and Non-Conservative Properties of Everglades Surface-Water Constituents

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge includes water conservation area number 1 (WCA-1), one of three WCAs that were built to maintain water storage and flood control as well as provide a protected refuge for the remnant Everglades ecosystem. In the 1950s and 1960s, WCA-1 was completely surrounded by perimeter canals and hydrologically isolated from its watershed by levees. Stormwater runoff primarily from the Everglades Agricultural Area, but also from urban sources, is pumped into the perimeter canal where it may flow to discharge structures or mix into the rainwater-dominated interior wetland.

Relative to the rainwater-dominated interior of WCA-1, the pumped stormwater has elevated concentrations of a number of constituents including chloride, calcium, sulfate, conductivity, total nitrogen, and total phosphorus. A pollutant-impacted fringe of marsh has developed between the relatively pristine interior and the perimeter canals. This impacted fringe marsh extends over a significant fraction of the total refuge area (Richardson et al. 1990).

This presentation will document a preliminary graphical assessment of the transformations of constituents introduced in the pumped stormwater passing down the perimeter canals and across the fringe marsh of WCA-1. In estuarine systems, mixing plots (also called concentration-salinity diagrams) are a widely used method to identify presence of sources and sinks of constituents during seaward transport and mixing (Middelburg and Nieuwenhuize 2001; Sharp et al. 1982; Steen et al. 2002; Uncles et al. 1998). Mixing plots graph a water quality parameter against salinity. For a purely conservative parameter, observations should fall on a straight line drawn from the parameter value and salinity characteristic of the freshwater inflow to value and salinity characteristic of the seaward boundary. If observations primarily fall above this mixing-line there is evidence that a source is present. If observations fall primarily below the mixing line there is evidence of some loss or sink mechanism for the parameter. A wide scatter above and below the mixing line may indicate presence of both a source and sink. An analogous approach is applied here to study the behavior of chemical properties during mixing of pumped stormwater with water originating as rainwater within the refuge interior. Here, chloride concentration rather than salinity is used to estimate the fraction of each water sample originating as pumped inflows to the refuge.

Data collected by the South Florida Water Management District from a continuing transect monitoring study were analyzed (McCormick et al. 2000). Sites analyzed include two in the perimeter canal, designated X0 and Z0, and 3 marsh sites, designated X4 Y4 and Z4, located respectively 4.4, 3.2, and 3.1 Km from the canal. Water quality parameters characteristic of pumped inflow were identified as the median value of canal observations when canal conductivity was above median. Similarly, parameters characteristic of the interior were estimated as the median for the 3 interior sites when marsh conductivity was

Table 1. Characterization of water qualityparameters.

Parameter	Canal	**Interior**
Sodium	C	C
Calcium	+	-
Sulfate	C	-
Potassium	+	C
Silica	+/-	+/-
Algal Growth Potential	+	-
Total Nitrogen	C	-
Total Phosphorus	+	-

below median. Plots were classified (Table 1) by visual inspection as being characteristic of a conservative, a source, or a sink (C + and – respectively).

The results summarized in Table 1 are mostly unsurprising. Loss of many constituents from interior marsh water could be attributed to biologically driven processes such as precipitation (calcium), microbial reduction (sulfate and inorganic nitrogen forms), and uptake (inorganic nitrogen and phosphorus). The existence of a source of total phosphorus in the perimeter canals is troubling. This source persisted after Stormwater Treatment Area-1W began operation, and appears at times when canal stage is below, as well as above marsh ground elevation. It is conjectured that the internal canal sources for total phosphorus and calcium are related to groundwater discharge and further that the phosphorus source results from internal loading caused by advection of re-mineralized sediment pore water phosphorus into the water column. Recent studies (Daroub et al. 2002) have documented a large pool of phosphorus in the highly organic sediments that have been deposited in the perimeter canals since their construction.

This study illustrates the utility of monitoring and analyzing a suite of water quality parameters rather than focusing on single parameters in isolation. Results from this study bear on fundamental questions in Everglades restoration including period required for recovery, possible unintended deleterious impacts of restoration projects, and STA performance. Continued research efforts will attempt to quantify the processes identified here, including estimation of the rate of canal internal loading of total phosphorus. These efforts may include statistical analysis, and steady state or dynamic water-quality modeling.

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Short Term Dynamics of Vegetation Change Across a Mangrove – Marsh Ecotone in the South West Coastal Everglades: Storms, Sea-level, Fire and Freeze

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Understanding the potential impacts of Global Climate Change, such as sea-level rise, on the newly initiated Comprehensive Everglades Restoration Plan (CERP) are crucial to its' success. The position of the mangrove – marsh ecotone (MME) is known to have changed through time at several locations in coastal Everglades and Florida Keys. Shifts in the upstream position of the MME have been suggested as a means of monitoring sea-level impacts and to serve as an indicator of global climate change in places such as Australia and Southeast Asia.

The ecology of a MME has been examined in detail for over seven years. The site is located along the Harney River, in Everglades National Park. We established a transect across the MME which spans a distance of >350m, running from a tall mangrove forest at the river's bank, into a sawgrass dominated plain. Five sediment porewater sampling sites are located along the transect. At each porewater site there are six porewater sippers, three at 30cm depth and three at 60cm depth. These sippers were sampled weekly for the first year (1997) and then bi-weekly thereafter. Porewater for nutrient analyses was collected at infrequent intervals. Permanent plots for measuring changes in the mangrove forest canopy and in the abundance of mangrove seedlings were established in 1998 and have been sampled yearly. An experiment was established to examine the impacts of a marsh fire on the subsequent establishment and growth of mangrove seedlings. Change in the position of this ecotone since 1927 has been determined by the analysis of aerial photographs.

The river's edge is dominated by tall mangrove forests, particularly *Rhizophora mangle* and L*aguncularia racemosa*. *Avicennia germinans* is present in low numbers over the first 200m of the transect (fig.1). Forest height and average stem size decrease inland. Both *Rhizophora* and *Avicennia* disappear from the inland areas of the transect, leaving *Laguncularia* as the only mangrove species where the forest gives way to a marsh dominated by sawgrass (*Cladium jamaicense*).

Long term change in the position of the ecotone has occurred. In 1927 the MME was approximately 100m from the river bank. By 1994, the MME was 350m from the river bank, an inland shift of approximately 250m, a distance readily measurable on the photographs. Stumps of the Cabbage Palm (*Sabal palmetto*) can be found inside of the current mangrove forest and provides strong evidence for a change in the vegetation. Our physical data indicate that this transect, located on a large coastal island, is disconnected from upstream hydrologic signals. We thus feel that the movement of this ecotone over the past 70 years is related to a rise in sea level.

Gross sediment nutrient concentrations vary significantly from river edge to interior marsh. Total nitrogen increases from just over 1ppm (mg per gm wet sediment) in the riverine mangrove forest to more than 2ppm in the sawgrass. The trend for phosphorus is the reverse. Sediment P is highest in the riverine forest (1.2ppm) and least in the sawgrass (0.4ppm).

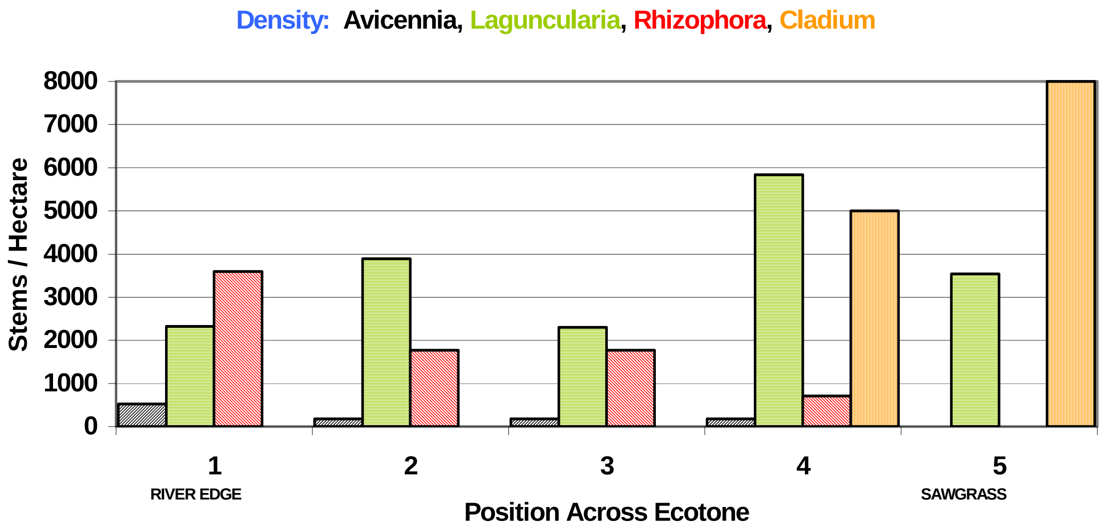

Figure 1. Stem density for the dominant species across the Harney River mangrove marsh ecotone transect (multiply *Cladium* by 100).

Tree mortality has been observed from a variety of sources over seven years including: wind (from both hurricanes and winter cold fronts), freezing temperatures, fire and lightning (fig. 2). Freezes and fires are more likely to affect stems at the ecotone. Both fires and freezes "top killed" numerous individuals of *Laguncularia* along the ecotone. This species stump sprouts readily. The frequent occurrence of fires and freezes may account to the large number of *Laguncularia* that are multi-stemmed.

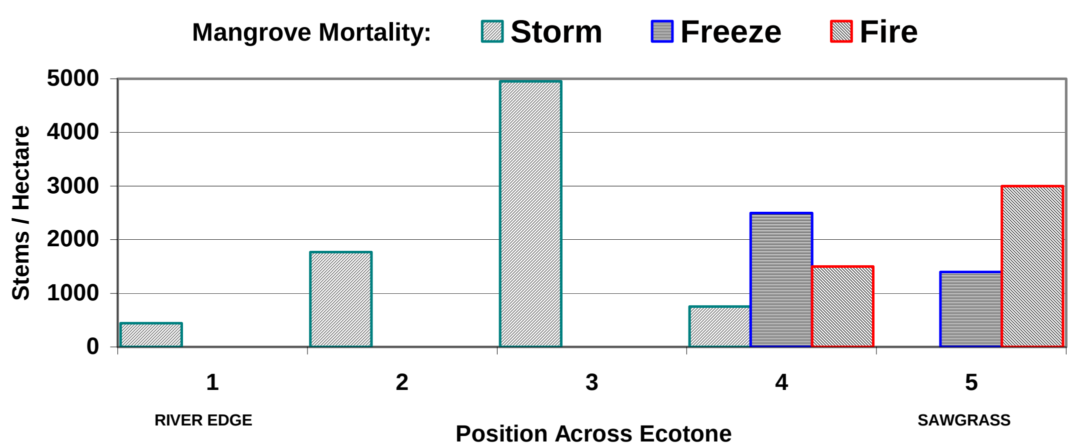

Figure 2. Causes of short term mortality along the Harney River transect. Storm related mortality is common near the river's edge and in the interior forest. Freeze and fire are the major mortality factors at the mangrove – marsh ecotone.

In terms of fire impacts, the preliminary results from our seedling transplant experiment are interesting. We hypothesized that seedlings planted into a recently burned sawgrass marsh would have higher survival rates than ones planted under an unburned sawgrass canopy. For all three mangroves, however, the reverse was true. Individuals in the unburned marsh had greater survival. The largest effect, however, was among species. *Avicennia*, in both burned and unburned marshes, died rapidly, whereas 45% or more of both *Laguncularia* and *Rhizophora* survived for at least 200 days.

Results of this study indicate the mangrove – marsh ecotone is a dynamic component of landscape, capable of changing and being changed over relatively short time periods. Mangrove - marsh ecotones at more upstream locations in the Everglades ecosystem will be useful locations at which to monitor the effects of increasing freshwater inflow.

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Design Models for Treatment Wetland Systems at Low Phosphorus Concentrations: DMSTA

William W. Walker and *Robert H. Kadlec*

The goal of the Everglades Protection Project (EPP) is to remove phosphorus from runoff waters before it enters the Everglades Protection Area (EPA). Treatment wetlands are the surviving option, out of dozens that have been tested. Those wetlands are characterized by varying proportions of three classes of communities: emergent plants, submerged plants, and periphyton (algae). The acronyms SAV (submergent aquatic vegetation) and PSTA (periphyton stormwater treatment area) have been commonly used to represent the submersed and periphyton communities, respectively. All three assemblages are capable of phosphorus removal.
The STA design model (Walker, 1995) embodied a first order, areal net uptake of phosphorus, and was constrained to be applied to long term average wetland performance. A modified version of the first order, areal model, containing such a lower limit, was proposed (Kadlec and Knight, 1996). That modification was subsequently adopted for design of STA3/4. For long term average wetland performance:

$$J_{net} = k(C - C^*) \qquad (1)$$

The STA design model effectively used C* ≈ 2 ppb, a result driven by rainfall P. The later k-C* version allowed C* as a calibration parameter, with resulting values in the 4 - 20 ppb range.

The goal of this work was to develop and calibrate the simplest, highly aggregated model that could mimic the major features of event driven behavior of treatment wetlands in the runoff environment. A simple extension of the STA and k-C* design models is the addition of P storage in the biota of the wetland ecosystem (Figure 1). During periods of high phosphorus availability, that storage will increase, and in periods of P-famine, the storage will decrease. At all times, the ecosystem produces the residual sediments containing unavailable P, that characterized the WCA2A calibration data of the STA design model (Walker, 1995). This extension has been named the Dynamic STA Design Model (DMSTA). It is a unsteady state model that removes phosphorus to permanent burial in proportion to the amount of labile P in storage, and is patterned after a similar model calibrated for other marshes (Kadlec, 1997). The labile pool is presumed to be drawn down by a return flux, or bleed-back. Temporal variations in the water budget (flows, rainfall, evapotranspiration, seepage, storage) are also simulated. The underlying philosophy of DMSTA is to maximize simplicity, while retaining features absolutely necessary for explaining P removal.

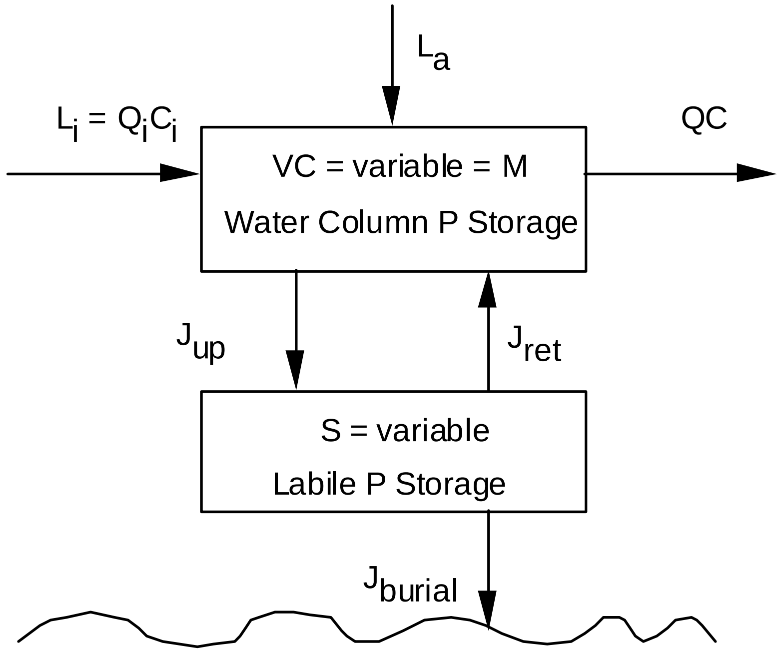

Figure 1. Concepts of the DMSTA structure.

C	=	P concentration in water, mg P/m^3
J	=	P flux, mg P/m^2•yr
L	=	P loading, mg P/m^2•yr
M	=	water column P storage, mg P/ m^2
Q	=	water outflow, 10^6 m^3/yr
M	=	water column P storage, mg P/ m^2
S	=	biomass labile P storage, mg P/ m^2
V	=	water volume, 10^6 m^3

The model presumes P removal from the water to labile biomass storage that is proportional to the water concentration and the storage size.

$$J_{up} = F_z K_1 C S \qquad (2)$$

This process transfers P from the water column to temporary (labile) storage.
A second principal premise of this model is a P return from labile storage to the water that is proportional to the square of the amount of stored labile P. This recycle rate is:

$$J_{ret} = K_2 S^2 \qquad (3)$$

A third premise is that labile stored P is partially converted to biologically unavailable P in soils and sediments:

$$J_{burial} = K_3 S \qquad (4)$$

Three rate constants K_1, K_2, and K_3 are adjustable parameters. The combination:

$$C_0 = K_3 / F_z K_1 \qquad (5)$$

is the lowest steady state (long-term average) concentration that can be attained by a specific calibration wetland community. Further details are given in Walker and Kadlec (2002).

Calibrations of DMSTA have been accomplished for three genera of treatment wetlands receiving low phosphorus waters: emergent, submergent and periphyton dominated systems. Calibration prototypes were selected based upon vegetation characteristics, size, and dataset duration. Central tendency parameters determined from single-platform calibrations have been determined for the three wetland types, and for combinations.

DMSTA has been used to investigate alternatives for future improvements to phosphorus removal from waters entering the EPA.

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Influence of Sediment Dredging on Phosphorus Flux Between Sediment and Overlying Water of a Shallow Subtropical Lake

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Internal nutrient load from sediments of shallow lakes has become a major concern in restoration programs. To determine the influence of dredging on P release or retention, we obtained sixty intact sediment cores from mud zone of Lake Okeechobee, Fl. The dredging treatments included: 0, 30, 45, and 55 cm mud removal. Five dissolved reactive P (DRP) levels (0, 0.016, 0.032, 0.064, and 128 ug L^{-1}) were evaluated, with water column replaced once every 60 days for 431 days. Significant decreases in water column DRP were observed in sediment cores with 30 cm dredging. Dredging sediments to 45 and 55 cm depth showed very little or no effect on water column DRP concentrations. At ambient water column DRP levels, P flux during the first 32 days was 11-38% of total P released during 431 days. The P flux during the first 99 days accounted for 49 to 71% of total P release and 66 to 100% during the first 156 days. Estimated EPC_w were in the order of 0.033, 0.008, 0.022, and 0.037 mg P L^{-1} for 0, 30, 45, and 55 cm dredging treatments, respectively. Above these values, sediments function as sinks for water column P. Laboratory experiments suggest that dredging can reduce internal P loading.

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Effects of Microhabitats on Stable Isotopic Composition of Biota in the Florida Everglades

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Attached algae (periphyton) serve an extremely important role in the Everglades ecosystem as a source of organic carbon to foodwebs. As important primary producers within the wetland ecosystem, they establish the isotopic composition of the base of the foodweb. However, this initial algal composition is established by the composition of the inorganic nutrients (DIC and DIN) in the water column, the compositions of which can vary significantly. Subsequently, the detrital foodweb begins with the decomposition of this plant material (composed of both emergent macrophytes and periphyton). The bacteria decomposing the detritus may have a lower $\delta^{13}C$ value than the original plant material – imparting a lower $\delta^{13}C$ signature to organisms consuming the detritus and assimilating the lighter bacterial carbon. Thus, foodwebs capitalizing on detrital components will exhibit isotopic variability due both to the variations in the original plant material and the processes decomposing the detrital material itself. An understanding of how these processes and linkages operate is critical to any interpretation of stable isotope data from the Everglades and to evaluating the success of the restoration process.

Aquatic vegetation and detritus samples were collected from various sites along two parallel transects in WCA 2A (Sites E1, E4, E5, F1, F4, F5, and U3). Sampling was carried out during the wet season (September 1998) and the dry season (March 1999) in order to discern any seasonal variations in isotopic composition. While the data indicate very little difference in $\delta^{13}C$ and $\delta^{15}N$ between seasons, there was a strong spatial trend moving from the canal into the marsh center. $\delta^{15}N$ values of vegetation (living and dead) tend to decrease (from around +5‰ to around 0‰) with distance from the canal, while $\delta^{13}C$ values show an increase with distance from the canal (from –30‰ to –26‰). Shrimp and other invertebrate samples collected at the same times also show an ~2‰ decrease in $\delta^{15}N$ and ~5‰ increase in $\delta^{13}C$ along the same gradient.

In addition to the sampling of the primary vegetation and detrital matter at each site, benthic macroinvertebrates were collected within several microhabitats at each site. Microhabitats sampled at each site varied but included open-water sloughs, cattail marsh, sawgrass marsh and spikerush stands. The microhabitats were not further than 100m apart within each site. At each site, there were differences between the $\delta^{13}C$ and $\delta^{15}N$ of invertebrates from different habitats. At U3, for example, there was a 0.5 to 1‰ variation in $\delta^{13}C$ and a 1 to 2‰ variation in $\delta^{15}N$ between marsh types (fig. 1). However, the only generalization that can be made for the microhabitat variations between sites was that invertebrates had lower $\delta^{13}C$ values in sloughs than in cattail or sawgrass marshes. The differences in isotopic composition of benthic macroinvertebrates within microhabitats at each site suggest localized influences, perhaps due to the relative rates of photosynthesis and respiration.

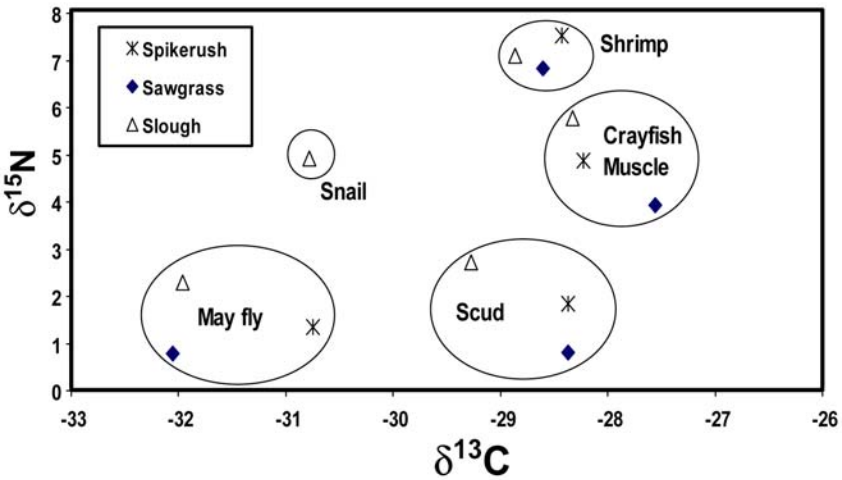

Figure 1. Differences in the $\delta^{13}C$ and $\delta^{15}N$ of selected invertebrates collected during the dry season (March 1999) at 3 different types of microhabitats (spikerush marsh, sawgrass marsh, open slough) near site U3 in WCA2A.

Additionally, in October 1997, algal growth experiments were conducted at site U3, a pristine marsh site within WCA 2A. Plexiglass plates were submerged within three slough-wet prairie habitats and allowed to colonize with algae for 8 weeks. Site U3-1 was a slough with abundant water lilies whereas the other two sites were spikerush marshes. Weekly samples collected from each site were analyzed for $\delta^{13}C$ and $\delta^{15}N$, as well as diatom species composition (fig. 2). $\delta^{13}C$ of the algae ranged from –32‰ to –27‰, while the $\delta^{15}N$ ranged from +2‰ to +6‰. Isotopic compositions showed discrete temporal trends over the 8-week experiment that correlated well with changes in the dominant diatom species. These data are consistent with spatial variation in local microhabitat biogeochemistry and species composition controlling bulk algal isotopic composition.

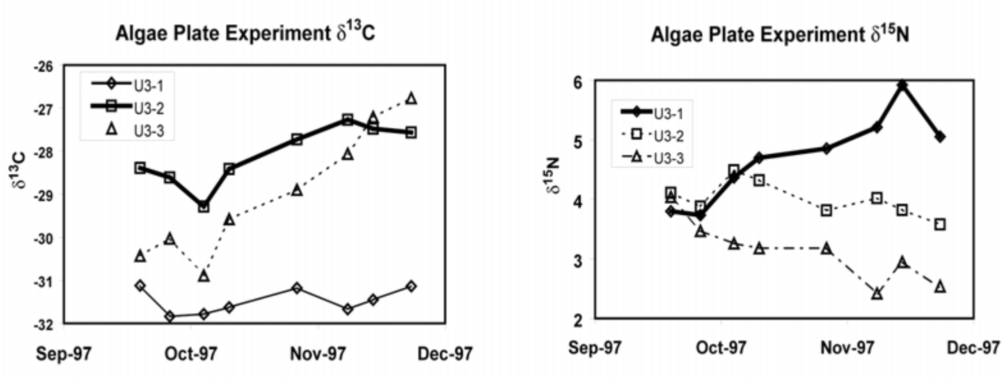

Figure 2. Changes in $\delta^{13}C$ and $\delta^{15}N$ of algae growing on plates at 3 locations near site U3 in WCA2A.

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Spatial and Temporal Patterns in Isotopic Composition of Aquatic Organisms at Everglades Nutrient Removal Project Sites

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The Everglades Nutrient Removal Project (ENR) began in 1994 with the goal of reducing the phosphorus (P) load downstream of the Everglades Agricultural Area. The effects of different vegetative habitats in treatment cells on P loads were evaluated. Cell 3 is dominated by emergent macrophytes such as cattails and water hyacinths, while cell 4 is dominated by an assemblage of submerged macrophytes and periphyton. During some sampling periods, there appeared to be significant differences in the mercury (Hg) concentrations of some aquatic organisms from the different cells, perhaps as a consequence of differences in food web structure (Hurley et al., 1999). We have analyzed sets of biota collected in 1997-98 from several locations in the four different cells of the ENR for $\delta^{15}N$ and $\delta^{13}C$ to (1) better understand the biogeochemical controls on the isotopic composition of Everglades foodwebs, and (2) assess whether there is any evidence for differences in food webs at the different sites that might explain differences in Hg concentrations.

Statistically significant differences in the isotopic composition (both $\delta^{13}C$ and $\delta^{15}N$) of muscle tissue from mosquitofish, least killifish, bluefin killifish, sailfin molly and grass shrimp in Cell 3 between June 1997 and June 1998 suggest a shift in the isotopic composition of the diets of these fish. Samples collected in June 1997, January 1998, and June 1998 show increasing $\delta^{15}N$ values and decreasing $\delta^{13}C$ values. For example, the $\delta^{15}N$ of least killifish increase from +11.3 to +13.2‰ while the $\delta^{13}C$ values decrease from -25 to -29‰. This swing in the isotopic composition of these fish can be explained either by a change in diet or by a shift in the isotopic composition of their food source. The close tracking of the isotopic compositions of omnivorous fish (mosquitofish, killifish) with herbivorous fish (sailfin molly) over time suggests changes in the isotopic compositions of the algae. Since the isotopic composition of algal material is controlled largely by the composition of the inorganic nutrients within the water column, the isotopic composition of the fish reflects changes in the biogeochemistry operating in the water column at the time of algal growth.

The $\delta^{15}N$ and $\delta^{13}C$ values for mosquitofish, sailfin molly, and shrimp collected in June 1998 from Cell 3 and Cell 4 show significantly different averages and distributions (fig. 1). The data from Cell 3 plot in distinct clusters whereas data from Cell 4 show a striking alignment along a negative slope. It is not clear whether these differences reflect differences in diet or just differences in the isotopic composition of plants at the base of the food webs. At both sites, sailfin mollys have the lowest $\delta^{15}N$ and highest $\delta^{13}C$ values, shrimp have intermediate values, and mosquitofish have the highest $\delta^{15}N$ and lowest $\delta^{13}C$ values. Hence, there appears to be no major differences in their relative trophic positions in June 1998. Therefore, it is likely that the differences in $\delta^{13}C$ and $\delta^{15}N$ of organisms between Cell 3 and Cell 4 reflect differences in the isotopic composition of the diets between cells. Aquatic plants from Cell 4 show a much greater range of $\delta^{13}C$ values than plants from Cell 3, but a similar range of $\delta^{15}N$ values. The larger range of $\delta^{13}C$ values in Cell 4 may be related to the higher amounts of open water and periphyton growth in Cell 4 compared to Cell 3. Increased light penetration may cause larger changes in the

$\delta^{13}C$ of dissolved inorganic carbon (DIC) in the water column by allowing more light penetration and therefore more benthic photosynthesis. Higher rates of benthic photosynthesis would lead to higher $\delta^{13}C$ values as seen in the organisms sampled in Cell 4.

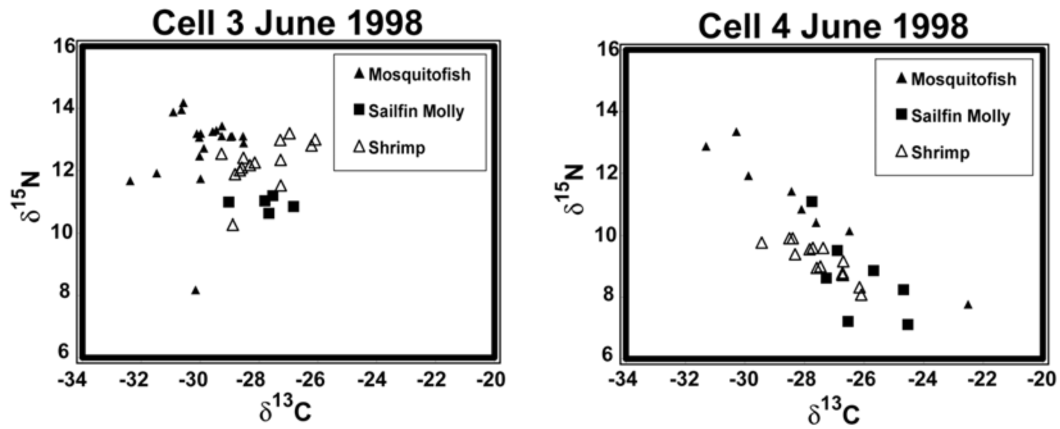

Figure 1. $\delta^{13}C$ and $\delta^{15}N$ values of selected biota collected from Cell 3 and Cell 4 in June 1998.

The variations in isotopic composition over both time and space within the ENR emphasize the importance of localized biogeochemistry for interpretation of stable isotope data. Fluctuations in water depth (hydroperiod) and plant cover over time in the ENR may explain a significant portion of the variability of $\delta^{13}C$ and $\delta^{15}N$ of primary consumers (mosquitofish, killifish, sailfin mollies). Understanding the mechanisms for the foodweb base shift, whether it is a shift in diet or isotopic composition of the diet (or both?), is critical to tracing contaminant bioaccumulation within these Everglades foodwebs.

References:

Hurley, J.P., Cleckner, L.B., and Gorski, P., 1999. Everglades Nutrient Removal Project small fish bioaccumulation study – final report to the SFWMD (contract PC C-8691-0300).

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Application of the Regional Simulation Model to Southwestern Florida

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The regional Simulation Model (RSM) is an object oriented hydrologic computer model being developed by the South Florida Water Management District. Currently, this model is being applied to southwestern Florida to support both the South Florida Feasibility Study (SFFS) and Water Supply Planning (WSP). Although this application is still in the set-up and calibration phase, it is already realizing benefits from the new technologies incorporated in the development of the RSM. These benefits have included the ability to more easily extend the physical processes simulated by the model, easy linkage to inverse modeling tools such as UCODE and efficient utilization of computational resources. This paper will cover the application of the RSM to the SWFFS and will focus on the advantages being realized in the application from the new technologies incorporated in the RSM.

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Periphyton Stormwater Treatment Areas Demonstration Project: Results of Three Years of Monitoring

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The Everglades ecosystem has been altered from changes in both the historic hydropattern and inflow nutrient concentrations. The Everglades Forever Act (EFA) (Section 373.4592, Florida Statutes) requires the South Florida Water Management District (District) to construct a series of large treatment wetlands called Stormwater Treatment Areas (STAs) to reduce phosphorus (P) nutrient levels to an interim target of 50 ug-P/L. However, the final P standard will most likely be less than 50 ug-P/L, therefore, the EFA has directed the District and Florida Department of Environmental Protection (Department) to initiate research and monitoring to generate sufficient water quality data to evaluate the effectiveness of Alternate Treatment Technologies (ATT) to meet the final P standard.

In 1996, the District completed a comprehensive evaluation of promising water quality treatment technologies, ranging from constructed wetlands to chemical treatment for the removal of P (PEER Consultants and P.C./Brown and Caldwell, 1996). The District, and other entities, such as the Department, has initiated demonstration studies on eight ATTs required by the U.S. Army Corps of Engineers 404 permit. Periphyton-based STAs (PSTAs) was one of the original technologies targeted for additional research.

In this ATT, post-STA water flows over a substrate colonized primarily with calcareous periphyton (attached algae) and sparse macrophytes, the latter primarily functioning as additional substrate and a stabilizing mechanism for the algal mats. Phosphorus is removed from the water column through biological uptake, chemical adsorption, and algal mediated co-precipitation with calcium carbonate within the water column (Jorge et al., 2002).

Demonstration and research PSTA projects are ongoing at various locations within STA-1W and adjacent to STA-2, but this presentation focuses on the results from three-years of steady-state monitoring of two 0.2-ha treatment wetlands dedicated to PSTA research. These wetlands are shallow, half-acre, lined wetlands, known as test cells, located within Cell 3 of STA-1W. The PSTA test cells have a sand surcharge directly on top of the liner, however, one test cells has 30 cm of peat on top of 30 cm of shellrock, while the other has only shellrock. Following a short start-up period, the test cells were operated with a mean HLR of 6 cm/d and a mean depth of 0.6 m for the first six months of operation, from 7 July 1999 to 11 January 2000. At this time, based on analysis of P removal performance of smaller mesocosm experiments, the depth was lowered to 0.30 m for the remaining period (through July 2002), while maintaining a mean HLR of 6 cm/d. Decreasing the depth, while maintaining the HLR resulted in a reduction of a nominal hydraulic residence time (HRT) of about 12 days to 6 days. All test cells received water from a common source and, in these cells, the water was distributed across the width of the cells by a manifold at the inlet.

Weekly grab and/or composite water quality samples were collected, depending on the parameter, at the inflow and outflow of all PSTA test cells and analyzed for various parameters. Total phosphorus (TP) is reported in this abstract. All sample collection and analyses have been conducted in accordance with APHA approved analytical methods (American Public Health Association, 1989).

The peat-based test cell, which quickly became dominated by cattails, had very little effect (7% concentration reduction) on reducing the inflow TP concentrations during this three-year period (July 1999 through July 2002), with mean inflow and outflow TP concentrations of 0.029 mg/L and 0.027 mg/L, respectively (Figure 1). This result is similar to other cattail dominated test cells operating at the same site. The STA Optimization peat-based, cattail dominated test cells, had a mean TP outflow concentration of 0.035 mg/L over this same three-year period. However, the shellrock test cell exhibited a 50% TP concentration reduction, with mean inflow and outflow TP concentrations of 0.026 mg/L and 0.013 mg/L, respectively.

With three-years of accumulated data from the PSTA test cells, the phosphorus removal from the limerock-based system continues to effectively reduce inflow TP concentrations and has achieved a long-term mean of 0.013 mg/L, making it a viable alternative to approaching the phoshorus targets defined by the Everglades Forever Act.

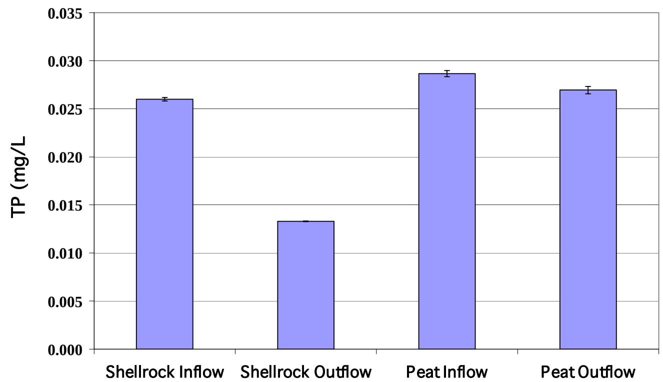

Figure 1. Mean total phosphorus inflow and outflow concentrations for the three-year analytical period (July 1999 through July 2002) for the PSTA shellrock and peat-based test cells located within STA-1W, Cell 3. The error bars represent the standard error.

References:

American Public Health Association (1989) Standard methods for the examination of water and wastewater, 17th edition, Washington, DC.

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PEER Consultants, P.C. & Caldwell, B.a. (1996). Desktop evaluation of alternative technologies. Final report, Rep. No. Contract C-E008 A3. South Florida Water Management District, West Palm Beach, FL.

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Proposed Experiment on the Effects of Microtopography and Deep-Water Refugia on Fish Concentrations in the Loxahatchee Impoundment Landscape Assessment (LILA) Research Facility

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One of the leading explanations for population declines of wading birds in the Everglades is the change in prey availability as a result of changes in hydropatterns. There is more to prey availability than the density of prey. Prey availability is defined as a composite variable consisting of prey density and the vulnerability of the prey to capture. Prey availability is linked to the seasonal drydown in water levels, but there is very little understanding of the specific conditions that produce patches of highly available prey. We hypothesize that microtopography (i.e. ridge and slough) plays a key role in determining the spatial and temporal arrangement of high quality prey patches. If true, then any changes in the historic microtopography of the Everglades would have had serious implications for wading bird foraging. The objective of this study is to determine the effects of microtopography and deep-water refugia on small-scale fish densities. To accomplish this, we plan to investigate the formation of these highly available food patches by evaluating prey response to seasonal drydown. By manipulating the water depth and measuring fish movements and fish density, we will be able to determine the extent of movement among fish, the degree of exchange between ridge and slough communities, and the concentrations of high-density patches formed during the drydown. With these studies, we will test our hypotheses that fish community composition, physical features of the marsh, and hydrologic factors have an effect on maximum prey density (i.e., the magnitude of prey concentration). In addition, we hypothesize that during drydown events, the exchange of fish from areas of higher elevations such as ridges to areas of deeper water found in the sloughs will create small-scale high-density patches. The alternative is to remain on the ridges and be subject to desiccation and/or capture.

These experiments will be conducted in the Loxahatchee Impoundment Landscape Assessment (LILA) research facility located on the premises of the Arthur R. Marshall Loxahatchee National Wildlife Refuge in Palm Beach County, Florida. The facility consists of four 7-hectare macrocosms constructed to mimic the key physical features of the Everglades landscape.

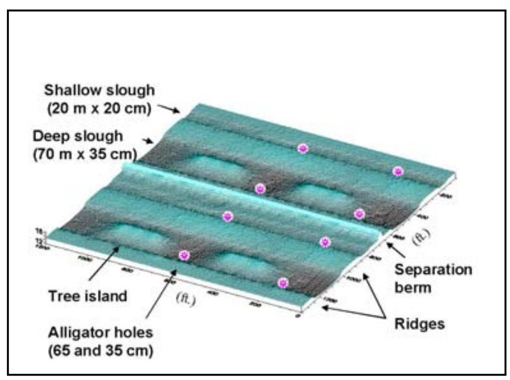

Figure 1. Landscape features of two macrocosms.

Each macrocosm will receive the same hydrologic treatment (flow rate and water depths). The microtopography treatment will come from elevation differences in ridges and sloughs and in alligator holes. Each macrocosm will contain a shallow and deep slough. Each slough will contain a shallow and deep hole 6-m in diameter designed to simulate alligator holes and provide deep-water refuges for fishes. In addition to the holes, the deep slough will contain two tree islands 14 m x 49 m in size and 0.91 m higher than the slough bottom.

Macrocosms will be randomly selected to receive either a shallow or deep refugia treatment. Holes at the depth that was not selected as a treatment for a given macrocosm will be encircled with impervious plastic material to keep aquatic animals from reaching them. Each macrocosm will be further divided with mesh fence into two subplots for the microtopography factor.

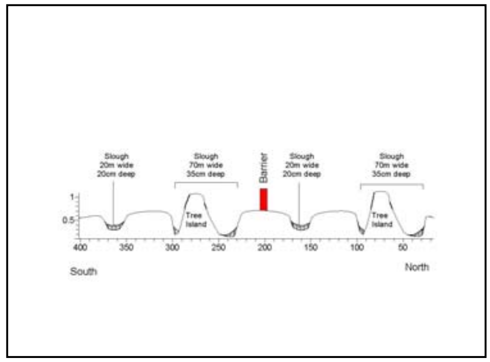

Figure 2. Cross-section of two macrocosms.

The plastic fence with a mesh size of 1 cm^2 will be erected so that it bisects lengthwise the widest ridge in each macrocosm, thus providing two microtopography treatments within each macrocosm. Fish that are too small to be preferred prey for wading birds (<4 cm in length) will pass through the mesh and will be monitored but will not be the focus of statistical analyses. One microtopography treatment will be a slough and ridge elevation difference of 20 cm and the other will be a slough and ridge elevation difference of 35 cm. Initial fish population densities in each plot will be controlled through removal or stocking, and final fish densities will be adjusted for the area of slough and ridges within plots. Fish densities will be measured in each slough weekly using throw-traps (Kushlan 1974b, Jordan et al. 1997). Sloughs will be delineated with flagging into 20 m segments. Initially, one throw trap sample will be taken randomly within each segment during each sampling period. The number of samples may be increased depending on the variability in samples.

Fish movements will be measured using radio telemetry and individual fishes implanted with radio transmitters. This will answer the question of how individual fishes move to and from the high-density prey patches preferred by birds. Radios have been used successfully to track movements of fishes in the southern Everglades (J. Trexler, Florida International University, pers. Comm.). Fifty sunfishes (Lepomis sp.) will be implanted with radio transmitter and released into randomly selected plots. Additional radios will be added as transmitters fail or are lost. The transmitters weigh approximately 1.5 g and will be inserted in the body cavity of fishes approximately 30 g in mass (100-150 mm in length) using established techniques that conform to accepted guidelines for the use of fishes in field research (Nickum 1988). Transmitter weight will be 5% of body weight. Longevity of transmitter battery life and transmitter range is inversely related. Using a target battery longevity of two months, transmitter range is expected to be approximately 100 m, accounting for heavy vegetation and 50 cm of water depth. Actual range may be greater because of the open structure of sloughs and the shallower water depths for much of the dry season. The location of all telemetered fishes will be monitored weekly from the perimeter levees using a hand-held Yagi antenna. Semi permanent antennas may be established later depending on the range of transmitters. It also may be necessary to supplement readings from the levee with those taken in the marsh. To determine short-term movement patterns and ensure that daily locations are indicative of diurnal movements, a random telemetered fish from each plot will be monitored hourly for one 24-h period each month.

The experiment is designed as a standard three-factor split-plot with impoundment as the replicate factor, refugia depth as the main-factor, and microtopography as the subplot factor. The response variable will be maximum fish density during the dry season. The experiment will be repeated in subsequent years.

Thus far we have tested the transmitter range to an acceptable distance of approximately 100-m. We are currently conducting a laboratory experiment to determine if the transmitters affect the behavior of the fish. To achieve this, we will use time activity budgets to analyze behavioral differences in the sunfish before and after implantation of the transmitters. We will begin the fish concentration studies during the 2004 dry season.

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Characteristics of Lightning Gaps in the Mangrove Forests of Everglades National Park

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Lightning gaps have been identified as a common disturbance in mangroves throughout the world. Lightning created canopy gaps are abundant in the mangrove forests of Florida. An average 9,900 cloud to ground strikes occur annually in Florida, the highest level found in the United States. The dynamics of Florida mangrove systems may result from the interactions of small-scale lightning gaps, large-scale hurricane disturbances and sea-level rise. In addition to these ecosystem forcing functions is the Greater Everglades restoration effort, known as the Comprehensive Everglades Restoration Plan (CERP). CERP will greatly influence hydrological flow through much of the 100,000 ha of mangroves in South Florida. Clearly, to understand how the mangrove ecosystems may change in response to restoration it is important to determine how these mangrove ecosystems respond to small- and large-scale disturbance along with sea-level rise.

The goal of this project is to characterize the role of lightning generated gaps within South Florida mangrove ecosystems. This is being accomplished by: following short-term changes in community level and environmental processes; evaluating community characteristics in a time series of gaps along a known salinity gradient; and appraising the regional signal for mangrove gap dynamics. Here we present findings of 39 gaps from the general region for canopy and expanded gap size and direction of orientation. Additionally, we present initial findings of habitat characteristics for six gaps of differing successional age located in the lower Shark River Region.

The mean canopy gap area was 212 m^2 and the expanded gap was 299 m^2 for the general gap survey. Gaps were slightly elliptical in shape with an average eccentricity of 1.28. There was a preferential directional bias to the longest axis of the gaps. However, there was no evidence of wind extensions to the gaps. Thirty-three percent of the variation in gap size was explained by average surrounding canopy height.

To understand the successional process it is important to determine a relative age of the recovering gap. The aging of tropical gaps has been a problem in a number of environments. Here we have developed a hypothetical relative aging of gaps based on the ratio of the coarse woody debris of the gap compared to the average of coarse woody debris amount for the study island. The average coarse woody debris was 52.52 tons ha^{-1} for the study island. The gap coarse woody debris varied from 16.7 to 182 tons ha^{-1}. There is a linear relationship between relative gap age and the amount of coarse woody debris present with older gaps having a higher ratio of coarse woody debris relative to younger gaps (Fig. 1).

It appears that roots within the lightning created gaps die as a consequence of above ground tree mortality and possibly from the lightning itself. Root death causes the physical properties of the sediment to differ from the surrounding forest type. We assessed sediment parameters for six gaps of different successional age and found that compaction is significantly lower in gaps (0.094 kg/cm^2) and higher in the surrounding closed canopy forest (0.124 kg/cm^2). The same was true for sediment shear strength (gap mean = 7.4 kg/cm^2 and forest mean = 8.8 kg/cm^2).

Shear strength and soil compaction taken together indicates soil cohesiveness. There is a linear relationship between these parameters and our data supports this linear relationship; however, all samples from gaps are consistently grouped towards lower end of this relationship (Fig. 2). Sediment shear strength and compaction are usually correlated with bulk density, however, our study does not support this finding. In addition, there was no difference in sediment bulk density between gaps and the surrounding forest. There are plans to extend this type of investigation of lightning gaps to the mid-stream and upstream areas of the Shark River Region. In this way we will investigate the effect of salinity on the recovery process.

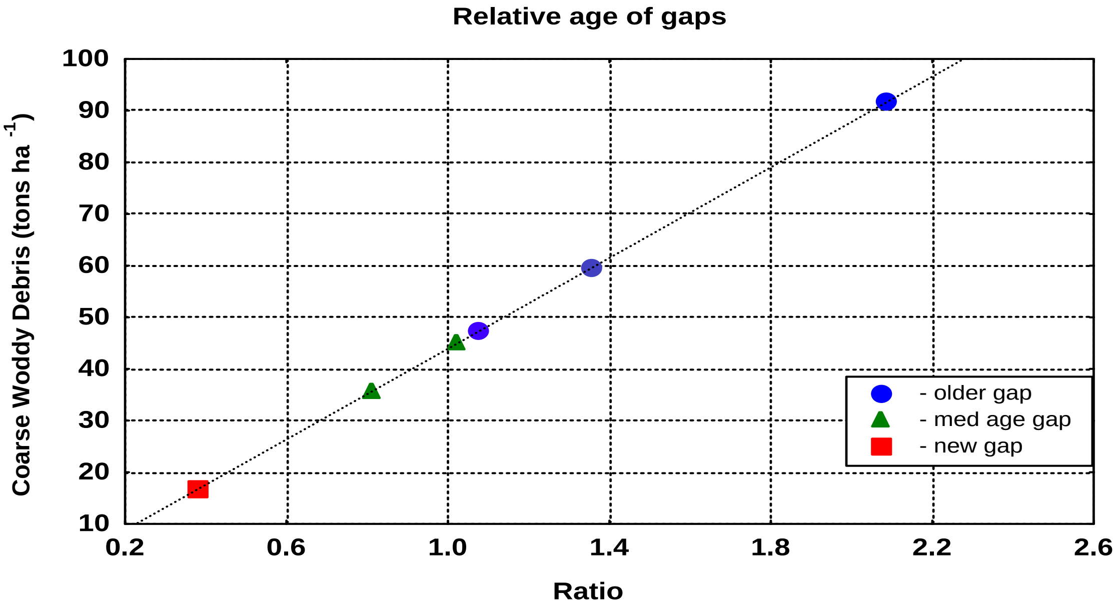

Figure 1. Hypothesized relationship between gap age and the amount of coarse woody debris.

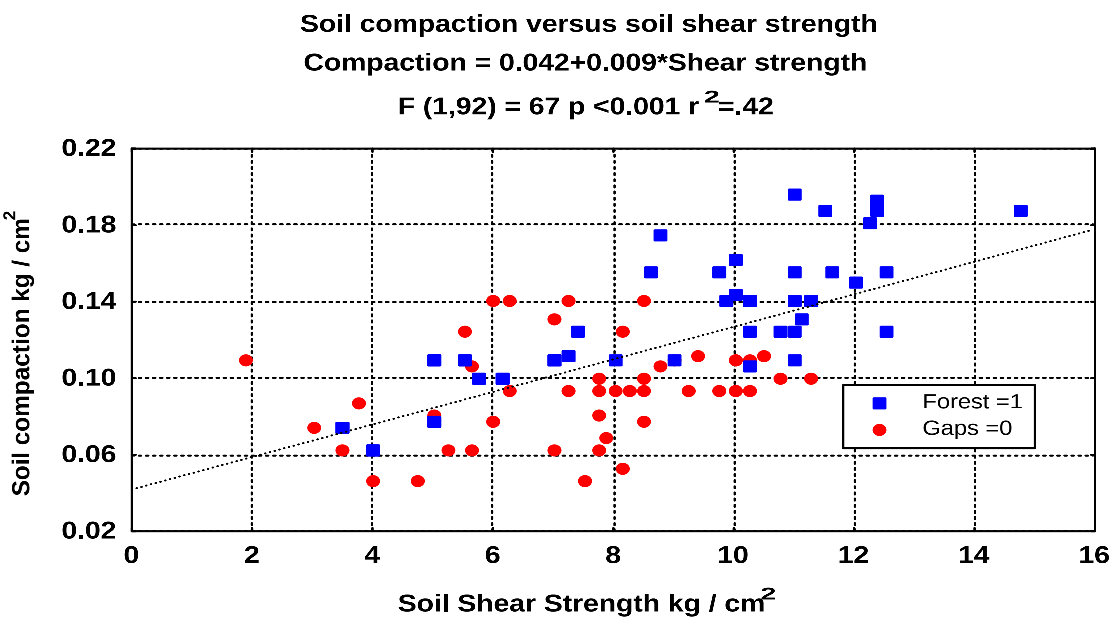

Figure 2. Relationship between soil compaction and soil shear strength for mangrove forested sites (squares) and gap sites (diamonds).

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An Evaluation of Contaminant Exposures and Potential Effects on Health and Endocrine Status for Alligators in the Greater Everglades Ecosystem

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Alterations in sexual differentiation, endocrine function and health has been documented among alligators in Central Florida as a potential response to environmental contaminants. These data suggest that exposure to site-specific sources, primarily agricultural sites and pesticides may be responsible for these toxicities. The assessment of exposures for alligators within the Greater Everglades Ecosystem is an essential component of current and future assessments of risks and potential effects of proposed and ongoing restoration.

To enable an assessment of contaminant risks for the Greater Everglades Ecosystems it is critical that an initial, complete food-chain, characterization of contaminants be conducted. These results would form the critical basis of any initial risk assessment and are necessary for any evaluation and/or assessment of risk that may be related to restoration of the Greater Everglades Ecosystem, In addition, these results would form the basis of any future evaluations of adverse effects, paired field and laboratory studies, and the critical assessments or evaluations of restoration success or resultant adverse effects.

The current study evaluated contaminant exposures and potential physiological effects for alligators in the Greater Everglades Ecosystem. Alligators (approximately 5 ft in length; n=10 animals per site during Fall 1999 and 2000) were collected and sacrificed from several specific sites involved in future restoration efforts: Everglades National Park, Loxahatchie National Wildlife Refuge, Big Cypress National Preserve, and Water Conservation Areas 2A, 3A-N and 3A-S. Several tissues were collected for contaminant analysis: blood, scute, liver, muscle, bile and fat. Contaminant analyses will include an assessment of chlorinated hydrocarbons (i.e. pesticides, PCB's, PAH's), water soluble herbicides, organophosphates, carbamates and metals (i.e. mercury, lead, selenium etc). Blood was utilized for blood chemistry assessments of health status and endocrine status (sex steroids and thyroid function). Gonadal and liver tissues were examined histologically for an evaluation of reproductive status and liver toxicity. Selected samples from several alligators were composited to assess the appropriate tissues for each contaminant analysis. Samples collected during 1999 (approx. 3 animals per site) were also composited and analyzed for selected contaminants (persistent pesticides and several current use pesticides). Plasma was analyzed for biomarkers of reproductive status (estradiol and testosterone) and metabolism/thryroid function (T3 and T4).

Results for the preliminary phase of this project indicated a differential tissue distribution for each class of contaminant. Lipid soluble pesticides (i.e. chlorinated hydrocarbons) were detectable in all tissues examined except blood and scute. Blood and scute concentrations of the chlorinated hydrocarbon pesticides were, in general, below detection limits. In contrast, analyses of water soluble pesticides (i.e. current use pesticides), organophosphates and carbamates were routinely detectable in blood. Muscle tissue (i.e. fillets) were chosen for the focus of these preliminary analyses for the organochlorine pesticides, while blood plasma was utilized for the other pesticide contaminants. Initial analyses were conducted on a composite of three alligators from each site and preliminary results are summarized in Figures 1 and 2.

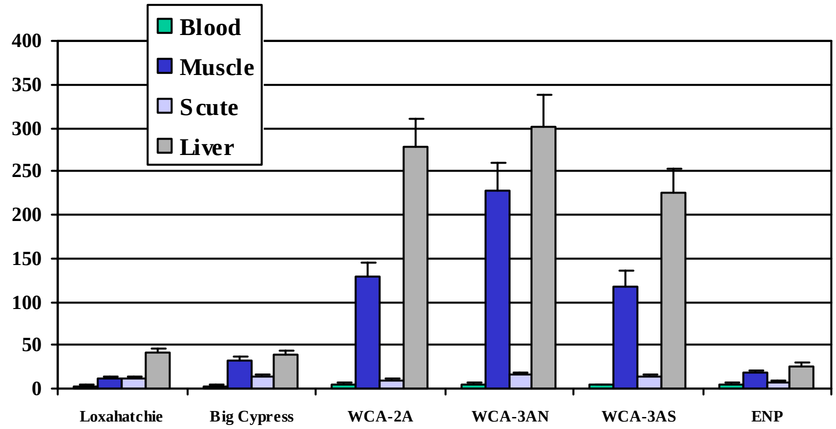

Figure 1: Preliminary analysis of total organochlorine hydrocarbon pesticides for several tissues from alligators across several broad regions of the greater everglades ecosystem. Results are as ppb for wet weight of tissue. Lipid concentrations did not differ between sites for each tissue. Note the differential distribution of pesticides across tissues

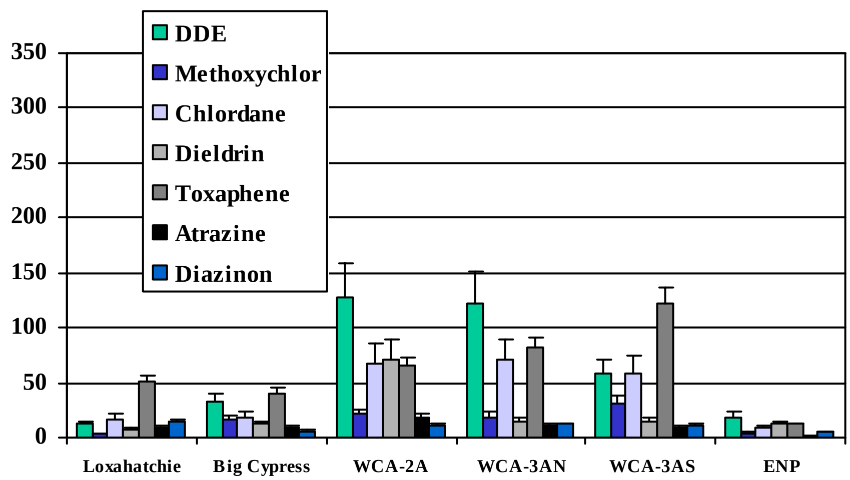

Figure 2: Preliminary analysis of organochlorine pesticides in muscle tissue for alligators across several regions within the greater everglades ecosystem. Data is listed as ppb. Note the increased exposures at the WCA;'s as compared to the other sites.

Results indicate site-specific patterns of contaminant exposure for alligators in the greater everglades ecosystem, and the potential for endocrine system and reproductive effects. These data demonstrate the need for a thorough assessment of exposures for wildlife within the Greater Everglades Ecosystem as an essential component of current and future assessments of risks and the potential effects of proposed and ongoing restoration.

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An Evaluation of Contaminant Exposures and Potential Effects on Health and Endocrine Status for Largemouth Bass in the Greater Everglades Ecosystem

Carla M. Wieser*, Jon J.Wiebe, D. Shane Ruessler* and *Timothy S. Gross*
USGS-FISC and the University of Florida, Gainesville, FL

Ted Lange
Florida Fish and Wildlife Conservation Commission

Alterations in endocrine function and reproductive success has been documented among largemouth bass in Central Florida as a potential response to environmental contaminants. These data suggest that exposure to site-specific sources, primarily agricultural sites and pesticides may be responsible for these toxicities. The assessment of exposures for largemouth bass within the Greater Everglades Ecosystem is an essential component of current and future assessments of risks and potential effects of proposed and ongoing restoration.
To enable an assessment of contaminant risks for the Greater Everglades Ecosystems it is critical that an initial, complete food-chain, characterization of contaminants be conducted. These results would form the critical basis of any initial risk assessment and are necessary for any evaluation and/or assessment of risk that may be related to restoration of the Greater Everglades Ecosystem, In addition, these results would form the basis of any future evaluations of adverse effects, paired field and laboratory studies, and the critical assessments or evaluations of restoration success or resultant adverse effects.

The current study evaluated contaminant exposures and potential physiological effects for largemouth bass in the Greater Everglades Ecosystem. Largemouth bass were collected and sacrificed from several specific sites involved in future restoration efforts (32 sites, n=20 per site, over 750 samples): Everglades NP, Loxahatchie NWR, Big Cypress NP, Canals: including C111, L39, L5, U3, S5A, G3, Holyland, STA's: 1, 2, 3, 4, 5 and 6, Water Conservation Areas 2A, 3A-N and 3A-S. Several tissues were collected for contaminant analysis: blood, liver, muscle, and gonad. Contaminant analyses will include an assessment of chlorinated hydrocarbons (i.e. pesticides, PCB's, PAH's), water soluble herbicides, organophosphates, carbamates and metals (i.e. mercury, lead, selenium etc). Blood was utilized for blood chemistry assessments of health status and endocrine status (sex steroids and thyroid function). Gonadal and liver tissues were examined histologically for an evaluation of reproductive status and liver toxicity. Sex was identified as follows: the presence of ovarian tissue and absence of testicular tissue = female; presence of testes and absence of ovarian tissue = normal male; and presence of testes with ovarian tissue = intersex . Selected samples from several fish were composited to assess the appropriate tissues for each contaminant analysis. Samples collected during 1999 (approx. 5 animals per site) were also composited and analyzed for selected contaminants (persistent pesticides and several current use pesticides). Plasma was analyzed for biomarkers of reproductive status (estradiol and testosterone) and metabolism/thryroid function (T3 and T4).

Results for the preliminary phase of this project indicated a differential tissue distribution for each class of contaminant. Lipid soluble pesticides (i.e. chlorinated hydrocarbons) were detectable in all tissues examined except blood. Blood concentrations of the chlorinated hydrocarbon pesticides were, in general, below detection limits. In contrast, analyses of water soluble pesticides (i.e. current use pesticides), organophosphates and carbamates were routinely detectable in blood and tissues at similar levels. Muscle tissue (i.e. fillets) were chosen for the focus of these preliminary analyses for the organochlorine pesticides, while blood plasma was utilized for the other pesticide contaminants. Initial analyses were conducted on a composite of five fish from each site and preliminary results are summarized in Figures 1 and 2.

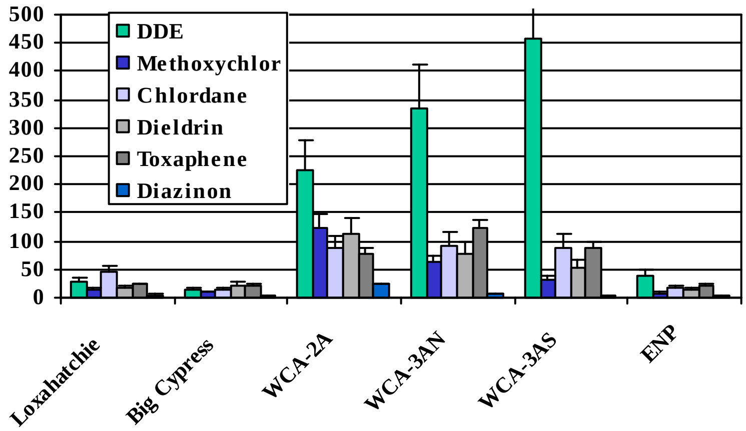

Figure 1: Preliminary analysis of chlorinated hydrocarbon pesticides for muscle tissue from largemouth bass across several broad regions of the greater everglades ecosystem. Results are as ppb for wet weight of tissue. Lipid concentrations did not differ between sites.

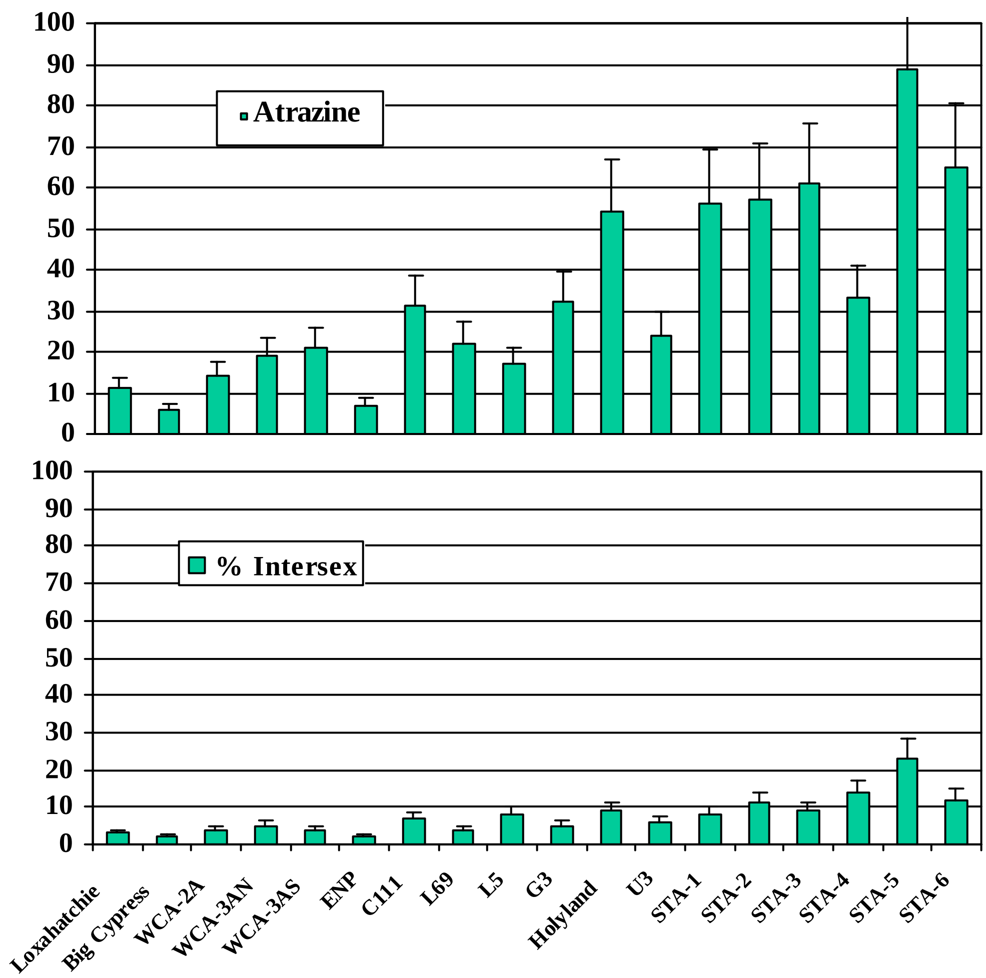

Figure 2: Preliminary analysis of plasma atrazine and incidence of intersex for sites throughout the greater everglades ecosystem. Atrazine data is listed as ppb. Note low background level of intersex for all sites and increased incidence of STA's 2, 4, 5 and 6.

Results indicate site-specific patterns of contaminant exposure for fish in the greater everglades ecosystem, and the potential for endocrine system and reproductive effects. These data demonstrate the need for a thorough assessment of exposures for wildlife within the Greater Everglades Ecosystem as an essential component of current and future assessments of risks and the potential effects of proposed and ongoing restoration.

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Water Allocation in Lake Okeechobee during Periods of Shortage and Drought

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South Florida Water Management District, West Palm Beach, FL

As part of the overall Water Shortage Plan (South Florida Water Management District 1991), the Supply Side Management (SSM) protocol was designed as a guideline for implementing restrictions on the quantities of water supply deliveries from Lake Okeechobee to the Lake Okeechobee Service Area (LOSA). When Lake Okeechobee levels fall below the SSM Trigger Line (Figure 1), water restrictions may be placed on users of Lake Okeechobee water.

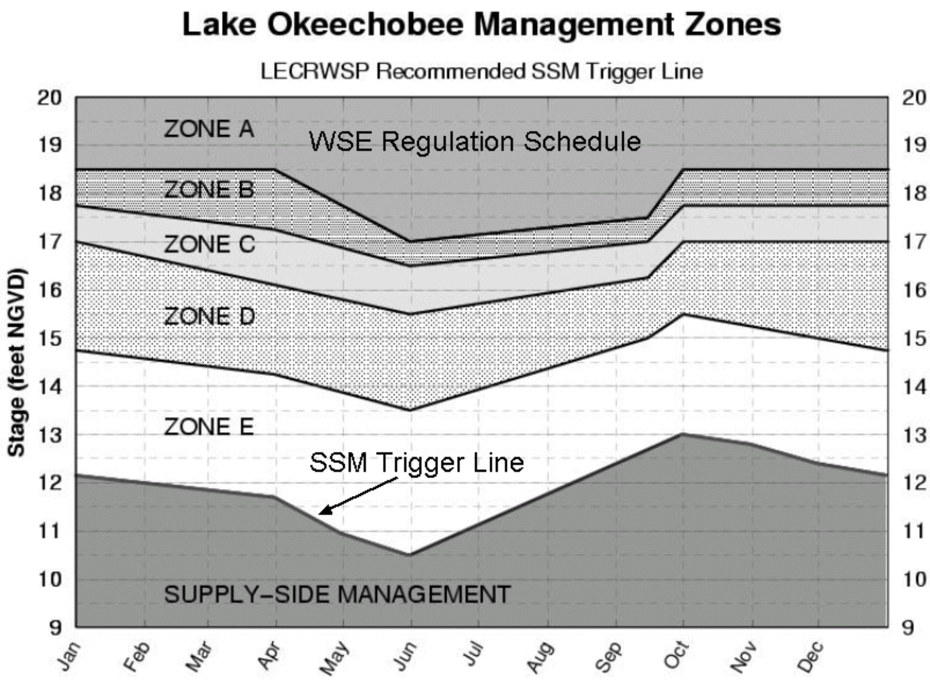

Figure 1

Due to persistent low Lake Okeechobee levels by the end of 2000, water shortage restrictions were initially declared on November 29, 2000 and remained in effect until the suspension of restrictions on October 10, 2001. Figure 2 shows Lake Okeechobee stages and LOSA allocation volumes, as calculated using the procedure outlined in the 1991 SSM protocol, for the entire 2000-2001 SSM implementation period. During the period of high dry season demand (October - May), approximately 380,000 ac-ft were allocated to LOSA.

In the process of managing the 2000-2001 drought, a better understanding of the system was realized and improvements to the current implementation of Supply Side Management were made. These included: 1) real-time AFSIRS modeling estimation of demand for the purposes of spatial distribution of allocation and 2) development of a methodology for implementing SSM during wet season months based on use of the South Florida Water Management Model (SFWMM) results. In addition, many additional improvements have been incorporated into a draft Supply Side Management computational procedure and methodology which, if adopted, could be used in future water shortages.

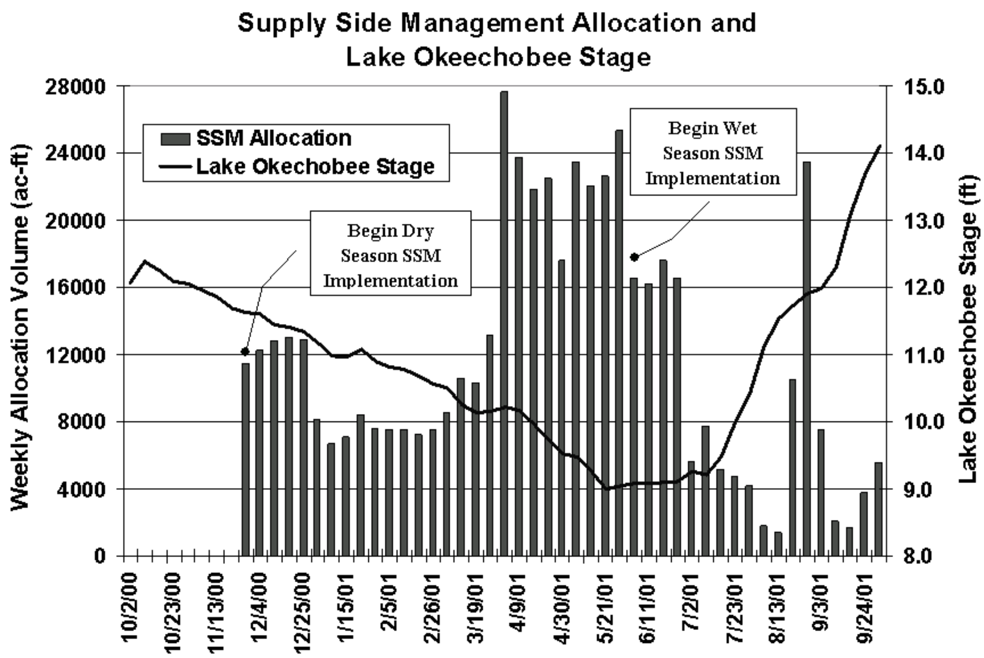

Figure 2

This presentation will review the SSM methodology as used in the 2000-2001 drought with emphasis on past and proposed modifications aimed at achieving more effective drought and water shortage management for Lake Okeechobee.

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Everglades Tree-Island Response to Hydrologic Change

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The stability of Everglades tree islands is influenced strongly by hydrologic parameters, including water depth, hydroperiod, and seasonality of flow. Based on analysis of pollen from sediment cores, we have reconstructed changes in vegetation and tree island size in response to hydrologic changes of the last century.

Transects of sediment cores were collected on 29 tree islands throughout the Everglades: five in Arthur R. Marshall Loxahatchee National Wildlife Refuge, two in Water Conservation (WCA) 2A, eleven in WCA 3A, two in WCA 3B, four in Shark River Slough, and five in Taylor Slough, Florida. The tree islands are geologically old features, with mature tree-islands present in the northern and southern Everglades for at least 2,000 and 1000 years, respectively. Even before classical tree-island formation, sites now occupied by tree-island heads were drier than surrounding marshes and sloughs; this finding is consistent with the hypothesis that topographic highs in the underlying limestone were favorable sites for tree-island development.

The response of tree-island vegetation to 20th century hydrologic changes varied with location within the greater Everglades ecosystem. On strand islands in Loxahatchee NWR, slight increases in abundance of shrubby taxa (holly, wax myrtle) and weedy species occurred in the early 20th century. After 1960, pollen of trees and shrubs increased at least fivefold, resulting in the dominance of holly and bays now seen on these islands. On a "drowned" tree island in WCA 2A, the abundance of tree-island taxa decreased greatly whereas water lily pollen increased during the 1960's; this finding is consistent with sustained flooding after construction of the Central & South Florida (C&SF) Project. The subsequent replacement of waterlily by sawgrass in the 1970's reflects altered water management practices, which incorporated periodic drawdowns into the management scheme. Overall, the vegetational pattern indicates the loss of tree-island vegetation after sustained high water for 10-15 years.

Sites in WCA 3A and B have insufficient sedimentation rates to resolve 20th century changes; however, assemblages from sediments deposited during the last 500 years show little change.

On and around tree islands in Shark River Slough in Everglades National Park, pollen of marsh taxa disappeared almost entirely ~1930, when initial canal and road construction was completed. After 1960, replacement of taxa characteristic of relatively wet conditions with tree-island taxa suggests that the tree island head expanded southward as fresh-water flow was reduced to Shark River Slough.

Our results indicate that tree-island response to future hydrologic response will not be uniform within the Greater Everglades ecosystem. Restoration pre-20th century hydroperiods and water depths to Shark River Slough is likely to result in a decrease in size of tree-island heads, whereas drowned tree islands in WCA 2A may see a gradual increase in size and restoration of previous tree-island plant communities. The distinctive composition of Loxahatchee strand islands also is a recent vegetational feature, and changes in biodiversity at those sites are likely as hydrology is altered. Our results highlight the variability of tree-island composition within the Everglades and indicate that no single performance measure should be devised to evaluate the success of tree-island restoration throughout the Everglades.

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Preliminary Results on the Effects of Environmental Parameters on Food-Web Complexity in the Florida Everglades

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Examination of food-web dynamics is vital to the understanding of basic ecosystem processes. Food-web dynamics are a result of ecological processes and interactions within the ecosystem. Changes within an ecosystem can produce variation in the mechanisms of feeding relationships. Food webs effectively determine system energy flow and material transfer, hierarchy of trophic relationships, and species interactions. Therefore, detailed knowledge of the factors affecting food-web structure and complexity are extremely important in the characterization of any ecological system.

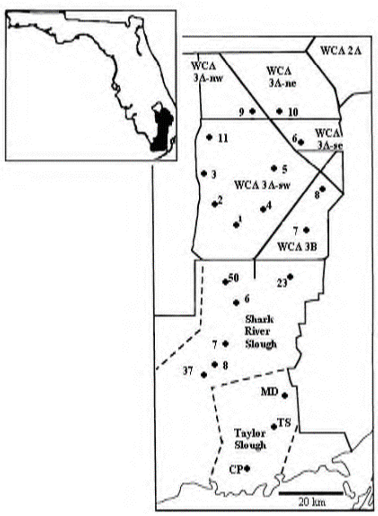

Fig. 1. Map of the 20 study sites

The Florida Everglades are a protected wetland ecosystem characterized by unique patterns of climate, hydrology, nutrient regime, and trophic structure. Unlike many other freshwater ecosystems, studies in the Everglades have depicted a system supporting unusually high standing crops of algae in periphyton mats, yet very low standing crops of consumers. To explore the origins of this distinctive trophic structure, we studied the relationship between food-web structure and the abiotic environment.

To estimate spatial variation in the length of Everglades marsh food webs, samples of representative groups from basal, intermediate, and top trophic levels were collected in Fall 2002 from 20 sites in three regions in the Everglades: Taylor Slough (TS), Shark River Slough (SRS), and the Water Conservation Areas (WCA) (Fig. 1). Food webs in any ecosystem are inherently complex, and it is virtually impossible to account for every species or functional group without relying upon significant assumptions. Therefore, to create an index of food-web complexity, we chose to sample target species at key points in the food web. These species were chosen based upon previously published Everglades diet studies. The basal portion of the Everglades food web is largely made up of a periphyton complex, comprised of both edible and inedible algal species, bacteria, and detritus. Due to this complex mat structure, it is difficult to separate the algal species and bacteria, possibly the base of the food web, from the structural components. Therefore, primary consumers were used as the basal level of the food web for this study. Specimens of small fishes and macroinvertebrates were captured using throw-trapping and large predatory fishes by electrofishing methods (Fig. 2).

Fig. 2. 1m^2 throwtrap used to sample fishes and macroinvertebrates

Trophic relationships among organisms for each marsh food web were estimated using stable isotope and gut content analysis. Traditionally, food webs were projected using only gut content analysis, but more recently, stable isotopes (C, N, S) have shown to be a useful method for food-web analysis. This technique, used in conjunction with gut content analysis, provides a quantitative, standardized method applicable across ecosystems. Stable isotope delta (δ) values indicate the ratio of the heavy/light isotope assimilated by living material. The light isotopic forms of nitrogen increase in frequency relative to the heavy one with increasing trophic level, revealing the trophic position of a species relative to the baseline organism (~3-4‰). Carbon isotopes remain relatively constant with increasing trophic position (~1‰), helping to reveal the base of the food web leading to that organism (e.g., algal or bacterial/detrital loops). Trophic structure can then be reconstructed based upon these predictable changes in elemental magnitude (Fig. 3). Food webs were analyzed and reconstructed at each site using an estimator of trophic position. Periphyton productivity was measured at each site using light/dark bottle incubation experiments. Hydrological data were obtained for each study site to characterize hydroperiod. Food webs were then compared among sites to examine possible relationships between food-web structure, hydroperiod, and local nutrient status.

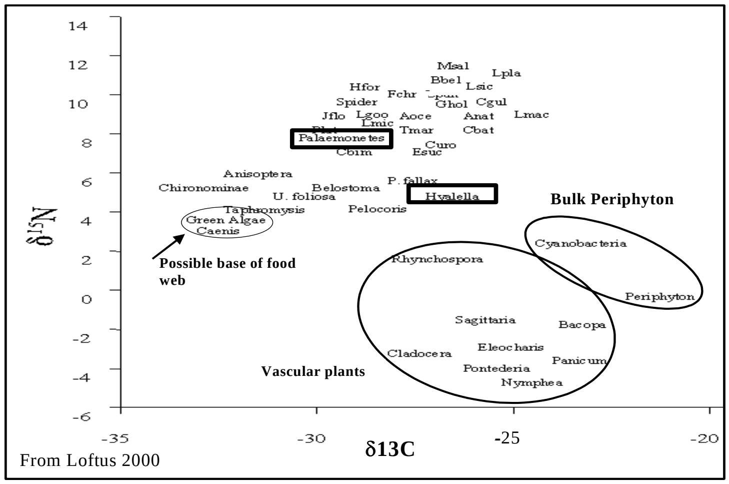

Fig. 3. Diagram of Everglades food-web by stable isotope methods

Loftus, W.F. 2000. Accumulation and fate of mercury in an Everglades aquatic food web. Ph.D. Dissertation. Florida International University. Miami, FL 33199

Preliminary results (first sampling season) show significant variation in trophic relationships among sites. Much variation is observed in $\delta^{13}C$ values, indicating a possible shift in the relative role of detrital vs. algal components at the base of the food web. This shift may also result from variation in the relative availability of heavy and light isotopes at each site (a non-biological explanation). To illustrate spatial variation in isotope signatures, we adjusted the average amphipod value from each site to the grand mean for that species (Fig. 4).

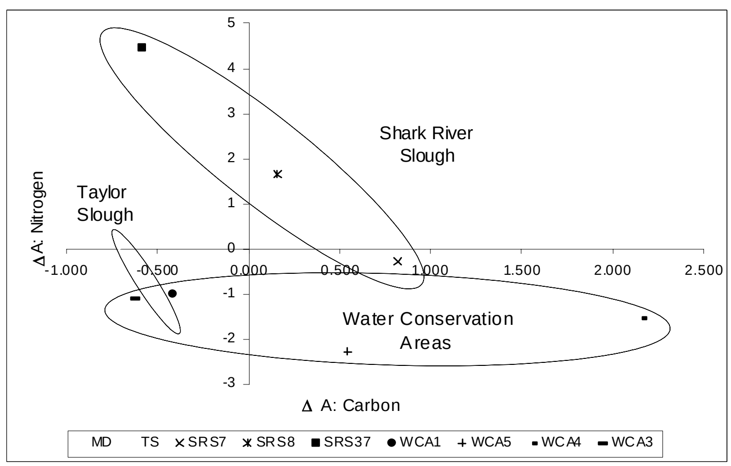

Fig. 4. Preliminary corrected stable isotope data for amphipods for nine sites

These data revealed wide variation within and among regions (TS, SRS, & WCA) in both $\delta^{13}C$ and $\delta^{15}N$ values amphipods. This variation may be due to changes in environmental parameters, or to a difference in diet at each site. Stable isotope data for mosquitofish at each site was corrected for environmental variation by subtracting the amphipod deviation values. $\delta^{15}N$ values for mosquitofish revealed little variation among sites (~2-3‰), with the exception of site SRS 37 which exhibited significantly lower $\delta^{15}N$ values than other eight sites. $\delta^{13}C$ values for mosquitofish revealed a much wider range, indicating possible differences in the relative roles of detrital vs. algal components as the food-web base.

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Ecosystem History of Central Biscayne Bay Based on Sediment Core Analyses

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During the last century, Biscayne Bay has been greatly affected by anthropogenic alteration of the environment through urbanization of the Miami/Dade County area and alteration of natural freshwater flow. Changes in the sources, timing, delivery, and quality of freshwater flow into the Bay have altered shoreline and sub-aquatic vegetation to unknown degrees. Land management agencies that focus on the restoration of natural flow of freshwater into Biscayne and Florida Bays can benefit from paleoecological and geochemical analyses documenting the impacts of past changes in freshwater input.

In order to establish targets and performance measures for restoration, research is being undertaken to determine pre-alteration baseline conditions and natural variation within the system. The USGS, in conjunction with South Florida Water Management District, Biscayne National Park, Duke University, Southern Illinois University, and University of Miami, is examining the natural patterns and causes of temporal change in salinity, water quality, vegetation, and benthic fauna in Biscayne Bay over the last 100-300 years.

The current studies extend prior knowledge of Biscayne Bay environmental history by obtaining cores from new sites, obtaining series of radiocarbon dates, evaluating lead-210 dating of Biscayne Bay sediments, utilizing multiple paleoenvironmental proxies, and applying quantitative methods of faunal and geochemical analyses. These analyses build on and expanding methodology utilized in research conducted in Florida Bay (1995 – ongoing) and Biscayne Bay (1996-2000) (Brewster-Wingard, et al, 2001; Cronin, et al., 2001; Dwyer and Cronin, 2001; Holmes, et al, 2001; Ishman, 1998).

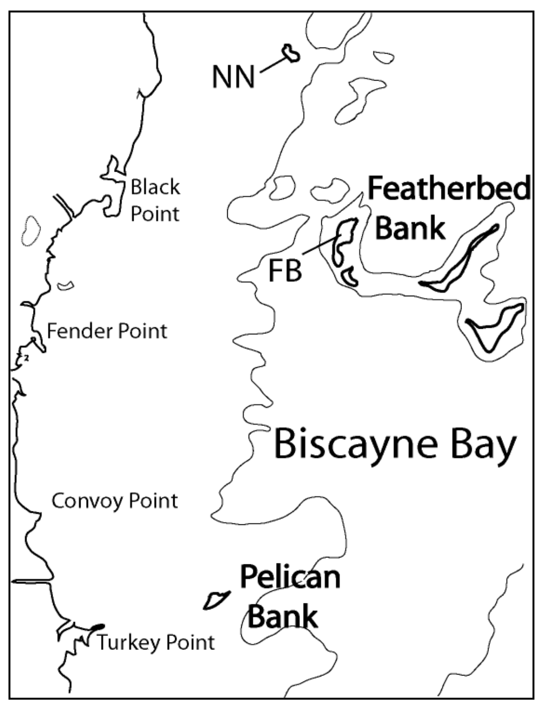

Figure 1. Map showing core locations in central Biscayne Bay. NN, No Name Core. FB, Featherbed Core.

Three sets of replicate cores were collected in March 2002 from sites in central Biscayne Bay, Featherbed Bank, and an unnamed bank (herein referred to as No Name Bank, equivalent to Black Shoal of Wanless (1969)) (fig. 1), and southern Biscayne Bay at Card Bank. Analyses of the two cores from central Biscayne are nearly complete. A preliminary age model using lead-210 geochronology places the base of the 2002 Featherbed Bank Core at 1741 and the base of No Name Core at 1874. Age models developed from radiocarbon and lead-210 dating of the 1997 and 2002 cores indicate mean sedimentation rates for Card, Featherbed, and No Name Banks were 0.25 cm yr^{-1}, 0.85 cm yr^{-1} and 1.22 cm yr^{-1}, respectively. The Card, Featherbed, and No Name cores yield paleoecological and geochemical records spanning the past 900, 500, and 150 years, respectively.

Analyses of fossil ostracode and molluscan faunal assemblages indicate a major shift in benthic communities in both central and southern Biscayne Bay during the late 1500's through 1600s, when epiphytal species indicative of seagrass (*Thalassia*) habitats became abundant. Moreover, there is preliminary evidence that a decline in seagrass-dwelling epiphytal species, unprecedented in the past 400 years, occurred at both No Name and Featherbed Banks during the mid-20th century. It is unclear what caused this decline; however, it may be due to changes in mean salinity, increased turbidity, nutrient influx, or other factors.

Ostracode shell magnesium to calcium (Mg/Ca) ratios, a proxy for salinity, indicate considerable short-term variability in Mg/Ca at No Name Bank during the past 150 years (fig. 2). The paleosalinity patterns are generally similar to those observed at Featherbed Bank and from Russell Bank in Florida Bay.

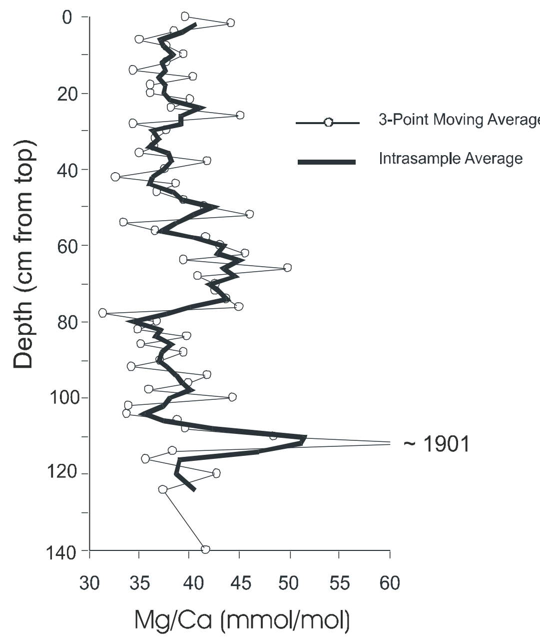

Figure 2. Ostracode Mg/Ca ratios from No Name Bank Core, Biscayne Bay.

Compilation of the data from the 2002 cores will provide additional data on the timing and causes of salinity variability and its relation to benthic faunal variability and benthic habitats. Comparisons will be made to cores collected in Biscayne Bay between 1996-1999, to determine trends in salinity, subaquatic vegetation, and shoreline vegetation for Biscayne Bay. A comparison to Florida Bay cores will provide information on ecosystem-wide changes. These data will provide the essential data necessary to establish performance criteria and restoration targets for CERP (Comprehensive Everglades Restoration Plan) and the agencies responsible for implementing CERP.

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Patterns of Movement of Florida Gar (*Lepisosteus platyrhincus*) in the Everglades Revealed by Radio Telemetry

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To build credible simulation models for the Everglades fish community for use in the restoration process, information on fish movement patterns and habitat use is a critical need. In this pilot project, we are testing the feasibility of using implanted radio transmitters to trace the movements of Florida gar across the open Everglades landscape. Beginning in March 2002, we monitored the movements of Florida gar (fig. 1) in the Everglades Wildlife Management Area, Conservation Area No. 3A (WCA-3A). An initial group of 20 was monitored from March to July and monitoring of the second group of 20 began in August and is ongoing. We collected gar using standard electrofishing techniques from an airboat, weighing and measuring each gar as it was collected. Fish were anesthetized in a solution of MS-222 for surgical implantation of transmitters (SB-2, Holohil Systems, Ltd.). Transmitters were inserted into the body cavity of the gar through a ventral incision posterior to the pelvic girdle, which was closed with three to five sutures and SuperGlue (fig. 2). The transmitter size maximizes the range and lifespan of the transmitter but cause no harm or mechanical interference to the fish. Each fish was released at the point from which it was captured and was monitored for the lifetime of the transmitter (approximately 3 months for the first group of fish). We captured the fish in two widely separated areas of WCA-3A, one short-hydroperiod area to the west (site 3; 26.014 N, 80.82 W), and a second, longer hydroperiod area in central 3-A (site 1; 25.86 N, 80.73 W). We tracked the gar using a Wildlife Systems receiver from an airboat. Fish that were unable to be located from the airboat were tracked by helicopter or airplane.

Figure 1: The Florida gar, *Lepisosteus platyrhincus*.

Figure 2: Ventral surface of gar after insertion of transmitter.

We tracked gar from the first group an average of 52 days between transmitter insertion to the time of last field record (Max. = 128, Min. = 1). Fish tracked at site 1 were monitored for an average of 50.5 days (Max. = 128, Min. = 3) and moved an average of 2.62 kilometers from the point of release (Max. = 7.339, Min. = 0.010). The majority of fish moving long distances swam to the southeast (fig. 3).

At site 3, the shorter hydroperiod site, the average tracking duration was nearly the same (54.8 days), but the average distance travelled was much less (0.913 km; Max = 2.96, Min. = 0.004). There was no trend in the direction of movements at that site, in contrast to the fish marked at site 1. This difference in movement may be related to local hydrology. At site 3, the gar travelled the greatest distances during the periods of March 12 – 24 and June 16 – July 1. Water depth at site 3 dropped substantially between March 24 and June 16 as the dry season progressed. Between May 6 and June 14, site 3 was unreachable because of low water levels. There was also a decrease in the distance per day travelled during this period (fig 4), which was probably related to the declining water depths.

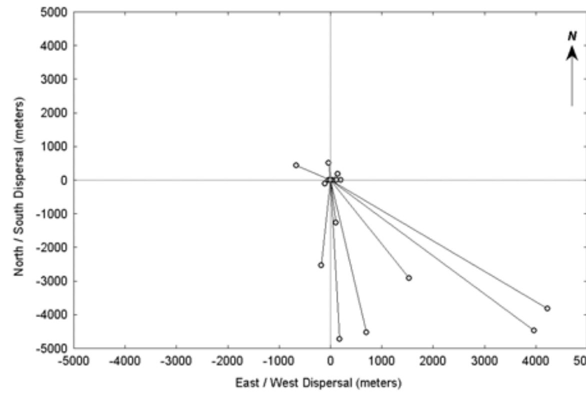

Figure 3. Gar dispersal from release point at Site 1.

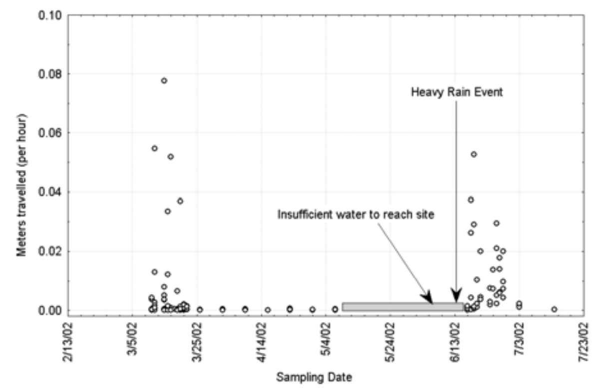

Figure 4. Distance traveled per hour for gar at Site 3.

We are presently monitoring a second group of gar at sites 1 and 3 that were tagged at the height of the 2002 wet season. We are tracking 14 individuals, of which four have moved beyond the range of our equipment. We believe this is a result of the deep, wet-season water depths that enable the gar to move longer distances than in the dry season.

In addition to long-term monitoring of the gar, we collected intensive diel movement and habitat-use data at both study sites by locating all fish at each site every 2 hours during a 24-hour period. As of November 2002, two diel studies have been completed from site 1 and two from site 3. Both diurnal sampling events from site 1 involved the most recent group of tagged gar, while at site 3, we collected one diurnal data set from each group. Preliminary analysis indicates that for 3 of the 4 tracks, there was no directional pattern to the movement of gar and no change between day and night movements. However, in one case (site 3, Group 1) the fish became more active at night and traveled longer distances. This coincided with shallow water depths at site 3; gar were found in alligator holes and deeper areas of the marsh during the day, moving into shallower areas during the night. This variation indicates that hydroperiod, and weekly variation in water depth at a particular site, play an integral role in the movement of gar. This study demonstrates the feasibility and effectiveness of using radio transmitters to describe movement patterns of large, mobile fishes across the wetland landscape. By collecting and analyzing movement data, we aim to develop a deeper understanding of survival, dispersal, and habitat use by these and other aquatic predators in the Everglades.

This research was funded by a cooperative agreement between the U. S. Geological Survey and FIU, under the CESI initiative (CA 1445-CA09-95-0112, Sub-agreement No. 1). Mention of specific manufacturers does not imply endorsement.

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Long-Term Water-Quality and Streamflow Monitoring in the Lake Okeechobee Watershed

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Lake Okeechobee is a large, shallow lake located in south-central Florida. With a surface area of 730 square miles, it is the second largest lake within the contiguous United States and has an average depth of 9 feet. The lake is the heart of South Florida's water supply and flood control system and is a major source of water for the Everglades. Agricultural development in the drainage area and construction of the Central and Southern Florida (C&SF) project during the last century has resulted in excess nutrient inputs and more efficient delivery of stormwater to the lake. As a result, in-lake phosphorus concentrations have doubled since 1970. This increase in phosphorus has shifted the natural balance of nutrients in the lake, led to conditions that are favorable for blue-green algal blooms, and contributed to the accumulation of phosphorus-rich bed sediments over an extensive area of the lake. The C&SF project canals that discharge waters from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries and to the Everglades have severely impacted these ecosystems.

Many agricultural sources of phosphorus pollution in the Lake Okeechobee watershed have been regulated under the Taylor Creek-Nubbin Slough Rural Clean Waters Program, the Dairy Rule, and South Florida Water Management District (SFWMD) Works of the District Program through installation of farm-level best management practices. Some reductions in phosphorus loads to the lake were observed in the mid-1980s to early 1990s, perhaps due to these activities. However, phosphorus loads into the lake have since been rising, and in-lake concentrations are well above the level needed to restore the lake to more natural conditions (fig. 1). Additional programs have been established under the Surface Water Improvement and Management (SWIM) Act and the Lake Okeechobee Protection Bill to help improve water quality, but these activities alone will not accomplish restoration of the lake and downstream waters.

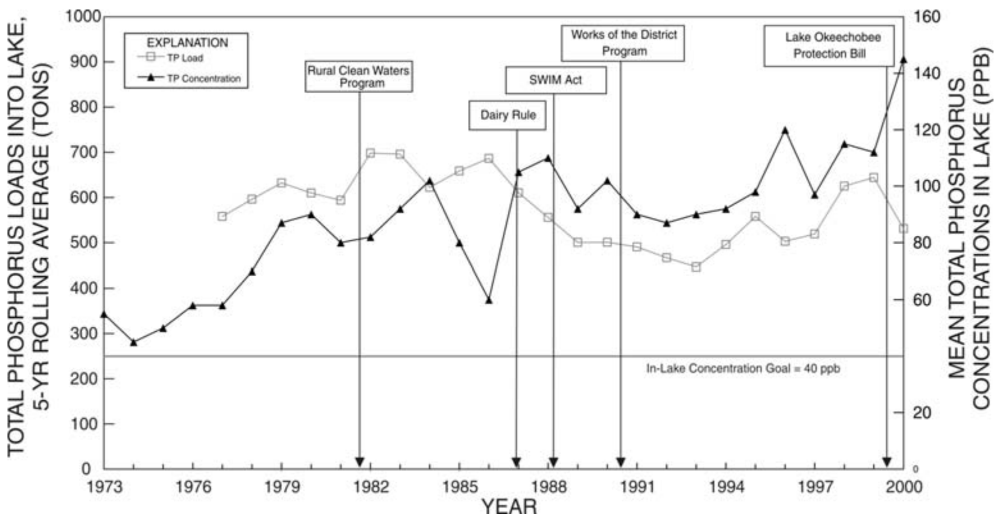

Figure 1. Five-year rolling average loads and annual mean concentrations of phosphorus in Lake Okeechobee. *Source: Surface Water Improvement and Management (SWIM) Plan, Update for Lake Okeechobee, SFWMD, 2002.*

In the 1990s, the U.S. Army Corps of Engineers re-evaluated the C&SF project and developed the Comprehensive Everglades Restoration Plan (CERP) for the restoration, protection, and preservation of water resources of central and southern Florida. This plan was signed into law by President Clinton in December 2000. To help fill the gap in Lake Okeechobee restoration and further understand watershed processes, the Lake Okeechobee Watershed Project (LOWP) was developed, incorporating 4 of the 68 major components of CERP. The LOWP has two major objectives; to improve water quality and to attenuate flood flows to Lake Okeechobee. LOWP activities will include the construction of stormwater treatment areas, restoration of wetlands, and dredging of sediment from canals.

As part of the LOWP, the U.S. Geological Survey (USGS) will conduct a 10-year water-quality and streamflow monitoring program at the sub-basin scale in the LOWP area. Previous water-quality monitoring in the watershed has been focused on concentrations, not loads, or has been limited in scale and frequency. The objectives of the monitoring program are to compute loads, examine spatial and temporal trends in loads, and compare pre- and post-restoration activity conditions. The monitoring network will be composed of 16 water-quality and streamflow monitoring sites and 1 streamflow-only monitoring site (fig. 2). Data collection is anticipated to begin in mid-2003. Load monitoring is currently conducted by the SFWMD at inflow points to the lake, and additional monitoring sites will be established at individual stormwater treatment areas and wetlands to evaluate the effectiveness of those restoration activities.

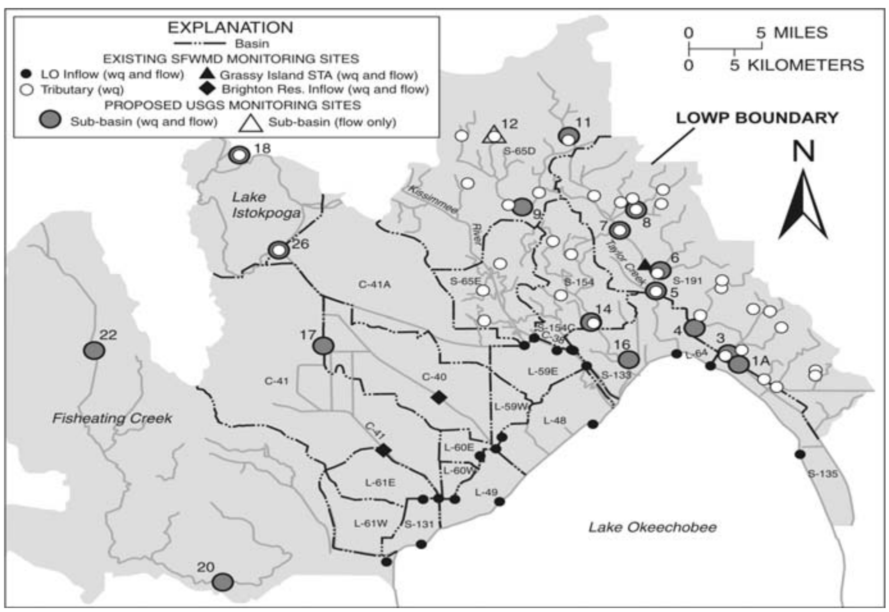

Figure 2. Existing and proposed monitoring sites in the LOWP area.

Two types of water-quality samples will be collected weekly by the USGS; flow-weighted composite samples collected using an autosampler and equal-width-increment samples collected manually. The samples will be analyzed for three forms of phosphorus, three forms of nitrogen, and total suspended solids. In addition, weekly field measurements of water temperature, specific conductance, dissolved-oxygen concentration, and pH will be made. Streamflow will be determined through continuous monitoring of stream stage and index velocity, using hydroacoustic Doppler instruments. This monitoring network poses unique challenges to the collection of high quality data. The LOWP area is a low-gradient watershed that has numerous flow-control structures, and streams are subject to bidirectional flow and backwater conditions.

These challenges present an opportunity to apply and test national data-collection protocols and cutting-edge instrumentation.

The establishment and operation of this monitoring network by the USGS provides a foundation for other research opportunities that are not part of CERP, thus adding value to the network. Integrated, multidisciplinary research will be possible, such as the co-location of biological research sites with water-quality monitoring sites and the subsequent sharing of data and observations. Additional water-quality parameters may be added relatively inexpensively because the primary cost of data collection is already covered within the monitoring network, thus leading to additional scientific research that may improve the understanding of the complex south Florida ecosystem and the effects of the Everglades restoration.

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A Tool for Measuring Landscape Changes (Ridge and Slough) in the Everglades

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Ridge & Slough reflects the Everglades landscape's corrugated microtopography, created by a linear, directional mosaic of aquatic sloughs (relatively low in topographic setting) with alternating elevated ridges. This mosaic is characterized by long, narrow, and parallel orientation of ridges and sloughs. Ridges are composed of sawgrass (*Cladium jamaincensis*) and elongated tree islands. The sloughs represent deeper water areas with sparse emergent vegetation, which would have lower hydraulic resistance. Thus instead of occurring as sheet flow over the entire land surface, water movement in the Ridge and Slough landscape occurred primarily through a network of parallel, partially interconnected open-channel flow paths, in which the term "sloughflow" maybe more appropriate for this largest landscape of the pre-drainage Everglades.

In the last century, water regulation practices have changed the historical hydrological regimes of the Everglades. Changes in water and sediment flows due to hydrological structures and water management have been identified as a possible critical factor responsible for alterations in the landscape patterns of ridge and slough in the Everglades. The goals of this research were to:

(1) Identify the critical parameters that can describe the changing patterns of the landscape;

(2) Classify landscape patterns that are similar to the "natural pattern";

(3) Recognize the threshold(s) that cause(s) the deteriorating landscape patterns.

Landsat TM imagery collected in 1993-4 was used to create base maps of recent ridge & slough patterns in the Everglades. Eighteen 4x6 km quads in ridge & slough areas from northern (Water Conservation Area-1, 2, & 3) and southern (Everglades National Park) Everglades was constructed with a resolution of 10 meters. Lacunarity index (LI) was used to delineate the landscape patterns. The LI of "natural patterns" ranged from 1.75 to 4.45. The LI of "deteriorating patterns" fell either below 1.75 or above 4.45, which can be recognized as the thresholds. Changing patterns might also be described by:

(1) Average length (m) of uninterrupted straight slough cross from north to south;

(2) Average width (m) of uninterrupted straight slough cross from west to east;

(3) Percentage of ridge area in the landscape;

(4) Average length-width ratio of ridge patches.

Results of comparing the patterns suggest that:

(1) There currently exists a wide range/variety of ridge & slough patterns in the Everglades, which can be identified using Lacunarity index and other metrics. These metrics could be used to determine a threshold where a catastrophic shift in the system maybe occurring.

(2) The "natural pattern" was created, maintained and balanced by historical flows through the system; the "deteriorating pattern" could be the result of hydrological

alteration; and the "damaged pattern" represents an altered landscape that has lost its ridge & slough patterns.

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Influence of Eddies on the Transport of Pre-Settlement Stages into Florida Bay

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In the South Florida aquatic ecosystem, keystone species such as snappers (*Lutjanus* spp.), the spiny lobster (*Panulirus argus*), and the pink shrimp (*Farfantespenaeus duorarum*) use the shallow, estuarine Florida Bay for a juvenile nursery, whereas a principal spawning ground for these species lies in the Dry Tortugas some 150 km upstream of the Bay. In such cases where spawning and juvenile habitats are spatially disjoint, larval transport/migration processes are important to successful recruitment.

Mesoscale eddies along the Loop Current-Florida Current front from the eastern Gulf of Mexico to the Straits of Florida may play a significant role in these processes. Eddies are often associated with larval transport and nutrient enhancement in the coastal marine ecosystem. A semi-permanent cyclonic eddy frequently resides at the Dry Tortugas for periods of 1-3 months. Its evolution is modulated by the flow configuration and frontal dynamics of the Loop Current upstream in the Gulf of Mexico. Eventually, the Tortugas eddy moves eastward from the Dry Tortugas, propagating downstream in the form of a transient eddy towards the Florida Keys Coastal Zone. The eddy diminishes in dimensions with progress and ultimately disintegrates. The evolution of the Tortugas eddy provides a mechanism for the retention and nourishment of early life stages spawned near the Dry Tortugas. The subsequent progress of the eddy downstream may aid the transport of pre-settlement stages onshore and through the inter-island channels of the Keys into Florida Bay. The association of eddy formation with the major boundary current, the Loop Current, in the Intra-Americas Seas also implies possible connections to Caribbean sources of recruits further upstream.

To investigate the influence of eddies on the supply of pre-settlement stages to Florida Bay, we first attempted to capture and study an eddy event in the coastal Florida Keys. We followed the evolution of the Tortugas eddy using satellite sea surface temperature (SST) and sea surface height (SSH) imagery in combination with the Navy Layered Ocean Model (NLOM) to anticipate the passage of a coastal eddy offshore of the middle Florida Keys. An Ocean Surface Current Radar (OSCR) array was set up to record in real time the alongshore current reversal and enhanced onshore flow that would be brought on by the leading edge of the eddy as it passes. At the same time, channel nets were deployed inshore of the OSCR domain at channels (Moser, Long Key, and Whale Harbor) connecting coastal waters with Florida Bay to monitor the onshore transport of pre-settlement stages (Figure 1).

Predicting the timing of an eddy event in the prescribed study area (Figure 1) was the most difficult and crucial part of the experiment. Regional oceanographic conditions were continuously monitored beginning in the summer of 2000. Both satellite imagery and NLOM showed clearly the cold-core signature of a cyclonic eddy situated east of the Dry Tortugas on

May 12, 2002 (Figure 1). The main eddy experiment thus proceeded between May 20 - June 23, 2002.

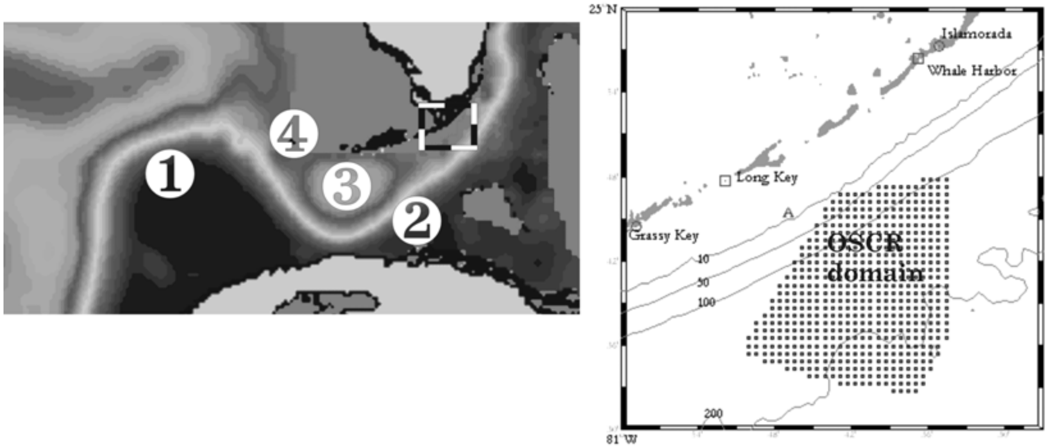

Figure 1. Regional SSH image generated by the NLOM on May 12, 2002, rendered in grayscale (left). Lighter tones depict colder water. 1 - Loop Current; 2 - Florida Current; 3 - Tortugas eddy; 4 – Dry Tortugas. The rectangle encloses the study area of the eddy experiment in June 2002 (enlarged at right). Channel nets were moored at Long Key and Whale Harbor, and the OSCR domain was situated offshore between the two channels (right).

The OSCR between Whale Harbor and Grassy Key recorded dominant Florida Current flow in the domain in the first half of June. Simulated drifter trajectories released in the flow field during this period tend to exit alongshore and downstream. Reversed flows and onshore convergence that could have signified the presence of an eddy started to appear in the domain in late June. In this period, simulated drifters tend to move onshore.

We had expected to find a correlation between the influx of early life stages through the channels with current reversal and onshore flow. The channel net sampling period, however, may have ended just before the peak of the onshore/countercurrent event. On initial examination of the channel net samples, there was no conclusive evidence to support the eddy transport hypothesis, except perhaps in the case of the pink shrimp. High density influx of spiny lobster and total fish larvae captured at Long Key channel between June 12-23, 2002 appeared to coincide with the first quarter of the moon phase rather than with the reversal of coastal currents. The preliminary results suggest that the influence of the eddy process on transport and recruitment is species-specific, confounded by behavior, particularly the timing of spawning and the swimming ability and orientation of the early stages.

To fully understand the implications of the eddy process to the South Florida ecosystem, it is necessary to cover the process over its entire spatial-temporal range. Particularly important is the Dry Tortugas region where the Tortugas eddy influences a rich ecological reserve and spawning ground. Synoptic oceanographic surveys that can capture large-scale physical and biological patterns over a relatively short time will be conducted in this next phase of the eddy investigation. The first survey occurred in August 2002. The survey area, which extended from the lower Keys and the Dry Tortugas to southeastern Gulf of Mexico, was defined according to the location of eddy features as shown by real-time oceanographic data. The main goal was to look into what is being entrained and transported by the eddy in the upstream region. Future surveys are planned.

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Vegetation Community Changes along the Loxahatchee River in Southeastern Florida: Examination along a Salinity Gradient

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The Loxahatchee River Watershed, located in northeastern Palm Beach County was historically connected as part of the Greater Everglades Watershed. Subsequent construction of canals and highways created hydrologic barriers between the Loxahatchee River headwaters and the Everglades Water Conservation Areas. Restoration efforts are presently looking at options that will reestablish hydrologic connections across these barriers to provide means to transfer water from Lake Okeechobee to the Loxahatchee River. In recognition of the historical connection of the Loxahatchee River drainage to the Everglades, the boundaries of the North Palm Beach Comprehensive Everglades Restoration Project have recently been extended to include this critical watershed as part of the greater Everglades restoration effort.

The Loxahatchee River is located in southeastern Florida and flows into the Atlantic Ocean through the Jupiter Inlet (Figure 1). The Loxahatchee is regarded as the last free flowing river in southeast Florida and 7.5 miles of the Northwest Fork were designated as Florida's first Wild and Scenic River in 1985. In addition, different portions of the river and estuary are also designated as an Aquatic Preserve, Outstanding Florida Waters, and a state park. Downstream segments of the Northwest Fork floodplain contain a dense red mangrove forest, while the upper segment contains one of the last vestiges of native cypress river-swamp within southeast Florida. Over the past century, downstream floodplain wetlands that were once dominated by swamp hardwoods and bald cypress have changed to mangrove-dominated swamp. This change in vegetation is believed to have occurred because of salinity intrusion into freshwater areas of the river, caused primarily by alteration of the watershed and river by human activities.

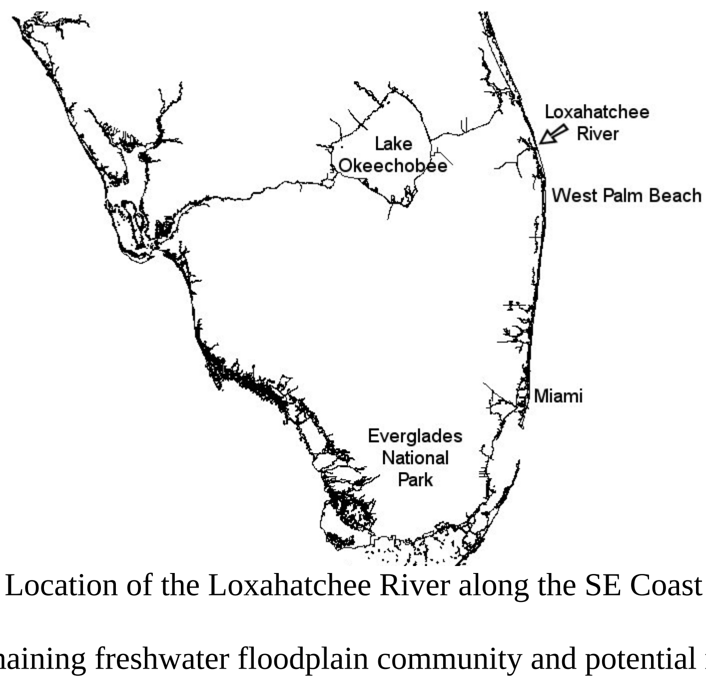

Figure 1. Location of the Loxahatchee River along the SE Coast of Florida.

Protection of the remaining freshwater floodplain community and potential restoration efforts require that sufficient freshwater conditions be provided. In order to understand the impact of salinity on the distribution of freshwater floodplain swamp vegetation, a relationship between salinity conditions (magnitude, duration and frequency of exposure) and distribution of "indicator species" was examined. The current distribution of floodplain vegetation was assessed by conducting field surveys along the Northwest Fork from 2000-2002 (see Figure 2 for location of survey sites) and long-term salinity conditions for some of these survey sites were calculated using a salinity model and field data.

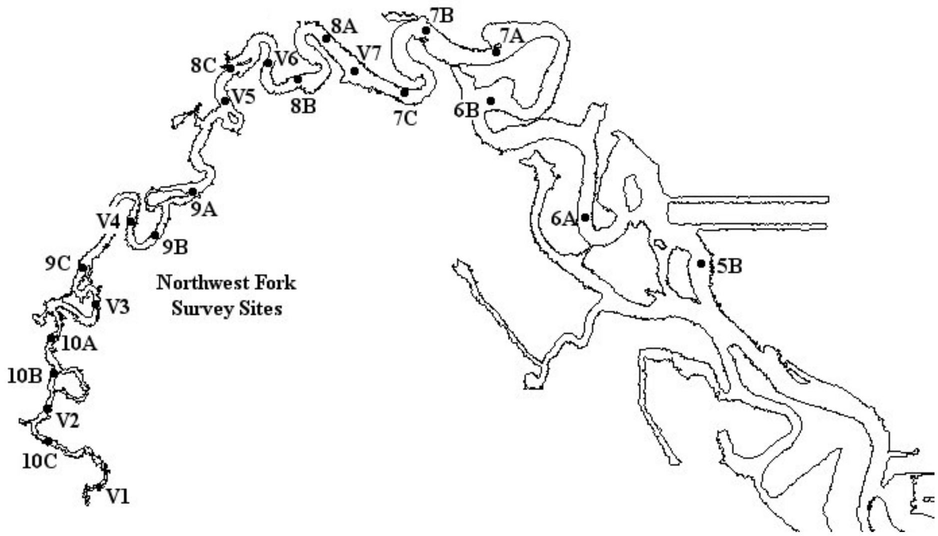

Figure 2. Location of Vegetation Survey Sites along the Northwest Fork of the Loxahatchee River

Field vegetation surveys included both semi-quantitative and quantitative methods to characterize plant community composition and number of species, as well as the height, stem diameter, and canopy diameter for dominant canopy species. A recording of the number of adults, stump sprouts, saplings and seedlings provided a measure of the reproductive success of key species at each site. The results of these surveys were highly correlated to distance from the Jupiter Inlet, the primary source of salinity in the Northwest Fork. Examination of these trends was useful as a means to describe relative salinity tolerances among a wide range of species in the absence of such information in the scientific literature. These data were also used to determine the point where the freshwater floodplain swamp was impaired (i.e. reproduction absent or reduced, canopy area reduced, etc.) and which species may be good indicators of salinity stress.

Long-term salinity sampling data were not available for all vegetation sites surveyed. In order to estimate a long-term salinity time series, a hydrodynamic/salinity model (utilizing RMA-2 and RMA-4 programs, and flow-salinity relationships for the Northwest Fork) was used to simulate salinity conditions at several upstream river sites for a 30-year period of record using existing measured flow data. Continuously sampled field data (1997-2000) from several of the vegetation survey sites were used to calibrate and verify the model. Model output was also compared to previous field data and regression models of studies developed for the Northwest Fork. Output from the model was used to calculate a unique value, *Ds/Db*, for each vegetation monitoring site. The *Ds/Db* value is obtained by dividing the duration of a salinity event (*Ds*) by the time duration between salinity events (*Db*) at a site, using a threshold value to define a salinity event. The *Ds/Db* value allowed three discrete salinity factors relative to salinity exposure (magnitude, duration, and frequency of salinity exposure) to be represented by a single value.

Use of this method allowed the determination of relative tolerance of different freshwater swamp species to salinity exposure and provided a tool to correlate salinity exposure to floodplain swamp species composition. Application of this method may be useful in other freshwater-saltwater transitional areas that are currently being considered for restoration or enhancement where little salinity tolerance data for species of interest is available.

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Body Condition Analysis for the American Alligator for Use in Everglades Restoration

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The American alligator (*Alligator mississippiensis*) is an integral part of the Everglades ecosystem. They effect and are affected by the landscape and changes in hydrology, which makes them an excellent organism to use in evaluating current Everglades restoration efforts. Information on alligators (census data, capture or morphometric data, blood chemistry, and reproduction statistics) has been collected in the Everglades since the 1950's. Available historical information includes a suite of life history characteristics and population parameters (health and condition, nesting effort, growth rate and survival, and density) that are useful for evaluating restoration. However, some life history traits (e.g. absolute density and survival) are difficult to accurately measure and can require decades of data to detect trends. In contrast, body condition can be measured using indices and requires less data to begin an analysis. If used properly, condition can be a useful monitoring tool to assess the health of a population and thus the health of its ecosystem. This project evaluated morphometric measurements taken for the American alligator, available condition indices and, using a stepwise process, recommends an appropriate index for use in ecological applications such as Everglades restoration.

Condition indices have been used to analyze the fitness of animal populations for the last 50 years. However, the indices are complex and can be used inappropriately if one is unfamiliar with the constraints. For example, condition for crocodilians has been calculated numerous times using Relative K, developed for fisheries in 1951 (LeCren 1951). Relative K is useful for comparing the condition of a population over time, but not appropriate among populations.

Alligators were captured during March, April and October from 1999 to 2002 by a multi-agency team that consisted of members from U.S. Fish and Wildlife Service, U.S. Geological Survey, University of Florida, and the Florida Fish and Wildlife Conservation Commission. Study areas were A.R.M. Loxahatchee NWR (LNWR, 1 site), Water Conservation Areas 2 (WCA2, 1 site) and 3A (WCA3A, 2 sites), and Everglades National Park (ENP, 2 sites: ENP-SS Shark River Slough, ENP-EST Estuaries). Animals were captured from all study areas in marsh habitats only.

We analyzed morphometric measurements of the captured animals to determine which are measured most accurately and are appropriate for condition analyses. Condition indices are functions of a body length indicator and a volumetric measurement, and are only as accurate as the measurement used. Head length (HL), snout-vent length (SVL) and total length (TL) are suitable for body length indicators and tail girth (TG), neck girth (NG), chest girth (CG), and mass can all be used as volumetric measurements. We then compared four condition indices and two models of volume/length relationships for their ability to distinguish between populations with known qualitative condition differences. Condition indices were Fulton's K, Relative K, a simple length/volume ratio, and relative mass. We also modeled volume/length with a residual index and ANCOVA.

It was determined through ANOVA/LSD analysis of the condition indices that the HL/Mass combination of Fulton's K and the SVL/Mass combination of ANCOVA were best able to distinguish differences in condition between areas of the Everglades. However, ANCOVA cannot be used to compare differences across populations, unless strict assumptions can be met. HL/Mass Fulton's K can be used to spatially and temporally compare populations of the American alligator, and is suggested by this study as the best condition factor to use for that purpose.

Condition is a very fluid measurement. Water management practices and rainfall can dramatically change condition of animals in a relatively short amount of time, because so many aspects of their life history (feeding, courtship, and nesting) depend on seasonally fluctuating water levels. In this study, we found that ENP-SS alligators had the highest condition (fig. 1), but Dalrymple (1996) and Barr (1997) observed Shark Slough alligators to be in very poor condition only five or six years earlier. Water levels were high during capture periods for these studies, possibly affecting food availability.

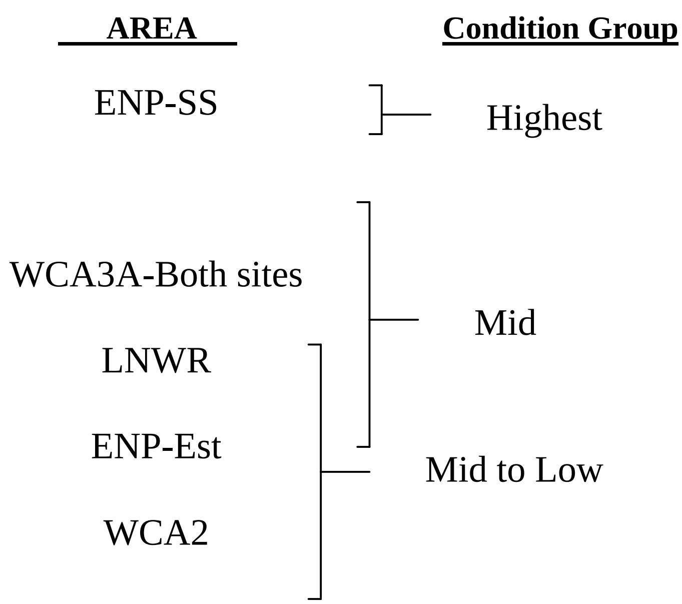

Figure 1. Hierarchy of body condition of alligators in several study sites in the Everglades of South Florida from 1999-2002 using a Fulton's K analysis (n = 395). Brackets indicate condition does not differ significantly within that group.

Since the alligator's life history is so closely linked to hydropattern, body condition can reflect the impacts of changes in hydrology. The condition indicies recommended here should provide a monitoring tool of alligator population health for the current restoration process.

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