Greater Everglades Ecosystem Restoration (G.E.E.R.) Science Conference

Defining Success

Naples Beach Hotel & Golf Club
Naples, Florida

December 11-15, 2000

Hosted by:
The Science Coordination Team
a Committee of the
South Florida Ecosystem Restoration
Task Force and Working Group

SOUTH FLORIDA ECOSYSTEM RESTORATION
TASK FORCE / WORKING GROUP

SCIENCE COORDINATION TEAM

Welcome to the GEER 2000 Science Conference!

Let us hope this will be the first of many Greater Everglades Ecosystem Restoration science conferences. As many of you know, this is actually the second Everglades science conference, with the first one being held over a decade ago. The scientists and other participants in the first conference helped build the foundation upon which the Greater Everglades will be restored. *A decade later, we bring to you the* ***Greater Everglades Ecosystem Restoration Science Conference*** **–** an opportunity for scientists to interact and share our wealth of information with others on the greater Everglades ecosystem.

Much progress was made during the past decade, culminating in commitments by the State of Florida and the Federal Government to undertake the world's largest and most ambitious ecosystem restoration program **–** ***the Comprehensive Everglades Restoration Plan.***

Indeed, this has been a banner year for the greater Everglades. Yet most of our work lies ahead, hence the theme for this first GEER Science Conference **–** ***Defining Success.*** 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 *defining success* 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?

We look forward to the next few days of interaction and presentations and to *Defining Success* for the future of Everglades restoration. You have my

Best Wishes,

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

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GEER Science Conference Program Committee

Steering Committee:

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

Robert Johnson, National Park Service, Everglades National Park

Frank Mazzotti, Ph.D., University of Florida/IFAS, Center for Natural Resources — South Florida

John C. Ogden, SCT Co-Chair, South Florida Water Management District

K. Ramesh Reddy, Ph.D., Soil and Water Science Department, University of Florida/IFAS

Hanley (Bo) K. Smith, Ph.D., U.S. Army Corps of Engineers

- *Also includes the Topic Chairs noted below with asterisks* (*)

Topic Chairs and Co-Chairs:

Ecology & Ecological Modeling

**Donald L. DeAngelis*, Ph.D., Topic Chair, U.S. Geological Survey

Thomas Armentano, Ph.D., National Park Service, Everglades National Park

Susan Gray, Ph.D., South Florida Water Management District

Hydrology & Hydrological Modeling

**Aaron Higer*, Topic Chair, U.S. Geological Survey

Jayantha (Obey) Obeysekera, Ph.D., South Florida Water Management District

Thomas Van Lent, Ph.D., National Park Service, Everglades National Park

Information Systems

**Gail Clement*, Topic Chair, Florida International University

David Buker, National Park Service, Everglades National Park

Roy Sonenshein, U.S. Geological Survey

Social & Human Sciences

**Bonnie Kranzer*, Ph.D., AICP, Topic Chair, Exec. Director, Governor's Commission for the Everglades

Mahadev Bhat, Ph.D., Florida International University

Water Quality & Water Treatment Technologies

**Nicholas G. Aumen*, Ph.D., Topic Chair, National Park Service, Everglades National Park

Thomas D. Fontaine, Ph.D., South Florida Water Management District

Jennifer Jorge, Ph.D., South Florida Water Management District

Conference Organizers:

Conference Chair: *G. Ronnie Best*, Ph.D., PWS, U.S. Geological Survey

Conference Coordinator: *Beth Miller-Tipton*, UF/IFAS Office of Conferences and Institutes

Conference Facilitator: *John C. Curnutt*, Ph.D., U.S. Geological Survey

Conference Dedication to Aaron Higer

The year 2000 Greater Everglades Ecosystem Restoration Science Conference is dedicated to Aaron Higer, member of the Working Group and Science Coordination Team of the South Florida Ecosystem Restoration Task Force. It is fitting that the first GEER conference should be dedicated to Aaron who has worked for the benefit of the Everglades ecosystem for over 40 years in capacities ranging from field researcher collecting fish samples for pesticide analysis, to his current position as Working Group and Science Coordination Team member, and U.S. Geological Survey South Florida Ecosystem Coordinator.

Airborne Aaron, 1961

After graduating from the University of Miami with a Bachelors Degree in Industrial Engineering in 1959, Aaron started working for the USGS in Miami, Florida, on a student appointment while studying Oceanography at the prestigious Rosenstiel School of Marine and Atmospheric Sciences. During the early sixties Aaron worked on a study to determine pesticide residues in fish, animal and plant tissue collected in Everglades National Park. This effort led to his interest in applying aerial photography and remote sensing techniques to hydrobiological research which he, with other researchers, did successfully in Everglades National Park, Biscayne Bay, Tampa Bay, Appalachia and the West Indies. Aaron, working with Milt Kolipinski, pioneered the use of multispectral data collection and processing techniques in delineating hydrologic and hydrobiologic features. In the seventies Aaron was a member of NASA's Working Group on Hydrology at the Goddard Space Flight Center, served as a consultant to the United Nation's AID Program on remote sensing for Jamaica, was the coordinator for both program development for the Earth Science Office at the Kennedy Space Center and the EROS School on Remote Sensing, and was a representative to the First Symposium on Remote Sensing for the Pan American Nations in Panama City, Panama. He was the Federal representative on the State of Florida Carrying Capacity Committee and a Task Force member on the President's Committee for Environmental Quality, Cross Florida Barge Canal.

Field work in the Everglades, 1967

By the eighties Aaron was a recognized expert on south Florida hydrology, consulting with the National Geographic Society for their Atlas on North America, serving on the U.S. Justice Department's Remedy Committee for the Everglades, chairing the USGS National Water-Use

Committee and serving on the Dade County Technical Committee for the location of new well fields. Aaron was also the Chairman of a workshop on Meteorology, Hydrology and Water Management held as part of a US-India Symposium in Ahmeabad, India and took part in the Symposium on the Ecology and Conservation of the Usumacinta-Grijaula Delta in Tabasco, Mexico.

In 1992 Aaron transferred to West Palm Beach, Florida, to serve as the USGS liaison with the South Florida Water Management District and other agencies co-located in their District Headquarters. This transfer represented a great personal sacrifice for Aaron and his family who were in the process of rebuilding a home devastated by Hurricane Andrew. Four years later, Aaron was tapped to serve as a member of the Working Group of the South Florida Ecosystem Restoration Task Force and as the Coordinator of the USGS South Florida Ecosystem Program. As Co-chair of the Working Group's Science Sub-Group and as the official spokesman for U.S. Geological Survey programs in south Florida, he significantly contributed to delineating the scientific needs for ecosystem restoration decision-making in south Florida. He then developed the most comprehensive integrated-science program within the U.S. Geological Survey that includes about 70 projects; all major agency scientific disciplines; and hundreds of partners from other agencies, academia, and private companies. Results from this ongoing program provide crucial scientific information on which to base ecosystem restoration decisions in south Florida and in other similar areas of the country and the world. Aaron also recognized that results of science programs of the U.S. Geological Survey and other agencies would be of most value to resource managers and others if presented and disseminated in useful formats. To this end, he has personally directed this aspect of the south Florida program to provide easy access to all scientific information through the Internet. Aaron is frequently called upon to brief the Department of Interior's Assistant Secretary for Science, State and Federal Legislators, and White House representatives.

Miami Subdistrict Luncheon, 1997

He also sits on the USGS's National Ecosystem Council and advises the other ecosystem programs on what works successfully and what has been tried and not worked as well. In recognition of his many outstanding contributions to the programs of the USGS, Aaron was presented with the U.S. Department of Interior's Meritorious service Award in 1993, and the Distinguished Service Award in 2000.

The multi-discipline and multi-agency approach to understanding the functioning of the Everglades ecosystem that has characterized much of the work of the South Florida Ecosystem Interagency Task Force can, in no small measure, be attributed to Aaron's view of the role of science in the service of public policy. Although his accomplishments are numerous and varied, Aaron may be most appreciated by his associates for his legendary vision and by his friends and coworkers for his selflessness and his willingness to mentor and advise. For these reasons and for his life-long efforts on behalf of the Everglades ecosystem and south Florida, this GEER conference is dedicated to Aaron Higer. All of us involved in greater Everglades restoration extend to Aaron and Francine our best wishes during retirement.

Aaron and his number one supporter,
Francine Higer

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

Broward County Department of Environmental Protection
City of Coral Gables
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 Commission for the Everglades
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
Southeast Environmental Research Center
South Florida Water Management District
Southwest Florida Regional Planning Council
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. 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

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. In 1989, the Everglades Restoration Conference succeeded in combining what was known concerning the ecology of the Everglades ecosystem and what was needed for restoration. Since that first conference, there have been a number of advances in our understanding of the ecology and history of the Everglades. 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.

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 first Everglades 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. Plenary sessions include main themes addressed by invited speakers. 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. The Friday closing sessions will focus on defining the critical science, technology and information needs for *Measuring Success* (the planning theme for the GEER 2002 Science Conference).

In the Closing Concurrent Session – *Setting the GEER in Motion* – all five (5) Topic groups will meet independently and *define the critical immediate [2-year] and near term [5-year] science and technology needs for implementing greater Everglades ecosystem restoration.* Then in the Closing Plenary Session – *Critical Needs for Measuring Success* – Part I, the topic chairs will present an overview of recommendations and lead an audience discussion on future directions for each topic. In the Closing Plenary Session – Part II, the conference Steering Committee will serve as a panel to lead discussions on the *Greater Everglades Ecosystem Conceptual Model.*

Restatement of Questions

This has been a banner year for the greater Everglades. Yet most of our work lies ahead, and hence the theme for this first GEER Science Conference – ***Defining Success.*** 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.

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- 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 divided by topic groups – Ecology and Ecological Modeling, Hydrology & Hydrological Modeling, Information Systems, Social & Human Sciences and Water Quality & Water Treatment Technologies.

Within each topic, oral abstracts are followed by poster abstracts. All abstracts, both Oral and Poster, are listed in alphabetical order by the presenting author's last name, which appears in bold.

An author index appears at the back of this book to assist you with finding a particular author's work.

A hotel meeting room diagram is located on the inside back cover, indicating where individual concurrent sessions will be held.

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

For more information about G.E.E.R., contact the Conference Chair:
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Restoration Ecology Branch
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Miami, FL 33199
PHONE: 305-348-3965
CELL: 305-903-5743
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.

Additionally, a Closing Plenary Session and Topical Synthesis will be held Friday morning. A panel discussion will summarize findings and identify future imperatives.

Poster Session Information

Poster Session I

Poster Participants: All *Ecology and Ecological Modeling* abstract submissions.

Set-Up Time: Set up time is 11:00am - 1:00pm on Monday, Dec. 11 in the Mangrove Ballroom located on Level One. *Posters must be set up by 1:00pm.*

Display Time: Displays will be up from 1:00pm on Monday, Dec. 11 through 10:00am on Wednesday, Dec. 13 in the Mangrove Ballroom.

Formal Poster Session: Poster presenters must be stationed at their posters during Formal Poster Session I, Tuesday evening, Dec.12 from 5pm-7pm in the Mangrove Ballroom.

Removal Time: Removal of displays will be held between 10:00am and 10:30am on Wednesday, Dec. 13. Posters MUST be removed by 10:30am to allow presenters in POSTER SESSION II to set up their displays.

Poster Session II

Poster Participants: All abstract submissions in the following categories: *Hydrology & Hydrological Modeling, Information Systems, Social & Human Sciences* and *Water Quality & Water Treatment Technologies*.

Set-Up Time: Set up time is 11:00am - 1:00pm on Wednesday, Dec. 13 in the Mangrove Ballroom located on Level One. *Posters must be set up by 1:00pm.*

Display Time: Displays will be up from 1:00pm on Wednesday, Dec. 13 through 8:00pm on Thursday, Dec. 14 in the Mangrove Ballroom.

Formal Poster Session: Poster presenters must be stationed at their posters during Formal Poster Session II scheduled Thursday evening, Dec. 14 from 5pm-7pm in the Mangrove Ballroom.

Removal Time: Removal of displays is between 8:00pm and 10:00pm on Thursday, Dec.14. Poster Session II displays MUST be dismantled by 10:30pm, as the exhibit services company will remove the poster boards at that time.

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
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://orcddwimdn.er.usgs.gov/public/plsql/mercury.proj_data?current_proj_name=GLADES

South Florida Ecosystem History Database
USGS National Center
http://flaecohist.er.usgs.gov/database/

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://library.fgcu.edu/big_cypress/

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 the south Florida
http://www.evergladesvillage.org/

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/cgi-bin/caloosa.taf?function=form

This list was prepared for the GEER Science Conference by the Chairperson, Information Systems Session. **Please note that listed web addresses are subject to change without notice.**

Conference Program Agenda

Monday, December 11, 2000

11:00am – 5:00pm	Registration Open - ***The Orchid Atrium (Level One)***
11:00am – 1:00pm	Poster Presenters to set up displays for Poster Session I - ***Mangrove Ballroom (Level One)***

Plenary Session: Defining Success

River of Grass Ballroom – Salons D, G & H (Level One)
***Session Moderator:* G. Ronnie Best**, *PWS, Conference Chair, U.S. Geological Survey*

1:00pm – 1:15pm	**Opening Comments: Setting the Stage for *Defining Success* — *G. Ronnie Best***, *PWS,* Co-Chair, Science Coordination Team, U.S. Geological Survey
1:15pm – 2:00pm	**Good Science: Essential Ingredient for Restoration Success — *Charles (Chip) G. Groat***, Director, U.S. Geological Survey and Denise J. Reed, University of New Orleans **(p. 91)**
2:00pm – 2:45pm	**The Use of a Total System Conceptual Ecological Model for Setting System-wide Performance Measures for the Greater Everglades Restoration Plan — *John C. Ogden***, South Florida Water Management District; *Nicholas G. Aumen*, National Park Service; *G. Ronnie Best* and *Donald L. DeAngelis*, U.S. Geological Survey; *Frank Mazzotti*, University of Florida/IFAS, Center for Natural Resources – South Florida **(p. 133)**
2:45pm – 3:00pm	**Special Dedication to Aaron Higer**
3:00pm – 3:15pm	Refreshment Break - ***Orchid Atrium & Solarium South***
3:15pm – 4:00pm	**Case Study – Water Quality Issues in the Greater Everglades: Setting the Stage for Integrated Science — *Nicholas G. Aumen***, National Park Service, Everglades National Park; *Richard Harvey*, U.S. Environmental Protection Agency; *Thomas D. Fontaine*, South Florida Water Management District; *Melissa Meeker*, Florida Department of Environmental Protection
4:00pm – 4:45pm	**Case Study – Measuring Success: The Chesapeake Bay Experience — *William Matuszeski***, Director, Chesapeake Bay Program Office, U.S. Environmental Protection Agency
4:45pm – 5:30pm	**Case Study – Restoration Evaluation With Specific Expectations: The Kissimmee River — *David H. Anderson***, Center for Environmental Studies; *Louis A. Toth*, South Florida Water Management District
6:00pm – 8:00pm	Welcome Reception - *Watkins Lawn*

Tuesday, December 12, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session I: Ecology and Ecological Modeling - AM
River of Grass Ballroom – Salons D, G & H (Level One)

Conceptual Models and Everglades Restoration – Part I
***Session Moderator: John C. Ogden**, South Florida Water Management District*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**An Overview of the Historical Everglades Ecosystem and Implications for Establishing Restoration Goals — *Sujoy Roy*** and *Steven A. Gherini*, Tetra Tech Inc. **(p. 151)**
8:45am – 9:15am	**Restoration of Lake Okeechobee: Fixing the Headwaters of the Everglades — *Alan Steinman***, South Florida Water Management District **(p. 162)**
9:15am – 9:45am	**The Caloosahatchee Estuary Conceptual Model — *Tomma Barnes***, South Florida Water Management District **(p. 54)**
9:45am – 10:15am	**Conceptual Model Development-Uncertainty Identification and Research Prioritization for the Comprehensive Everglades Restoration Plan — *Steve Davis***, South Florida Water Management District **(p. 76)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
10:30am – 11:00am	**Multiple Approaches for Evaluating Hydrology and Vegetation Monitoring Data to Demonstrate Wetland Restoration Success at the Disney Wilderness Preserve — *Michael Duever***, South Florida Water Management District; *Jean McCollom*, The Nature Conservancy **(p. 82)**
11:00am – 11:30am	**The Next 100 Years of Evolution of the Greater Everglades Ecosystem in Response to Anticipated Sea Level Rise: Nature, Extent and Causes — *Harold R. Wanless***, *Peter Oleck*, University of Miami and *Lenore P. Tedesco, Bob E. Hall*, Indiana University/Purdue University at Indianapolis **(p. 174)**
11:30am – 1:00pm	Lunch on Own

Tuesday, December 12, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session II: Ecology & Ecological Modeling – AM
River of Grass Ballroom – Salons F & I (Level One)

Hydrologic Effects on Tree Islands
Session Moderator: John C. Volin*, Florida Atlantic University*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Hydrologic and Topographic Gradient Effects on Woody Vegetation of Tree Islands in the Everglades Wildlife Management Area — *Michael Anderson***, Florida Atlantic University, Division of Biological Science **(p. 53)**
8:45am – 9:15am	**Investigating the Response of Tree Island Function to Increased Water Flow in a Southern Everglades Ecosystem — *Tiffany Gann***, Florida International University **(p. 90)**
9:15am – 9:45am	**Predicting the Response of Everglades Tree Islands to Changes in Water Management — *Lorraine Heisler***, US Fish and Wildlife Service-A.R.M. Loxahatchee National Wildlife Refuge **(p. 100)**
9:45am – 10:15am	**Tree Island Studies at the Arthur R. Marshall Loxahatchee National Wildlife Refuge — *Laura A. Brandt***, U.S. Fish and Wildlife Service - A.R.M. Loxahatchee National Wildlife Refuge **(p. 55)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
10:30am – 11:00am	**Spatial Differences of Litter Fall and Basal Area of Tree Island Species in Water Conservation Area 3 in the Central Everglades — *Michael S. Korvela***, *Fred H. Sklar*, *Carlos Coronado* and *Megan Jacoby*, South Florida Water Management District **(p. 115)**
11:00am – 11:30am	**Trends In Tree-Island Development In The Florida Everglades — *Debra Willard***, U.S. Geological Survey **(p. 275)**
11:30am – 1:00pm	Lunch on Own

Tuesday, December 12, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session III: Ecology & Ecological Modeling – AM
Immokalee Room (Level Three)

Estuaries and Adjacent Coastal Systems
Session Moderator**:** ***Thomas J. Smith III***, *U.S. Geological Survey*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**The Effect of Enhanced Freshwater Inflow on Sedimentation and Elevation Change in Mangrove Forests of Southwestern Florida —** ***Donald Cahoon***, U. S. Geological Survey National Wetlands Research Center **(p. 65)**
8:45am – 9:15am	**Mangrove Prop-Root Fish Assemblages As Indicators Of Salinity Change —** ***George Dennis***, U. S. Geological Survey, Biological Resources Division, Florida Caribbean Science Center **(p. 79)**
9:15am – 9:45am	**Patterns in the Distribution and Abundance of Mangrove-Associated Fishes and Crustaceans along a Salinity Gradient in Shark River Everglades National Park —** ***Carole McIvor***,U. S. Geological Survey, Biological Resources Division, Florida Caribbean Science Center **(p. 123)**
9:45am – 10:15am	**Predicting Salinity In Florida Bay —** ***Bruce Wardlaw***, U. S. Geological Survey **(p. 177)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
10:30am – 11:00am	**Sea-Level Rise And The Future Of Florida Bay In The Next Century —** ***Robert Halley***, U.S. Geological Survey **(p. 94)**
11:00am – 11:30am	**Manatee Aerial Surveys in South Florida —** ***Bruce B. Ackerman*** *and Holly H. Edwards*, Florida Marine Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL **(p. 49)**
11:30am – 1:00pm	Lunch on Own

Tuesday, December 12, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session IV: Water Quality & Water Treatment Technologies – AM
Chokoloskee Room (Level Two)

Water Quality Treatment
Session Moderator*: *Jennifer Jorge, *South Florida Water Management District*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Chemical Treatment: An Advanced Treatment Technology for Everglades Agricultural Area (EAA) Stormwater — *Earl E. Shannon***, *T. C. Emenhiser* and *T. Horan,* HSA Engineers and Scientists; *J. L. Lopez* and *D. Campbell,* South Florida Water Management District **(p. 445)**
8:45am – 9:15am	**Sequenced Vegetation Communities for Optimizing Phosphorus Removal within Stormwater Treatment Areas — *Thomas DeBusk***, Azurea, Inc. and DB Environmental, Inc.; *Forrest Dierberg, John Juston* and *Scott Jackson,* DB Environmental, Inc. **(p. 431)**
9:15am – 9:45am	**Nitrogen Reduction for Periphyton Stormwater Treatment Area (PSTA) Research in the Everglades Nutrient Removal Project Test Cells — *Lori Wenkert***, and *Jana Majer Newman*, South Florida Water Management District; *Ron Clarke* and *Steve Gong,* CH2M HILL **(p. 450)**
9:45am – 10:15am	**The Effects of Flow Rates on Phosphorus Uptake by Periphyton — *Steve Simmons*** and *John Volin,* Florida Atlantic University **(p. 447)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
10:30am – 11:00am	**First Year Total Phosphorus Mass Balance for STA Optimization Research in the Everglades Nutrient Removal Project North Site Test Cells — *Tammy Lynch*** and *Jana Majer Newman,* South Florida Water Management District **(p. 437)**
11:00am – 11:30am	**The Effect of Drawdown and Presence of macrophytes on P Stability in Soils from the Everglades Nutrient Removal Project — *John R. White*** and *K. Ramesh Reddy,* Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida/IFAS **(p. 452)**
11:30am – 1:00pm	Lunch on Own

Tuesday, December 12, 2000

Concurrent Session I: Ecology and Ecological Modeling - PM
River of Grass Ballroom – Salons D, G & H (Level One)

Conceptual Models and Everglades Restoration – Part II
Session Moderator*: *Mike Duever, *South Florida Water Management District*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**Using Adaptive Management to Assess Biotic Response to Environmental Change — *Michael Runge***, U.S. Geological Survey, Patuxent Wildlife Research Center **(p. 154)**
1:45pm – 2:15pm	**Regional Controls of Population and Ecosystem Dynamics in an Oligotrophic Wetland-dominated Coastal Landscape - Introducing a New Long Term Ecological Research (LTER) Project in the Coastal Everglades — *Daniel L. Childers***, Florida International University **(p. 68)**
2:15pm – 2:45pm	**Unexpected Responses in Ecosystem Restoration - A Case Study of Submerged Plants Turbid Water and a Strong Wind Event at Lake Okeechobee Florida — *Karl Havens***,South Florida Water Management District **(p. 98)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**Escherian Features in the South Florida Landscape and Their Implications For Restoration — *Patrick Kangas***, University of Maryland **(p. 110)**
3:30pm – 4:00pm	**The Natural and Changing Role of Fire in South Florida Ecosystems — *Jerome A. Jackson***, Florida Gulf Coast University **(p. 107)**

Population Studies: Invertebrates

4:00pm – 4:30pm	**Life History, Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration — *Noble Hendrix***, School of Aquatic Sciences and Fisheries-University of Washington **(p. 101)**
4:30pm – 5:00pm	**Apple Snail Populations: Persistence in Hydrologically Fluctuating Environments — *Phil Darby***, Biology Department, University of West Florida **(p. 74)**
5:00pm – 7:00pm	Reception and Formal Poster Session I — *Ecology and Ecological Modeling* - ***Mangrove Ballroom (Level One)***

Tuesday, December 12, 2000

Concurrent Session II: Ecology & Ecological Modeling – PM
River of Grass Ballroom – Salons F & I (Level One)

Hydroperiod Effects on Animal and Plant Populations

Session Moderator*: *William Loftus, *U.S. Geological Survey at Everglades National Park*

1:00pm – 1:15pm — Opening Remarks – Session Overview

1:15pm – 1:45pm — **Impact of Hydroperiod on Planktonic Copepod Communities in Everglades National Park: Preliminary Results —** ***M. Cristina Bruno***, South Florida Natural Resources Center - Everglades National Park **(p. 62)**

1:45pm – 2:15pm — **Relationships between Aquatic Diptera Communities and Hydropattern in the Rocky Glades-Everglades National Park —** ***Richard E. Jacobsen***, South Florida Natural Resources Center **(p. 108)**

2:15pm – 2:45pm — **The Role of Seasonal Hydrology in the Dynamics of Fish Communities Inhabiting Karstic Wetlands of the Florida Everglades —** ***Robert Kobza***, Florida International University, Department of Biological Sciences **(p. 113)**

2:45pm – 3:00pm — Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***

3:00pm – 3:30pm — **The Effect of Physical Structures and Hydrologic Cycles on Population Genetic Structure of Gambusia holbrooki in the Florida Everglades —** ***Thomas C. McElroy***, Florida International University **(p. 122)**

3:30pm – 4:00pm — **Encroachment by Cypress into Desiccated Areas with Historical Hydoperiods of Long Inundation and Deep Depths Is Not Reversed by Subsequent Rewatering —** ***John Volin***, Florida Atlantic University, Division of Biological Science **(p. 173)**

4:00pm – 4:30pm — **Land Cover Change Detection in Southwest Florida and Application to the Florida Panther Habitat Model —** ***Randy S. Kautz***, *Beth Stys*, and *Cory Morea*, Florida Fish and Wildlife Conservation Commission **(p. 111)**

4:30pm – 4:45pm — Closing Remarks

5:00pm – 7:00pm — Reception and Formal Poster Session I — *Ecology and Ecological Modeling* - ***Mangrove Ballroom (Level One)***

Tuesday, December 12, 2000

Concurrent Session III: Hydrology & Hydrological Modeling – PM
Immokalee Room (Level Three)

Hydrologic Evaluation of Restoration Plans
Session Moderator**: *Thomas Van Lent***, *National Park Service at Everglades National Park*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**Recipe for Restoration — *Robert Johnson***, Everglades National Park
1:45pm – 2:15pm	**Sensitivity of the Comprehensive Everglades Restoration Plan to Individual Project Components** — *Everett R. Santee*, ***Jenifer Barnes***, *Raul Novoa, Kenneth C. Tarboton, Lehar M. Brion, Alaa Ali, Luis G. Cadavid,* and *Calvin J. Neidrauer,* South Florida Water Management District **(p. 279)**
2:15pm – 2:45pm	**Uncertainty Analysis of Regional Simulation Models — *Wasantha Lal***, *Paul Trimble,* South Florida Water Management District **(p. 293)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**Using a Salinity Model for Biscayne Bay to Assess Salinity Variations Resulting from Alterations in Freshwater Inflows — *John D. Wang*** and *Jiangang Luo,* University of Miami **(p. 312)**
3:30pm – 4:00pm	**A Retrospective and Critical Review of Aquifer Storage and Recovery and Conceptual Frameworks of the Upper Floridan Aquifer in Southern Florida — *Ronald S. Reese***, U.S. Geological Survey, Miami **(p. 298)**
4:00pm – 4:30pm	**Spatial Simulations of Tree Islands as Ecosystem Indices for Everglades Restoration — *Yegang Wu***, *Fred H. Sklar, Ken Rutchey, Weihe Guan,* and *Les Vilcheck,* South Florida Water Management District **(p. 314)**
4:30pm – 5:00pm	**Sound-bite Hydrology — *Richard Punnett***,U.S. Army, Corps of Engineers **(p. 297)**
5:00pm – 7:00pm	Reception and Formal Poster Session I — *Ecology and Ecological Modeling* - ***Mangrove Ballroom (Level One)***

Tuesday, December 12, 2000

Concurrent Session IV: Water Quality & Water Treatment Technologies – PM
Chokoloskee Room (Level Three)

Water Quality Monitoring and Trends
Session Moderator*: *Benjamin McPherson, *U. S. Geological Survey*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**Geochemical Monitoring Of Restoration Progress — *Kimberly Yates*** and *Robert Halley*, U.S. Geological Survey **(p. 453)**
1:45pm – 2:15pm	**An Analysis Of Changes In Basin-Wide And Farm-Scale Phosphorus Loading From The Everglades Agricultural Area Due To Implementation Of Best Management Practices — *Randy McCafferty*** and *William Baker*, South Florida Water Management District **(p. 439)**
2:15pm – 2:45pm	**Characterization of Phosphorus Cycling and Speciation in the Northern Florida Everglades by High Resolution Mass Spectrometry — *William T. Cooper*** and *Jennifer Llewelyn*, Department of Chemistry; *William M. Landing*, Department of Oceanography; *Vincent J. M. Salters* and *Yang Wang*, Department of Geology and National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL **(p. 429)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**Water Quality Monitoring of Tidal River and Canal Systems in the Ten Thousand Islands Estuaries: Implications for Essential Fish Habitat and Watershed Dynamics — *Matt Finn***, Huckleberry Fisheries; *Anne-Marie Eklund* and *Jennifer Schull*, National Marine Fisheries Service **(p. 432)**
3:30pm – 4:00pm	**Water Quality Impact Analysis of Southwest Florida: Wetland Permitting Alternatives on Surface Water Quality** — *Terry L. Rice*, Florida International University; ***Dennis J. Peters***, *Jeffrey Q. Rhodes* and *Paul Szerszen*, Science Applications International Corporation (SAIC) **(p. 444)**
4:00pm – 4:30pm	**Nutrient and Sulfer Contamination in the South Florida Ecosystem: Synopsis of Phase I Studies and Pland for Phase II Studies — *William H. Orem***, *Harry E. Lerch*, *Anne L. Bates*, *Margo Corum*, and *Marisa Chrisinger*, U.S. Geological Survey; *Robert A. Zielinski*, U.S. Geological Survey **(p. 441)**
4:30pm – 4:45pm	Closing Remarks
5:00pm – 7:00pm	Reception and Formal Poster Session I — *Ecology and Ecological Modeling* - ***Mangrove Ballroom (Level One)***

Wednesday, December 13, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session I: Ecology and Ecological Modeling - AM
River of Grass Ballroom – Salons D, G & H (Level One)

Population Studies: Coldblooded Vertebrates
***Session Moderator*: Laura A. Brandt**, *U.S. Fish and Wildlife Service*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Hydrology and Fish Community Dynamics in the Florida Everglades: Perspectives from a 20-Year Study — *Joel Trexler***, Florida International University Department of Biological Science **(p. 169)**
8:45am – 9:15am	**Dispersal and Successional Patterns of the Fish Community of the Rockland Wetland Complex of Southern Florida — *Bill Loftus***, U. S. Geological Survey, Biological Resources Division **(p. 117)**
9:15am – 9:45am	**Trophic Interactions of Large-carnivorous and Small-omnivorous Fishes in Freshwater Marshes of the Florida Everglades — *John Chick***, Illinois Natural History Survey **(p. 67)**
9:45am – 10:15am	**Spatial and Stage-Structured Models of American Alligator Populations in Support of ATLSS — *Jon Allen***, University of Florida, IFAS, Entomology & Nematology Department **(p. 51)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)*** *(Poster Session I displays MUST be removed by this time)*
10:30am – 11:00am	**An Assessment of Potential Contaminant Exposures and Effects for Alligators in the Greater Everglades Ecosystem — *Timothy Gross***, U. S. Geological Survey, Biological Resources Division, Florida Caribbean Science Center **(p. 93)**
11:00am – 11:30am	**American Alligator Nesting And Reproductive Success In Everglades National Park — *George Dalrymple***, Everglades Research Group **(p. 72)**
11:00am – 1:00pm	Poster Presenters to set up displays for Poster Session II ***Mangrove Ballroom (Level One)***
11:30am – 1:00pm	Lunch on Own

Wednesday, December 13, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session II: Ecology and Ecological Modeling – AM
River of Grass Ballroom – Salons F & I (Level One)

Everglades Macrophyte and Landscape Ecology
Session Moderator: Robert Twilley*, University of Louisiana at Lafayette*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Patterns, Niches and Mechanisms in the Ridge and Slough Landscape: Implications for Restoration — *Christopher McVoy***, South Water Florida Management District **(p. 125)**
8:45am – 9:15am	**Vegetation: Environment Relationships and Water Management in Shark Slough-Everglades National Park — *Michael Ross***, Florida International University **(p. 150)**
9:15am – 9:45am	**Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem — *Jack Fisher***, Fairchild Tropical Garden **(p. 86)**
9:45am – 10:15am	**Community Patterns of Seedling Recruitment After Summer Fire in Two Pine Rocklands — *Suzanne Koptur***, Department of Biological Sciences, Florida International University **(p. 114)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)*** *(Poster Session I displays MUST be removed by this time)*
10:30am – 11:00am	**Dispersal, Reproduction and Physiological Ecology of Two Invasive Non-Indigenous Fern Species - *Lygodium microphyllum* and *Lygodium japonicum* — *Michael Lott***, Florida Atlantic University, Division of Biological Science **(p. 120)**
11:00am – 11:30am	**Seedling Dynamics Across a Mangrove - Sawgrass Ecotone in the Southwest Florida Everglades — *Kevin Whelan***, AScI / USGS-BRD-Co/ SERC **(p. 180)**
11:00am – 1:00pm	Poster Presenters to set up displays for Poster Session II ***Mangrove Ballroom (Level One)***
11:30am – 1:00pm	Lunch on Own

Wednesday, December 13, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session III: Hydrology and Hydrological Modeling- AM
Immokalee Room (Level Three)

FLOW WORKSHOP: *How important is the flow for Everglades Restoration?*
Session Moderator: Nicholas G. Aumen*, National Park Service*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 9:15am	Brief overview by Workshop Panelist **– Christopher McVoy**, **Tom MacVicar**, **Randy VanZee**, **Steve Davis**, **Dan Childers** and **Peter Stone**

WORKSHOP QUESTIONS:

- **What were the historic patterns of flow in the greater Everglades both temporally and spatially?**
- **What is the linkage between flow and landscape patterns?**
- **How important is flow for restoration of the remnant greater Everglades and coastal ecosystems?**

9:15am – 10:15am	**Discussion and Interactions between Panel Members**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)*** *(Poster Session I displays MUST be removed by this time)*
10:30am – 11:00am	**Audience and Panel Discussion**
11:00am – 11:30am	Closing remarks
11:00am – 1:00pm	Poster Presenters to set up displays for Poster Session II ***Mangrove Ballroom (Level One)***
11:30am – 1:00pm	Lunch on Own

Wednesday, December 13, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session IV: Water Quality and Water Treatment Technologies – AM
Chokoloskee Room (Level Two)

Nutrient/Biology Interactions
***Session Moderator*: Tom Crisman**, *University of Florida/IFAS, Center for Wetlands*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Spatial Changes in Redox Conditions and Food Web Relations at Low and High Nutrient Sites in the Everglades — *Carol Kendall***, *Steven R. Silva*, and *Cecily C. Y. Chang*, U. S. Geological Survey, Menlo Park, CA; *Robert F. Dias*, Old Dominion University; *Paul Garrison*, Wisconsin Department of Natural Resources; *Ted Lange*, Florida Fish and Wildlife Conservation Commission; *David P. Krabbenhoft*, U. S. Geological Survey; *Q. Jerry Stober*, U. S. Environmental Protection Agency **(p. 434)**
8:45am – 9:15am	**Nutrients Sequestered in Microbial Mats Reflect Remote Source Water Quality in Everglades National Park — *Evelyn E. Gaiser***, *Leonard J. Scinto*, *Krish Jayachandran*, and *Ronald D. Jones*, *Jennifer H. Richards*, *Daniel L. Childers*, and *Joel Trexler*, Florida International University **(p. 433)**
9:15am – 9:45am	**Nutrient Ratios and the Eutrophication of South Florida Coastal Waters — *Larry E. Brand*** and *Maiko Suzuki Ferro*, University of Miami, RSMAS **(p. 425)**
9:45am – 10:15am	**Salinity, Turbidity, Algal Blooms, and Seagrass Dieoff in Florida Bay – Spatial, Temporal, and Causal Relationships — *Larry E. Brand*** and *Maiko Suzuki Ferro*, University of Miami, RSMAS; *Thomas W. Schmidt*, South Florida Natural Resources Center, Everglades National Park **(p. 427)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)*** *(Poster Session I displays MUST be removed by this time)*
10:30am – 11:00am	**Factors Influencing the Dissolved Oxygen Profiles in the Northern Everglades — *Panchabi Vaithiyanathan*** and *Curtis J. Richardson*, Wetland Center, Nicholas School of the Environment, Duke University **(p. 449)**
11:00am – 11:30am	**Factors Influencing the Calcium Carbonate Precipitation in the Everglade Sloughs — *Panchabi Vaithiyanathan*** and *Curtis J. Richardson*, Wetland Center, Nicholas School of the Environment, Duke University **(p. 448)**
11:00am – 1:00pm	Poster Presenters to set up displays for Poster Session II ***Mangrove Ballroom (Level One)***
11:30am – 1:00pm	Lunch on Own

Wednesday, December 13, 2000

Concurrent Session I: Ecology and Ecological Modeling - PM
River of Grass Ballroom – Salons D, G & H (Level One)

Population Studies: Birds
Session Moderator: Joseph Schaefer, *University of Florida/IFAS, Center for Natural Resources*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**Is the Everglades a Demographic Sink for Wading Birds? — *Peter Frederick***, University of Florida, Department of Wildlife Ecology and Conservation **(p. 88)**
1:45pm – 2:15pm	**Linkages between the Snail Kite Population and Wetland Dynamics in a Highly Fragmented South Florida Hydroscape — *Wiley M. Kitchens***, U.S. Geological Survey-Florida Cooperative Fish and Wildlife Research Unit **(p. 112)**
2:15pm – 2:45pm	**The Role of Fire in Sustaining Populations of Cape Sable Seaside Sparrows Within the Southern Everglades — *Julie Lockwood***, University of California-Environmental Studies **(p. 116)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**The Sensitivity of an Endangered Species to Changes in Demographic and Landscape Level Parameters: an Individual-Based Model for the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) — *John L. Curnutt***, U. S. Geological Survey - Restoration Ecology Branch **(p. 85)**
3:30pm – 4:00pm	**Non-Breeding Season Ecology Of The Cape Sable Seaside Sparrow: Field Observations And Implications For Management — *Joan Morrison***, Department of Biology, Trinity College **(p. 130)**
4:00pm – 4:30pm	**Demonstrating the Destruction of the Habitat of the Cape Sable Seaside Sparrow — *Stuart Pimm***, Columbia University, Center for Environmental Research & Conservation **(p. 137)**
4:30pm – 5:00pm	**Reintroduction of Brown-headed Nuthatches and Eastern Bluebirds to Everglades National Park — *Gary Slater*** and *Kenneth D. Meyer,* Avian Research and Conservation Institute, Inc.; *Skip Snow*, South Florida Natural Resources Center **(p. 160)**
5:00pm – 5:15pm	Closing Remarks
5:15 pm	Sessions Conclude and Evening on Own

Wednesday, December 13, 2000

Concurrent Session II: Ecology and Ecological Modeling – PM
River of Grass Ballroom – Salons F & I (Level One)

Regional Environmental Monitoring and Assessment Program (REMAP)
***Session Moderator: Susan Gray**, South Florida Water Management District*

1:00pm – 1:15pm	**REMAP –** Opening Remarks – Session Overview
1:15pm – 1:45pm	**REMAP: Landscape Water Quality Gradients and Tissue Concentrations in the Everglades Ecosystem — *Jerry Stober***, United States Environmental Protection Agency, Region 4 SESD **(p. 166)**
1:45pm – 2:15pm	**REMAP: Soil Subsidence and Soil Preservation in the Public Everglades — *Daniel Scheidt***, United States Environmental Protection Agency **(p. 157)**
2:15pm – 2:45pm	**REMAP: Using Diatoms for Risk Assessment in the Everglades — *Evelyn Gaiser***, Southeast Environmental Research Center **(p. 89)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**REMAP: Macrophyte Species Distributions and Community Structure across the Everglades Ecosystem — *Jennifer H. Richards***, Department of Biological Sciences, Florida International University **(p. 145)**
3:30pm – 4:00pm	**REMAP: Leaf Morphology and Tissue Nutrients of Two Everglades Macrophytes with Respect to Soil Physiochemistry —** *Christopher Ivey* and ***Jennifer H. Richards***, Department of Biological Sciences, Florida International University **(p. 144)**
4:00pm – 4:30pm	**REMAP: Aerial Photo Vegetation Assessment in the Everglades Ecosystem —*Marguerite Madden*** and *Roy Welch*, Center for Remote Sensing and Mapping Science (CRMS), University of Georgia **(p. 121)**
4:30pm – 5:00pm	**REMAP: Bioaccumulation of Mercury in the Everglades: Patterns in the Foodweb — *William Loftus***, U. S. Geological Survey, Biological Resources Division and *Joel Trexler,* Florida International University **(p. 119)**
5:00pm – 5:30pm	**REMAP: Conceptual Models and Path Analysis - Analyzing Large Scale Patterns in the South Florida Everglades Ecosystem — *Kent W. Thornton***, FTN Associates, Ltd. **(p. 168)**
5:30pm – 6:00pm	**REMAP: Policy and Management Implications from the Everglades Ecosystem Assessment Project — *Ron Jones***, Southeast Environmental Research Center, Florida International University **(p. 167)**
6:00pm – 6:15pm	Closing Remarks
6:15pm	Session Concludes and Evening on Own

Wednesday, December 13, 2000

Concurrent Session III: Hydrology and Hydrological Modeling – PM
Immokalee Room (Level Three)

Restoration Science – Hydrology
Session Moderator*: *Jayantha [Obey] Obeysekera, *South Florida Water Management District*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**(Invited) Overview of the Science Needs for Restoration — *Carl Goodwin***, U.S. Geological Survey
1:45pm – 2:15pm	**Concepts and Algorithms for an Integrated Surface Water/Groundwater Model for Natural Areas and Their Application —** *Lahar M. Brion,* ***Sharika U.S. Senarath****, A. M. Wasantha Lal, Mark Belnap, Randy J. Van Zee,* South Florida Water Management District **(p. 280)**
2:15pm – 2:45pm	**Development of Numerical Tools for Defining Wetland Hydrologic Processes: SICS and TIME — *Eric D. Swain***, U.S. Geological Survey **(p. 304)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**Quantification Of Ground-Water Seepage Beneath Levee 31N, Miami-Dade County, Florida —** *Mark Nemeth* and ***Helena Solo-Gabriele****,* University of Miami **(p. 301)**
3:30pm – 4:00pm	**Effect of Water Management in the Everglades Nutrient Removal Area (ENR) on Hydrologic Interactions with Groundwater — *Jungyill Choi****,* and *Judson W. Harvey,* U.S. Geological Survey, Reston **(p. 282)**
4:00pm – 4:30pm	**Ground-Water Discharge to Biscayne Bay — *Christian Langevin***, U.S. Geological Survey **(p. 294)**
4:30pm – 5:00pm	**Simulation of Anthropogenic Impacts to the Regional Climatic Patterns of Central and Southern Florida** — *Craig A. Mattocks*, Scientific Software Solutions, Inc., and ***Paul Trimble***, South Florida Water Management District **(p. 307)**
5:00pm – 5:30pm	**Object-Oriented Hydrologic Simulation Models for South Florida — *Randy Van Zee***, *Mark Belnap, A. M. Wasantha Lal*, Hydrologic Systems Modeling Division, South Florida Water Management District **(p. 311)**
5:30pm	Sessions Conclude and Evening on Own

Wednesday, December 13, 2000

Concurrent Session IV: Ecology and Ecological Modeling - PM
Chokoloskee Room (Level Two)

Florida Bay Indicators

Session Moderator*: *Joel Trexler, *Florida International University*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**Historical Reconstruction of Seagrass Distribution-Water Quality and Salinity Using Molluscan Indicator Species — *G. Lynn Brewster-Wingard***, U.S. Geological Survey **(p. 57)**
1:45pm – 2:15pm	**Ostracode Shell Chemistry as a Paleosalinity Proxy in Florida Bay — *Gary Dwyer***, Duke University **(p. 84)**
2:15pm – 2:45pm	**Historical Trends in Epiphytal Ostracodes from Florida Bay: Implications for Seagrass and Macro-benthic Algal Variability — *T. M. Cronin***, U.S. Geological Survey **(p. 71)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**Water Birds in Florida Bay: Conspicuous Ecological Indicators? — *Joan Browder***, Southeast Fisheries Science Center **(p. 60)**
3:30pm – 4:00pm	**Diatoms as Indicators of Environmental Change in Sediment Cores from Northeastern Florida Bay — *J. K. Huvane***, U.S. Geological Survey **(p. 105)**
4:00pm – 4:30pm	**Ecological Controls on Benthic Foraminifer Distributions in Biscayne Bay, Florida — *Scott Ishman***, Southern Illinois University **(p. 106)**
4:30pm – 5:00pm	**The Potential for Filter Feeding Sponges to Control Phytoplankton Blooms in Florida Bay — *Bradley J. Peterson***, Florida International University, Department of Biological Sciences **(p. 135)**
5:00pm – 5:30pm	**Nutrient Cycling and Transport at the Florida Bay - Everglades Boundary — *David T. Rudnick***, South Florida Water Management District **(p. 152)**
5:30pm	Sessions Conclude and Evening on Own

Thursday, December 14, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session I: Ecology and Ecological Modeling - AM
River of Grass Ballroom – Salons D, G & H (Level One)

Population Studies:Mammals
***Session Moderator:* Wiley M. Kitchens**, *U.S. Geological Survey, Florida Fish & Wildlife Coop Unit at the University of Florida*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Movements and Habitat Use by Florida Manatees in the Everglades Ecosystem — *Jim Reid***, U. S. Geological Survey **(p. 140)**
8:45am – 9:15am	**The Influence of Habitat on the Distribution and Abundance of Small Mammals in the Southwest Everglades — *Diane Riggs***, Florida International University **(p. 148)**
9:15am – 9:45am	**Modeling Spatial Use Patterns of White-tailed Deer in the Florida Everglades — *Christine Hartless***, Department of Wildlife Ecology and Conservation, University of Florida **(p. 96)**
9:45am – 10:15am	**Corridors, Landscape Linkages and Conservation Planning for the Florida Panther *(Puma concolor coryi)* — *Rebecca P. Meegan*** and *David S. Maehr* University of Kentucky and *Thomas S. Hoctor*, University of Florida **(p. 127)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***

Quantitative Modeling – Part I

10:30am – 11:00am	**Application of the Everglades Landscape Model in Restoration Initiatives — *Carl Fitz***, South Florida Water Management District **(p. 87)**
11:00am – 11:30am	**An Overview of the Across Trophic Level System Simulation Program — *Donald DeAngelis***, U. S. Geological Survey, Biological Resources Division, Florida Caribbean Science Center-University of Miami **(p. 77)**
11:30am – 1:00pm	Lunch on Own

Thursday, December 14, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session II: Ecology and Ecological Modeling – AM
River of Grass Ballroom – Salons F & I (Level One)

Nutrients, Soils, and Biotic Communities – Part I
***Session Moderator*: Sue Newman**, *South Florida Water Management District*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	**Linkages between Microbial Community Composition and Biogeochemical Processes along Nutrient Gradients in the Everglades Agricultural Areas — *Andrew Ogram***, University of Florida **(p. 134)**
8:45am – 9:15am	**The Ecological Basis for a Phosphorus (P) Threshold in the Everglades: Directions for Sustaining Ecosystem Structure and Function — *Curtis Richardson***, Duke University Wetland Center **(p. 147)**
9:15am – 9:45am	**Macroinvertebrate Response to Nutrient Enrichment in the Florida Everglades — *Robert Shuford III***, South Florida Water Management District **(p. 159)**
9:45am – 10:15am	**The Effect of Fish Detritus on an Oligotrophic Everglades Marsh — *Chris Stevenson***, Florida International University **(p. 165)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
10:30am – 11:00am	**Slough Macrophyte Community Changes In The Northern Everglades - Influence Of P Enrichment And Hydrology — *Panchabi Vaithiyanathan***, Duke University **(p. 172)**
11:00am – 11:30am	**Microbial Indicators of Phosphorus Enrichment in Everglades Soil — *A. L. Wright***,Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida **(p. 183)**
11:30am – 1:00pm	Lunch on Own

Thursday, December 14, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session III: Hydrology and Hydrological Modeling - AM
Immokalee Room (Level Three)

Hydrologic Science for Restoration
Session Moderator: Carl Goodwin, *U.S. Geological Survey*

8:00am – 8:15am	Opening Remarks – Session Overview
8:15am – 8:45am	(Invited) **Operation of the Everglades System: Present and Future — *Cal Neidrauer***, South Florida Water Management District
8:45am – 9:15am	**Topography of the Florida Everglades — *Gregory Desmond***, *Edward Cyran, Vince Caruso, Gordon Shupe, and Robert Glover*, U.S. Geological Survey, Reston **(p. 284)**
9:15am – 9:45am	**Quantity, Timing, and Distribution of Freshwater Flows into Northeastern Florida Bay — *Clinton D. Hittle***, U.S. Geological Survey **(p. 289)**
9:45am – 10:15am	**Regional Evaluation of Evapotranspiration in the Everglades — *Edward R. German***, U.S. Geological Survey, Altamonte Springs **(p. 287)**
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)*** *(Poster Session II displays MUST be removed by this time)*
10:30am – 11:00am	**Long-Term Daily Evapotranspiration Estimation in South Florida — *Kenneth C. Tarboton***, South Florida Water Management Disrict **(p. 306)**
11:00am – 11:30am	**Determination of Resistance Coefficients for Flow through Submersed and Emergent Vegetation in the Florida Everglades —** *Jonathan K. Lee, Harry L. Jenter*, and *Hannah M. Visser*, U.S. Geological Survey, Reston, VA; ***Lisa Roig***, Roig and Associates, Reston, VA **(p. 291)**
11:30am – 1:00pm	Lunch on Own

Thursday, December 14, 2000

7:00am – 8:00am	Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session IV: Social and Human Sciences - AM
Chokoloskee Room (Level Two)

Characteristics of the South Florida Community

***Session Moderator*: Daniel Suman**, *University of Miami, RSMAS-Division of Marine Affairs & Policy*

8:00am – 8:15am	Opening Remarks—***Walter (Tony) Rosenbaum***, *University of Florida* – Session Overview
8:15am – 8:30am	**The Human Side of Everglades Restoration — *Carolyn A. Dekle***, South Florida Regional Planning Council **(p. 404)**
8:30am – 8:45am	**Space, Place, and Environmental Attitudes in South Florida — *Hugh Gladwin*** and *Elena Sabogal,* Florida International University **(p. 406)**
8:45am – 9:00am	**Integrating Environmental Justice Into The Comprehensive Everglades Restoration Master Program Management Plan —** *Bonnie Kranzer*, Governor's Commission for Everglades; and ***Richard David Gragg III***, Center for Environmental Equity and Justice, Environmental Sciences Institute, Florida A&M University **(p. 407)**
9:00am – 9:15am	**The 8 1/2 Square Mile Area: A Case Study of the Social Impacts of Everglades Restoration — *Daniel Suman***, Rosenstiel School of Marine and Atmospheric Science, University of Miami **(p. 416)**
9:15am – 10:15am	Discussion / Q&A with Speakers
10:15am – 10:30am	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***

Land Use and Restoration Policy Development and Analysis

***Session Moderator*: Ken Lipartito**, *Florida International University*

10:30am – 10:45am	**Land-use Changes and Flood Protection Policies in South Florida — *Mahadev Bhat***, *Ken Lipartito and Irma Alonso,* Florida International University **(p. 400)**
10:45am – 11:00am	**From Boon to Affliction: How the *Melaleuca quinquenervia* Became a Weed — *Jorge Schmidt***, Florida International University, Miami, FL **(p. 415)**
11:00am – 11:15am	**A Model for Ecosystem Management Through Land-Use Planning: Understanding the Mosaic of Protection Across Ecological Systems in Southern Florida — *Samuel Brody***, University of North Carolina **(p. 401)**
11:15am – 11:30am	Discussion / Q&A with Speakers
11:30am – 1:00pm	Lunch on Own

Thursday, December 14, 2000

Concurrent Session I: Ecology and Ecological Modeling - PM
River of Grass Ballroom – Salons D, G & H (Level One)

Quantitative Modeling – Part II
***Session Moderator: Lou Gross**, University of Tennessee*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**A Comparison of Ecosystem Attributes among Four South Florida Wetland Habitats — *Johanna Heymans***, University of British Columbia Fisheries Centre **(p. 104)**
1:45pm – 2:15pm	**The Utility of Mangrove Unit Models in the Greater Everglades Ecosystem Restoration Program — *Robert Twilley***, University of Louisiana at Lafayette **(p. 170)**
2:15pm – 2:45pm	**Population Modeling of the American Crocodile (*Crocodylus acutus*) for Conservation and Management in South Florida — *Paul Richards***, University of Miami, Department of Biology **(p. 146)**
2:45pm – 3:00pm	Refreshment Break- ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**Modeling the Everglade Snail Kite — *Wolf Mooij***, Netherlands Institute of Ecology, Centre for Limnology **(p. 129)**
3:30pm – 4:00pm	**Sensitivity and Uncertainty Analysis of a Spatial-Explicit Fish Population Model Applied to Everglades Restoration — *René Salinas***, University of Tennessee **(p. 156)**
4:00pm – 4:30pm	**ALFISHES: A Size-Structured and Spatially-Explicit Model for Predicting the Impact of Hydrology on the Resident Fishes of the Everglades Mangrove Zone of Florida Bay — *Jon Cline***, The Institute for Environmental Modeling **(p. 70)**
4:30pm – 5:00pm	**Development of a GIS Tool to Visualize and Analyze ATLSS Models Result for Resource Managers —** *Antonio Martucci*, Johnson Controls World Services, Inc. at USGS-National Wetlands Research Center, ***James B. Johnston*** and *Steve Hartley*, USGS-National Wetlands Research Center **(p. 109)**
5:00pm – 7:00pm	Reception and Formal Poster Session II — *Hydrology & Hydrological Modeling, Information Systems, Social & Human Sciences, Water Quality & Water Treatment Technologies* ***Mangrove Ballroom (Level One)***

Thursday, December 14, 2000

Concurrent Session II: Ecology and Ecological Modeling – PM
River of Grass Ballroom – Salons F & I (Level One)

Nutrients, Soils, and Biotic Communities - Part II
***Session Moderator*: Curtis J. Richardson**, *Duke University, Durham, NC*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**Ecological Exchanges between a Mangrove Creek and Surrounding Wetlands in the Southern Everglades — *Enrique Reyes***, Coastal Ecology Institute, Louisiana State University **(p. 143)**
1:45pm – 2:15pm	**Responses of Periphyton, Water Lily, and Soil to P Enrichment of an Everglades Slough — *Sue Newman***, *P.V. McCormick*, and *S.L. Miao*, South Florida Water Management District **(p. 132)**
2:15pm – 2:45pm	**Hydrology, Nutrient Supply and the Lower Trophic Levels of the Everglades Marshes — *Quan Dong***, Florida International University **(p. 80)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***

Concurrent Session II: Information Systems – PM
River of Grass Ballroom – Salons F & I (Level One)

Technology Update
***Session Moderator:* Gail Clement**, *Florida International University & U.S. Geological Survey*

3:00pm – 3:30pm	**Everglades National Park Scientific Database: Lessons Learned in Developing an Integrated Relational Database Using Historical Data — *Darrell Tidwell***, Everglades National Park **(p. 374)**
3:30pm – 4:00pm	**South Florida Ecosystem Database Access — *Roy Sonenshein***, U.S. Geological Survey **(p. 373)**
4:00pm – 4:30pm	**Some Lessons from the ATLSS Project: Modeling and Everglades Restoration — *Louis J. Gross***, The Institute for Environmental Modeling- University of Tennessee **(p. 372)**
4:30pm – 5:00pm	**The Data Web Pages of the Tides and Inflows in the Mangroves of the Everglades (TIME) Project — *Michael Duff***, U.S. Geological Survey **(p. 371)**
5:00pm – 7:00pm	Reception and Formal Poster Session II — *Hydrology & Hydrological Modeling, Information Systems, Social & Human Sciences, Water Quality & Water Treatment Technologies* ***Mangrove Ballroom (Level One)***

Thursday, December 14, 2000

Concurrent Session III: Hydrology and Hydrological Modeling – PM
Immokalee Room (Level Three)

Multi-objective management of the Greater Everglades System
Session Moderator:* *Hanley K. [Bo] Smith, *U. S. Army Corps of Engineers*

1:00pm – 1:15pm	Opening Remarks – Session Overview
1:15pm – 1:45pm	**(Invited) Meetings The Needs Of The Urban And Agricultural Systems —** ***Patrick Gleason***, South Florida Water Management District
1:45pm – 2:15pm	**Five-year Incremental Analysis of the Lower East Coast Regional Water Supply Plan —** ***Jayantha Obeysekera***, *Everett R. Santee, Kenneth C. Tarboton, Luis G. Cadavid, Lehar Brion, Raul Novoa,* South Florida Water Management District **(p. 296)**
2:15pm – 2:45pm	**Establishing Minimum Water Levels for the Everglades —** ***Joel VanArman*** *and David Swift*, South Florida Water Management District **(p. 309)**
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***
3:00pm – 3:30pm	**USDA-Everglades Agro-hydrology Computer Model - Interaction of Surface and Subsurface Water Flow —** ***M. Reza Savabi***, USDA-ARS, SHRS, Miami **(p. 300)**
3:30pm – 4:00pm	**Operational Planning for Everglades Restoration —** ***Luis Cadavid***, *Paul Trimble, Alaa Ali, Cary White and Jayantha Obeysekera,* South Florida Water Management District **(p. 281)**
4:00pm – 4:30pm	**The ATLSS High Resolution Topology and High Resolution Hydrology Models —** ***Scott M. Duke-Sylvester*** *and Louis J. Gross,* University of Tennessee **(p. 286)**
4:30pm – 4:45pm	Closing Remarks
5:00pm – 7:00pm	Reception and Formal Poster Session II — *Hydrology & Hydrological Modeling, Information Systems, Social & Human Sciences, Water Quality & Water Treatment Technologies* - ***Mangrove Ballroom (Level One)***

Thursday, December 14, 2000

Concurrent Session IV: Social and Human Sciences - PM
Chokoloskee Room (Level Two)

Behavioral Methods of Restoration Planning and Management
Session Moderator*: *J. Walter Milon, *University of Central Florida* and *University of Florida*

1:00pm – 1:15pm	Opening Remarks—***Bob Leeworthy***, *U.S. Dept. of Commerce, NOAA*, – Session Overview
1:15pm – 1:30pm	**Forecasting the Human Population of South Florida: The State of the Art and Directions for the Future — *Alice L. Clarke***, Florida International University **(p. 403)**
1:30pm – 1:45pm	**Measuring the Economic Benefits of Everglades Ecosystem Restoration — *J. Walter Milon***, University of Central Florida **(p. 413)**
1:45pm – 2:00pm	**Adaptive Learning in Ecological Policy and Management — *Clyde F. Kiker***, University of Florida / IFAS, Food and Resource Economics Department **(p. 408)**
2:00pm – 2:45pm	Discussion / Q&A with Speakers
2:45pm – 3:00pm	Refreshment Break - ***Orchid Atrium & Solarium South (Level One)***

Policy Making Processes for Restoration
Session Moderator*: *Frank Mazzotti, *University of Florida/IFAS, Center for Natural Resources – South Florida*

3:00pm – 3:15pm	**Ways to Make Science More Usable for Policy Makers and Managers in Greater Everglades Ecosystem Restoration and Management — *Frank J. Mazzotti***, University of Florida **(p. 411)**
3:15pm – 3:30pm	**A Strategic Plan for Everglades Restoration: Defining Success - The Marshall Plan — *John Arthur Marshall***, Arthur R. Marshall Foundation **(p. 410)**
3:30pm – 3:45pm	**Environmental Decisionmaking by Stakeholder Consensus — *Michael R. Bauer***, National Wildlife Federation **(p. 399)**
3:45pm – 4:30pm	Discussion / Q&A with Speakers
4:30pm – 4:45pm	Closing Remarks
5:00pm – 7:00pm	Reception and Formal Poster Session II — *Hydrology & Hydrological Modeling, Information Systems, Social & Human Sciences, Water Quality & Water Treatment Technologies* ***Mangrove Ballroom (Level One)***

<u>Friday, December 15, 2000</u>

7:30am – 8:30am Early Morning Refreshments - ***Orchid Atrium & Solarium South (Level One)***

Closing Concurrent Sessions: Critical Needs for *Measuring Success*

Five Concurrent Sessions: Setting the *GEER* in Motion *(Moderated by Topic Chairs)*

8:30am – 9:30am **Topic Discussion Charge: Define Critical Immediate (2-year) and Near-Term (5-year) Science and Technical Needs**

<u>Concurrent Session I</u>: Ecology & Ecological Modeling

River of Grass Ballroom – Salons D, G & H (Level One)

<u>Panel Members:</u>

Donald L. DeAngelis, Ph.D., Topic Chair, U.S. Geological Survey

Thomas Armentano, Ph.D., National Park Service, Everglades National Park

Susan Gray, Ph.D., South Florida Water Management District

<u>Concurrent Session II</u>: Hydrology & Hydrological Modeling

Immokalee Room (Level Three)

<u>Panel Members:</u>

Aaron Higer, Topic Chair, U.S. Geological Survey

Jayantha (Obey) Obeysekera, Ph.D., South Florida Water Management District

Thomas Van Lent, Ph.D., National Park Service, Everglades National Park

<u>Concurrent Session III</u>: Information Systems

Goodland Room (Level Two)

<u>Panel Members:</u>

Gail Clement, Topic Chair, Florida International University

David Buker, National Park Service, Everglades National Park

Roy Sonenshein, U.S. Geological Survey

<u>Concurrent Session IV</u>: Social & Human Sciences

Chokoloskee Room (Level Two)

<u>Panel Members:</u>

Bonnie Kranzer, Ph.D., AICP, Topic Chair, Exec. Director, Governor's Commission for the Everglades

Mahadev Bhat, Ph.D., Florida International University

<u>Concurrent Session V</u>: Water Quality & Water Treatment Technologies

River of Grass Ballroom – Salons F & I (Level One)

<u>Panel Members:</u>

Nicholas G. Aumen, Ph.D., Topic Chair, National Park Service, Everglades National Park

Thomas D. Fontaine, Ph.D., South Florida Water Management District

Jennifer Jorge, Ph.D., South Florida Water Management District

Friday, December 15, 2000 *(continued)*

Closing Plenary Session I: Critical Needs for *Measuring Success* — Summary Presentation and Brief Discussion of Each Topic

***Session Moderator*: G. Ronnie Best**, *PWS, Conference Chair, U.S. Geological Survey*

Panel Members*: Topic Chairs** and ***Co-Chairs

9:30am – 9:45am	**Ecology & Ecological Modeling** *(DeAngelis, Armentano, Gray)*
9:45am – 10:00am	**Hydrology & Hydrological Modeling** *(Higer, Obeysekera, Van Lent)*
10:00am – 10:15am	**Information Systems** *(Clement, Buker, Sonenshein)*
10:15am – 10:30am	Refreshment Break
10:30am – 10:45am	**Social & Human Systems** *(Kranzer, Bhat)*
10:45am – 11:00am	**Water Quality & Water Treatment Technologies** *(Aumen, Fontaine, Jorge)*

Closing Plenary Session II: Critical Needs for *Measuring Success* — Enhancing the Greater Everglades Ecosystem Conceptual Model

11:00am – 12:00pm **Panel and Audience Discussion**

***Session Moderator*: G. Ronnie Best**, *PWS, Conference Chair, U.S. Geological Survey*

***Co-Moderator and Panel Lead*: John C. Ogden**, *SCT Co-Chair, South Florida Water Management District*

Panelists*: Steering Committee** and ***Topic Chairs

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

Robert Johnson, National Park Service, Everglades National Park

Frank Mazzotti, Ph.D., Director, University of Florida/IFAS, Center for Natural Resources – South Florida

John C. Ogden, South Florida Water Management District

K. Ramesh Reddy, Ph.D., Graduate Research Professor and Chair, Soil and Water Science Department, University of Florida/IFAS

Hanley (Bo) K. Smith, Ph.D., US Army Corps of Engineers

Donald L. DeAngelis, Ph.D., Topic Chair, U.S. Geological Survey

Aaron Higer, Topic Chair, U.S. Geological Survey

Gail Clement, Topic Chair, Florida International University

Bonnie Kranzer, Ph.D., AICP, Topic Chair, Exec. Director, Governor's Commission for the Everglades

Nicholas G. Aumen, Ph.D., Topic Chair, National Park Service, Everglades National Park

12:00pm Conference Concludes — *Have a Safe Trip Home!*

Poster Directory – Session I

Poster Directory

Poster Session I - Tuesday, December 12, 2000, 5:00pm-7:00pm

Ecology and Ecological Modeling

19....... **Recent Patterns in the Vegetation of Taylor Slough — *Thomas V. Armentano***, *David T. Jones,* and *Brandon W. Gamble*, South Florida Natural Resources Center, Everglades National Park, Homestead, FL

1......... **An Evaluation of Methyl-Mercury as an Endocrine Disruptor in Largemouth Bass and Freshwater Mussels** — ***Beverly Arnold***, *Nicola Kernaghan, D. Shane Ruessler, Carl Miles, Jon J. Wiebe, Carla M. Wieser* and *Timothy S. Gross*, U.S. Geological Survey - BRD, Florida Caribbean Science Center and the University of Florida, Gainesville, FL

16....... **Monitoring the Loss of Natural Cover in Southwest Florida (1973-1995) Using Landsat Data and a Hybrid Change Detection Technique —** *Jeffrey L. Michalek* and *John E. Colwell* and ***Laura Bourgeau-Chavez***, Veridian – ERIM International, Ann Arbor, MI

13....... **Mapping Invasive Plants in Florida with High-Resolution Spectroscopy — *Marcus Borengasser***, Midwest Research Institute, Palm Bay, FL; *V. V. Vandiver, Jr.*, University of Florida, Fort Lauderdale, FL; *M. W. Brodie, Roberto Erb*, and *C. Elroy Timmer*, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Fort Myers, Hialeah, Pompano Beach, FL

42....... **Inventory, Monitoring, and Research at the Arthur R. Marshall Loxahatchee National Wildlife Refuge — *Laura A. Brandt***, U.S. Fish and Wildlife Service – A.R.M. Loxahatchee NWR, Boynton Beach, FL

7......... **Molluscan Faunal Distribution in Florida Bay, Past and Present: An Integration of Down-Core and Modern Data — *G. Lynn Brewster-Wingard***, and *Jeffery R. Stone*, U.S. Geological Survey, Reston, VA; *Charles W. Holmes*, U.S. Geological Survey, St. Petersburg, FL

55....... **Applications of New Performance Measures for use with Everglades Restoration Hydrology Models —** *Robert A. Evans, Jessica M. Files* and ***Christopher J. Brown***, U.S. Army, Corps of Engineers, Jacksonville District, Jacksonville, FL

39....... **Demographical Analysis of a Spatially-Explicit Individual-Based Cape Sable Seaside Sparrow Model — *Eric A. Carr*** and *Louis J. Gross*, University of Tennessee, Knoxville, TN; *M. Philip Nott*, The Institute for Bird Populations, Point Reyes Station, CA

31....... **A Comparison of Everglades Alligator Production in Marsh and Canal Habitats —** *H. Franklin Percival*, ***Matthew D. Chopp***, U. S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL; *Kenneth G. Rice*, U. S. Geological Survey, Florida Caribbean Science Center, Homestead, FL

47....... **Genetic Analysis of Introduced Predatory Asian Swamp Eels *(Synbranchidae)* — *Timothy Collins***, *Joel Trexler and Timothy Rawlings*, Department of Biological Sciences, Florida International University, Miami, FL; *Leo G. Nico*, Florida Caribbean Science Center, U.S. Geological Survey, Gainesville, FL

40....... **A Simulation Model for Florida Panthers and White-tailed Deer in the Everglades and Big Cypress Landscapes — *Jane Comiskey*** and *Louis J. Gross*, University of Tennessee, Knoxville, TN

41....... **PanTrack: Analysis of Panther Locations and Movements through Time and Space — *Jane Comiskey***, University of Tennessee, Knoxville, TN

56....... **Seasonal Movements, Migratory Behavior, and Site Fidelity of Radio-tagged West Indian Manatees in Southeastern Florida — *Charles J. Deutsch***, U.S. Geological Survey, Florida Caribbean Science Center and Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL; Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL; *James P. Reid, Robert K. Bonde, Dean E. Easton* and *Howard I. Kochman*, U.S. Geological Survey, Florida Caribbean Science Center, Gainesville, FL; *Thomas J. O'Shea*, U.S. Geological Survey, Midcontinent Ecological Science Center, Ft. Collins, CO

57....... **Evaluation of Strip-transect Aerial Surveys for Monitoring Manatee Population Trends in the Ten Thousand Islands Region** — ***Terry J. Doyle***, U.S. Fish and Wildlife Service, Naples, FL; *Dean Easton* and *Lynn Lefebvr*, U.S. Geological Survey, Gainesville, FL

20....... **Effects of Water Management on the Growth and Survival of Red Mangrove Recruits — *Thomas W. Doyle***, U.S. Geological Survey, Lafayette, LA

11....... **Mycorrhizae Required for Native Plant Growth on Pine Rockland Soils — *Jack B. Fisher*** and *K. Jayachandran*, Fairchild Tropical Garden and Florida International University, Miami, FL

10....... **Protection of Florida's Native Bromeliads by Biocontrol of *Metamasius Callizona* (A Mexican Weevil) — *J. H. Frank*** and *Barbra Larson Vasquez*, Entomology & Nematology Dept., University of Florida/IFAS, Gainesville, FL; *M. C. Thomas*, Florida Dept. of Agriculture & Consumer Services; *R. D. Cave*, Escuela Agrícola Panamericana, El Zamorano, Honduras

23....... **The Demography of Sargent's Cherry Palm (*Pseudophoenix sargentii* ssp. *sargentii*) on Elliott Key (Biscayne National Park) — *Dena Garvue***, *David LaPuma*, *Hannah Thornton*, and *Susan Carrara*, Fairchild Tropical Garden, Research Center, Coral Gables (Miami), FL

44....... **The Effects of Prey Availability on the Feeding Tactics of Wading Birds — *Dale E. Gawlik***, Everglades Department, Watershed Research and Planning Division, South Florida Water Management District, West Palm Beach, FL

58....... **Omnivory and Periphyton Mats: Uncoupling Consumption and Consumer-Mediated Stimulatory Effects — *Pamela Geddes***, University of Chicago, Chicago, IL; *Joel C. Trexler*, Florida International University, Miami, FL

24....... **USDA - Wetland Reserve Program in the Everglades Region — *Greg Hendricks***, *Ron Smola* and *Ken Murray*, USDA Natural Resources Conservation Service, West Palm Beach, FL; *Jay Herrington*, USDOI, U.S. Fish and Wildlife Service, Jacksonville, FL

38....... **A 2D Graphical Visualization System for Integrated ATLSS Hydrology, Fish, and Wading Bird Simulation Data —** *Paul A. Fishwick* and ***John F. Hopkins***, University of Florida, Gainesville, FL

36....... **South Florida Multi-Species Recovery Plan: A Species Plan, An Ecosystem Approach — *Dawn P. Jennings***, U.S. Fish and Wildlife Service, Vero Beach, FL

54....... Analysis and Synthesis of Existing Information on Higher Trophic Levels: Factors Affecting the Abundance of Fishes and Macro-invertebrates in Florida Bay — *Darlene Johnson*, *Joan Browder, Anne Marie Eklund, Doug Harper, David McClellan* and *Hoalan Wong*, National Marine Fisheries Service, Miami, FL; *James A. Colvocoresses* and *Richard E. Matheson, Jr*., Florida Fish Wildlife Conservation Commission, St. Petersburg, FL; *Allyn B. Powell* and *Gordon W. Thayer*, National Ocean Service, Beaufort, NC; *Michael Robblee*, U.S. Geological Survey; *Thomas W. Schmidt*, Everglades National Park, Homestead, FL; *Susan M. Sogard*, National Marine Fisheries Service, Newport, OR

61....... Development of a GIS Tool to Visualize and Analyze ATLSS Models Result for Resource Managers — *Antonio Martucci*, Johnson Controls World Services, Inc. at USGS-National Wetlands Research Center, Lafayette, LA; ***James B. Johnston*** and *Steve Hartley*, USGS-National Wetlands Research Center, Lafayette, LA

18....... Vegetation Pattern and Process in Tree Islands of the Southern Everglades and Adjacent Areas — *David T. Jones*, *Thomas V. Armentano* and *Brandon W. Gamble*, South Florida Natural Resources Center, Everglades National Park, Homestead, FL; *Michael S. Ross*, Southeast Environmental Research Center, Florida International University, Miami, FL

17....... The Derivation of Land Cover Characteristics for Hydrologic Research in the Everglades — *John W. Jones*, U.S. Geological Survey, Reston, VA

59....... Seasonal Variation in Habitat use by Decapods and Fishes in the Northern Everglades — *Frank Jordan*, Loyola University, New Orleans, LA

60....... Food Web Responses to Enhancement of the Altered Kissimmee River Ecosystem — *Frank Jordan*, Loyola University, New Orleans, LA; *D. Albrey Arrington*, Texas A & M University, College Station, TX

50....... Development of Monitoring Protocols for Freshwater Fish Assemblages of the Rocky Glades, Everglades National Park — ***Jeffrey L. Kline*** and *Sue A. Perry*, Everglades National Park-South Florida Natural Resources Center, Homestead, FL

15....... Vegetation Density Mapping from Multispectral and SAR Imagery Using Artificial Neural Network Techniques — *George P. Lemeshewsky*, U.S. Geological Survey, Reston, VA

6......... Testing the Effects of Changes in Water Quality on Coral Survivorship — *Diego Lirman*, *Wendell P. Cropper Jr.*, and *John Wang*, University of Miami, Miami, FL

51....... Trophic Patterns of an Everglades Freshwater Fish Community Across Habitats and Seasons — *William F. Loftus*, U. S. Geological Survey-BRD, Homestead, FL; *Joel C. Trexler*, Florida International University, Miami, FL

29....... Ecology and Conservation of the American Crocodile in Florida — *Frank J. Mazzotti*, *Michael S. Cherkiss, Michelle Moller* and *Stephanie Kovac*, University of Florida, Belle Glade, FL; *Laura A. Brandt*, U.S. Fish and Wildlife Service - A.R.M. Loxahatchee NWR, Boynton Beach, FL

30....... Historical Ecology of the American Alligator in Greater Everglades Ecosystems — *Frank J. Mazzotti*, *Christa Zweig* and *Michelle Moller*, University of Florida, Belle Glade, FL; *Kenneth G. Rice*, U.S. Geological Survey - Biological Resources Division, Homestead, FL; *Laura A. Brandt*, U.S. Fish and Wildlife Service - A.R.M. Loxahatchee NWR, Boynton Beach, FL; *Clarence Abercrombie*, Wofford College, Spartanburg, SC

28....... A Multi-Species/Habitat Ecological Evaluation of Alternative Everglades Restoration Plans — *Frank J. Mazzotti*, *Christa Zweig* and *Michelle Moller*, University of Florida, Belle Glade, FL; *Laura A. Brandt*, U.S. Fish and Wildlife Service - A.R.M. Loxahatchee NWR, Boynton Beach, FL; *Leonard G. Pearlstine*, University of Florida, Gainesville, FL

48....... Fish and Aquatic Invertebrate Assemblages in Everglades National Park in Relation to Changes in Hydrology — *Eric B. Nelson*, *Elizabeth L. Nance* and *Sue A. Perry*, Everglades National Park, Homestead, FL

53....... Influence of Hydrology on Life History Parameters of Common Freshwater Fishes in Southern Florida — *Leo G. Nico* and *Jeffrey J. Herod*, U.S. Geological Survey, Florida Caribbean Science Center, Gainesville, FL; *William F. Loftus*, U.S. Geological Survey, Florida Caribbean Science Center, Everglades National Park Field Station, Homestead, FL; *Joel Trexler*, Florida International University, Miami, FL

52....... The Asian Swamp Eel: A Recent Invader in Peninsular Florida — *Leo G. Nico* and *Jeffrey J. Herod*, U.S. Geological Survey, Florida Caribbean Science Center, Gainesville, FL; *William F. Loftus*, U.S. Geological Survey, Florida Caribbean Science Center, Everglades National Park Field Station, Homestead, FL

25....... Adaptive Management Strategies for the Construction and Engineering Phase of the Hole-in-the-Donut Wetland Restoration and Mitigation Program - Everglades National Park — *Michael R. Norland*, Everglades National Park, Homestead, FL; *George Dalrymple* and *Nancy O'Hare*, Everglades Research Group, Inc., Homestead, FL

12....... A Method for Successful Wetland Restoration on Former Farmlands Dominated by Brazilian Pepper in the Hole in the Donut of Everglades National Park — *Nancy O'Hare* and *George Dalrymple*, Everglades Research Group, Inc., Homestead, FL; *Michael Norland*, Everglades National Park, Homestead, FL

32....... ATLSS American Alligator Production Index Model — *Mark R. Palmer* and *Louis Gross*, University of Tennessee, Knoxville, TN; *Kenneth G. Rice*, U.S. Geological Survey Biological Resources Division, Florida Caribbean Science Center, Homestead, FL

5......... Estimating Suspended Solids Concentrations in Estuarine Environments Using Acoustic Instruments — *Eduardo Patino*, and *Michael Byrne*, U.S. Geological Survey, Fort Myers, FL

33....... Thermal Regulation of the American Alligator (*Alligator mississippiensis*) in the Everglades — *H. Franklin Percival* and *Stanley R. Howarter*, U.S. Geological Survey - Biological Resources Division, Florida Cooperative Fish and Wildlife Research Unit, Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL; *Kenneth G. Rice*, U. S. Geological Survey-BRD, Florida Caribbean Science Center, Homestead, FL; *Cory R. Morea*, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL; *Clarence L. Abercrombie*, Wofford College, Spartanburg, SC

46....... Restoring Crayfish Populations in the Stressed Wetlands of Eastern Everglades National Park — *Charles A. Acosta* and ***Sue A. Perry***, South Florida Natural Resources Center, Everglades National Park, Homestead, FL

4......... **Trace Metal Concentrations in Osprey Populations in Everglades National Park: A Pilot Study**, *M. J. Lounsbury-Billie*, and ***G. M. Rand***, Department of Environmental Studies and Southeast Environmental Research Center (SERC), Florida International University, Miami, FL; *Yong Cai*, Department of Chemistry and Southeastern Environmental Research Center (SERC), Florida International University, Miami, FL; *Brien Mealey*, Department of Environmental Sciences at Miami Museum of Science, Miami, FL; *Oren L. Bass*, Daniel Beard Research Center at Everglades National Park, Homestead, FL

34....... **Home Range and Movement of the Alligator in the Everglades — *Kenneth G. Rice***, U.S. Geological Survey-BRD, Florida Caribbean Science Center, Homestead, FL; *Cory R. Morea*, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL; *H. Franklin Percival*, U. S. Geological Survey-BRD, Florida Cooperative Fish and Wildlife Research Unit, Gainesville, FL; *Stanley R. Howarter*, University of Florida, Gainesville, FL

2......... **An Assessment of Contaminant Exposures and Effects for Freshwater Mussels in the Greater Everglades Ecosystem**, ***D. Shane Ruessler***, *Nicola J. Kernaghan, Carla M. Wieser*, *Jon J. Wiebe* and *Timothy S. Gross*, U. S. Geological Survey-BRD Florida Caribbean Science Center and the University of Florida, Gainesville, FL

37....... **Predictive Spatial Models of Wading Bird Distribution in Everglades National Park — *Gareth J. Russell***, University of Tennessee, Knoxville, TN; *Stuart L. Pimm*, Columbia University, New York, NY; *Oron L. Bass*, Everglades National Park, Homestead, FL

3......... **An Assessment of Potential Contaminant Exposures and Effects for Largemouth Bass in the Greater Everglades Ecosystem — *Marisol S. Sepulveda***, *William E. Johnson, Carla M. Wieser, Jon J. Wiebe* and *Timothy S. Gross*, U. S. Geological Survey-BRD, Florida Caribbean Science Center and the University of Florida, Gainesville, FL; *Ted Lange* and *William Johnson*, Florida Fish and Wildlife Conservation Commission, Eustis, FL

27....... **Estimation and Population-Based Simulation Modeling of American Alligator Populations in Support of ATLSS — *Daniel H. Slone*** and *Jon C. Allen*, University of Florida, Gainesville, FL

45....... **Effects of Above-ground and Below-ground Fire on Soil Properties and Cattail Seedling Growth Potential in a Northern Everglades Marsh — *S. M. Smith***, *S. Newman, J.A. Leeds*, and *P.B. Garrett*, South Florida Water Management District, West Palm Beach, FL

43....... **Reintroduction of the Florida Wild Turkey to Everglades National Park — *Skip Snow***, South Florida Natural Resource Center, Homestead, FL; *Gary L. Slater*, Avian Research and Conservation Institute, Inc., Gainesville, FL

21....... **Long-term Experimental Study of Fire Regimes in South Florida Pinelands — *James R. Snyder***, *Holly A. Belles* and *James N. Burch*, U.S. Geological Survey, Ochopee, FL

14....... **Automated Vegetation Mapping and Change Detection Using Remotely-Acquired Spectral Imagery** — *Stefanie Tompkins*, *Jessica M. Sunshine* and ***Paul G. Szerszen***, Science Applications International Corporation (SAIC), Chantilly, VA and Miami Beach, FL

22....... **Vegetation on Elevated Tree Islands in the Central Everglades Water Conservation Areas, Broward and Dade Counties, Florida — *Tim Towles***, Florida Fish and Wildlife Conservation Commission, Vero Beach, FL; *Robert Pace* and *Tim Pinion*, U. S. Fish and Wildlife Service, Vero Beach, FL; *Lorraine Heisler*, U. S. Fish and Wildlife Service, Boynton Beach, FL

49....... Landscape Analysis of Fish Communities in the Florida Everglades — ***Joel Trexler***, *Frank Jordan* and *William Loftus*, Florida International University, Miami, FL; Loyola University, New Orleans, LA; U. S. Geological Survey-BRD, Homestead, FL

26....... Preliminary Differences in Abundance and Sex-Size Distribution of Pig Frog *Rana Grylio* Populations from South Florida Wetlands — *Cristina A. Ugarte*, Florida International University, Miami, FL; *Kenneth G. Rice*, U.S. Geological Survey-BRD, Florida Caribbean Science Center, Miami, FL

35....... Amphibian Inventory of Everglades and Big Cypress National Parks — *Kenneth G. Rice*, ***J. Hardin Waddle***, U.S. Geological Survey - BRD, Everglades National Park, Homestead, FL; *H. Franklin Percival* and *Raymond R. Carthy*, University of Florida, Gainesville, FL

8......... Introduction to Paleoecological Studies of South Florida and the Implications to Land Management Decisions — *Bruce R. Wardlaw*, U.S. Geological Survey, Reston, VA

9......... Trends in Tree-Island Development in the Florida Everglades — *Debra A. Willard* and *William H. Orem*, U.S. Geological Survey, Reston, VA

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16....... **Interrelation of Everglades Hydrology and Florida Bay Dynamics to Ecosystem Processes and Restoration in South Florida: Regional Simulation of Inundation Patterns in the South Florida Everglades — *Maria H. Ball*** and *Raymond W. Schaffranek*, U. S. Geological Survey, Reston, VA

15....... **Using Time-Series Satellite Imaging Radar Data to Monitor Inundation Patterns and Hydroperiod in Herbaceous Wetlands of Southern Florida — *Laura Bourgeau-Chavez***, *Kevin B. Smith*, *Suzanne Brunzell*, and *Jeff Michalek*, Veridian ERIM International, Inc., Ann Arbor, MI

6......... **Modeling Evolution of Topography and Hydrology of the Greater Everglades Ecosystem —** *Sherry Mitchell-Bruker* and ***Elizabeth Crisfield***, South Florida Natural Resources Center, Everglades National Park, Homestead, FL

13....... **Estero Bay Watershed Integrated Surface Water Ground Water Model — *Clyde Dabbs***, South Florida Water Management District, Fort Myers, FL; *Akintunde Owosina*, South Florida Water Management District, Fort Myers, FL;

4......... **The Atlantic Multidecadal Oscillation and its Relationship to Rainfall and River Flows in the Continental U.S. — *David B. Enfield***, NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, FL; *Alberto M. Mestas-Nuñez*, Cooperative Institute for Marine and Atmospheric Studies, University of Miami, Miami, FL

9......... **Canal Operations and Alternative Plans: Computer Simulations using MODBRANCH —** *Robert A. Evans*, ***Jessica M. Files*** and *Christopher J. Brown*, U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, FL

20....... **Summary of Ground-Water Related Geophysical Investigations in Everglades National Park — *David V. Fitterman*** and *Maria Deszcz-Pan*, U.S. Geological Survey, Denver, CO

14....... **Hydrogeology of the Northern Everglades — *Cynthia J. Gefvert*** and *Steven L. Krupa*, South Florida Water Management District, West Palm Beach, FL

21....... **Hydrologic Interactions between Surface Water and Ground Water in Taylor Slough, Everglades National Park — *Judson W. Harvey*** and *Jungyill Choi*, U.S. Geological Survey/WRD, Reston, VA

25....... **Water Budget Analysis for Stormwater Treatment Area 6, Section 1 — *R. Scott Huebner***, South Florida Water Management District, West Palm Beach, FL

26....... **A Pipe Manometer for the Determination of Very Small Water-Surface Slopes in the Florida Everglades —** *Jonathan K. Lee,* ***Harry L. Jenter****, Vincent C. Lai, Hannah M. Visser* and *Michael P. Duff*, U. S. Geological Survey, Reston, VA

19....... **Quantifying Hydrologic Exchange Between Surface and Ground Water in the Florida Everglades, WCA-2a —** ***James M. Krest***, U.S. Geological Survey, Reston, VA; National Research Council Associate, *Judson W. Harvey*, U.S. Geological Survey, Reston, VA

24....... **Southwest Coast of Everglades National Park Broad, Harney, and Shark River Hydrodynamics and Discharges during 1999 —** ***Victor A. Levesque***, U.S. Geological Survey, Tampa, FL

27....... **The Environmental Science and Technology Academy at Forest Hill Community High School, West Palm Beach, FL** — ***Sasha Linsin*** and *Patrick J. Gleason*, Forest Hill High School Environmental Academy, West Palm Beach, FL

23....... **Avoiding Incremental Losses of Short Hydroperiod Marl-Forming Wetlands in the Greater Everglades Ecosystem —** ***Sherry Mitchell-Bruker*** and *Elizabeth Crisfield*, South Florida Natural Resources Center, Everglades National Park, Homestead, FL

11....... **Quantifying Internal Canal Flows in Southern Florida —** ***Mitchell H. Murray***, U.S. Geological Survey, Miami, FL

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2......... **Synthesis on the Impact of 20th Century Water-Management and Land-Use Practices on the Coastal Hydrology of Southeastern Florida —** ***Robert A. Renken****, Joann Dixon, Jeff Rogers* and *Steven Memberg*, U.S. Geological Survey, Miami, FL; *Scott Ishman*, University of South Illinois, Carbondale, IL; *John Koehmstedt*, U.S. Geological Survey, Reston, VA

5......... **Development and Testing of a Surface-Water Flow Model for Shark River Slough —** ***James E. Saiers*** and *Carl Bolster*, Yale University, New Haven, CT; *Thomas J. Smith*, USGS-BRD, Miami, FL

28....... **Calculating Pollutant Travel Times to Public Water Supplies Using the Enhanced Reach File and Real-Time Stream Flow —** ***William B. Samuels****, Rakesh Bahadur* and *David E. Amstutz*, Science Applications International Corporation, McLean, VA

8......... **Recent Enhancements to the South Florida Water Management Model —** ***Everett R. Santee****, Kenneth C. Tarboton, Lehar M. Brion, Paul J. Trimble* and *Luis G. Cadavid*, South Florida Water Management District, West Palm Beach, FL

12....... **Flow Velocities in Wetlands Adjacent to Canal C-111 in South Florida —** ***Raymond W. Schaffranek*** and *Maria H. Ball*, U. S. Geological Survey, Reston, VA

10....... **Modeling the Flow Dynamics of the Southern Everglades Using a Continuous, Distributed Model —** ***Sharika U. S. Senarath****, Lehar M. Brion, A. M. Wasantha Lal* and *Mark Belnap*, South Florida Water Management District, West Palm Beach, FL

22....... **Seepage Beneath Levee 30, Miami-Dade County, Florida —** ***Roy S. Sonenshein***, U.S. Geological Survey, Miami, FL

1......... Prehistoric Hydrologic Shifts in the Everglades and Implications to Restoration — ***Peter A. Stone***, SC Department of Health and Environmental Control, Columbia, SC; *Patrick J. Gleason*, Camp, Dresser & McKee, Inc., West Palm Beach, FL

7......... Modeling Water Budget for Wetlands with Complex Plateaus — ***Marcel K. Tchaou***, *Mahendra Rodrigo*, and *Mark Renna*, The Louis Berger Group, Inc., Florham Park, NJ

3......... Seasonal to Multi-decadal Climate Variability and its Contribution to South Florida Hydrology — ***Paul J. Trimble***, *Jayantha T. B. Obeysekera*, *Luis G. Cadavid* and *E.Ray Santee*, Hydrologic Systems Modeling Department, Water Supply Division, South Florida Water Management District, West Palm Beach, FL

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35....... Communication of Hydrologic Modeling Results via the Internet — ***Jenifer A. Barnes***, *Kenneth C. Tarboton*, *Raul Novoa*, *Mark M. Belnap* and *Randy J. Van Zee*, South Florida Water Management District, West Palm Beach, FL

32....... The Everglades National Park Relational Scientific Database — ***David G. Buker*** and *Darrell V. Tidwell*, Everglades National Park, Homestead, FL

31....... Unpublished Data and Document Search and Rescue for South Florida — ***A. Y. Cantillo***, NOAA/National Ocean Service, Silver Spring, MD; *L. Pikula*, NOAA/Miami Regional Library, Miami, FL

33....... Development of a Digital Bio/Geo-library for the Greater Everglades Ecosystem — ***Gail Clement***, Florida International University, Miami, FL; *Charles Boydstun*, U.S. Geological Survey, Florida Caribbean Science Center, Gainesville, FL

30....... Spatially-Explicit Species Index Models in Application to Everglades Restoration — *E. Jane Comiskey* and ***Louis J. Gross***, University of Tennessee, Knoxville, TN

36....... South Florida Information Access (SOFIA) Website — ***Heather S. Henkel***, U.S. Geological Survey, St. Petersburg, FL

37....... The ELM Web Application — ***Jeff M. Hines***, *Dennis Dunn* and *Terry Dodge*, Florida Center for Environmental Studies, Palm Beach Gardens, FL

38....... Region Science Plan for Southwest Florida's Big Cypress Basin — ***Gary D. Lytton***, Rookery Bay National Estuarine Research Reserve, Naples, FL

34....... Design and Development of the Florida Bay Salinity Database — ***Michael Robblee***, U.S. Geological Survey, Florida Caribbean Science Center, Miami, FL; *Gail Clement*, Florida International University, Miami, FL; *DeWitt Smith*, U.S. National Park Service, Everglades National Park, Homestead, FL; *Robert Halley*, U.S. Geological Survey, Center for Coastal Geology, St. Petersburg, FL

29....... Development of the Cook Inlet Information Management/Monitoring System (CIIMMS) — ***William B. Samuels***, Science Applications international Corporation, McLean, VA

36....... South Florida Information Access (SOFIA) Metadata — ***Jo Anne Stapleton***, U.S. Geological Survey, St. Petersburg, FL

Social and Human Sciences

39....... Smart Growth for Wildlife — *Michael R. Bauer*, Everglades Project Office, National Wildlife Federation, Naples, FL

40....... The Florida Earth Project — *Stanley C. Bronson*, PBC Cooperative Extension Service, University of Florida, Gainesville, FL

41....... Environmental Restoration of Lake Trafford — *Eric Flaig*, Lake Trafford Restoration Task Force, Collier County, FL

Water Quality and Water Treatment Technologies

55....... Interactions between Dissolved Organic Matter and Mercury — ***George Aiken*** and *Mike Reddy*, U. S. Geological Survey, Boulder, CO; *Mahalingam Ravichandran*, U. S. Environmental Protection Agency, National Exposure Research Lab, Athens, GA; *Joseph N. Ryan*, Department of Civil, Environmental and Architectural Engineering, University of Colorado, Boulder, CO

54....... Trace Metal Contamination in the Everglades Ecosystem — *Yong Cai* and *Myron Georgiadis*, Florida International University, Miami, FL

56....... Origin of Elevated Mercury Concentrations in Fish from Florida Bay — *David W. Evans* and *Peter H. Crumley*, NOAA/Center for Coastal Fisheries Habitat Research, Beaufort, NC

42....... Water Quality of Lake Trafford, Florida — *Eric G. Flaig*, South Florida Water Management District, Immokalee, FL; *George Vilmaz*, Collier County Pollution Control, Naples, FL; *Frank Morello*, Florida Freshwater Fish and Game Commission, West Palm Beach, FL; *Frank Grant*, *Kenneth Dugger and John Zediak*, U.S. Army, Corps of Engineers, Jacksonville, FL; *Jon Ingelghart*, Florida Department of Environmental Protection, Ft. Myers, FL

51....... Investigation of Polycyclic Aromatic Hydrocarbons and Quinone Photoproducts Everglades Canals C-11 and C-111 — *S. Haynes* [1,2], ***R. Gragg***[1], *C. Orazio*[2], *J. Lebo*[2], *W. Cranor*[2], *R. Clark*[2], *J. Petty*[2], and *J. Huckins*[2], [1]Environmental Sciences Institute, Florida Agricultural and Mechanical University, Tallahassee, FL, [2]U.S.Geological Survey–Columbia Environmental Research Center, Columbia, MO

58....... Linking Aquatic Monitoring with Remote Sensing: Neuse River, NC — *Ronald S. Kaufmann*, *Jeffery L. Beacham* and *Raul Mercado*, Earth Tech, Inc, Boca Raton, FL; *Mark Karaska*, *Robert Huguenin*, Applied Analysis, Inc., Billenca, MA; *John Jensen*, University of South Carolina, Columbia, SC

53....... Aquatic Cycling of Mercury in the Everglades (ACME) Project: Synopsis of Phase I Studies and Plans for Phase II Studies — *David P. Krabbenhoft*, *Mark L. Olson* and *John DeWild*, U.S. Geological Survey, Middleton, WI; *Cynthia C. Gilmour*, Academy of Natural Sciences, Benedict Estuarine Laboratory, St. Leonard, MD; *William H. Orem*, U.S. Geological Survey, Reston, VA; *George R. Aiken*, U.S. Geological Survey, Boulder, CO; *Carol Kendall*, U.S. Geological Survey, Menlo Park, CA

47....... **Nutrient Loading to Biscayne Bay and Water-Quality Trends at Selected Sites in Southern Florida — *A. C. Lietz***, U.S. Geological Survey, Miami, FL

43....... **Water Quality in the Everglades and other South Florida Basins, 1996-98 — *Benjamin F. McPherson***, *Ronald L. Miller*, *Kim H. Haag* and *Anne Bradner*, U.S. Geological Survey, Tampa, FL

44....... **South Florida Water Quality Protection Program —** *Melissa L. Meeker*, *Kris McFadden* and ***Emily Murphy***, Florida Department of Environmental Protection, West Palm Beach, FL

50....... **Modeling the Assimilative Capacity for Phosphorus through the Canal System of 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

52....... **Assessment of Sediment Toxicity in the St. Lucie River Watershed and Everglades Agricultural Area — *G. M. Rand***, *J. Carriger* and *T. Lee*, Florida International University, North Miami, FL

48....... **Benthic Nutrient Fluxes Near Florida Bay's Mangrove Ecotone — *David Rudnick***, *Stephen Kelly*, *Chelsea Donovan*, *Karl Picard* and *Ben Reufer*, Everglades Department, South Florida Water Management District, West Palm Beach, FL; *Jeffrey Cornwell* and *Michael Owens*, Horn Point Environmental Laboratory, University of Maryland, Cambridge, MD

57....... **Assessment of Methylmercury Risk to Three Species of Wading Birds in the Florida Everglades — *Darren Rumbold***, Environmental Monitoring and Assessment, South Florida Water Management District, West Palm Beach, FL

46....... **Toward Integrated Water Resource Quality Monitoring in South Florida Estuaries — *Cecelia A. Weaver***, South Florida Water Management District, Miami, FL

45....... **Status of Water Quality Criteria Compliance in the Everglades Protection Area** — ***Kenneth Weaver***, *Temperince Bennett* and *Grover Payne,* Florida Department of Environmental Protection, Tallahassee, FL

49....... **Optimal Conditions for the Determination of Total Phosphorous in Water — *Meifang Zhou*** and *David Struve*, South Florida Water Management District, West Palm Beach, FL

Oral Abstracts

Ecology and Ecological Modeling

Manatee Aerial Surveys in South Florida

Bruce B. Ackerman and Holly H. Edwards
Florida Marine Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL

Aerial surveys of Florida manatees (*Trichechus manatus latirostris*) are an effective tool for monitoring manatee populations in south Florida. Many protection efforts are based on documented aerial sightings of manatees. Aerial surveys have been conducted since 1967 in Florida and are valuable for rapidly assessing manatee distribution, relative abundance, population size and trends, and use of habitat types. Three kinds of surveys are used: year-round distribution surveys, winter aggregation surveys, and winter synoptic surveys (Ackerman 1995).

Year-round distribution surveys are conducted in nearshore waters by the Florida Fish and Wildlife Commission (FWC) and other agencies. Most surveys are twice-monthly for two or more years, using small, high-winged airplanes. Distribution studies have been made in 27 counties since 1984, by FWC and contractors, and other agencies. All of the counties in South Florida have been well studied in the 1990's (Lee, Collier, Ten Thousand Islands, Monroe, Everglades National Park, Florida Bay, Florida Keys, Palm Beach, Broward, Dade counties) by FWC and contractors. Similar surveys are ongoing by the Dade County Department of Environmental Resource Management and the USFWS Ten Thousand Islands Refuge.

Aerial survey data are used for manatee protection at all levels of government, and are important components of manatee protection plans, county growth management plans, boat speed zones, and reviews of permits for coastal activities. Most manatee aerial survey data and flight paths since 1984 are available on the 2000 FWC Atlas of Marine Resources CD-ROM in ArcView GIS software format. An FWC technical report summarizing the manatee aerial survey research is in preparation.

These aerial survey approaches have also been used for other special purposes. During the winter and spring of 1996, 11 multi-plane flights were made to document the distribution of manatees in southwest Florida during the red tide mortality event. Strip-transect surveys were made in the Ten Thousand Islands in 1993 to test an innovative method for estimating population trends, as developed previously for the Banana River (Miller et al. 1998). This method will be tested again in the Ten Thousand Islands by the USFWS.

Statewide synoptic winter aerial surveys cover all manatee wintering habitats in Florida and southeast Georgia, and are conducted 2-3 times each winter after cold fronts, when manatees aggregate at natural springs and thermal discharges. Manatees are counted by 28 survey teams, including 20 airplanes and helicopters. Forty biologists from 15 state, federal, county and private agencies, and research labs and universities participate.

Synoptic surveys were conducted 15 times from 1991 to 2000. Most of the manatees are found at powerplants and natural springs, but sometimes many are counted at unheated sites, such as deep canals in south Florida (e.g., Matlacha Isles, Cape Coral, Port of the Islands, Miami). The record statewide count was 2,639 manatees in February 1996 (1,457 manatees on east coast of Florida; 1,182 manatees on west coast). Three surveys were conducted in 1999. The highest count was 2,353 manatees on 6 March 1999 (east coast, 956; west coast, 1,397, the highest count ever recorded for the west coast). In 2000, two surveys were made. The highest count was 2,222 manatees on

January 27, 2000. More manatees were counted in southeast (800) and southwest (620) Florida than in recent years.

Winter aerial surveys of manatees at powerplants were conducted (Reynolds and Wilcox 1994, Reynolds 2000, etc.) at 8 powerplants, 4 of them in south Florida. These surveys have been conducted several times each winter after cold fronts since 1977, for more than 130 flights. These flights provide valuable data on manatee winter distribution, minimum population size, and trends. Detailed studies of the statistical trends in the winter counts have been conducted by Garrott et al. (1994) and Craig et al. (1997) using state-of-the-art statistical methods. Counts at the east coast power plants were shown to be increasing significantly in 1977-92. Additional studies are being conducted in 2000, to assess the accuracy of these counts. These trends probably reflect actual growth in the manatee population, but may also be related to other changing factors. Of particular importance are counts of 300-500 manatees in winter near some powerplants. Large concentrations of manatees may set the stage for high numbers of deaths, from disease, cold, red tide, oil or chemical spills, etc. Deaths in 1982 and 1996 from red tide in southwest Florida occurred when large winter aggregations of manatees dispersed in spring towards feeding grounds (O'Shea et al. 1991, Bossart et al. 1999).

Anticipated powerplant de-regulation may cause changes in plant operations that affect how the manatees use the powerplants. De-regulation may cause some powerplants to be used fewer hours in the day and fewer days each winter.

Proposed changes to the hydrology of the Greater Everglades in southeast and southwest Florida will change the habitat for manatees, likely affecting freshwater sources, deep canals used for warmth in winter, and seagrass beds used by manatees. Studies previously conducted in these areas provide valuable background data.

Aerial surveys and population models suggest manatee numbers have slowly increased, but this trend could reverse as human impacts increase. Therefore manatee protection efforts must continue. Manatees are threatened by increasing human populations, increasing watercraft, increasing manatee mortality rates, and habitat degradation. Catastrophic events remain important, unpredictable factors. Reducing human-related mortality of manatees must remain a primary emphasis of the recovery process.

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Spatial and Stage-Structured Models of American Alligator Populations in Support of ATLSS

Jon C. Allen and Daniel H. Slone
University of Florida, Gainesville, FL

A map-driven spatial simulation model for alligator population densities in the Everglades is introduced. Supporting the ATLSS (Across Trophic Level System Simulation) model of the USGS-BRD, this simulation model uses GIS maps of land elevation, habitat types, and daily water levels from a 3,000 km^2 section of the Everglades. Its purpose is to simulate the south Florida ecosystem, and estimate alligator population densities and spatial distributions under varying management strategies.

The age-structured alligator population is represented as a 3-dimensional array, $N(i, j, k)$, indexing the number in age group k at spatial location (i, j). This array interacts with the habitat, elevation and water level maps, and other inputs such as fish density and alligator life-table data to determine growth rates, reproduction and survival of the alligators, and the production of “alligator holes”: deep pools of water created by alligators that trap water and fish during times of low water level.

Dispersal of the alligators is performed with discrete spatial convolution, where a dispersal probability density function (pdf) known as a dispersal kernel interacts with the population density map to ‘spread out’ the existing population. This process is similar to a ‘blur filter’ applied to a 2-d image in a photo editing computer program, except we are able to specify the precise attributes of the filter. It is possible to apply different dispersal kernels to specific areas on the map, depending on existing geologic and climatic conditions.

As part of this project, we will use water management structure maps to develop spatially varying dispersal patterns. In particular we will examine the habitat with & without canals and dykes in various locations in order to assess the effect on alligator population growth and survival under different management options. The finite rate of increase, λ, will be mapped and compared under different management scenarios, and the alligator response will be judged on both spatial distribution and total abundance criteria.

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The Expectation Approach to Evaluating Restoration Projects

David H. Anderson
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Louis A. Toth
South Florida Water Management District, West Palm Beach, FL

One of the challenges in defining successful restoration for south Florida ecosystems is the development of success criteria or expectations. Often restoration goals are broad, historical (pre-impact) data are lacking, and regional reference sites are unavailable. We met this challenge for the Kissimmee River restoration by devising a strategy for developing multiple expectations using the best available reference condition (historical, other rivers, best professional judgement).

An expectation describes the anticipated qualitative (e.g., directional) or quantitative response of a system attribute to restoration. Each expectation lists endpoints, which relate it to the Kissimmee River restoration's broad goal of reestablishing ecological integrity. Baseline data for the impacted system and the reference condition are identified, and the difference between the two indicates the magnitude of the impact. Providing a mechanism for each expectation reduces the chance that differences between baseline and reference conditions represent temporal (historical reference) or spatial (reference site) variability.

Scientists involved in the collection of baseline data for this project used this process to draft sixty-one expectations for the Kissimmee River restoration that address abiotic (e.g., hydrology and water quality) and biotic (e.g., plant communities, fish, wading birds) components of this system. These expectations are based on different kinds and sources of information and are likely to vary in their reliability as indicators of restoration success. Thus, a final step in the development of expectations is to rank them by their reliability as indicators of restoration success and to integrate them as an overall measure of restoration success. Expectations can be ranked by criteria related to their accuracy (quantity and quality of the reference condition) and the power to detect a change (signal-to-noise ratio). Ranking analysis can be used to reject less reliable expectations or to split them into groups, which can be weighted differently in the integration.

Determination of restoration success depends on evaluating each expectation and integrating the results. Integration can be expressed as the number achieved, the number achieved relative to the anticipated trajectory, or a narrative considering the relationships among expectations. These different forms of integration are not mutually exclusive and can be used to communicate appropriate levels of detail for different audiences.

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Hydrologic and Topographic Gradient Effects on Woody Vegetation of Tree Islands in the Everglades Wildlife Management Area

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Water management within the Everglades Wildlife Management Area (EWMA) has been a longstanding challenge. Currently, efforts are underway to restore hydrological patterns such as flow, quantity, and quality of water. However, it is unknown what effects these restoration efforts will have on the tree islands present in the area. Although tree islands make up a relatively small spatial area within the EWMA, they are essential for the functional integrity of the Everglades ecosystem. For example, greater than 80% of the woody diversity of the EWMA is found exclusively on tree islands, and they provide important habitat for local fauna.

Because of the gradual sloping nature of tree islands with respect to the surrounding marsh, determining appropriate hydrology is particularly difficult. Therefore, we determined environmental gradients of native woody species of vegetation on a subset of tree islands located in two hydrological zones within the EWMA. Nine islands were chosen in the hydrologically dry northern zone of the EWMA and ten were chosen in the moderately wet zone just south of Alligator Alley. At each site, relative elevation, woody species diversity, richness, and density were collected. In addition, Arcview Spatial Analyst was utilized to interpolate both hydroperiod and ponding depth for the entire area using actual water gauge data. Gauge data from 1980 to 2000 were used and the average elevation at each gauge site was determined for hydroperiod calculations.

Both hydroperiod and ponding depth were significant independent variables when analyzed together or separately. It was found that hydrology explained 20-50% of the woody vegetation characteristics present on tree islands. Relative elevation by itself did not explain as much of the variability in the data as hydrology, but when these were analyzed together in multivariate regression analyses, they explained 50-74% of the data.

This study showed that hydrology is a determinant of woody vegetation characteristics on tree islands. In addition, the tree islands that most resemble the species composition of those found in the 1940's were surrounded by marshes with hydroperiods of 80-90% and average ponding depths of 0.24-0.43 m. It was also found that the tail and fringe community, which is lower in relative elevation than the head community, was higher in woody species diversity. The tail community represents an intermediate stress area. The surrounding hydrology is producing a disturbance within this community sufficient enough to initiate succession and therefore, causing an increase in diversity. It was also found that tree islands without a tail and fringe community had a much higher density of nonnative species than those with a tail and fringe community. The tail and fringe community appears to be acting as a buffer against invasion by exotic woody species. Most of the tree islands in the hydrologically dry zone have lost this buffering community through drought conditions and severe muck fires, and have become infested with nonnative woody species. In light of these findings, it is important to reestablish the tail and fringe communities when restoring tree islands of the Everglades. The Everglades restoration process needs to consider appropriate hydroperiod, ponding depth and community type when determining hydrological success criteria within the sawgrass marsh region of the greater Everglades ecosystem.

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The Caloosahatchee Estuary Conceptual Model

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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). An essential step in this strategy has been the creation and refinement of a set of 9 conceptual ecological models, each for a different physiographic region of south Florida. The models link physical stressors on the ecosystem to ecological attributes that are considered to be indicators of ecosystem health. Each of these linkages represents a working hypothesis based upon current knowledge of the ecosystem.

The Caloosahatchee Estuary Conceptual Model is an example of these models. Two workshops were conducted in 2000, with special efforts made to invite local scientists, to refine an earlier version of this model. Four stressors were identified for this region. They include Sea Level Rise, Land Use and Development, Water Management, and Navigation. Likewise, six ecological attributes were chosen as endpoints to be measured in a system-wide monitoring program. These attributes are predominately based on specific habitat found within the estuary and include oyster bar community structure and function, open bottom community structure and function, SAV community structure and function and shoreline mangrove habitat. Two additional attributes were identified to cover overlap between the habitat-based attributes. These are fisheries and manatee population abundance and health.

Scientists were also asked to identify key uncertainties in the model and to refine the performance measures identified for each attribute. We summarize the creation of the conceptual models, their function, and give and example of a model (Caloosahatchee) with identified uncertainties and refined performance measures.

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Tree Island Studies at the Arthur R. Marshall Loxahatchee National Wildlife Refuge

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Tree islands have been identified as a critical habitat in the Everglades and are a signature feature of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (refuge). Little is known about the flora and fauna of tree islands or how the native flora and fauna are impacted by exotic species and water management practices. The vision of the refuge is "To serve as an outstanding showcase for ecosystem management that restores, protects and enhances a portion of the unique northern Everglades biological community..." This includes managing to maintain tree islands and their ecological function. To successfully do this, data are needed that describe the characteristics of tree islands, monitor how they change over time, and to address why those changes occur. With this in mind, in 1999, studies were initiated on tree islands to better understand their ecology, and to begin the process of addressing management related questions particularly relating to patterns of hydrology and invasion by exotic species.

Ideally, science should progress from initial observation through a series of logical steps to the recognition of the functional relationships in the system. The first steps in the process are primarily descriptive and set the stage for developing cause effect relationships and hypotheses for testing. Because few studies have been conducted on tree islands in the refuge, their importance to wildlife, their vegetation structure and elevation, our first task was to learn more about the physical and biological characteristics of the islands. Initial studies fall into three broad categories: tree island biological diversity, effects of exotics, and tree health and growth.

Initial studies of tree island biological diversity at the refuge have focused on vertebrate species richness. One year of trapping and observation has been conducted on five small (< 100m in length) bayhead islands within the interior slough located along a north-south hydrologic gradient. Islands were selected that had similar structure and were not connected to other islands. Trapping consisted of drift fences with funnel traps, minnow trapping along the edge of the islands, small mammal trapping, track stations, point counts, and observation of sign and individuals. Seventy-one vertebrate species (11 amphibians, 12 reptiles, 36 birds, 6 mammals, and 6 fish) were observed or trapped on or along the edges of the islands from June 1999-June 2000. Islands showed differences in species, and less than a third of the species were observed on all five islands. These data will contribute to baseline data for studies of the effects of exotics and water management on tree islands. Future studies will include inventories of insect and plant community structure as well as collection of physical data on topography.

Lygodium microphyllum is a fern native to Asia that has been introduced into south Florida and poses a potential threat to native communities. Fern ladders grow over vegetation and appear to blanket and change the existing vegetation structure and composition. In the refuge, Lygodium is estimated to cover almost 9,100 ha of the interior of the refuge and is spreading at a rapid rate. A basic question is what effect does Lygodium have on native plant and animal communities. This study examined vegetation species richness and percent cover in ground cover, shrub layer, and overstory in one 4 x 5 m plot on each of 10 tree islands in the refuge. Five of the islands had dense infestations of Lygodium and five had very low or no infestation. Species richness was similar between infested islands and non-infested islands; however, percent cover of native species was reduced in infested plots from 64% to 3%, 33% to 4%, and 66% to 9% in the ground, shrub, and overstory, respectively. This study illustrates the impact that Lygodium can have on native tree island communities in south Florida.

Next year a study will be initiated that examines the effect of both Melaleuca and Lygodium on the food base for passerines. The objective of this study is to inventory and compare the flora and fauna of tree islands infested with Lygodium and Melaleuca to bayhead islands that are uninfested to assess the impacts of these two exotics on native communities. Results from this study will provide data on how these two exotics may be changing native community composition by changing vegetative structure or displacing native species and will address the impacts of these two exotics on the food base (fruits and insects) for neotropical migratory birds.

A minimum of twelve islands will be used for this study, three heavily impacted with Melaleuca, three heavily impacted with Lygodium, and six unimpacted islands. Vegetative structure and composition will be quantified for the ground cover, shrub layer, and canopy on each island using a combination of quadrat and transect techniques. Occurrence of vertebrates, insects and the presence of fruits will be quantified monthly. Species richness, community composition, and structure will be compared among the island types. This project will provide much needed information on the differences in flora and fauna between islands with native vegetation and those impacted with exotics.

A study initiated in 1999 is underway to examine the health and growth of trees on the five islands used for the biological diversity studies. In December-February, 457 trees were tagged and coded as the condition of their canopy. Trees were reassessed in July, 2000. One hundred ninety-four (42%) of the trees were *Persea borbonia*, 123 (27%) *Myrica cerifera*, 110 (24%) *Ilex cassine*, 27 (6%) *Chrysobalanus icaco*, and 3 (<1%) *Salix caroliniana*. The differences between the winter and summer assessment reflect seasonal patterns of leaf out. Hereafter assessments will be conducted quarterly and will be linked with changes in hydrology. Concurrently, dendrometer bands are being placed on 18 trees on each of the five islands. Six trees of *P. borbonia*, *I. cassine*, and *M. cerifera* will be banded to measure their growth and/or shrinkage over time. This will lead to a greater understanding of how trees on tree islands respond seasonally, and to changes in hydrology.

All of these data will form the basis for the development of an Ecological Characterization of tree islands within the refuge. Additional data will be collected on island elevation, vegetation, and surrounding water levels. The five islands used for the biological diversity and tree growth and health studies will be the base, but randomly selected islands will be included to get a better representation of the variability of structure and function of islands within the refuge. The overall goal of these projects is to provide data on refuge resources that can be used to develop a framework for testing cause effect relationships that will lead to better management decisions.

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Historical Reconstruction of Seagrass Distribution, Water Quality and Salinity, Using Molluscan Indicator Species

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Molluscan fauna have been used successfully to reconstruct historical information for the last 200 years on seagrass distribution, water quality, salinity, biodiversity, and faunal abundance in Florida Bay. Molluscan assemblages identify significant perturbations of an environment and filter out "noise" caused by day-to-day or short-term fluctuations, such as those caused by tropical storms. Estuarine molluscs tolerate a wide range of fluctuating environmental conditions, yet on a scale of seasons, their populations will migrate to more ideal conditions as Lyons (1996, 1998) has demonstrated. Individual molluscs, however, are relatively limited in their movement in post larval stages, and typically provide information about a specific site for the duration of their lifetime. In addition, molluscs occupy a number of trophic levels and represent a diverse, significant component of the biomass of the Florida Bay ecosystem. Lyons (1999) recorded 235 species of molluscs over the course of a three-year sampling period (1994-1996). These molluscs occupy components of the micro-, meio-, and macro-fauna of the bay and they employ a number of feeding strategies, including filter feeding, grazing, scavenging, and carnivory. Their diverse strategies allow this single group to serve as a proxy for the trophic structure and ecologic health of the system.

Evidence for significant changes in abundance and distribution of seagrass and sub-aquatic vegetation (SAV) in Florida Bay can be seen by examining the distribution of epiphytic species. Molluscs that live on macro-benthic algae or seagrass have increased during the 20th century in the Bob Allen, Russell Bank and Taylor cores. Species that live on seagrass exclusively have declined relative to the general SAV dwellers since approximately 1970 at Bob Allen and Russell, and in the upper portions of Pass and Taylor. While substrate data are very site specific, repetition of this trend in these four cores (as well as other cores not reported on here) indicates this may reflect a genuine increase in SAV during the 20th century throughout eastern and central Florida Bay. If, through examination of additional cores, this trend can be substantiated, it would have a profound impact on restoration efforts. These data imply that the abundance of seagrass in Florida Bay in the latter half of the 20th century may represent an anomaly.

Brachidontes exustus is a euryhaline species that can tolerate diminished water quality, and it is nearly ubiquitous at sites in central and eastern Florida Bay today. Beginning around 1980, *Brachidontes exustus* becomes the most dominant species at Russell Bank and Bob Allen, and it increases in dominance in the upper portion of the cores from Pass Key and Taylor. The concentration of this euryhaline opportunist species in the upper portion of all the cores implies that the system has been under increasing stress in the last 20 years, either due to increased salinity fluctuations and/or diminished water quality.

Molluscan faunal data illustrates important changes in the distribution of fresh and low salinity water in northern transitional, eastern, and central Florida Bay. Since approximately1900, there has been a steady decline in fresh water and mesohaline (<12 ppt) molluscs at the mouth of Taylor Creek. *Anomalocardia auberiana*, typical of the northern transitional zone, has remained relatively constant at this site. Pass Key core, southeast of Little Madeira Bay, records significant fluctuations in *Anomalocardia auberiana* and other species indicative of the northern transition zone in the latter half of the 20th century. Changes in salinity at Taylor Creek and Pass Key may be due to water management practices, fluctuations in average annual precipitation, sea level, or a combination of all of these. Russell Bank core, in eastern Florida Bay, shows distinctive changes in the molluscan assemblage between 1910 and 1930; *Anomalocardia auberiana*, consistently present in low percentages prior to 1920, completely disappears from the site after that time, indicating more saline conditions. At Bob Allen mudbank, in central Florida Bay, a dramatic shift in faunal assemblages occurred between 1900 and 1910 when a *Brachidontes exustus* assemblage becomes dominant. Changes that occur between 1910 and 1920 at Bob Allen and between 1910 and 1930 at Russell indicate a shift toward less stable conditions. During this time period, average rainfall did not fluctuate significantly in southern Florida, but substantial human alteration of the environment occurred with the construction of Flagler Railroad in the Keys. Given the current data, it is impossible to determine if the construction contributed to changes in the molluscan fauna, but evidence indicates that the railroad restricted the natural exchange of water between the bay and the Atlantic Ocean (Swart *et al.*, 1996).

Several measures of diversity were calculated for the cores: 1) total number of individual molluscan specimens; 2) faunal richness; 3) evenness; and 4) Shannon's diversity index. Evenness is a measure of how evenly dispersed the total number of individuals are among the faunal categories; the higher the value, the more evenly dispersed the individuals are. Shannon's diversity index (Shannon and Weaver, 1949) is a measure of the degree of uncertainty that a randomly selected individual will belong to a certain species. In general, these measures of diversity all fluctuate over time, which is to be expected in an estuarine environment. However, at Bob Allen and Russell Bank, evenness shows an inverse relationship to the percent abundance of *Brachidontes* in the upper portion of the core. This is consistent with our hypothesis that the increase in *Brachidontes* in the last two decades indicates a stress-induced system.

Molluscan data help to clearly define restoration goals on a number of components critical to successful resource management. Information on seagrass distribution, salinity, water quality, and biodiversity, interpreted from molluscan data, can be used in models by water and land managers. By establishing what the system was like prior to significant human influence, and examining how the system has changed during the 20^{th} century, mangers can establish realistic success criteria for restoration efforts. By answering the question "What was the system like 100 years ago?" we can answer the question "What should the system look like after restoration?" and we also can answer the question "How will the system respond to the changes induced by restoration?"

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Water Birds in Florida Bay: Conspicuous Ecological Indicators?

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Water birds are conspicuous consumers that allow an aerial view of ecosystem function. A monthly aerial census of Florida Bay provides the first comprehensive multi-species, bay-wide view of the abundance, spatial distribution, and seasonality of large water birds in the Bay. In this census, wading birds, diving birds, and raptors, are counted by species, specific location, type of habitat, and behavior. The aerial survey is a joint environmental project of the National Marine Fisheries Service and Everglades National Park. It is made possible by the Miami Air Station of the U.S. Coast Guard, which provides the platform, an HH65 Dolphin helicopter, as well as the pilot and flight mechanic.

The flights started in March, 1995, and almost five complete years' of monthly records have been entered into a data base. The data show the pattern of variation in abundance through the entire year and allow comparison of patterns of abundance among years. The first two survey years (1995-1996 and 1996-1997) were relatively wet years in South Florida (except for the months January-March, 1997). The summer of 1998 was a relatively dry wet season. The strongest dry season occurred January-May, 1999.

For the first nine months of the survey, regular-spaced (1-nautical-mile-spaced) transects were flown. Flights departed from transects to circle every island within 1/2 mile distance from the transect and to identify birds spotted from a distance; then the transect was re-entered and along-transect flight continued. The transects were oriented north to south, and flights were initiated in the western part of each area being covered on a given day in order to be roughly in phase with the progression of tidal stage across the bay. Beginning in January, 1996, and based on our experience the first 9 months, we developed a more efficient means of covering the Bay and reduced our flight time to two days per month. In doing this, we discontinued the transect pattern and focused our coverage on islands and exposed banks. We either circle them or fly along their longer axes. We have roughly the same geographic coverage each month, which includes all of the Bay except the southwestern outer banks.

We record behavior and habitat, as well as number. Behaviors recorded in the survey include wading in or floating on the water, perching on posts or snags over water, roosting in trees, nesting, standing on the ground, standing on the shore at the water's edge, and flying. Flying birds are distinguished depending on whether they are flying over islands, banks, or open water. In summarizing the data or preparing it for spatial analysis, birds loafing or nesting on islands (in trees or on the ground or shore) and on posts, are compiled separately from those wading, and presumably feeding, on interior ponds of the islands or wading on banks or floating in the bay (the pond and bay water birds also are distinguished). By compiling the data in this manner, we can examine how the different habitats of the Bay are being used by the birds at the time of our flights. Nesting birds are distinguished so that the temporal and spatial distribution of nesting can be analyzed for each nesting species.

Study objectives are to (1) determine waterbird usage of various types of bay habitat, (2) determine overall abundances, (3) compare present to past abundances for the few species that have been counted previously, (4) compare abundances and seasonal usage of the bay to that in mangrove and freshwater areas of Everglades National Park, and (5) determine whether annual variations in waterbird abundance in the Bay could be related to water management.

One focus of the study is to determine the extent to which wading birds are able to feed on the banks and shallow flats of the bay at lower tidal stages. Our observations allow us to estimate the extent to which the aquatic resources of the bay support water bird populations, the effects of daily, lunar, and annual cycles of the tide, and how the parts of the bay differ in their support value for the various water bird species. Wading and water birds, because they can be seen from the air, provide a view of the productivity of the bay and a means to compare one part of the bay to another. This analysis may provide some insight on ecological ramifications of the sea grass dieoffs and algal blooms that affect some areas.

There has been no other recent monthly systematic survey or census of wading and water birds in the Bay, although other natural areas of South Florida are covered routinely. Published and unpublished information from past censuses of some wading bird species may allow us to make comparisons with their abundances in previous years.

Wading birds are viewed as indicators of large scale ecological conditions in the Everglades, but little is known about the extent to which these birds depend on Florida Bay for food. A comparison of the absolute numbers and seasonal patterns in abundances of birds in the Bay to birds in mangrove and freshwater areas of the mainland may provide some insight on the relative usage and movements of various wading bird species between these two major habitats. Abundance estimates from the long-term Systematic Reconnaissance Survey of the freshwater and mangrove part of Everglades National Parks are now available and will be compared with abundance estimates from the aerial census of Florida Bay.

Our most important study objective is determine how waterbird usage of Florida Bay is affected by freshwater inflow to the Bay. These flows are affected not only by rainfall but also by management of the Central and Southern Florida Water Management Project. The C&SF Project presently is undergoing review and reconfiguration in an effort to reduce its impacts on natural areas such as the Everglades and Florida Bay. Large water birds may be useful indicators of the ecological health of Florida Bay as well as that of the Everglades. Determining relationships between waterbird abundance and freshwater inflow require time series of data. The longer the time series, the more likely a valid relationship can be found.

Our study has revealed that many small wading bird species feed in Florida Bay. Until our Project, it was know that several small wading bird species nest on certain islands in the northern Bay, but they were thought to feed in coastal and freshwater wetlands. We now know from our flights that the feeding distribution of Little Blue Herons, Snowy Egrets, and Tri-colored Herons extends deeply into the bay, not just along the northern fringe. For example, large numbers of Little Blue Herons have been observed feeding on the broad bank between Man O' War Key and Sandy Key.

Our comparison of species abundances in the southern Everglades to those in Florida Bay indicates that some wading bird species are using the Bay more than the southern Everglades during some years. The Great Blue Heron was consistently more abundant in the Bay than in the southern Everglades during the first three study years. There is considerable year to year variation, both in the number and proportion of birds feeding in Florida Bay. Some of these differences appear to be related to variation in seasonal patterns of rainfall and freshwater inflow.

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Impact of Hydroperiod on Planktonic Copepod Communities in ENP: Preliminary Results

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1) Introduction

Although major effects of altered hydropatterns on some aquatic communities of ENP have been demonstrated, the effects on zooplanktonic communities have not been studied. Copepods are the zooplanktonic group with highest density in ENP. There are no historical data on copepod richness, but the low species richness recorded in ENP, which is lower than in much of North America, might have resulted from past and present water management, with the consequent periodic droughts and frequent drydowns due to canal operations.

The restoration of the historical hydroperiods in the Everglades is a major conservation issue, and the Rocky Glades and Eastern Everglades have been particularly affected by hydrological diversions, and by operational and structural water management.

During the dry season 1999, we investigated planktonic copepods communities in solution holes in short-hydroperiod habitats (Rocky Glades). We assessed whether differences in depth classes or in site were the responsible for the main differences in species composition and total number of individuals among the stations. During the wet season 1999, we focused on locations with short to intermediate hydroperiods, to assess if and how the different hydroperiods affected the species assemblages of copepod communities.

The information obtained will help us to understand how the copepod communities will respond to anticipated increases in hydroperiod. Given the importance of copepods as food for several common fish species living in the marshes, a better knowledge of copepod species composition and dynamics in the different habitats will be useful in modeling food-web changes in the system as a consequence of water management operations.

2) Materials and Methods

During the dry season 1999, when in the short hydroperiod sites solution holes were isolated from each other, i.e. from 12 January 1999 until the solution holes dried (30 March), we sampled at each of three sampling sites, named LPK5, LPK7 and LPK8, within the shortest hydroperiod Rocky Glades region. At each LPK site, we selected three solution holes of different depths (deep, medium, and shallow, designated LPK5D, LPK5M, LPK5S, etc, within an area of about 100 m^2. Each week during the dry season 1999,), were we collected quantitative samples.

During the wet season 1999, from the beginning of July, we used Brakke's modified Whiteside-Williams pattern samplers (multiple-funnel trap) to collect planktonic copepods that follow dial movements into the water column. Samples were collected on July 14-19, August 12-18, September 16-20, October 12-13 (for this date only at Long Pine Key and Pa-hay-okee sites, because of the Hurricane Irene impact on water levels in the long hydroperiod sites), November 9-11, December 7-9 (from this date on, Long Pine Key sites dried, and samples were not collected), January 19-20, February 17-18 (Chekika samples not collected, since the site dried).

The sampling stations were:

- Chekika (CKK) (25°38.598" N, 080°34.556W);
- North Taylor Slough (NTS)25°26.171" N, 080°35.353W);
- South Taylor Slough (STS) (25°18.438" N, 080°374.516W);
- Long Pine Key station 7 (LPK7), (25°25.608" N, 080°39.394W);
- Long Pine Key, station 8 (LPK8), (25°25.706" N, 080°39.440W);
- Pa-hay-okee, near NP62 NPS monitoring station (25°26.256" N, 080°46.961W).

For each station, 10 traps were set randomly and retrieved after 24 hours.
Water depth, temperature, pH, conductivity, salinity and dissolved oxygen were recorded for each sampling station.

3) Results and discussion

3.1) Dry season

The results from the plankton study showed that sampling site was responsible for the main differences in species composition and total number of individuals among the stations. There were no significant differences in total numbers of copepods among the depth classes of stations when considered together regardless of site. The solution holes were characterized by a high level of environmental instability, and yet the sites were quite similar in species richness. Cluster Analysis showed that the shallow and medium holes were quite similar, whereas the deep ones differed in total number of copepods. Within the deep stations, LPK5 had the lowest diversity, and LPK7 had the highest diversity but low numbers of individuals. LPK8D differed from the other sites because of the high number of individuals and species, but low diversity.

3.2) Wet season

The analysis of chemical-physical characteristics of the stations showed that
NTS differs from all the other stations, even on a temporal scale: the water management operations on L31 canal through S-175 and S-332 introduce water with high conductivity, which impacts the naturally oligotrophic ENP habitats.
CKK being impacted by NESS water management operation, has an altered hydroperiod, and its chemical-physical characteristics were similar to the Rocky Glade short hydroperiod marl prairies.
For short hydroperiod sites, while LPK7 and LPK8 are very similar, PHK was impacted by Hurricane Irene and retained water for a long time; this station was as average more similar to STS, and considering temporal variations it was similar to the other Rocky Glades stations at the beginning of the wet season.

At the onset of the wet season, richness and diversity were low at all sites, as can be expected, because the populations are re-established after the drought from resting stages, re-colonization from groundwater or surface water, and anemochorous and biochorous dispersal. The total number of individuals was comparatively high, confirming a high emergence from resting stages. The population growth and species recruitment were rapid, since in a month diversity and richness almost doubled, even if total number decreased in the Rocky Glades sites (LPK7, LPK8, PHK), and it increased in the long hydroperiod sites (STS, NTS, CKK). Total numbers continued to increase until they reached a maximum in December, when diversity and evenness started to decrease. There has been a species turnover: some rare, or late-season species appeared, or some species became very abundant, just before producing resting stages.

In January LPK sites were dry, and in February CKK was also dry. The other sites, which should have been dry, according to the rain pattern, were kept flooded because of water management procedures in pumping sites along L31W canal. In these two months evenness and diversity increased: it can be assumed that when the water levels dropped, at the end of the wet season, habitat became more selective, and towards the end of the period only few euriecious species were exploiting the habitat. Nonetheless, as soon as the water level artificially rose again, population restarted to reproduce.

4) Conclusions

The research developed during the season, showed that hydroperiod has a primary influence on planktonic copepod communities: the short hydroperiod habitats, even if very selective, have been colonized by a group of very eurioecious, opportunistic species of copepods. The more detailed study on community composition, carried on during the wet season, underlines again the importance of solution holes in the Rocky Glades area, and the consequent higher spatial heterogeneity, leading to more complex communities. The East Everglades appear to be a sensitive area, which are strongly affected by water management operations due to its proximity to the pumping stations and canals.

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The Effect of Enhanced Freshwater Inflow on Sedimentation and Elevation Change in Mangrove Forests of Southwestern Florida

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The $8 Billion dollar restoration of the Greater Everglades Ecosystem is being guided in large part by decisions based on science. However, scientists working on the restoration acknowledge that our understanding of the complete ecosystem will forever be incomplete. The Science SubGroup of the Everglades Task Force has provided a list of priority research areas and items needed to address the ecological success of the restoration (Science Subgroup 1994). Additionally they provide a compilation of Ecological and Precursor Success Criteria for this project (Science Subgroup 1997). Among the most urgent of science information needs is knowledge of processes leading to soil formation in the various wetland communities, which make up the Everglades. These include sawgrass plains, marl prairies and mangrove forests. One of the most dramatic changes in the Everglades ecosystem has been alteration, and loss, of the organic soils caused by drainage (Stephens 1984).

Mangrove forests comprise the downstream, brackish and saline end of the Everglades ecosystem. A dominant tree in these forests is the red mangrove, Rhizophora mangle. This species is unusual in that it has a tremendous peat building capability which is much greater than other tree species considered to be mangroves (Cohen and Spackman 1977). This peat is primarily composed of root material which is highly refractory. Questions have recently arisen concerning the ability of mangroves to "keep up" with sea level rise induced by global warming. In the southwest Everglades an additional factor to consider is salinity and how salinity affects belowground production and hence peat accumulation. If belowground production is related to sediment porewater salinity, and the anticipated restoration leads to changes in the timing and amount of freshwater inflows, then one might expect changes in peat accumulation in mangrove forests.

The purpose of the research described herein was to determine how enhanced freshwater inflow and input of nutrients could affect soil accretionary processes in mangrove forests of the southwest Florida coast. Rates of vertical accretion, sediment elevation change, and shallow subsidence were measured simultaneously in two mangrove sites - Ten Thousands Islands NWR and Everglades National Park. Vertical accretion was measured from artificial soil marker horizons and elevation change was measured using a surface elevation table. Shallow subsidence was calculated as the difference between vertical accretion and elevation change (Cahoon et al. 1995).

Ten Thousand Islands NWR. In 1997, sampling stations were established within mangroves in the vicinity of Faka Union Canal which shunts freshwater draining from Golden Gates Estates into the eastern portion of Ten Thousand Islands. This site represents the high freshwater inflow site. Sampling stations were also established within mangroves in the vicinity of the Blackwater River which drains a comparatively unaltered watershed. This site represents the low freshwater inflow site. Data were collected from fringe, interior, and overwash mangrove settings four times over three years. The accretion rate was virtually the same for both regions (3.5 (0.3) vs. 3.2 (0.2) mm y^{-1}, Blackwater and Faka Union, respectively) suggesting there was little difference in sediment delivery at the two sites. However, Faka Union mangroves gained elevation at a significantly greater rate than Blackwater mangroves (5.5 (0.5) vs. 3.5 (0.3) mm y^{-1}). In addition, the rate of elevation gain significantly exceeded the accretion rate at Faka Union (p=0.006) indicating that the increase in elevation was caused by subsurface processes. The influence of subsurface processes was most prevalent in interior mangrove forests. These data suggest that the increased freshwater inflow from the Faka Union Canal enhanced sediment elevation gain in interior forests by increasing soil volume through either increased root volume or increased porewater storage, or a combination of the two.

Everglades National Park. In 1998, sampling stations were established in the upper and lower reaches of the Shark River and in the marine-dominated mangrove forests along Big Sable Creek. The upper Shark River sites were located at the ecotone between mangroves and freshwater marsh while the lower Shark River sites were located about 1 km from the mouth of the river. Hence, there is a strong salinity and tidal energy gradient. All stations were established in interior forests. The accretion rate increased while elevation change decreased from upstream to downstream (accretion = 1.7 (0.2), 5.8 (0.3), and 7.0 (1.6) mm y^{-1}; elevation = 1.2 (3.3), -2.3 (2.5), and -8.4 (3.4) mm y^{-1}). The tidally influenced sites had significant rates of shallow subsidence indicating that subsurface processes strongly influenced elevation. Also, the upper and lower river sites showed strong seasonal changes (up to 20 mm) in elevation, perhaps caused by changes in freshwater inflow, with the lower site responding later than the upper site. However, there was no seasonal pattern to elevation change in the marine-dominated site. These data suggest that subsurface processes influencing elevation in these mangrove forests respond directly to changes in freshwater inflow and tidal energy.

Implications. The findings from these two studies clearly indicate that subsurface processes, such as root growth or water storage, have a significant impact on sediment elevation in mangroves of southwest Florida. Given that sea level is likely to rise, our findings suggest that an increase in freshwater inflow to the coastal systems may help mangroves keep pace with sea-level rise even if no additional sediment is transported to the coast.

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Trophic Interactions of Large-carnivorous and Small-omnivorous Fishes in Freshwater Marshes of the Florida Everglades

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Two important features of freshwater marshes in the Everglades have not been thoroughly researched. First, a lack of information about large-carnivorous fishes has led to dichotomous descriptions of their importance, from suggestions that they control population growth of small fishes to suggestions that they are too rare to be ecologically important. Second, Everglades marshes support an unusually large standing stock of periphyton, often manifested in a calcareous floating mat. Interactions between grazers, including small-omnivorous fishes, and periphyton are complex because nutrient regeneration by omnivores can stimulates algal growth and physical features of mature periphyton mats can impede grazing. We conducted caging experiments to clarify the role of large-carnivorous and small-omnivorous fishes in the Everglades food web. Closed treatments demonstrated that mosquitofish, the numerically dominant small-omnivorous fish, significantly reduced recruitment of macroinvertebrates, but had no significant net effects on either mature periphyton mats or new growth of epiphytic algae. We also used open and refuge treatments to examine effects of large-carnivorous fishes, and found significantly greater use of the refuge treatment by small fishes, amphibians, and macroinvertebrates. Greater abundance of grazers in the refuge treatment significantly reduced new growth of epiphytic algae, but did not affect mature periphyton mats. Our experiments suggest large fishes in the Everglades may be abundant enough to at least influence habitat selection by prey taxa. Additionally, patterns of grazer effects suggest physical features of mature periphyton mats that impede grazing may be critical to food web interactions in this system.

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Regional Controls of Population and Ecosystem Dynamics in an Oligotrophic Wetland-dominated Coastal Landscape - Introducing a New Long Term Ecological Research (LTER) Project in the Coastal Everglades

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Estuaries and coastal landscapes experience a range of stresses, both natural and anthropogenic. Among these, cultural eutrophication affects most U.S. coastal ecosystems. As a result, most coastal ecological research has been conducted in systems that are experiencing eutrophication. In our new Florida Coastal Everglades LTER project (FCE LTER), we are investigating how variability in regional climate, freshwater inputs, disturbance, and perturbations affect land-margin ecosystems. This coastal LTER project is particularly appropriate for studying these questions because the entire system is oligotrophic, it is the focus of the largest watershed restoration effort ever implemented, and freshwater flow is controlled in different ways by the highly variable precipitation regime and water management. Our long term research program focuses on the following central idea and hypotheses:

Regional processes mediated by water flow control population and ecosystem level dynamics at any location within the coastal Everglades landscape. This phenomenon is best exemplified in the dynamics of an estuarine oligohaline zone where fresh water draining phosphorus-limited Everglades marshes mixes with water from the more nitrogen-limited coastal ocean.

Hypothesis 1: In nutrient-poor coastal systems, long-term changes in the quantity or quality of organic matter inputs will exert strong and direct controls on estuarine productivity, because inorganic nutrients are at such low levels.

Hypothesis 2: Interannual and long-term changes in freshwater flow controls the magnitude of nutrients and organic matter inputs to the estuarine zone, while ecological processes in the freshwater marsh and coastal ocean control the quality and characteristics of those inputs.

Hypothesis 3: Long-term changes in freshwater flow (primarily manifest through management and Everglades restoration) will interact with long-term changes in the climatic and disturbance (sea level rise, hurricanes, fires) regimes to modify ecological pattern and process across coastal landscapes.

We are testing these hypotheses along freshwater to marine gradients in two Everglades drainage basins. We have observed a clear productivity peak in the low salinity zone of one but not the other. This peak appears to be the result of low P, high N freshwater meeting higher P, lower N marine water. We are quantifying nutrient regeneration from dissolved organic matter (DOM), and expect this to be a major contribution to this oligohaline productivity peak. We are also examining how this stimulus of the microbial loop affects secondary production. This LTER will thus focus on how changes in freshwater flow and climatic variability control the relative roles that nutrients and organic matter play in regulating estuarine and coastal productivity.

Our transect design is conceptually analogous to a Lagrangian approach in which we follow parcels of water as they flow through freshwater marshes and mangrove estuaries to offshore. Along the way, we quantify patterns and processes in the water and in the wetlands through which it is flowing using long-term sampling and short-term mechanistic studies. We are quantifying: 1) primary productivity; 2) concentrations and turnover dynamics of inorganic nutrients and organic matter (particularly DOM); 3) organic matter accretion and turnover in soils and sediments, and; 4) consumer dynamics and productivity. We use process-based simulation models to link key components, such as the relationships between DOM quantity and quality, microbial loop dynamics, and higher trophic levels. Data synthesis also includes hydrologic models to simulate water residence times along the transects, and a GIS-based project database that integrates data from this LTER research with information from other related projects. The GIS database will be linked to our FCE LTER web site to maximize the exchange and dissemination of information within the south Florida scientific, management, and regulatory community as well as within the NSF LTER Network.

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ALFISHES: A Size-Structured and Spatially-Explicit Model for Predicting the Impact of Hydrology on the Resident Fishes of the Everglades Mangrove Zone of Florida Bay

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A model (ALFISH) for functional fish groups in fresh-water marshes in Greater Everglades area of Southern Florida is extended to create a new model (ALFISHES) to evaluate the spatial pattern of fish densities in the community of resident fishes of the Everglades mangrove zone of Florida Bay. Both the ALFISH and ALFISHES models were developed as part of the Across Trophic Level System Simulation (ATLSS) project. (The model simulates fish from a single functional group, small fish (<110 mm in length). The model is size-structured and spatially-explicit. These fish constitute an important prey base for large fish, reptiles, and birds, which are important indicators of ecosystem health. The model combines field data assessing the impact of salinity of fish biomass with hydrology data from the USGS Southern Inland Coastal Systems (SICS) numerical model.

The estuarine landscape consists of a spatial grid of 500 × 500 meter cells across the coastal areas of the Florida Bay. Each cell is divided into two habitat types, flats, which are flooded only during the wet season, and creeks, which are always wet and serve as refugia during the dry season. Daily predictions of water level and salinity are obtained from the SICS model. As in the fresh-water model, the fish spread out into the flats during flooded conditions. As the cells dry out, the fish either retreat by moving into creeks, move to other spatial cells, or die if their cell dries out. The model output may be used to assess the impact of changes in hydrology on fish biomass and its availability to wading bird and other consumer populations.

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

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We investigated living and fossil epiphytal ostracodes from central and eastern Florida Bay to determine historical trends in seagrass and macro-benthic algal habitats during the past century. Living assemblages collected in February and July, 1998 from 15 sites throughout Florida Bay revealed that *Loxoconcha matagordensis* and *Malzella floridana* are the dominant species living on *Thalassia* and that *Xestoleberis* spp. is the most abundant ostracode group living on *Syringodium* and marine algae such as *Chondria*. *Peratocytheridea setipunctata* is a species that is common on muddy substrates and on *Halodule*.

Temporal trends in epiphytal ostracodes were reconstructed from radiometrically-dated sediment cores from Whipray mudbank, Russell Banks, Bob Allen mudbank, Pass and Park Keys, Taylor Creek (near Little Madiera Bay) and Manatee Bay. The results show that there have been frequent changes in the relative frequencies of *L. matagordensis, M. floridana,* and *Xestoleberis* over the past century. Prior to the mid-20th century, seagrass- and algal-dwelling ostracode species were relatively rare at our sites in central and eastern Florida Bay. Ostracode assemblages living between about 1900 and 1940 were characterized by moderate to large proportions (10 - >60%) of *Peratocytheridea setipunctata* when *Thalassia* and macro-benthic algal species were significantly less common than during the later half of the 20th century. Beginning about 1930, and continuing until 1950, *P. setipunctata* populations experienced significant declines while *L. matagordensis* and *Xestoleberis* increased progressively from 0 - 10% to >25 - 40%, depending on the site. This long-term faunal shift in central Florida Bay suggests that there has been a much greater abundance and/or density of subaquatic vegetation ver the past 50 years compared to the prior half century. Since 1950, our sites in central and eastern Florida Bay have experienced high amplitude swings in the proportion of seagrass and macro-benthic algal-dwelling species suggesting subaquatic vegetation has been extremely dynamic both spatially and temporally over decadal timescales. Some of these oscillations, such as the decline in *L. matagordensis, Xestoleberis,* and *M. floridana* during the 1970s and early 80s, appear to be synchronous across the study area and may represent large-scale dieoffs. [This abstract is from the volume "Paleoecology Studies of South Florida" edited by Bruce R. Wardlaw, American Bulletin of Paleontology, in press].

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American Alligator Nesting and Reproductive Success in Everglades National Park

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Wherever it is found, the activities of the alligator have led to the use of the term keystone species to emphasize its ecological importance in wetlands dynamics. Alligators are a top predator in Everglades wetlands and help to shape the trophic-dynamics of the ecosystem. Alligators excavate and maintain "gator holes" that serve as dry season refugia for fishes and aquatic invertebrates and, therefore, more prey for wading birds. Finally, alligator nests serve as important oviposition sites for other reptiles. Hydrological conditions are known to have effects on the percent of the female population nesting, the percent of the eggs in nests that flood, and the growth rates and condition of young alligators.

This project will develop a thorough analysis of alligator nesting effort and reproductive success in relation to water conditions in Everglades National Park. The analysis is based upon data collected between 1985 and 1998 as part of the Systematic Reconnaissance Flight (SRF). The alligator data are valuable for evaluation of greater Everglades restoration hydrological planning alternatives, modeling, and independent evaluation of breeding potential models for this species. The analysis of the SRF alligator data will give the National Park Service an independent method for assessing the impacts of suggested water management modifications on this keystone species. The results will be used to evaluate water management alternatives developed by the Central and Southern Florida Project Comprehensive Review Study.

All of the data for nests from 1985 through 1998 have been entered into two databases. The first database deals with all nests observed during all SRF trips and are now plotted on the ENP GIS by sub-basin. The second database has all of the data available for all subsets of nests that were visited on the ground. The number of eggs per nests, the number of fertile and infertile eggs, the number of flooded eggs, predated eggs, and hatched eggs are included.

The vast majority of alligator nesting occurs in the Shark Slough. Nests have been analyzed by year and by basins. A total of 931 nests have been observed on flights of standard transects in ten basins and 785 or 84% were from Shark Slough. All analyses for patterns and trends have been analyzed for all basins. Likewise, in 1985 and 1986, some non-standard transects were surveyed. All results to date have been analyzed for each and all basins, and for standard and non-standard transects and no inconsistencies have been found.

The data from the flights was mapped using the park's GIS facilities. The maps permit us to evaluate nest locations in relation to condition (percent flooding, fertility), proximity to other nests, elevation, water depths, soil and vegetation conditions.

Results are preliminary, since all the water depth data have not been entered into the database to date. Additional work needs to be done to find data for water depth at nests for some years, or to extrapolate water depth from recording gages. Plots of nests by geographic location using the park's GIS have not demonstrated any strong relationship between location and nest flooding.

The year 1993 not only had the most nests observed on standard flight transects, it also was the only year in which no surveyed nests (ground truthed) flooded. Therefore, 1993 is particularly important for evaluating hydrological conditions prior to nest preparation and prior to hatching. The years 1985 and 1989 had the fewest nests observed. Year 1988 has a very high average percent of eggs flooded per nest (61%), but the sample size of only 14 nests was exceptionally small (the mean number of nests sampled per year from standard transects was 31). The recent high water years of 1994 -1997 do not show significantly higher numbers of eggs flooded per nest.

Previous studies of alligator populations in the Everglades National Park suggested that the major problem facing the alligators in the park since scheduled deliveries of water began in 1971 was higher than natural levels of nest flooding. The hypothesis proposed in some earlier work suggests that in the period before the first full year of scheduled deliveries started in 1971, there was a very significant correlation between early summer (June) water levels and later maximum water levels in the Shark River Slough. After 1971 there was no correlation. Alligators in Shark River Slough used to be able to build nests in relation to early summer water levels that were correlated with maximum water levels later in the season. Therefore, egg mortality due to late summer increases in water level was minimized. Since 1971 there has been no or reduced correlation between early summer water levels and late summer levels, and hence there is a greater likelihood of egg mortality from nest flooding. This hypothesis is based upon the idea that pre-nesting water depths determine the height at which alligators build their nests and later flooding is exacerbated by managed releases in excess of expected natural increases. In the total sample of ground surveyed nests from 1985 through 1998 (N = 477), 22.2 percent of all the nests were listed as having some number of eggs flooded and only 17.8% had more than 95% of the eggs in the nests flooded. While nest flooding may have always been an important source of egg mortality for alligators in Shark Slough, it does not appear to be at a level that should severely impact the population. However, water management practices may be able to significantly increase egg mortality in some years, e.g. 1988. Levels of nest flooding may have been lower in the past, and reduction in nest flooding is one possible ”target” for improved conditions for alligators under future schedules. However, a better "target" might be hydrologic conditions that increase the percentage of females nesting per year or hydropatterns that both increase nesting rate while reducing nest flooding. The results of the current analyses will evaluate and rank such alternative "targets".

Preliminary review of the data on the height of the clutch in individual nests, the characteristics of the proximal habitat and elevation of the nest, as well as the widely dispersed pattern of flooded nests (when plotted on maps) indicate that predicting nest flooding by general location may not be possible. The importance of this to future SRF survey work is that nest location alone will not predict nest flooding, i.e. more than an aerial evaluation is required. The follow-up ground surveys of selected nests would still be required to determine nest flooding. In the final analyses the distribution of flooding by geographic location, elevation, and water conditions at the beginning of the nesting season (July 1st) will be included. In addition, the relationship between nest location, number of females nesting, and nest flooding in relation to releases of water from management structures versus local rainfall will be evaluated.

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Apple Snail Populations: Persistence in Hydrologically Fluctuating Environments

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The apple snail *(Pomacea paludosa*) is a critical food web component in Florida wetlands, one for which further research needs have been identified in the South Florida wetlands restoration efforts. Adult-sized (>25 mm shell width) Florida apple snails (FAS) are the exclusive food of the endangered snail kite (*Rostrahamus sociabilis plumbeus*). Other documented predators of snails include limpkins (*Aramus guarauna*), white ibis (*Eudocimus albus*),boat-tailed grackles (*Cassidix mexicanus*), alligators (*Alligator missippienisis*, redear sunfish (*Lepomis microlophus*), and soft-shelled turtles (*Trionyx ferox*).

Despite their long recognized importance in Florida wetlands, especially for the endangered snail kites, surprisingly little is known about the life history, ecology, and population dynamics of FAS. The primary impetus for FAS ecological research stems from managing wetland and lake water levels to support Florida's population of endangered snail kites. Wetland habitats that are important to snail kites periodically dry down (the hydrologic condition wherein the water table falls below ground level). Increased frequency and duration of dry downs beyond natural levels are generally accepted as detrimental to snail kites. The detrimental impact is assumed be depressed FAS populations, although scant data exist. For 30 years researchers have suggested that continuous inundation benefits snails, and therefore snail kites. However, dry downs are a natural process in the evolution and maintenance of Florida's mosaic of wetland plant communities. We hypothesize that dry downs may be necessary for the long-term maintenance of suitable snail habitat, as has been suggested for snail kites.

The overall goal of our research has been to elucidate the relationship between hydrologic fluctuations and FAS population demographics. Specifically our objectives were to 1) determine the behavioral responses of apple snails to drying events, 2) estimate size-class-dependent survival rates of FAS in dry down conditions, and 3) describe the life cycle of apple snails in the context of seasonal fluctuations in water level.

Our approach to observing snail populations and hypothesis testing involved two parallel efforts: 1) field studies of egg cluster production and monitoring adult-sized snails using radio-telemetry; and 2) controlled laboratory studies using snails from all size classes (3-5 mm hatchlings up to 35 mm adults). Females oviposit egg clusters on emergent vegetation above the water line. We monitored egg cluster production using the same three transects of 1x2.5 m quadrats (n=15 per transect) for the past 4.5 years. Radio transmitters were glued to snail shells and monitored for 1) movements in response to hydrologic gradients, and 2) survival during inundated and dry down conditions. In laboratory studies we simulated drying events and monitored survival for large snails (>25 mm) in pre-reproductive, reproductive, and post-reproductive condition. More recently we looked at dry down survival for hatchling (<6 mm), small juvenile (>6-9 mm) and larger juvenile (10-15 mm) snails.

Telemetry studies revealed that apple snails do not seek out deep-water refuge during a dry down. Ten centimeters appears to be a threshold level at which snail movements become impeded and snails soon become stranded. As residual water levels recede, these stranded snails become subjected to dry down conditions wherein they aestivate. During aestivation snails contend with moisture loss, energy loss (metabolism continues at a reduced rate) and predation by substrate probing birds. The predation rate on stranded snails during a two-month dry down was 48%. This far exceeded predation on adult snails in water (5% per month).

Telemetry studies revealed that regardless of hydrologic conditions, adult apple snail populations decline rapidly from May through August. Egg cluster production occurred from March through October, but peak production occurred between early April and late June. The adult die off begins during peak reproduction, so it appears there is an annual post-reproductive die-off.

In 1998, snails were collected prior to the onset of egg cluster production for a laboratory study designed to simulate a dry down. We found that these pre-reproductive snails survived at a rate of 75% after 3 months and 50% after 4 months of aestivation. In another experiment, we used snails collected in August, therefore including some post-reproductive and some young of the year snails. Initially survival declined, reflecting deaths of post-reproductive adults. This survival drop was followed by 4 months survival at 48% attributed to the remaining young of the year snails.

We tested our hypothesis that hatchling snails experience rapid early growth (13 mm per month) in part as a strategy for surviving an ensuing dry down. We conducted laboratory studies with <6 mm, >6-9 mm, and 10-15 mm snails to see if survival varied due to snail size. Hatchlings in dry conditions survive for just 1 week at 48% and 0% after 3 weeks. It appeared that once snails exceed 9 mm in width they had the capacity to survive dry downs in excess of 1 month with survival rates greater than 40%. Larger juveniles (10-15 mm) exhibited a survival rate of 60% over the same period.

The newly acquired information on FAS ecology, coupled with earlier reports, reveal the importance of understanding snail life history strategy in the context of water management during the dry season. Apple snail reproductive strategy appears well adapted to receding waters. Oviposition peaks during the spring dry season. Receding water benefits the eggs because they avoid inundation, which terminates developing embryos. Rising temperatures increase hatch success and hatchling growth rates. We hypothesize that rapid growth enables juveniles to survive an ensuing dry down, and our recently acquired data appear to support this hypothesis. [It is also likely that predator avoidance contributes to selection for rapid snail growth]. Dry downs may be essential for apple snails because they help maintain the emergent vegetation necessary for oviposition and aerial respiration. Despite some short term localized population losses due to desiccation, suppressed recruitment, and increased predation by probing foragers (e.g., white ibis), we encourage water management agencies to allow dry downs in support of persistent vigorous snail populations. The relationship between snail abundance and hydroperiod has not yet been established, but clearly Florida apple snail life history is adapted to periodic dry downs under natural hydrologic conditions.

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Conceptual Model Development, Uncertainty Identification and Research Prioritization for the Comprehensive Everglades Restoration Plan

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Conceptual ecological models have been developed for 9 physiographic regions of south Florida to guide the Comprehensive Everglades Restoration Plan (CERP) regarding restoration performance measures, targets and uncertainties. Models developed to date include Everglades Ridge and Slough, Marl Prairies and Rocky Glades, Big Cypress, Mangrove Estuarine Transition, Florida Bay, Biscayne Bay, Lake Okeechobee, Caloosahatchee Estuary, and St. Lucie Estuary/Indian River Lagoon. Each model links physical stressors on the ecosystem, such as altered hydrology or water quality, to ecological attributes that are considered to be indicators of ecosystem health, such as fish or alligator populations. The linkages, or causal pathways, between stressors and attributes represent working hypotheses based upon our current knowledge of the ecosystems.

A series of workshops during summer 2000 gathered scientists working in each of the physiographic regions to clarify the hypotheses underlying the linkages in the models and to critically evaluate each hypothesis regarding our level of certainty in the causal relationships. Areas of highest uncertainty were identified as the highest research priorities to better predict and interpret ecosystem changes as CERP is implemented.

We summarize the key restoration hypotheses and uncertainties from the workshops, and examine commonalities and differences between the physiographic regions, to suggest an integrated and prioritized research strategy in support of CERP.

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Across Trophic Level Systems Simulation (ATLSS) Program

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The USGS Florida Caribbean Science Center's Restoration Ecology Branch has developed a set of computer simulation models at the landscape level: Across Trophic Level System Simulation (ATLSS). These models can provide detailed projections of effects of different hydrologic conditions on several key species on the Greater Everglades landscape and have played a role in assessing Everglades restoration plans. The strategy of this modeling approach to restoration is reviewed here, key results of the program to date are reviewed, and future directions are discussed.

The immediate objective of the USGS's ATLSS Program has been to utilize the outputs of hydrologic models to drive a variety of ecological models that compare the relative impacts of alternative hydrologic scenarios on the biotic components of South Florida. This approach provides a rational, scientific basis for ranking the hydrologic scenarios as input to the planning process. The longer term goals of ATLSS are to help achieve a better scientific understanding of components of the Everglades ecosystem, to provide an integrative tool for empirical studies, and to provide a framework for long-term monitoring and adaptive management.

ATLSS is constructed as a multimodel, meaning that it includes a collection of linked models for various physical and biotic systems components of the Greater Everglades. The ATLSS models are all linked through a common framework of vegetative, topographic, and land use maps that allows for the necessary interaction between spatially-explicit information on physical processes and the dynamics of organism response across the landscape. This landscape modeling approach is the work of USGS scientists and collaborators from several universities.

The ATLSS multimodeling approach uses input hydrology from the South Florida Water Management Model, which uses a 2 x 2 mile spatial grid. First, ATLSS models translates this hydrologic information to a finer spatial resolution appropriate for some biotic components. The development of such a high resolution hydrology uses GIS vegetation maps and empirical information relating hydroperiods associated with various vegetation types, to infer an approximate hydrology with 500 x 500 meter resolution water derived from the 2-mile resolution hydrology model.

The simplest level models of the ATLSS family are the Spatially-Explicit Species Index (SESI) models, which make use of the spatially-explicit, within-year dynamics of hydrology compute indices for breeding or foraging success of several species. These indices are computed for each year (or summations over a number of years) and at each 500 x 500 meter spatial cell, to produce index maps. Maps generated for different water management scenarios are then compared. SESI models have been constructed and applied during the Central and Southern Florida Comprehensive Review Study (Restudy) to the Cape Sable seaside sparrow, the snail kite, short- and long-legged wading birds, and white-tailed deer, and American alligators.

Considerably more detailed models have been developed for the distribution of functional groups of fish across the freshwater landscape. This model considers the size distribution of large and small fish as important to the basic food chain that supports wading birds. It has been applied to assess the spatial and temporal distribution of availability of fish prey for wading birds.

Individual-based models, which track the behavior, growth and reproduction of individual organisms across the landscape, have been constructed for the Cape Sable seaside sparrow, the snail kite, The white-tailed deer, the Florida Panther and various wading bird species. The models include great mechanistic detail, and their outputs may be compared to the wide variety of organism distribution data available, including that from radio collared individuals. An advantage of these more detailed models is that they link each individual animal to specific environmental conditions on the landscape. These conditions (e.g., water depth, food availability) can change dramatically through time and from one location to another, and determine when and where particular species will be able to survive and reproduce. ATLSS models have been developed and tested in close collaboration with field scientists who have years of experience and data from working with the major animal species of South Florida.

The most important need in Greater Everglades restoration is the ability to predict the relative effects of different alternative restoration plans, compared with the based case of no restoration. The ATLSS integrated family of models has been used extensively for that purpose in Everglades Restoration planning. In particular, it has been used in the evaluation of the effects of Restudy, ModWaters, and C-111 hydrology scenarios on key biota.

To date, the focus of ATLSS to date has been on the freshwater systems, with emphasis on the intermediate and upper trophic levels. The ATLSS structure was purposely formulated to provide for extension to estuarine and near-shore dynamic models once physical system models for these regions are completed. Modeling of the mangrove vegetative community, estuarine fish, crocodiles, and roseate spoonbills is now underway. Additional species, such as the manatee, may be added. Future plans for the ATLSS Program also include development of vegetative succession models for important community types.

To make the outputs of the ATLSS models easy to view and analyze in a variety of ways, one of the ATLSS projects is developing an Internet based GIS visualization tool. This will be expanded into a full-scale decision support system, giving agencies the capability of accessing information relevant to any particular management issues, as well as the capability of running any of the ATLSS models.

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Mangrove Prop-Root Fish Assemblages as Indicators of Salinity Change

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Diversion of freshwater from the C111 canal into Taylor Slough changes the salinity characteristics of northeastern Florida Bay where it adjoins the Everglades. In this area, the estuary is dominated by a red mangrove fringe. We examined the mangrove prop-root fish assemblage in the wet and dry seasons to ascertain what changes might occur more permanently from freshwater diversion. We used diver visual census to compare fish assemblages across a salinity gradient in northeastern Florida Bay and Manatee Bay. Diver census allows non-consumptive survey of the fish assemblage but lower visibility in the prop-root environment makes diver interaction with the fishes unavoidable. We used an innovative remote underwater video platform (RVP) to view the fishes with less disturbance and without diver interaction. This allowed us to determine biases associated with the diver census such as the attraction or repulsion of fishes by the diver and view fish behavior in the mangroves under more normal conditions. Cichlids, snook, and grunts were noted to flee from the diver leading to slight under representation in the divers counts. While mangrove snapper that appeared to be attracted to the diver exhibited the same behavior in the RVP footage. Among the fish, the best indicator of low salinity conditions was the absence of blue-striped grunts and low abundance of silversides. In addition, there was a change taxonomic change from hardhead to tidewater silversides when moving from high to low salinity conditions. Concurrent sampling of larval fishes with light traps suggests that under present conditions northeastern Florida Bay is a poor recruitment and spawning area for fishes.

Further long-term monitoring of mangrove-prop root fishes could be used as an inexpensive non-consumptive performance measure of the success of water diversion into Taylor Slough.

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Hydrology, Nutrient Supply and The Lower Trophic levels of The Everglades Marshes

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Hydrology and nutrient supply are two major environmental forces of the Everglades marshes. They drive the dynamics of aquatic food webs and determine the distribution and abundance of many taxa and ecological guilds. The primary producers and primary consumers comprise the lower trophic levels of food webs. Their abundance sensitively respond to the changes in hydrology and nutrient supply. Their responses may further affect the abundance of their predators, thus "trickle up" the effects of hydrology and nutrient supply to the higher trophic levels of the food web. In the ecological restoration of the Everglades, to restore natural hydrology and to reduce nutrient enrichment are two primary measures. The food web structure is an important attribute of restoration success.

This presentation describes a model of the lower trophic levels of the aquatic food webs in the Everglades marshes. The model simulates trophic interactions and the influence of hydrology and nutrient supply. The model contains seven trophic groups: periphyton, macrophytes, detritus, herbivorous grazers, detritivores, omnivores, and predators. Periphyton and macrophytes are primary producers. They produce detritus as they die. Periphyton, macrophytes, and detritus comprise the base level of trophic structure. Herbivores mainly graze on periphyton, omnivores consume both periphyton and detritus, and predators prey upon grazers, detritivores and omnivores. Grazers, detritivores, and omnivores are primary consumers. They comprise the second trophic level.

Phosphorus limits primary productivity in the oligotrophic Everglades marshes. The phosphorus supply mainly affects the growth of periphyton and macrophytes. The growth rates increase with phosphorus concentration in water column, following the Michaelis-Menton equation. The Michaelis-Menton model assumes that the growth rate increases rapidly with P at low concentrations of P, while the increase per unit increment of P diminishes and becomes insignificant at high P concentrations. At high concentration, phosphorus has a detrimental effect on the integrity of periphyton assemblage, and leads to breakdown of floating periphyton mats. This negative effect is represented by a response of the maximum physically supportable standing crop to phosphorus concentration. Thus, the periphyton standing crop can be high at low phosphorus concentration and declines to a low level when phosphorus concentration rises.

Hydrology affects the performance of trophic groups, and thereafter, the food web dynamics. Hydrological effects were examined in two ways. First, in simulation analyses, the water depth was chosen as an environmental forcing variable. The model used a simple hydrological engine that simulates the dynamics of water depth and produces different dynamic scenarios. The hydrological engine is a sinusoidal equation with three parameters, based on the study of Nuttle (1997). The water depth determines survival of aquatic organisms. The mortality is minimal and the abundance potential of a trophic group is maximal in a certain range of water depth. If the surrounding water is either too deep or too shallow, the survival probability and thus the abundance are low. Secondly, the effects of hydroperiod on food webs were examined implicitly in the analysis of long term behaviors. The mortality was assumed to be proportional to the length of dry phase. The effects of hydroperiod were revealed by comparing consequences of different mortality corresponding to certain hydroperiods.

Both steady state analyses and dynamic simulations were conducted. These model analyses reconstructed the aquatic food web patterns and led to three hypotheses. The steady-state analysis presented a general picture of the trophic interactions. The interior equilibrium appears to depend on both trophic transfer efficiencies and mortalities in a complicated way. At the steady states, the standing crops of periphyton and detritus and the abundance of predators are linearly positively correlated. Among primary consumers, the abundance of herbivorous grazers and detritivores are negatively and linearly correlated to the abundance of omnivores. The mortality of herbivores and detritivores and the mortality of omnivores play opposite roles in determining the trophic structure of food web. Similarly, the trophic transfer efficiencies of herbivores and detritivores and that of omnivores also play opposite roles.

Omnivores often do better than either herbivores or detritivores, or both. They persist with a large range of trophic transfer efficiencies and mortality. For example, the survivorship of either herbivores or detritivores or both needs to be higher than that of omnivores, for all of them to coexist, even if the trophic transfer efficiency of omnivory is moderately lower. I call this the omnivory dominance hypothesis.

An increase in the trophic conversion efficiency from detritus into either detritivores or omnivores or both can reduce the abundance of herbivores and increase the abundance of periphyton. A strong detrital channel may support abundant predators that in turn suppress herbivores. This will create a trophic cascade in the herbivorous food chain. I call this the apparent trophic cascade hypothesis. The apparent trophic cascades differ from the traditional trophic cascades in the maintaining mechanism. The maintaining mechanisms of the apparent trophic cascade include shared predators of different groups of primary consumers and food subsidies from the detrital pathway.

The simulation output show several patterns. First, the primary producers show seasonal fluctuations. The seasonal pattern concurs with the seasonal pattern of hydrology. Among the primary producers, macrophytes show a small seasonal variability. Periphyton shows a large seasonal variability. Both show an unimodal pattern. These patterns are consistent with field observations.

Primary consumers appear to fluctuate more irregularly. The irregularity appears to result from the fluctuation caused by predator-prey interaction superimposed on the cycles driven by hydrology. The detrital transfer to higher trophic levels is strong. Herbivores are rare. Predators show a great seasonal variability. They are relatively abundant. Field data are lacking to identify the seasonal patterns.

The simulations with low or high phosphorus supply shows the effects of nutrient enrichment on the aquatic food web. Phosphorus enrichments increase primary productivity significantly and secondary productivity moderately. Phosphorus enrichment enlarges the detrital channel, reduces the herbivorous channel, and thus alters the trophic structure of food web. This is the nutrient enrichment hypothesis. Overall, the lower trophic levels of the aquatic food web in the Everglades marshes respond to hydrology and phosphorus enrichment sensitively and nonlinearly. The food web structure depends on hydrological conditions, phosphorus supply and the characters of trophic interactions.

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Multiple Approaches for Evaluating Hydrology and Vegetation Monitoring Data to Demonstrate Wetland Restoration Success at the Disney Wilderness Preserve

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Wetland restoration on the Disney Wilderness Preserve involved restoring natural hydrologic and fire regimes to wetlands and their watersheds. In fall 1993, four wetlands were restored by plugging or filling ditches that had drained them for over 40 years. The one ditch plugged in 1993 was completely filled in 1996. Periodic growing-season fire was also reinstated on the Preserve after many years of primarily dormant season fires. This paper describes results of hydrology and vegetation monitoring of four wetlands before restoration in 1993 and following restoration through 1998.

While drainage associated with the ditches was eliminated in late summer 1993, pre-drainage water levels were not restored until sufficient wet season rainfall occurred during summer 1994 to refill the wetland and raise the water table in the surrounding watershed. Since then pre-drainage water levels have been maintained in the three ditch-filled wetlands. After the fourth wetland's ditch was completed filled in 1996, it has also maintained pre-drainage water levels.

However, restoration was confounded by organic soil loss that had occurred while the wetlands were drained. This resulted in greater water depths and longer hydroperiods than existed prior to drainage in the deeper portions of these wetlands. The cypress plant community showed little change associated with increased wet season water depths of about 1 foot. The composition of marsh communities changed with water depth increases of 2 or more feet and vegetation density decreased. One hardwood forest, with an increased water depth of 0.5 feet, had many stressed or dead trees, but was recovering due to rapid growth of saplings of impacted canopy species. In another, with an increased water depth of about 1.5 feet, virtually all trees were killed and it is recovering very slowly. A herbaceous groundcover is beginning to dominate large portions of this wetland. These communities' susceptibility to impacts from increased water depths and hydroperiods were related to their adaptations to different hydrologic regime characteristics and degrees of change in these characteristics as a result of restoration. While in some cases the post-restoration plant communities are different from those present prior to drainage, all four wetlands are developing natural wetland plant communities appropriate for their current hydrologic regimes. Pre-drainage characteristics can be expected to develop over the long term as organic soils reestablish their pre-drainage elevations.

Along our monitoring transects, increased wetland cover, sometimes substantially upslope of the wetland water surface edge, was related to the proximity of the wet season water table to the base of a surface soil layer with a high organic content.

Vegetation was sampled on transects extending along the topographic gradient from within restored wetlands into the adjacent uplands during the summer prior to restoration and for five summers after restoration. Ground cover and canopy vegetation were sampled separately.

Differences both between and within wetlands, including topography, degree of hydrologic change associated with restoration, plant community type, and fire history, made use of a single method for evaluating success difficult. Overall, an increase in wetland species abundance upslope was observed, but often it was necessary to evaluate the data at a species level to detect real change. At one bayhead, density and location of each wetland tree species over time showed a definite shift upslope that was not obvious in a wetland vs. upland comparison because of differences in the degree of upslope movement by each species. Another bayhead showed recruitment of herbaceous wetland species upslope, but the presence of dense established upland shrubs, which could potentially be removed or reduced over time with growing season fires, made a wetland vs. upland comparison uninformative. Certain species, like *Gordonia lasianthus*, were very sensitive to hydrologic change and quickly shifted upslope, making them excellent indicators of hydrologic change where they were present. Other species, like *Lyonia lucida*, were so ubiquitous along the entire topographic gradient that they consistently muddled evaluation of shifts in wetland boundaries. Taking these species traits into account made detection of success easier.

Because DWP is a mitigation site, we must show whether restoration is working in a relatively short period of time. While hydrologic restoration was relatively simple to document, short-term detection of long-term vegetative restoration was maximized by using a variety of sampling strategies, selective use of certain species, and more than one approach for interpreting the data.

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Ostracode Shell Chemistry as a Paleosalinity Proxy in Florida Bay

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We investigated the use of ostracode metal/calcium ratios (Mg/Ca, Sr/Ca, and Na/Ca) to reconstruct the salinity history of central Florida Bay from its sedimentary record. We first developed provisional partition coefficients ($K_{D\text{-}Mg}$ and $K_{D\text{-}Sr}$) from the average Mg/Ca and Sr/Ca ratios for modern Florida Bay water and 171 modern shells of *Loxoconcha matagordensis* at a mean Florida Bay water temperature of 26.5 ^{o}C. Trends in Mg/Ca ratios for *L. matagordensis* and *Peratocytheridea setipunctata* from radiometrically dated sediment cores from Russell Bank, Park Key, and Bob Allen Keys appear to provide a reasonable estimate of Florida Bay salinity history for the past 130 years. The most complete Mg/Ca record from Russell Bank extends back to 1875 and shows a good correspondence between estimated paleosalinity and measured annual rainfall in south Florida. Paleosalinity estimates for the Russell Bank area range from ~13 to ~55 ppt. Estimates for the post-1950s period are comparable to instrumental measurements of salinity near the Russell Bank site. The overall record indicates a decadal-scale variability in salinity in which large amplitude shifts in ostracode Mg/Ca ratios with high Mg/Ca (higher salinity) values corresponding to periods of low rainfall from ~1895 to ~1920 and from 1940 to present. The intervening 20 years (~1920 - 1940) are characterized by relatively low amplitude shifts in Mg/Ca and rainfall. Since 1950, periods of high salinity (~45 to ~55 ppt) occur during each decade. Prior to 1940, salinity never exceeded ~45 ppt and generally remained below 40 ppt, despite evidence in the rainfall record of dry intervals in the early 1900s equivalent to those of the last 50 years. Salinity minima associated with the decadal-scale oscillations range from ~15 to ~25 ppt. Four of the five extreme low values (~1915, ~1940, ~1983, ~1998) appear to correspond with times of strongly negative values of the Southern Oscillation Index, that is, El Nino Conditions that bring anomalously high winter rainfall in the southeastern U.S.

These results support the hypothesis that seasonal and decadal-scale salinity fluctuations are a natural part of the Florida Bay Ecosystem, and that these fluctuations are largely a function of natural variability of regional climate (rainfall). The relatively low peak salinity values associated with apparent dry periods in the early 1900s suggests that, since ~1950, anthropogenic factors played a role in the magnitude of the salinity fluctuations in more recent times. [This abstract is from the volume "Paleoecology Studies of South Florida" edited by Bruce R. Wardlaw, American Bulletins of Paleontology, in press].

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The Sensitivity of an Endangered Species to Changes in Demographic and Landscape Level Parameters: an Individual-Based Model for the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*)

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The Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), a federally listed endangered species since 1967, occurs in the short-hydroperiod marl prairies of the Everglades of South Florida. Recently, the sparrow population has declined within portions of its breeding territory, due to changes in the region's hydrology as well as changes in the sparrow's habitat. In order to determine the relative effects of a changing landscape on sparrow population dynamics, a spatially-explicit individual-based Monte Carlo model incorporating both temporal and spatial dynamics was constructed and applied to the western sub-population of the sparrow. The model (SIMSPAR) includes the topography, vegetation and hydrology of the western sub-population's habitat as well as demographic parameters derived from numerous field studies.

To explore the population's sensitivity to behavioral, demographic and landscape level changes, we altered a number of parameters within the model and documented their effects on population size and the variability between simulation runs. The sparrow population was highly sensitive to changes in maximum number of clutches, adult mortality, juvenile mortality, and female dispersal distance. When overall water levels were raised across the landscape, the sparrow population declined by 6% per one-centimeter increase in water level. As water level rose, the coefficient of variation in population change also increased. Degradation of sparrow habitat resulted in a greater than proportional decrease in overall breeding population size and an increased coefficient of variation in population size. When degradation of habitat and male dispersal were altered in a factorial set of runs, habitat degradation decreased population levels while increased dispersal range increased population numbers. However, with increased dispersal, the coefficient of variation increased to asymptote at a dispersal distance of 1000 meters.

The spatial pattern of degradation relevant to habitat type also affected overall numbers. If high elevation breeding habitat was degraded systematically, the population levels declined to a greater extent than if low elevation breeding habitat was degraded by marsh expansion, or if all breeding habitat was degraded by spatially random processes. Although the population was highly sensitive to changes in both demographic and behavioral parameters, these results highlight the sparrow's sensitivity to landscape level changes. Our conclusion is that only with appropriate water and land management in the southern Everglades, especially to assure the quality of high elevation refugia, will the sparrow population be able to increase in numbers.

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Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem

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The biology of this federally listed endangered plant species is being studied in a multidisciplinary way with a focus on immediately applying new biological understanding to the successful restoration of the species and its eventual delisting. This member of the morning glory family (Convolvulaceae) grows along the southeast coast of Florida and is close to extinction because of habitat loss with a continuing decline in numbers of plants and population sites. We have mapped all known plants in a GIS data base, are following phenology and demography, quantifying seed banks and seed germination (and dormancy), clarifying the breeding system, the reproductive biology, and the genetic variation of remaining populations by DNA variation, and demonstrating the requirement of mycorrhizal fungi for successful establishment and growth of seedlings. We will soon initiate experimental habitat manipulation (increased soil moisture, decreased shading by vegetation, fire) and measure the effects on plant growth and recruitment. *Ex situ* collections supply the large numbers of seed and plants needed for our research. We are coordinating the work of botanists and graduate students from three institutions who are carrying out the scientific research needed to implement this species recovery plan.

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Application of the Everglades Landscape Model in Restoration Initiatives

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The Everglades Landscape Model (ELM) evaluates ecosystem responses to modified water and nutrient management at the landscape scale within most of the remnant Everglades and Big Cypress. In its quantitative description of landscape dynamics, the ELM simulates the direct and indirect interactions associated with hydrology, phosphorus cycling, detrital decomposition, plant dynamics, and habitat succession. The first version of this model was calibrated to extensive ecological data for Water Conservation Area-2A, and a significantly revised version is being evaluated and applied to the full model domain.

This current version (2.1) includes the full suite of ecological dynamics, but is not fully calibrated or verified for all of the soil dynamics and vegetative/periphyton community responses in all parts of the system. For the first application of the ELM to evaluate regional system response to management scenarios, the focus is primarily on phosphorus transport and fate in surface waters. For the different management alternatives in the Modified Water Deliveries to Everglades National Park (Modwaters) project, we are starting to evaluate the total phosphorus (TP) in surface waters as the water flows are redistributed towards areas such as Northeast Shark Slough. Altered sources, and thus TP concentrations, can change the TP loading to particular areas of the Everglades system. The ELM is now being used as a quantitative indicator of any potential water quality constraints that may need consideration in implementing the Modwaters project, and will be further developed and applied in evaluating Comprehensive Everglades Restoration Plan (CERP) initiatives.

Prior to applying this modeling tool, we evaluated the degree to which the ELM hydrology is consistent with historical observations and with the South Florida Water Management Model (SFWMM) calibration/verification simulation runs. In general, water budgets and stage observations are consistent between the SFWMM and the ELM, and both models effectively predicted stage in approximately 40 locations throughout the Everglades region. For example, under conditions of both long and short hydroperiods, the ELM predicted hydrologic behavior reasonably well (http://www.sfwmd.gov/org/erd/esr/elm.html).

Coupled to the hydrologic flows is the transport and fate of phosphorus in the system as it moves through the canal network and is transformed via biologic and biogeochemical processes in the landscape mosaic. We were able to effectively capture the distinct gradients in TP at approximately 40 locations from north to south in the Everglades, including temporal responses to high loading events and drydowns over the 16-year calibration period (http://www.sfwmd.gov/org/erd/esr/elm.html).

In preparation for evaluating the Modwaters project and CERP initiatives, the ELM's WWWeb site (http://www.sfwmd.gov/org/erd/esr/elm.html) was updated for rapid communication of model documentation and results. The ELM program is undergoing further development from the criteria of both ecological model performance and communication of model results.

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Is the Everglades a Demographic Sink for Wading Birds?

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Although wading birds have frequently been counted in the Everglades, an understanding of the demography of these animals has been hampered by basic life-history information. In this paper, we report on the importance of nonbreeding (birds that remain in the Everglades during the breeding season but do not breed). Between 1986 and 2000, we counted numbers of breeding pairs of ciconiform birds in the central Everglades using aerial and ground survey techniques, and during 6 of those years also collected information on reproductive parameters (nest success, clutch and brood size). We also estimated numbers of birds on the marsh during the breeding season using systematic low altitude strip transect sampling (SRF). From these estimates of breeding and "marsh" birds, we have estimated the proportion of adults using the marsh that are actually breeding.

Birds on the marsh are assumed to be composed of breeders, nonbreeders, and juveniles. Using population models, we estimated the species-specific proportion of juveniles and subtracted these from the total "marsh" birds in each year. We also assumed that one member of each breeding pair would be typically be counted on the marsh (the other member would be incubating on the nest during the April counts). After subtracting both juveniles and breeding birds from the marsh counts, we are left with an estimate of numbers of nonbreeding birds. For White Ibises, Great Egrets, and Wood Storks, we found that nonbreeding adults averaged 60.2%, 43.7% and 72% of the population, respectively, over the period 1986 – 2000. In some years (1992, 1999, 2000), almost 100% of adults were breeding.

To test whether these levels of nonbreeding were sustainable, we constructed species-specific population models, which used reproductive and survival parameters at the high end of those measured in the Everglades. Thus these models were biased towards simulating sustainable populations. However, when we used the actual annual record of nonbreeding to generate the numbers of adults breeding, simulated populations of all three species declined rapidly. In contrast, actual breeding populations of these species were either stable (ibises) stable/increasing (Wood Storks) or increasing (Great Egrets) through the period. This comparison of actual vs modeled populations suggests that either the parameters we are using are wrong, or that the Everglades is a net demographic sink. Causes of nonbreeding are being investigated, with access to food, and contamination as primary suspected causes. The high interannual variability in breeding effort in the Everglades and the suggestion of net demographic losses both suggest that other wetland ecosystems in the southeastern U.S. and Caribbean often serve as demographics sources of "Everglades" wading birds. This reinforces the idea that the Everglades cannot be managed effectively in isolation from other wetland systems.

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USEPA--REMAP
Using Diatoms for Risk Assessment in the Everglades

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In conjunction with the USEPA REMAP assessment, diatoms were collected from sites throughout the Everglades to determine their applicability in monitoring environmental quality. A total of 117 taxa were identified from periphyton samples from 91 sites in the dry season (May-June) and 69 sites in the wet season (September-October) of 1999. Variation in taxon relative abundances were related to environmental variation by multivariate analysis. Assemblages differed significantly among the Water Conservation Areas and Everglades National Park. Within basins, diatom taxa assorted along chloride, pH, hydroperiod and phosphorus gradients. Abundances of several taxa were correlated with measures of biotic accumulation of methyl mercury. Experimental data from other studies provide mechanistic corroboration of correlations observed in this study. Continued monitoring of diatom composition could provide useful assessments of the pace of ecosystem response to altered water delivery and quality in the Everglades.

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Investigating the Response of Tree Island Function to Increased Water Flow in a Southern Everglades Ecosystem

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Freshwater flow is the subject of great interest concerning Everglades restoration. The effects of restoring freshwater flow to the system is suggested to also increase nutrient inputs to downstream communities. Tree islands are ecologically important communities in the Southern Everglades, and this area is currently receiving canal water delivery as part of hydrologic restoration. Local nutrient cycling and forest dynamics of the islands are key to understanding the relationship between wetland management and tree island function. To investigate this relationship, we are currently quantifying the structure, growth, nutrient utilization and soil dynamics of the mixed swamp tree islands. A three treatment experimental design is being utilized with "flow" (islands experience both flow and nutrient effects of canal water delivery), "walled" (islands experience only nutrient effects), and "no flow" (islands have greatly reduced flow and nutrient effects). Nitrogen imports due to canal water delivery may be taken up by these forested wetlands, and are hypothesized to increase litterfall production, tree growth rates, decomposition rates, and decrease nitrogen use efficiency. Preliminary data show that tree island communities are highly efficient systems, and that, within one year, effects from increased freshwater flow are most pronounced in the "flow" treatment, specifically with respect to soil oxidation-reduction and litter turnover.

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Good Science: Essential Ingredient for Restoration Success

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The restoration of ecosystems and aquatic habitats provides great challenges and great opportunities for science. Providing credible and objective scientific data and information is a necessary but not sufficient condition for effective restoration. The role for science is not to make the restoration and management decisions but to provide a technical basis for decision-making, forcing issues to be clearly and technically defined; to resolve uncertainties about the system that limit restoration planning, answering questions posed by other groups but also developing tools and information proactively; and to assess the effectiveness of restoration actions in meeting program goals, providing information and synthesis in a usable, timely format. A general review of current restoration efforts suggests the success of integrating science into ongoing restoration activities has been mixed.

On September 21 and 22, 2000, U.S. Geological Survey Director Charles Groat, in partnership with Dr. Denise Reed of the University of New Orleans, convened a group of scientists and managers in New Orleans to discuss the challenges involved in incorporating science in the design, implementation, and monitoring of ecosystem restoration programs. Scientists and managers engaged in ecosystem restoration activities, including representatives of the Everglades Restoration, discussed lessons learned, including successful efforts as well as efforts that did not reach their intended aim, and developed recommendations for structuring effective future restoration science programs.

There are formidable challenges involved in getting science used in the design and implementation of restoration programs. These include recognition by the implementing body that scientific understanding is critical to successful restoration programs; placement of the science program in the organizational structure where it can influence decisions; relevant science information delivered to managers in a timely manner and useful format; and a commitment to monitoring restoration projects to adapt their operation and the design of future projects to systems responses.

There was broad agreement among workshop participants that:

- Clearly, to make science a more effective part of the restoration process requires an early recognition from the highest levels of the implementing body that science has an integral role in restoration. Managers must ensure that scientists are on the planning teams as well as recognize that scientific understanding is crucial to the success of the restoration activity.

- The availability of scientific studies pertinent to restoration goals and objectives does not guarantee that the knowledge can be effectively used in restoration planning and implementation. Scientists need to accept that policy-makers are accustomed to working with risk and that absolute certainty is not necessary for information to be of value. Risk should be communicated but will never be completely eliminated.

- The use of review panels and the peer-review process for evaluating both the selection of investigators/contractors and the final products is important to retain the credibility of the science developed under the program. Independent peer review, such as is provided by the National Academy of Sciences Committee on the Restoration of the Greater Everglades

Ecosystem (CROGEE) is an effective means to provide scientific guidance, broader perspectives, and increase awareness about the system and its problems.

- Essential to ensuring the use of available knowledge in planning and management decisions is the communication of current scientific understanding in ways that are relevant, timely, and in useful, user-friendly formats. Models, such as the conceptual models used in the Everglades Restoration, can be powerful communication tools for providing a structured synthesis of our current understanding of the system, identifying critical gaps in our knowledge, and developing appropriate monitoring approaches to assess project success.

- A commitment to the role of science in natural systems restoration should come from the executive level of government – state or federal. This requires coordination and dialog amongst agencies to support independent funding for science as part of any restoration program.

- To make science work in the restoration context requires dedicated funding, identification of a science leader at an early stage, and the inclusion of science in early planning for organizational structures.

Many factors—social, economic, political, scientific-- must be weighed and balanced as restoration plans are developed and implemented. Sound science, effectively communicated, is an essential part of successful ecosystem restoration.

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An Assessment of Potential Contaminant Exposures and Effects 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 (muck-farm) properties and agricultural pesticides may be responsible for these toxicities. Most importantly, these observations point to a complex process involving reclamation/restoration and the exposure of adult female alligators to persistent pesticides, possibly leading to developmental toxicity in addition to endocrine disruption. The current study evaluated contaminant exposures and potential physiological effects for alligators in the Greater Everglades Ecosystem. Adult alligators (approximately 5 ft in length; n=6 animals per site) 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 and 3A. Several tissues were collected for contaminant analysis: blood, scute, liver, muscle, bile and fat. Contaminant analyses included 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 also utilized for blood chemistry assessments of health status and endocrine status (sex steroids and thyroid function). Gonadal and liver tissues were also examined histologically for an evaluation of reproductive status and liver toxicity. Initial results demonstrate significant, site specific, exposures to pesticides and mercury. These results also indicate altered endocrine status in response to contaminant exposures. Additional efforts have included the assessment of contaminant exposures for alligator eggs and embryos at many of these same sites. 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 efforts.

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Sea-Level Rise and The Future of Florida Bay in The Next Century

R. B. Halley, K. K. Yates and C. H. Holmes

During the next century the physiography of Florida Bay will slowly change due to the complex interplay between sediment production, transport, and accumulation and the local, relative rate of sea-level rise. Recent process studies, including estimates of sediment production (Bosence, 1989; Halley et al, 1999; 1999; Yates and Halley, 1999), transport (Stumpf et al., 1999; Prager and Halley, 1999), and accumulation (Robbins et al., in press), indicate that the subtle changes that have characterized the physiographic evolution of the Bay during the 1900s will continue through this century.

The bulk (60%) of Florida Bay sediment has accumulated in mud banks during the past four thousand years (Scholl, 1964). Islands, tidal channel deltas, and filled solution holes account for only a few percent of the sediment in the Bay. About 90-95% is carbonate skeletal debris and 5-10 % is organic debris, mostly mangrove and seagrass. There is a small detrital fraction, generally less than a few percent, consisting of quartz, clays and dolomite (Prager and Halley, 1997). The sand-enriched surface sediments result from winnowing processes that preferentially transport fine sediment to mud banks leaving a sand veneer over large areas of the Bay floor.

Sediment is continuously produced by living organisms and is remobilized by erosion. Erosion occurs along unprotected shorelines, exposed mud banks, and areas recently denuded by seagrass mortality. Eroding islands show the most rapid erosion rates, with extreme shoreline retreat rates that approach 1 m yr^{-1}. The presence or absence of seagrass is a first-order control of subtidal erosion and deposition. Some mud banks that erode on exposed margins are accreting on protected margins, causing a net migration on the order of a few decimeters yr^{-1}. Areas of seagrass mortality may expose extremely fluid mud to transport, resulting in local redeposition of several centimeters of sediment per year.

Wave modeling and direct measurement help to understand the complexities of erosion and deposition and the importance of seagrass. Waves form in the basins and propagate most effectively across basins with long axes parallel to the wind. Refraction effectively turns waves parallel to the banks. However, seagrass dampens out wave energy along bank margins (Prager and Halley, 1999). If seagrass is absent, significant erosion may occur on bank margins. Although summer thunderstorms account for some erosion and turbidity, remote sensing studies indicate that winter cold fronts account for most of the turbidity and sediment transport in the Bay. Turbidity patterns also reveal a seasonally consistent west-central clear zone, indicating that little sediment from the central and eastern Bay escapes the estuary (Stumpf et al, 1999). Only hurricanes are energetic enough to redeposit sediment on islands and along shorelines.

Sedimentation rates of 0.5 - 2 cm yr^{-1} have been measured on the accreting margins of mud banks (Holmes et al., in press). These rates are greater than sea-level rise and indicate that mud banks can outpace sea-level rise. However, coring reveals that mud banks are just keeping up to sea level, not catching up or becoming islands. It is hypothesized that seagrass dynamics prevent the banks from growing above sea level. Periodic episodes of seagrass exposure and mortality limit the ability of the banks to accrete above the annual low tide.

Nuclear bomb radiocarbon can be used as a tracer of sediment produced since the late 1950s. Only a fraction of a percent of new carbonate sediment has been produced in the past 40 years (Halley at al., in preparation). Although carbonate production rates are estimated in the range of 100s gms m^{-2} yr^{-1} (Bosence, 1989), much of this production is redissolved (Walter and Burton, 1990). Net accumulation over the past 3500 yrs has been approximately 0.2 mm yr^{-1} (2.2 gms m^{-2} yr^{-1}). These production rates are similar to carbonate productivity estimates calculated from alkalinity and pH measurements made during 1998 and 1999.

Production rates are insufficient to keep up with sea-level rise. But the continuous redistribution of sediment, preferentially accumulating in seagrass on mud banks, maintains the banks close to the annual low tide. The basins, on the other hand, slowly deepen because sediment produced there is removed and transported to the mudbanks. Basin deepening will result directly from sea-level rise and can be approximated using the methods of Titus and Narayanan (1995). The long-term evolution of Florida Bay, forced by sedimentation and sea-level change, defines the context within which long-term restoration activities will occur.

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Modeling Spatial Use Patterns of White-tailed Deer in the Florida Everglades

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The main objective of this study was to develop an individual-based spatially explicit (IBSE) simulation model of movement patterns of adult white-tailed deer in the Florida Everglades. The model provides a means of exploring patterns of spatial use of deer in response to environmental catastrophes (e.g., tropical storms) and to different management regimes (e.g., water control). Furthermore, the statistical methodologies used to calibrate and validate this IBSE model provide a foundation for the development of future simulation models.

As reliance on ecological simulation models increases, proper tools to facilitate their calibration and to increase their reliability become more important. Computer simulations enable scientists to model the effects of environmental catastrophes or management strategies on target populations without conducting expensive or difficult field experiments. A variety of statistical tools and methods were integrated into an iterative approach for a more rigorous calibration of the simulation model.

The specific objective of the simulation model was to predict how temporal landscape changes (i.e., rising and falling water levels) affect movement patterns of deer in the Florida Everglades. Radio-telemetry data obtained from 46 yearling and adult white-tailed deer on the boundary between Big Cypress National Preserve and Everglades National Park during normal-to-dry weather conditions (1989-92) were used to develop and calibrate the IBSE simulation model. The same simulation model also was run under flood conditions, like those experienced during the Everglades flood that began in the fall of 1994, to evaluate the changes in movement patterns during an environmental catastrophe. The model was validated with radio-telemetry data from 36 yearling and adult white-tailed deer collected just prior to and during the flood of 1994-95. The simulation model can help predict impacts of changes in water management strategies and the impacts of floods and hurricanes on white-tailed deer in the Florida Everglades.

The algorithms that were developed for these simulations focused on movement patterns as reflected in the maintenance of home ranges, habitat preferences, and avoidance of deep water. These movement patterns were evaluated on an annual basis and a hydrologic season basis. The evaluation of the final model, relative to the calibration data, indicated that simulation performed well for the most important measured parameters. Validation with radio-telemetry data obtained during the flood of 1994-95 indicated that the simulation model was sensitive to flood conditions, as simulated deer were observed in tree islands more frequently and females reduced their home range size. However, the changes in the movement patterns of the simulated deer were not as large as expected, based on the observed field data. Because the simulated deer population was static (i.e., mortality excluded), the inclusion of stress-related mortality due to stranding in deep water in the simulation, may improve the predictive capabilities of the simulation.

This model is one of the many tools that can be used for planning to restore the Everglades. Part of this large restoration effort has been the development of the suite of simulation models, Across

Trophic Level System Simulation (ATLSS), to predict and compare the effects of alternative hydrologic scenarios on this ecosystem. These movement algorithms for deer could be incorporated into the model as a comparison to or in conjunction with the deer component currently used in the ATLSS model.

Another potential application of the model would be to predict the impact of catastrophic events on white-tailed deer in south Florida. On average, south Florida is subjected to a tropical storm once every 3 years. Some of those storms are relatively dry, like Hurricane Andrew in 1992, and some are extremely wet, like Tropical Storm Gordon in 1994. This simulation model can aid in predicting the severity and longevity of the impact on the deer population for various scenarios such as strong hurricanes in several consecutive years, or several hurricanes in a single year.

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Unexpected Responses in Ecosystem Restoration - A Case Study of Submerged Plants, Turbid Water, and a Strong Wind Event at Lake Okeechobee, Florida

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Our expectations regarding the response of an ecosystem to restoration efforts are largely based on observations of past behavior of that ecosystem. When conditions push the ecosystem outside this "envelope" of past observations, unexpected responses may subsequently occur. This may especially be true for regions such as Florida, where extreme stochastic events including flood, drought, fire and wind-storms periodically occur.

The effect of an atypical event on an ecosystem's response to management actions is illustrated by a case study of Lake Okeechobee, the large (>1,800 km^2) shallow lake that occurs at the center of the south Florida peninsula. From 1995 to 1999, resource managers and the public expressed concern about loss of submerged aquatic vegetation (SAV), and possible fishery declines, in Lake Okeechobee that they attributed to high water levels. In summer 1999, there was some recovery of SAV at the south end of the lake when stage declined to 13.5 ft NGVD for several weeks, but SAV biomass sharply declined by the subsequent spring.

In spring-summer 2000, approximately 1 ft of water was removed from the lake via its outlets, so that more widespread SAV recovery could occur. As a result of this "managed recession operation" and the coincident evaporative losses and water supply withdrawals, lake stage declined from 15.5 ft in early April to below 12.0 ft NGVD in late June. Submerged vegetation responses were evaluated by monthly sampling at 42 long-term stations where SAV biomass and species composition have been studied since April 1999.

Despite lake stage being 1.5 ft lower than in 1999, there was less SAV in spring 2000 than in the previous year. In May 1999, 10 of the 42 sites had SAV, while in May 2000, plants occurred at just 6 sites. Plant densities also were lower in 2000 with a smaller portion of total biomass attributed to vascular plant species (as opposed to *Chara*, a macro-alga). The subdued SAV response in May 2000 coincided with substantially greater turbidity in the water than was observed in the previous year. However, after a number of weeks at the low-lake stage, water clarity did increase in 2000, and a more widespread SAV response was observed (primarily *Chara*).

It may be the case that the differences observed between 1999 and 2000 simply reflect a long-term deterioration of conditions in the near-shore region of the lake. There is no historical record of SAV between the early 1990s and 1999 to confirm this, although we do know that in 1989 an explosive response of SAV occurred when lake-stage declined to below 12 ft NGVD during a drought. An alternative explanation proposed here is that a windstorm impacted the south end of the lake between 1999 and 2000, causing conditions in that particular region (where plant growth was concentrated in the preceding summer) to deteriorate at an even greater rate than already occurring.

In October 1999, a Category I hurricane (Irene) passed just south of Lake Okeechobee. Meteorological data from a mid-lake monitoring platform indicate that wind velocities during that event exceeded 50 mph and were greater than 30 mph for more than 24 hrs. At these wind velocities, the District's lake hydrodynamic model indicates that substantial shearing stress could be imposed on the lake sediments and that there could be considerable uplift of mud sediments into the water column, where it can be transported lake-wide by underwater currents. Water quality monitoring data provide support for this scenario of vertical and horizontal transport of phosphorus-rich mud sediments. In early October 1999, two weeks before the hurricane, lake-wide total phosphorus concentrations averaged near 90 ppb, slightly below the median of 100 ppb for the last decade in the 'windy season' (October-April). In early November, two weeks after the hurricane, lake-wide total phosphorus averaged more than 220 ppb, higher than any previous observation. Likewise, total suspended solids increased from near 15 ppm to 85 ppm. Concentrations of total phosphorus and solids at near-shore stations (SAV habitat) also were beyond the upward bounds of previous records. This lake-mixing event may have had impacts on light availability in the water column, as transparencies (measured with a Secchi disk) were reduced from near 40 to below 20 cm lake-wide from early November 1999 to spring 2000. At near-shore sampling sites, Secchi disk depths were the lowest ever recorded.

It is hypothesized that wind-driven mixing of sediment material in the lake carried fine muds into the near-shore region, adding to the burden delivered in previous years of high lake stage. The near-shore region normally has sand and peat sediments, which are not readily mixed into the water column by wind. With greater local sources of mud, this region continued to experience high turbidity through June 2000, even when lake stage was reduced to a level where the near-shore region typically (in the late 1980s) develops very clear water. Increased turbidity results in lower underwater irradiance, thus delaying responses of SAV to the lake recession. As of July 2000, regions in the north still did not have SAV, even at sites with relatively clear water. This may reflect a loss of the sediment seed bank or deep seed burial at certain locations (this is under investigation), perhaps due to wind-driven waves and underwater currents.

In the case of Lake Okeechobee, our findings indicate that additional management efforts may be necessary to achieve a substantial recovery of SAV, especially in areas heavily impacted by mud sediments (e.g., the north near-shore region). From a more general perspective, the results illustrate how a stochastic event like a hurricane can lead to unexpected responses of an ecosystem to management actions. If such events are adequately evaluated by science and monitoring, they can serve as learning experiences for developing a better understanding of system response to stress and in-turn a better ability to predict future system behavior.

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Predicting the Response of Everglades Tree Islands to Changes in Water Management

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Tree islands are a distinctive component of the Everglades landscape, and one that has been significantly impacted by water management during the past several decades. Restoration and protection of tree islands depends on the development of appropriate evaluation tools that can predict the ecological response of tree islands to changes in hydrology and identify appropriate monitoring locations and criteria. Ideally, such "performance measures" for tree islands will be based on sound empirical data, will provide accurate (if imprecise) predictions of the ecological response across a range of conditions and tree island types, and will be linked to a monitoring effort that will allow predictions to be tested and improved. Toward that end, we have employed a multiple regression approach to investigate potential predictive relationships between vegetation characteristics of elevated tree islands in Everglades Water Conservation Area 3A and estimates of hydrology during the two decades prior to data collection. Collectively, estimates of the intensity of drought conditions and of island flooding explain statistically significant and sometimes large fractions of the variance in species richness, island spatial extent, and woody species cover. Based on analysis to date, richness of tree and shrub species is the most promising vegetation indicator of hydrologic impacts over a 10-50 year time scale. Using this and other vegetation indicators, a predictive formula was developed to compare the relative response of tree islands across the landscape of Water Conservation Area 3A. Results are discussed in light of key assumptions and limitations of this approach, along with appropriate application of observational studies in planning and implementing large-scale ecological restoration.

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Life History, Ecology, and Interactions of Everglades Crayfishes in Response to Hydrological Restoration

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Crayfish species composition and abundance are indicators of hydroperiod and are predictably influenced by hydro-management. Two species of crayfish inhabit south Florida marshes (Figure 1). The Everglades crayfish, *Procambarus alleni,* is found in locations that dry seasonally (typically with a hydroperiod of less than 10 months), and it burrows when water recedes from the surface. The slough crayfish, *P. fallax*, is found in perennially flooded habitats and, although capable of burrowing, has not been observed in burrows in the field. Sympatric populations were found in locations that were flooded from 9 to 11 months (intermediate hydroperiod), or at sites that remained flooded in the dry season. This distribution pattern is useful in back casting and in predicting the relative occurrence of species.

Life-history characteristics of each species are tied to different hydrologic requirements. For example, reproduction in the Everglades crayfish occurs synchronously and coincides with loss of water from the surface, whereas the slough crayfish breeds almost continuously. The species-specific responses to hydropattern are predictable and can be modeled (Figure 2). Spatially explicit models that incorporate the dynamics of crayfish response to variation in hydrology are being constructed. The results of this project will address how the loss of spatial extent, fragmentation of habitat, and compartmentilization of the watershed, has combined to affect crayfish distributions and abundance. These topics are important when considering that White Ibis (*Eudocimus albus*) consume crayfish almost exclusively during nesting, and that foraging flight distance is markedly reduced when crayfish are locally available. Using ATLSS wading bird models, the role of crayfish as an intermediate through which hydrology may affect nesting success can be addressed.

Currently, a spatially explicit, non size-structured model is being constructed, calibrated, and tested for each species. The model assumes that each population grows exponentially and that periodic perturbations in the physical environment reduce population numbers before density dependence arises. Thus, the model structure includes terms for hydrologically modified survival and colonization. Hydrology is the only physical driving force incorporated into the model. Cross correlation analyses revealed that *P. alleni* density has the strongest correlations with hydrology during the previous year, whereas *P. fallax* density has the strongest correlation with hydrology from three years prior. Finally, a density dependent recruitment function is included, because local resources may become depleted due to large recruitment events. Time series data of approximately 15 years from northeast Shark Slough and from central Shark Slough were used to calibrate each model (Figure 3). Data from a single site, north central Shark Slough, was used to compare model predictions to field data. The result of these site specific modeling efforts and their inclusion into a spatially explicit landscape model will be presented.

Relevance to Everglades Restoration

- We will use simulation, coupled with a Natural System hydrologic model, to estimate historic relative abundance in the Florida Everglades and to simulate crayfish response to proposed hydro-management scenarios.
- This project will help determine the effect of hydropattern on trophic structure and energy flow.
- The Everglades Conceptual models for the Ridge and Slough and Marl Prairie habitats use fishes and macro-invertebrates as key indicators, crayfish may serve in this role to gauge the progress and success of the Restudy.
- This study helps meet the objective identified in the Science Information Needs Report (1996) for the Water Conservation Areas and Everglades National Park, namely the quantification and modeling of the dynamics of productivity and composition of aquatic animal communities across the landscape.
- The crayfish models will advance two aspects of the ecological and precursor success criteria for south Florida ecosystem restoration, namely success criteria for inland fish populations and the reestablishment of healthy wading bird populations.

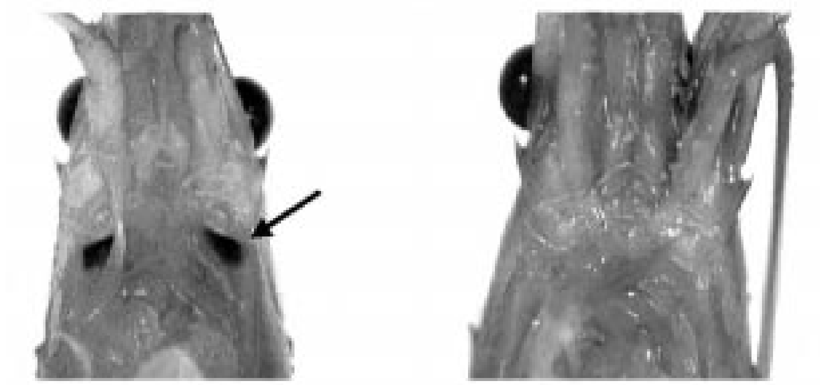

Figure 1. The Everglades crayfish (*Procambarus alleni*, left) has conspicuous dark markings below the antennae, whereas the slough crayfish (*P. fallax*, right) lacks this coloration.

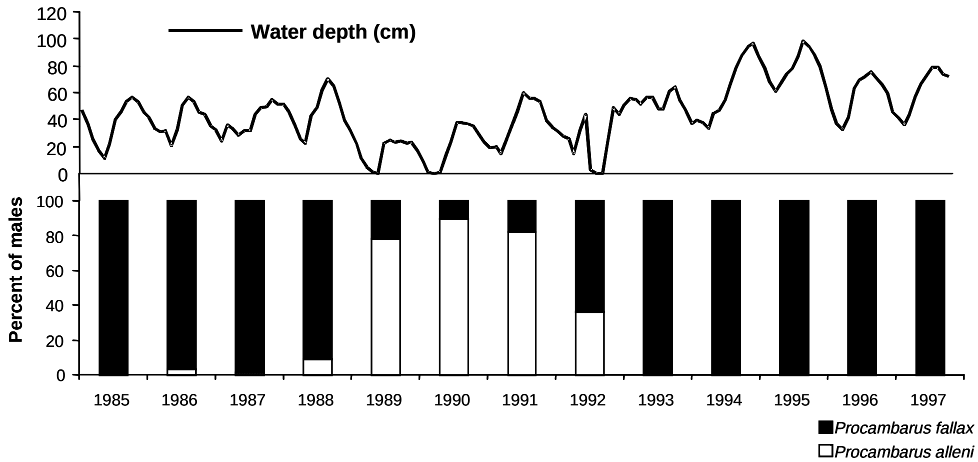

Figure 2. Relative composition of *Procambarus alleni* and *P. fallax* males in relation to average monthly water depth in central Shark Slough. *Procambarus fallax* percent of total males is positively correlated to days flooded per year (r = 0.68, p = 0.011).

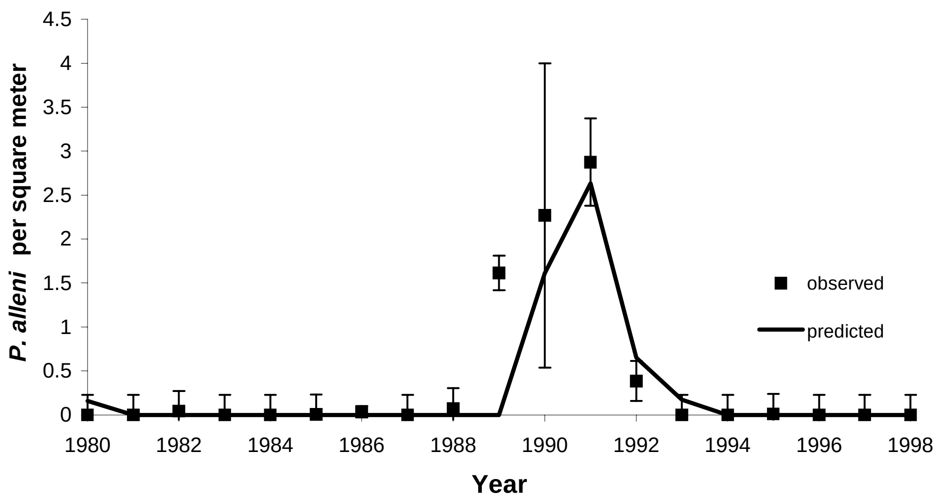

Figure 3. Model prediction and observed density of *P.alleni* from central Shark Slough. Error bars represent one standard deviation. This site was used to parameterize the model.

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A Comparison of Ecosystem Attributes among Four South Florida Wetland Habitats

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The magnitudes of trophic transfers of carbon have been estimated during both wet and dry seasons within four distinct wetland habitats of South Florida -- graminoid prairies, forested cypress swamps, mangrove estuaries and Florida Bay. The data collected in this exercise will be used in calibrating the USGS Across Trophic Levels System Simulation (ATLSS) of the wetland ecosystems of South Florida. The collection of habitats affords comparisons along two clines in salinity (graminoid- mangrove- bay and cypress- mangrove- bay) and between two systems that differ mainly in vertical extent (cypress vs. graminoid.) Whole- system attributes, such as throughput, ascendency, overhead and development capacity are compared within this framework, as are sub-system features, such as domains of recycling and aggregated trophic ladders. Furthermore, numerous species are common to more than one habitat, and their roles within these distinct domains are contrasted.

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Diatoms as Indicators of Environmental Change in Sediment Cores from Northeastern Florida Bay

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Diatom assemblages found in two sediment cores from northeastern Florida Bay indicated fluctuations in both salinity and sub-aquatic vegetation cover during the past 100 years. Diatoms from Russell Bank core 19A indicate that salinity was high prior to the 20th century. Between 1890 and 1920, assemblages dominated by *Mastogloia* species prevail. After 1920, there is a dramatic shift to assemblages dominated by an epipelic (bottom-dwelling) taxon, *Nitzschia granulata*. Around 1950, this taxon declines in abundance and epiphytic species increased. Epiphytic species remain common until about 1972. After 1972, epiphytic diatoms decrease in abundance, and diatoms indicative of higher salinity increase. Similar trends are seen in the Pass Key core 37 (which only spans about 35 years, between 1960-1996). Epiphytic diatoms are common between about 1967-1977, and there is a general trend towards increasing salinity upcore. These findings are in general agreement with other studies of fossil indicators related to salinity and seagrass cover found in Florida Bay sediment cores. [This abstract is from the volume "Paleoecology Studies of South Florida" edited by Bruce R. Wardlaw, American Bulletin of Paleontology, in press].

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Ecological Controls on Benthic Foraminifer Distributions in Biscayne Bay, Florida

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Four benthic foraminiferal assemblages are recognized from surficial sediment samples collected in Biscayne Bay. The assemblages include: 1) a productivity assemblage, 2) a restricted environment assemblage, 3) an open-bay grass assemblage, and 4) an open-bay coarse sediment assemblage.

The distribution patterns of these assemblages appear to be controlled by salinity, substrate, and organic input. The restricted environment assemblage is controlled by salinity and occurs in oligohaline to polyhaline conditions where point source fresh water input is a major factor. The productivity assemblage is associated with a region of Biscayne Bay with high surface water productivity and organic input. The open-bay seagrass assemblage occupies part of the open portion of Biscayne Bay with free circulation and exchange with the Atlantic Ocean. The open-bay coarse sediment assemblage overlaps the previous open-bay assemblage but is distinct in its faunal composition and higher species dominance associated with coarse sandy substrates. [This abstract is from the volume "Paleoecology Studies of South Florida" edited by Bruce R. Wardlaw, American Bulletin of Paleontology, in press].

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The Natural and Changing Role of Fire in South Florida Ecosystems

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This paper is a review and synthesis of geological, meteorological, and ecological data with a focus on the evolutionary and ecological dynamics of fire in south Florida. Isolation during Pleistocene interglacials, a warmer climate, and perhaps even greater frequency of lightning, were strong selective forces that not only promoted physical and behavioral characteristics that allow species survival under a fire regime, but a dependence on fire, and in the case of some plants, characteristics that promote fire. The products of these selective forces include such plants and animals as longleaf (*Pinus palustris*) and slash pine (*P. elliottii*) and red-cockaded woodpeckers (*Picoides borealis*).

Use of fire by native Americans may have increased the frequency with which south Florida ecosystems burned. The arrival of Europeans and their construction of roads that act as firebreaks, drainage of swamplands, introduction of exotic plants, fire suppression, and other activities have further altered both the patterns and frequency of wildland fire. Recognizing the natural role of fire, land managers now use it in conservation efforts. For such efforts to be meaningful, however, understanding of the timing of natural fire and the intricacies of its impacts on natural communities and individual species is essential. For example, prescribed burns in March have different ecological affects than natural fires that would occur later; fire in a young forest can have different ecological impacts than fire in an old growth forest; and a prescribed fire started using aerial techniques likely has impacts that differ from natural fires beginning at a lightning strike.

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Relationships between Aquatic Diptera Communities and Hydropattern in the Rocky Glades, Everglades National Park

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The Rockland marshes or "Rocky Glades" of eastern Everglades National Park have experienced substantially shorter and more unnatural hydroperiods since flow patterns throughout the Everglades were altered by drainage, and these altered hydropatterns are believed to be detrimental to invertebrate community diversity and function. Information on the composition of invertebrate communities and their responses to variations in hydroperiod is needed to assess the effects of present reduced and unnatural water deliveries into the Rocky Glades and to model invertebrate responses to changes in hydrological regimes in future restoration scenarios. To assess how structure and composition of nematoceran Diptera, the dominant Everglades aquatic insect group, vary with changes in hydroperiod length, we collected samples of pupal exuviae monthly from short-, medium-, and long-hydroperiod sites along 7 transects in the Rocky Glades and neighboring marshes. Over 150 aquatic dipteran species (approximately 100 Chironomidae, 30 Ceratopogonidae, and 20 from other families) have been identifed from samples, including several new to science. Monthly dipteran community abundance and species richness generally increased with hydroperiod length. Cumulative species richness for both Chironomidae and Ceratopogonidae were also highest at long-hydroperiod sites.

Detrended correspondence and cluster analyses indicate that community composition changed markedly with hydroperiod length. Compositional changes appear to be largely in response to hydrologically-mediated changes in their environment (changes in vegetation & soil formation) as opposed to direct selection for species with compatible life histories. However, certain species, such as the recently described *Beardius reissi*, show highly-adaptive life history strategies for survival in short-hydroperiod environments. The strong species-substrate relationships of many taxa present suggest that environmental factors that affect plant community composition, such as hydroperiod, will alter aquatic dipteran community composition.

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Development of a GIS Tool to Visualize and Analyze ATLSS Models Result for Resource Managers

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For the past several years, the U.S. Geological Survey (USGS) and other agencies have worked on a modeling approach, the Across Trophic Level System Simulation (ATLSS), to predict the responses of a suite of higher trophic level species to different alterations in the Everglades/Big Cypress hydrology regime. The ATLSS project has produced many scenarios for the Everglades/Big Cypress region of south Florida to represent the biotic community and various factors affecting this community. ATLSS is also being used to view different hydrologic scenarios in relation to the south Florida landscape. A tremendous amount of digital data has resulted from running these scenarios. This project concerns the development of a customized ESRI-ArcView based spatial query and visualization tool that provides capabilities of loading ATLSS models data and showing alternative water management changes and their effects on numerous species modeled in ATLSS, as opposed to one species, and compare numerous scenarios for one species. Model index values can be averaged spatially and temporally, and displayed as maps or tables. This tool integrates the results of running ATLSS models with spatial and no-spatial data from different sources, allows users to extract statistic information for defined areas, and generates simple outputs in form of maps, time series graphs, summarized tables, and reports. Most of the outputs generated by the system can be saved to files using standard exporting formats for text, graphic, and table documents.
Particular attention has been devoted in defining final users common tasks and implementing procedures that perform those tasks. Particular emphasis has also been given in designing a graphical user interface that assures product usability for not highly trained GIS users.
This tool will be used as prototype server application for a future Internet based visualization system.

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Escherian Features in the South Florida Landscape and Their Implications for Restoration

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M. C. Escher's prints provide a wealth of complex images, many of which are visual paradoxes. The qualities of his work arise largely from the application of several artistic principles which he experimented with for many years. These include 1) division of the plane into regular interlocking patterns, 2) mirrored reflections, 3) perspective games and 4) interlocking forms. Interest in these principles extends beyond art into a number of areas of science and mathematics because of their algorithmic nature and their wide applicability. In this presentation Escher's artistic principles are used as models for examining and understanding certain complex landscape features in South Florida. Comparisons are made between Escher's prints and vegetation maps and matches are found at certain map scales. It is proposed that Escher's art provides a new kind of language for studying landscape ecology. Furthermore, Escherian features in the South Florida landscape may pose special challenges to restoration efforts due to their complexity.

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Land Cover Change Detection in Southwest Florida and Application to the Florida Panther Habitat Model.

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In 1990, the Florida Fish and Wildlife Conservation Commission completed a project to map vegetation statewide in Florida. Landsat Thematic imagery dated 1985-89 (mostly 1986-87) was used to map 22 vegetation and land cover types. Over the last decade, we have used this vegetation base map for multiple purposes including: (1) creation of potential habitat maps for 130 rare and imperiled Florida vertebrates, (2) determination of the conservation status of each species with respect to security on public lands, and (3) identification of strategically located habitats that should be protected to ensure the long-term persistence of biodiversity in Florida. However, given the rapid growth of the human population in Florida, the vegetation map is becoming out of date. In an effort to update our previous work, we have undertaken a project to perform a change detection analysis for all of Florida on a county-by-county basis. The change detection employs the following steps: (1) obtain 1996-97 Landsat imagery, (2) clip the imagery by county, (3) perform an unsupervised classification to identify lands with spectral signatures indicating disturbance, (4) overlay the disturbed lands layer on our original vegetation map to identify lands disturbed since the late 1980s, (5) determine which lands disturbed over the 10 year period were converted to urban uses and which were converted to agricultural uses by overlaying the newly disturbed lands grid on available land use/land cover data layers and digital ortho quarter quads, and (6) produce 30 m grids of newly disturbed lands and tabular reports of habitat loss by county for the study period. In five southwest Florida counties (i.e., Collier, Hendry, Lee, Charlotte, and Glades), disturbed lands covered 41% of the region in 1996, and 31% of disturbed lands had been converted from natural habitats to agricultural and urban uses between 1986-96 (a 46% increase in 10 years). Agricultural lands accounted for 76% of the natural habitats converted to human uses, and urban lands accounted for 24%.

We used the results of the change detection to evaluate the impacts of land use conversions on the habitat of the endangered Florida panther (*Puma concolor coryi*). The grid of lands disturbed between 1986-96 was overlaid on our model of Florida panther habitat (created from our original land cover map based on 1986 Landsat imagery). We found that 13% of lands mapped as panther habitat in 1986 had been converted to urban and agricultural uses between 1986-96. Most (77%) of the habitat lost was due to conversion of panther habitat to agricultural uses. Of equal concern, the map produced by this project showed that landscape linkages that provide for panther movements throughout the southwest Florida region are being severed by conversion of native habitats to intensive human uses. These are alarming results given that the panther population consists of no more than 60-70 individuals, and that at least half of the population occupies habitats on private property.

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Linkages between the Snail Kite Population and Wetland Dynamics in a Highly Fragmented South Florida Hydroscape

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The Snail Kite (*Rostrhamus sociabilis plumebus*) is an endangered species whose entire U.S. population is restricted to the wetlands in central and southern Florida. The watersheds of this region have experienced, and continue to experience, substantial degradation from drainage, impoundment, changes in water flow regimes, increased nutrient loadings, and invasion by exotic plants and animals. This has resulted in the current planning for some of the largest scale ecosystem restoration efforts ever undertaken (e.g, the Central and South Florida Project Restudy, Kissimmee River Restoration, and the South Florida Ecosystem Restoration Initiative). Although other endangered species occur in central and southern Florida, snail kites can be considered indicator species relative to evaluating restoration success. This is because of their dependency on the entire network of wetlands scattered across this landscape and because they are restricted to the watersheds within the central and southern Florida ecosystems.

Habitat quality for this species is dependent on hydrology and wetland plant communities that support their principal food source, the apple snail. There is a direct linkage between changes in hydrology to changes in habitat quality for the kite. Previous management recommendations have focused on stabilizing hydrologic conditions in impounded wetland units to provide critical habitat for this species. However, both kites and wetlands respond to changes in hydrological regimes. Kites are capable of behavioral responses on the order of days or population responses on the order of months to year, whereas the plant communities respond through successional processes at time scales spanning months to several decades. A focus is needed that addresses both snail kite population dynamics and plant community dynamics at spatial and temporal scales that are pertinent to each. We describe habitat quality for snail kites in the context of fulfilling their forage and reproductive requirements and the linkages between the population dynamics of this species and ecosystem processes that regulate habitat quality.

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The Role of Seasonal Hydrology in the Dynamics of Fish Communities Inhabiting Karstic Wetlands of the Florida Everglades

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We studied the role of hydrological variation and availability of dry-season refugia in shaping the structure of fish communities in karstic wetlands of the Florida Everglades. The Rocky Glades is a wetland region of the extreme southeastern Everglades that is flooded for less than 6 months in most years. Solution holes serve as refugia for aquatic organisms, especially fishes, during the dry season. Our study addressed the following questions: Do fishes accumulate into predictable assemblages in solution holes during the dry season? Do abiotic characteristics of solution holes such as depth, water quality, or habitat complexity determine the assemblage of fishes that persist there? And, how do biotic interactions, especially predation, influence which species survive the dry season to recolonize the marsh surface when the rainy season arrives?

We sampled between December 1999 and July 2000, with non-destructive activity traps, coupled with mark-release-recapture techniques, to assess the relative abundance of fishes in solution holes located in the Everglades National Park. In 1999, we collected over 2,500 fishes in 17 species. The abundance of fishes increased early in the dry season, followed by intense mortality in mid-April. Principal components analysis indicated that fish relative abundance changed during the dry season with early colonization by bluefin killifish and sailfin mollies, followed by piscivorous species in mid-March, and the concomitant decline in small-sized species. Over 50% of the piscivorous fish were introduced species, such as walking catfish and two cichlids. Introduced fishes appeared to tolerate the stressful solution-hole environment in the late dry season better than most native species. Using a null model testing community structure, we found that fish species occurred together less often than predicted by chance as the dry season progressed. And the composition of these communities at the end of the dry season were segregated into refugia supporting either native, small fishes or non-native and piscivorous fishes. The results of year 2000 work will also be presented. Our results so far suggest that secondary production of fishes in the Rocky Glades is limited by mortality during the annual dry season when solution hole refugia are limited in number and experience poor water quality.

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Community Patterns of Seedling Recruitment after Summer Fire in Two Pine Rocklands

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As part of a study to examine the effects of hurricane-induced fuel heterogeneity on the composition of pine rockland understory vegetation, we followed the appearance and persistence of all forb seedlings in study plots at Lostman's Pines (in Big Cypress National Preserve) and Pine Island (Everglades National Park). We monitored trios of plots with high and low fuel levels: naturally-occurring high (under fallen pine tree crowns) and low (not under fallen crowns), and artificially high, under piled pinestraw.

At Pine Island, seedling emergence increased each month following the fires with summer rains, reaching a peak at six months post-fire. At Lostman's Pines, seedlings appeared initially, but the plots were then underwater for four months. After that time, many more seedlings emerged and established.

High fuel levels favored the establishment of certain forb species, and inhibited the establishment of others. At the drier Pine Island site, species with more seedlings in high fuel plots included *Cassia aspera, Chamaesyce porteriana, Dyschoriste oblongifolia* var. *angusta, Physalis viscosa, Pluchea rosea*, and *Stillingia sylvatica*. Species with more seedlings in low fuel plots were *Acalypha chamaedrifolia, Centrosema virginiana, Chamaesyce adenoptera, Melanthera parvifolia, Phyllanthus pentaphyllus, Piriqueta caroliniana, Ruellia caroliniensis*, and *Samolus ebracteatus*. In the wetter Lostman's site, cattails (*Typha* sp.) established only in high fuel plots. Fuel heterogeneity clearly plays and important role in maintaining the diversity of the understory of pine rockland habitat.

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Spatial Differences of Litter Fall and Basal Area of Tree Island Species in Water Conservation Area 3 in the Central Everglades

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Tree productivity and its relationship to hydrologic conditions are currently being studied on nine tree islands throughout Water Conservation Area 3. Productivity was measured on 14 tree species using leaf litter production and basal area changes. The 14 species were divided into three groups: upland-tropical hammock species *(Bursera simaruba, Chrysophyllum oliviforme, Cocolobo diversifolia, Eugenia axillaris, Ficus aurea, Myrcianthes fragrans)*; moderately water tolerant species *(Acer rubrum, Ilex cassine, Magnolia virginiana, Myrica cerifera, Persea barbonia)*; and water tolerant species *(Annona glabra, Chrysoblanus icaco, Salix caroliniana).*

Leaf litter production was determined utilizing eight 0.25m2 litter traps per plot, with two plots on each of the nine islands. Aluminum dendrometer bands measured basal area changes on 346 trees throughout the nine islands of study. Preliminary results suggest that inundation of upland-tropical hammock species and moderately water tolerant species decreased rates of production. Even water tolerant tree species had low production rates on islands with extended periods of inundation and higher rates of production on islands where dry-downs occurred annually. This study will result in a better understanding of tree island ecology in relation to water levels and hydroperiods. Subsequently, these data will be used to measure the successes of the Comprehensive Everglades Restoration Plan.

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The Role of Fire in Sustaining Populations of Cape Sable Seaside Sparrows within the Southern Everglades

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Frequent fires maintain the characteristically open, marl prairies of the southern Everglades. The Cape Sable seaside sparrow, an inhabitant of these prairies, thus relies on fire for its long-term persistence. We explore how time since fire, soil depth, and vegetation cover interact to maintain sparrow habitat. We begin by reviewing research to date on this interaction and in so doing, explicitly develop a mechanistic explanation for the effects of fire on sparrows. By overlaying fire records and point count information on sparrow abundance, we find three patterns consistent with the proposed mechanism. First, vegetation over deep soil recovers after a fire (measured as increases in percent coverage of vegetation) at a faster rate than vegetation over shallow soils. Second, sparrow abundance is positively correlated to increases in vegetation cover. Third, sparrow abundance increases at a faster rate post-fire over deep soil sites than over shallow soil sites and sparrows return to sites over deep soil faster after a fire than they will return to shallow soil sites. Overall, our results support past recommendations that southern Everglades marl prairies should be burned on an eight to 10 year rotation in order to maintain sparrow habitat. However, spatial patterns in soil depth suggest that fire management plans must explicitly address the extent of these fires, as burns over shallow soil sites will leave sites unsuitable for sparrows for several years.

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Dispersal and Successional Patterns of the Fish Community of the Rockland Wetland Complex of Southern Florida

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As part of a larger effort to assess the role of Rockland aquatic refuges and subterranean habitats in system restoration, we are collecting baseline data on the constituent aquatic communities, their ecology, and their environment. The Rocky Glades region has been adversely affected by water diversions and has been reduced in areal extent by land conversion for agriculture and urban development. The Rocky Glades represents an endangered landscape of the south Florida ecosystem that remains intact only within the boundaries of Everglades National Park (ENP). Yet it is believed that this region may once have provided an important summer and early dry-season feeding sites for wading birds and good habitat for alligators before it was affected by drainage. The highly eroded landscape offers dry-season refuge to aquatic animals in shallower solution holes and by allowing them access to groundwater via deep solution holes. These fishes and invertebrates appear to emerge onto the surface of the wetlands as soon as the rains reflood the area in the early summer. However, little has been published about the species composition of the animals that survive below-ground through the dry season, their dispersal and recruitment patterns once above-ground, and their movements back into holes as water recedes in autumn.

This first project year is a pilot study in which we are testing designs and methods to use in detecting directional animal dispersal. Because fishes appear to make mass seasonal movements in the Rocky Glades (Loftus, personal observation), we have begun to measure the directionality of dispersal by testing the use of drift fences and funnel traps. Several questions arise from these observations of dispersal in the Rocky Glades. Are the movement patterns of animals related to water flow? Are the animals dispersing 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?

We erected four x-shaped drift-fence arrays with 12m wings made of black groundcloth along the main park road of ENP. The wings of the fences direct the animals into traps that face the compass directions. When the wetlands reflooded in June, we made intensive daily collections for the first two weeks, then reduced the frequency of collections to twice weekly for three weeks, and are now making weekly collections. All animals are identified, weighed, and measured in the lab. The numbers of animals in each trap on a particular day is related to the water flow and depth to assess directional movement. At this point, it appears that most animals disperse rapidly after the wetlands reflood and follow the flow of water. Fishes and crayfish reappeared in the traps on the same day that the wetlands reflooded, demonstrating the existence of local subterranean refuges. Subsequent sampling provided data on community-succession patterns as new species appeared in the traps and relative abundances changed. We have also been able to document the onset of recruitment using the size-structure data. 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 reflooding.

We have saved samples of fishes for stable-isotope analysis as they appeared on the surface to compare with isotope signatures after several weeks aboveground. These data will demonstrate how the trophic patterns change as species begin to forage on the wetland surface. We will also examine the reproductive status of the fishes to learn whether they are ready to spawn when they emerge.

We have set up 24 visual-survey plots, six at each array, to obtain independent estimates of species composition and densities. The mosquitofish is the most commonly counted species because it is constantly in movement. Sedentary, cryptic species are more difficult to survey. This is a new sampling technique for shallow-water marshes with open, rugged terrain, where other methods fare poorly. We are testing the sampling characteristics of this method. We will continue to follow animal-community patterns by visual survey and by trapping until the marshes dry in the fall.

Following the end of the pilot study, we will evaluate the results of the project and decide how to design and implement a more spatially expansive study for next year. The study of ecological interrelations between surface and subterranean habitats will help determine how 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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USEPA--REMAP
Bioaccumulation of Mercury in the Everglades: Patterns in the Foodweb

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We examined patterns of diet and total mercury in eastern mosquitofish (*Gambusia holbrooki*) across the Everglades landscape to search for possible correlations between trophic position and mercury level in this omnivorous fish. Mosquitofish have proven to be a useful indicator species for mercury study because of their ubiquity across the Everglades ecosystem. Mosquitofish were collected in September, 1997, September 1999, and March 2000 from over 100 locations using the REMAP stratified random design and analyzed for gut contents. A separate collection of mosquitofish was made simultaneously and analyzed for total mercury. We used Adam's formula to calculate a weighed estimate of trophic position and Levin's measure of niche breadth for each sample of fish. There was no correlation between trophic score or niche breadth and mercury in these samples. In a separate study, we observed a significant correlation between mercury level and trophic score ($r = 0.73$) when comparing a large sample of Everglades fish species (trophic score 1-5, Hg level 64-784 ng/g). However, the difference in mercury level between adjacent trophic groups was not significant. Trophic score for mosquitofish varied from 1.3 to 2.7, suggesting that we probably did not have the statistical power to observe changes in mercury level within this species. While the diet of mosquitofish is quite varied and changes spatially and temporally in their dependence on surface, benthic, and water-column prey, as well as herbivory, most of these prey have similar mercury levels and this diet variation has little impact on mosquitofish relative mercury level.

We conducted a mercury uptake experiment by placing neonate mosquitofish in cages at short and long-hydroperiod sites located at 3 different regions of the Everglades. These experiments indicated greater uptake of mercury in short-hydroperiod marshes than in long-hydroperiod marshes, except where the long-hydroperiod cages were placed in a mercury "hot spot" indicated by analysis of mercury in periphyton samples. This underlying environmental signal of unknown origin eliminated the hydroperiod effect seen at the other study sites. This suggests that complex spatial patterns of mercury availability may interact with other mercury bioaccumulation processes, obscuring general patterns resulting from trophic relationships.

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Dispersal, Reproduction and Physiological Ecology of Two Invasive Non-Indigenous Fern Species, *Lygodium Microphyllum* and *Lygodium Japonicum*

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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. The Florida Exotic Pest Plant Council has listed over 100 introduced plant species that disrupt or have potential to disrupt native plant communities. Among these, *Lygodium microphyllum* and *L. japonicum* have reached a critical concentration in the environment, where they are both growing exponentially. Furthermore, these two species are able to disperse great distances from known source populations. Once established in a community, these two species eventually dominate the native ecosystem completely, causing the collapse of the natural community. The effective management for these species is difficult because of a substantial lack of information on their life history strategies. Therefore, we are currently examining several life history characteristics of these two species. Specifically, we are studying: 1. their germination and mode of sexual reproduction; 2. the seasonality of spore production and release; and 3. their relative growth rate at different light levels. In particular, we are studying growth by examining its allocational, morphological and physiological determinants.

Of the above studies, the first has been largely completed, while the second and third are in progress. For the reproduction study, fertile fronds from both *Lygodium* species were collected in the field in October 1999 and May and June 2000. *L. japonicum* fronds have been collected from two populations found on Suwannee River Water Management District lands in northern Florida. Fertile fronds of *L. microphyllum* were collected from Jonathan Dickinson State Park and from the Big Cypress Seminole Indian Reservation, located in Martin and Hendry counties, respectively. Fronds were stored in freezer bags and allowed to dry for several weeks, allowing the spores to be released. Spores were than sieved to remove leaf material. Spores collected in October 1999 were utilized in an experiment to examine intragametophytic selfing and intergametophytic crossing in *L. microphyllum* and *L. japonicum.* An experiment was initiated in January 2000 and concluded in June 2000. To test for intragametophytic selfing 60 gametophytes (30 from each population) were transferred into individual petri dishes. Intergametophytic crossing was examined by establishing 60 pairs of gametophytes, with one gametophyte originating from each population. This experiment will be repeated beginning in July 2000. At this time, intergametophytic selfing rates will also be examined. The sexual status of each gametophyte will also be determined at 4, 8, and 12 weeks. Preliminary analysis suggests that both species are capable of intragametophytic selfing, which supports the hypothesis that sexual reproduction in *L. microphyllum* and *L. japonicum* is capable of producing viable offspring through self-fertilization. As a result, since spores are dispersed readily by wind, this will aid the ability of both species of *Lygodium* to rapidly infest new habitat. With these studies, we expect to increase our understanding of the ecology and physiology of these invasive species. This, in turn, will help natural resource managers prevent and control their rapid invasion.

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Oral, Ecology and Ecological Modeling

USEPA--REMAP
Aerial Photo Vegetation Assessment in the Everglades Ecosystem

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Broad-scale and long-term monitoring of the Everglades Ecosystem, including observations of plant communities as indicators of biogeochemical changes, can be implemented using remote sensing and geographic information system (GIS) techniques. The Center for Remote Sensing and Mapping Science (CRMS) at The University of Georgia has cooperated with the U.S. Environmental Protection Agency (USEPA) Science and Ecosystem Support Division, Athens, Georgia, to conduct a vegetation assessment study in support of the USEPA South Florida Ecosystem Assessment Project. Based on the EMAP probability sampling design, the USEPA randomly generated coordinate locations for approximately 260 monitoring stations distributed throughout the South Florida Water Management District (SFWMD) Water Conservation Area (WCA) 1, WCA 2, WCA 3, the Everglades Agricultural Area (EAA) and Everglades National Park. Vegetation communities within square plots 1 by 1 km in size were extracted from existing Everglades vegetation databases created by the CRMS, the National Park Service (NPS) and the SFWMD using 1994/1995 U.S. Geological Survey (USGS) National Aerial Photography Program (NAPP) color infrared aerial photographs. Vegetation in areas outside of the existing databases was interpreted from USGS digital ortho quarter quad (DOQQ) digital data. The classification system followed the Everglades Vegetation Classification System developed for the CRMS/NPS/SFWMD mapping project and included dominant, secondary and tertiary levels of vegetation identification.

Data analysis included summarization of the area covered by dominant and secondary vegetation types within the 1 km^2 sample areas of all monitoring stations and a comparison with total areas summarized from the existing vegetation databases to validate the sampling procedures. Cumulative distribution plots for major plant communities such as sawgrass, muhly grass, maidencane/spike rush, cattail, mixed graminoids, non-graminoid emergents, bayheads and pine/hardwood forests provided information on the range of vegetation types from abundant to sparse within latitudinal bands distributed north to south throughout the Everglades system. The spatial relationship between vegetation distributions and environmental factors such as water depth, hydroperiod and selected biogeochemical parameters available from the USEPA abiotic database for South Florida also was examined. Results are discusses in terms of major patterns of vegetation community change across the system and implications of community changes related to anthropogenic alterations. This effort establishes a baseline of conditions existing in 1994/1995 and a methodology for efficiently monitoring future vegetation distributions and assessing changes in the Everglades system over space and time.

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The Effect of Physical Structures and Hydrologic Cycles on Population Genetic Structure of *Gambusia holbrooki* in the Florida Everglades

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The Everglades is physically divided into several regions by a series of levees and canals which may impede migration between regions. Within these regions local water levels cycle through wet and dry seasons. These hydrologic cycles create a seasonal advance and retreat of water into and out of the marsh. Data from ecological surveys suggest that *G. holbrooki* are among the first species to colonize newly available habitat as water advances into the marsh. The pattern of migration of *G. holbrooki* into the marsh and sources of migrants are unknown. Further, as the water retreats from the marsh much of the Everglades marsh area is exposed leaving little refuge for fish. We tested two hypotheses: 1. Canals and levees would create regional differences in the genetic structure of populations of *G. holbrooki* as a result of limited migration, and 2. Local hydrology would create local differences in the genetic structure of populations of *G. holbrooki* as a result of the pattern of migration into the marsh from the source populations (permanent water refuges).

In May 1999, specimens of *G. holbrooki* were collected from a total of 43 different sites with various hydroperiods in WCA 3A, WCA 3B, Shark River Slough and Taylor Slough. Fifty specimens from each site were frozen at –82^{o}C and later sexed, measured and their species identification was confirmed. Polymorphism was detected at 12 allozyme loci by horizontal starch-gel electrophoresis. Migration rates between populations and regions were calculated with "Migrate" (Beerli, P 1999). Patterns of migration into the marsh were estimated from the pattern of migration rate across hydrologically different sites.

The data do not support the hypothesis that canals and levees impede migration between regions. The data suggest that migration of *G. holbrooki* into the marsh follows a leptokurtic distribution. Sites further from source populations have fewer colonizing individuals and tend to be genetically distinct from other distant populations. These populations also tend to have short hydroperiods and thus may experience long periods of isolation and genetic drift.

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Patterns in the Distribution and Abundance of Mangrove-Associated Fishes and Crustaceans along a Salinity Gradient in Shark River, Everglades National Park

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The fish and crustacean faunas of tidally flooded fringing mangrove forests of Shark River contain representatives from regional freshwater, estuarine and marine species pools. We sample fishes and crustaceans bi-monthly using 2 X 3 m^2 lift nets and 1 X 1.5 m blocking nets across the mouths of intertidal rivulets. These latter geomorphic structures are small drainages, approximately 0.5-0.75 m wide, and 20-30 cm lower than the adjacent forest floor. They flood earlier on the flood tide and hold water later on the ebb tide than the adjacent undissected forest floor.

The fishes entering the forest on a flood tide are uniformly small-bodied, probably due to relatively shallow flooding depths, at least when considered on a worldwide basis. Only a few families dominate the fauna. These include Fundulidae (killifishes), Gobiidae (gobies), Gerridae (gerrids), and Aplocheilidae (rivulins). The latter family contains only one species in North America, mangrove rivulus. This fish, whose physiology and behavior more closely resemble amphibians than other fishes, is being considered for listing as an endangered or threatened species. Nonetheless, it is common on the forest floor along the entire salinity gradient we sampled in Shark River.

Marsh and rainwater killifishes, inland silversides, mangrove rivulus and gerrids of the genus *Eucinostomus* dominate the fauna in the tidal fresh to oligohaline Tarpon Bay reach. The mesohaline site on the Harney River is flooded less deeply than other sites and is dominated by *Eucinostomus* and *Rivulus*. There are no species uniquely or characteristically present at the Harney River site. The site nearest the mouth of Shark River is polyhaline and shows the highest species richness. *Eucinostomus* and *Rivulus* are again abundant, but other species rarely captured further upriver are common here, i.e., frillfin and crested gobies, young-of-year gray snapper, and bay anchovies. We have captured three species of exotic fishes (walking catfish, pike killifish, Mayan cichlid) in relatively small numbers, and none to date at the most downstream site. This observation might indicate that the route of invasion is therefore from a freshwater rather than a marine source.

Amongst the decapod crustaceans, we tabulate only natant (swimming) forms as our lift and rivulet nets sample semi-terrestrial crabs poorly. The most common decapods are caridean shrimps of the genus *Palaemonetes*: at least three species are present. Considerably less common are blue crabs of the genus *Callinectes*.

Intertidal rivulet nets sample an unknown but considerably larger area than lift nets that sample 6 square meters. Perhaps not surprisingly, intertidal rivulet nets also contain consistently more species. It is possible, however, that this consistent pattern is also due to other factors. It is likely that these rivulet nets, situated directly on the forest/creek interface, capture species that use only the very fringe of the mangrove forest. In contrast, lift nets placed 9-16 meters into the forest are more likely to capture species that routinely penetrate further into the forest, and that make use of generally shallower waters than fishes taken in rivulet nets.

As sampling continues, we anticipate integrating biotic and physicochemical factors, defining patterns of temporal variability, and designing experiments to determine causal as opposed to strictly correlational relationships in the data. Further, we plan to extend the sampling to Lostmans River, to begin life history studies of the more abundant species, and to work with ATLSS modelers to begin parameterization of a mangrove fish model for the southwest coast. Such a model will be used to judge alternative restoration scenarios.

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Patterns, Niches and Mechanisms in the Ridge and Slough Landscape: Implications for Restoration

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This study in landscape ecology examined historical narratives, soil maps, vegetation maps, and aerial photographs along with soil core data, archaelogical studies and drainage history to understand: (1) original landscape pattern and hydrology of the pre-drainage Everglades of the 1800s; (2) post-drainage changes; and (3) the present-day Everglades.

Synthesis of the evidence and documentation of post-drainage changes together suggest a clear picture of pre-drainage conditions. The largest landscape, Ridge and Slough, formed a highly directional pattern of peat microtopography. This in turn created a directional mosaic of distinct but adjacent ecological niches: elevated, seasonally-emergent sawgrass ridges alternating with lower elevation sloughs that nearly always contained water. Mapping of the directionality suggests a flow field of long, parallel flow paths without sharp bends. The implied regional topography would have been very uniform. A broad, shallow central rise created two outflows, to the east and southwest. These results are consistent with pre-drainage soil patterns, vegetation patterns, survey lines, and with historical accounts of water depths, flow directions and a central dividing ridge.

Pre- and post-drainage observations indicate that the pre-drainage peat microtopography and associated ecological niches represent an unstable configuration. Mass balance considerations indicate that a mechanism for exporting carbon from sloughs is required to preserve the difference between Ridge and Slough ground surface elevations. Without an export mechanism, a more stable configuration of a uniformly flat peat surface appears to evolve. Such an extensive, flat landscape was in fact present in the upstream portion of the pre-drainage Everglades—the Sawgrass Plains (present day Everglades Agricultural Area). It appears to have supported only very restricted bird and wildlife populations. Under post-drainage, managed conditions, recent detailed vegetation mapping indicates that large areas that were originally Ridge and Slough landscape have been losing the original pattern and becoming progressively more like the original Sawgrass Plains (e.g., northern Water Conservation Area 3A, WCA 3B, and Shark Slough). This loss of peat microtopography and spatial heterogeneity also implies loss of ecological niches.

Preservation and restoration of the pre-drainage ridge and slough landscape therefore requires accurate understanding of the mechanism(s) that prevented sloughs from filling in with organic matter.

Two hypothesized mechanisms are: (1) atmospheric export of carbon through peat fires and (2) downstream export of carbon through water flow. Shortcomings of the peat fire mechanism are: (a) evidence of recurring <u>peat</u> fires (as opposed to vegetation fires) has not been found; (b) evidence of a peat fire in the shape of a slough has not been found; (c) evidence of peat fire in a slough with simultaneous absence of peat fire in the adjacent ridges has not been found; and (d) spatial patterns of known peat fires are very different from the Ridge and Slough pattern. The lack of peat fire evidence either reflects pre-drainage hydrology too wet for peat fires, or it may be the result of the technical difficulty of distinguishing peat from vegetation fires, and of spatially mapping ancient fires. The strong disparity between currently observed fire patterns and the pre-drainage Ridge and Slough pattern seems to be a separate, serious limitation to the hypothesis.

Shortcomings of the water flow hypothesis are: (1) very low surface slopes; (2) very low average flow velocities; (3) very long transport distances required to completely export carbon from the landscape. All three shortcomings make it hard to envision complete export of particulate carbon under known average flow conditions. Two possibilities have been considered: (a) that the export is based solely on transport of dissolved organic carbon, and (b) that transport of particulate organic carbon is also involved, especially from the flocculent layer (specific gravity very close to 1.0). Transport based on dissolved carbon alone would occur at any non-zero velocity, and would export completely out of the landscape, but it is not yet known whether the volume exported would be sufficient to prevent slough in-fill over time.

The hypothesized flocculent transport mechanism could be the cumulative effect of many separate, incremental downstream steps generated by transient high-velocity flow fields created by local storms, or by large-scale transients created by hurricanes. Although casual observations of flocculent transport under storm conditions exist, a shortcoming of this hypothesis is the lack of quantitative measurements. Installation of continuously monitoring dataloggers is planned for measuring such transient phenomenon.

It is generally agreed that it would be undesirable for areas of Ridge and Slough landscape to continue transforming into flatter, more uniform, and ecologically less diverse habitats like the Sawgrass Plains. Prevention of this undesired transformation requires evaluation of the hypothesized causal mechanisms that originally preserved the landscape, and their subsequent incorporation into restoration plans.

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Corridors, Landscape Linkages and Conservation Planning for the Florida Panther (*Puma concolor coryi*)

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Southwest Florida is experiencing rapid human population growth, infrastructure development in areas that may be critical to juvenile dispersal and Florida panther (*Puma concolor coryi*) population growth. The southwest Florida landscape is a patchwork of agricultural, urban, and natural areas that includes some of the largest tracts of public conservation lands in the eastern United States. The bulk of public lands are in extreme southern Florida - the northern portions of the area are dominated by private lands. Panther habitat on private lands can be of high quality but it often occurs in a patchy distribution. These features not only limit the ability of panthers to inhabit remaining forests, but the associated fragmentation reduces the ability of individual panthers to disperse away from the panther population core. Further, the sporadic documentation of panther use in this area has created a set of ambiguous circumstances that have made it difficult and often contentious for private property owners, local governments, and regulatory agencies to reach consensus on the trajectory of local development.

As development moves eastward away from coastal urban centers, the pathways used traditionally by dispersing panthers have been reduced or eliminated. Should such trends continue unabated, the potential for natural expansion of the south Florida panther population may be lost entirely. Because development permits are usually considered by local, state, and federal regulatory agencies on an individual basis, it is difficult to gauge the potential impact of individual developments on wildlife habitat and other ecological processes. Further, because so few panthers have been studied in the northern reaches of panther range in southwest Florida, it is difficult to objectively quantify the appropriate mitigation required for an individual project.

We are using analytical methods from conservation biology and landscape ecology to create a regional landscape approach to Florida panther conservation. ESRI-based software such as ArcView and ArcInfo are used to relate telemetry data to landscape features, and to identify strategic linkages that are vital to continued dispersal and occupation of panthers in the southwest Florida region. Landscape features and panther movement data examined with Ramas GIS software suggest that maintaining or enhancing connectivity of forests may facilitate population persistence and possible growth. Further, potential future trajectories of development and Florida panther population trends are best understood with current land cover data and an examination of existing development permits in the region. For example, unconstructed developments that exist only as an approved permit may negate the potential for a wildlife corridor identified only with land cover data. Similarly, challenges to restoration, land management, and acquisition can only be surmounted with accurate projections of future land uses.

The objectives of this study are to (1) delineate existing Florida panther habitat in the region; (2) quantify the quality of this habitat; (3) measure the degree of connectivity of this region with core habitat farther south in the context of known ecological and behavioral attributes of the species; (4) identify key land features that act as dispersal pathways, or that have potential to be integrated into a regional network of core areas and corridors or landscape linkages; and (5) develop a regional blueprint for landscape restoration that enhances the capacity for southwest Florida to accommodate panther dispersal and population colonization to the north, and that can serve as a tool for future land use decisions in the region.

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Modeling the Everglade Snail Kite

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The Everglade snail kite (Rostrhamus sociabilis) is an endangered wetland hawk inhabiting the freshwater marshes of southern and central Florida. According to annual count data (1969-94), the number of birds in this isolated population ranged form ca. 100 birds in the early seventies to ca. 1500 birds at present. During the past decades a significant correlation was observed between population decline and the occurrence of droughts. In particular, system-wide droughts had a strong negative effect on population size. Local droughts could be overcome by the kites by moving into areas where conditions were still favorable. As part of the Across Trophic Level System Simulation (ATLSS) Program, a spatially-explicit population model (SEPM) was developed to capture these dynamics. The aim of the model is to analyze the viability of the kite population under the set of hydrological scenarios for southern Florida that are currently being developed and evaluated. In the model 15 of the major wetlands of south and central Florida are distinguished. The model is individual based and therefore takes demographic stochasticity, a process that may be important in such a small population, into account. The time step of the model is one week. An initial set of runs showed an increased viability of the kite population under the proposed restoration scenarios.

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Non-Breeding Season Ecology of the Cape Sable Seaside Sparrow: Field Observations and Implications for Management

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The federally endangered Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), endemic to south Florida, is widely recognized as a focal species of the Greater Everglades Ecosystem. The sub-species occurs in a series of spatially disjunct patches, or sub-populations, many of which have experienced large declines in abundance over the past two decades. As one important goal of restoration, recovery of the Cape Sable seaside sparrow across the Greater Everglades Ecosystem necessitates a thorough knowledge of the sparrow's ecology and population biology. Extensive research by our colleagues at the University of Tennessee has provided broad information about the species' breeding season ecology and demography. To manage effectively for this sparrow, however, it is essential to understand its habitat needs, ecology, and behaviors throughout all aspects of its life history. During 1998 and 1999, we studied these features of the Cape Sable seaside sparrow during the non-breeding season, when sparrows are particularly secretive and difficult to observe. Using radiotelemetry, we obtained data for 13 juvenile and 27 adult Cape Sable seaside sparrows during this part of their life history. An evaluation of several condition parameters indicated no detrimental effects of the transmitters on the sparrows during extended periods of 1-7 months in which we tracked these individuals.

Our study sought to address questions regarding distributional changes, the frequency and scope of movements, the behavior of individuals and their association with other individuals, age-specific survivorship, and habitat selection, particularly with regards to changing hydrologic conditions, for the Cape Sable seaside sparrow during the non-breeding season.

During the non-breeding season, sparrows are relatively sedentary and maintain a home range that is larger than average breeding season home ranges. At the landscape scale, sparrows consistently occurred in open prairies. Individuals perched occasionally in sawgrass sways and small tree islands, but generally avoided large tree islands and tree-lines. Sparrows regularly occurred in old agricultural areas but avoided old-grove agricultural areas that contained clumps of tall sawgrass and small trees or shrubs. Examination of micro-habitat selection by sparrows under different hydrologic conditions revealed that selection of most habitat characteristics changed relative to the water depth at the site. Sparrows used muhly-dominated sites less frequently and used sawgrass-dominated sites and sawgrass clumps more frequently as water depth increased.

Sparrow surveys in the prairies provided supplementary evidence that sparrows do not dramatically change distribution or habitat use between the breeding and the non-breeding seasons. A documented decline in detectability of sparrows beginning in late October, immediately after completion of molt, and continuing through December represents a behavioral change towards more secretive behavior rather than changes in overall movement patterns or habitat use.

During the non-breeding season, sparrows were generally solitary but occasionally joined small aggregates that occupied the same site. Aggregates included several juveniles and 1-3 adult sparrows and apparently do not constitute a family group. Observations suggest that membership in these aggregates changes over time, despite the fact that group sizes remain similar.

The disjunct nature of populations throughout the range of the Cape Sable seaside sparrow in south Florida raises questions regarding whether they function as a metapopulation, in which case movements by individuals among suitable habitat sites would serve to maintain the overall population through colonization of new sites as populations at other sites become extinct. Radiotracking data for juvenile and adult sparrows indicated that individual sparrows were generally consistent in their scope and frequency of movements. Although most returned to previous home ranges after occasional longer movements outside the home range, some individuals moved distances of up to 7 km from their previous home ranges, indicating that sparrows are capable of moving long distances within the muhly prairies. No radiotracked sparrows used habitats other than the open muhly- and sawgrass-dominated prairies, however.

We used radiotracking data supplemented with resighting information for banded-only sparrows to estimate annual survival for the Cape Sable seaside sparrow at our study site. Annual survival estimates ranged from 0.38 for juveniles to 0.46 for adults and generally are lower than survival estimates from other published sources. These differences are mainly due to the fact that our estimates were calculated using statistical estimators therefore are likely to be more appropriate for demographic modeling efforts.

Recovery efforts for the Cape Sable seaside sparrow in the Greater Everglades Ecosystem will entail synthesis of information about the sub-species' entire life history. Observational and descriptive data compiled to date should be used to formulate testable hypotheses and design experiments to evaluate different management scenarios. For example, using fire to manipulate habitat while conducting parallel telemetry studies may permit evaluation of habitat changes on movement patterns and habitat use of individuals or on distributional changes of sub-populations. While current studies have focused on population-level parameters collected for a sample of the sub-populations, experiments conducted at the landscape scale to evaluate effects of habitat alteration or variation in hydrologic patterns will ultimately provide the most useful information toward planning recovery for the subspecies.

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Responses of Periphyton, Water Lily, and Soil to P Enrichment of an Everglades Slough

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The Everglades developed as a nutrient-poor, rain-fed ecosystem. However, it has received elevated P loads for the past 30 yr. In this study, the effect of P loading was examined using 21 1.8 m^{-2} enclosures that were placed in a pristine open-water (slough) wetland and subjected to 7 inorganic phosphorus (P) loads; 0. 0.4, 0.8, 1.6, 3.2, 6.4, and 12.8 $g \cdot m^{2}$ yr^{-1}. Metaphyton (unattached floating and suspended periphyton) accumulated P more rapidly than epipelon (benthic periphyton); however, both assemblages stabilized at P concentrations around 2.5 g kg^{-1} after 1 yr. Water lily, a dominant slough macrophyte, accumulated P more slowly than periphyton, but achieved a similar plateau after 2 yr. Increased P loads were associated with an increase in leaf size and surface area of this species. In contrast, soil TP concentrations remained fairly constant except at the highest load. Porewater P also showed little change except at the highest load, where SRP concentrations increased dramatically after 1 yr. Nitrogen concentrations in periphyton and water lily also generally increased in response to increased P loads. The high affinity of periphyton and water lily for P, combined with their subsequent influence on N uptake, suggests that these components can play an important role in wetland nutrient cycling. In addition, although periphyton responded more rapidly, both periphyton and water lily tissue P concentrations were sensitive indicators of P enrichment and may be used as early indicators of ecological impacts caused by elevated P loading.

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The Use of a Total System Conceptual Ecological Model for Setting System-wide Performance Measures for the Everglades Restoration Plan

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The Comprehensive Everglades Restoration Plan (CERP) has used a formalized Applied Science Strategy as a means for maximizing the effectiveness of science in planning and evaluating the Everglades restoration program. The key component in the Applied Science Strategy is a set of conceptual ecological models. These models are used, (1) to build scientific consensus regarding the objectives and components of the restoration plan, (2) to create and evaluate the hypotheses that explain the effects of the key anthropogenic stresses on the natural system, and (3) to establish specific performance measures as a basis for assessing the success of the plan. An Everglades Ridge and Slough conceptual model is briefly reviewed to illustrate the organization and use of the models. At this GEER conference we present the first draft of a Total System conceptual model, which has recently been created as a basis for defining a set of total system performance measures for the restoration of wetland systems in south Florida. To be successful, this model must incorporate the key stressor-effects hypotheses that are operating at system-wide scales in south Florida. Participants at the conference are asked to review the Total System model and its supporting hypotheses before the final day of the conference week. A revised Total System Model will be presented on the final day.

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Linkages between Microbial Community Composition and Biogeochemical Processes along Nutrient Gradients in the Everglades Agricultural Areas

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The compositions and activities of microbial communities in the Everglades likely depend in part on their position along nutrient gradients. An understanding of the relationships between community composition, nutrient status, and biogeochemical cycling may yield sensitive indicators of nutrient impacts. Bacteria respond to environmental change much more rapidly than do plants, and characterization of shifts in the composition of bacterial assemblages as a response to changes in nutrient concentrations may provide very sensitive early warning indicators of ecosystem change. These indicators could be useful in identifying ecologically sensitive concentrations of nutrients, and conversely, may be used to determine appropriate restoration endpoints.

We are currently using molecular genetic approaches to characterize components of microbial communities at selected sites along nutrient gradients in the Blue Cypress Marsh and the Everglades Agricultural Area. This type of research will lead to a greater understanding of the response of microbial communities to nutrient impacts, and may lead to identification of sensitive indicators of the nutrient status and degree of impact along these gradients. In addition, this research will ultimately provide a greater understanding of the linkage between biogeochemical cycles and the bacteria that drive these cycles.

Our approach is to use selected bacterial genes that will yield insight into community composition (e.g. ribosomal RNA genes and. genes encoding enzymes involved in nitrogen, sulfur, and carbon cycling). Two levels of resolution are being studied: specific DNA sequence analysis that will yield information on the fine structure of communities, and a more general community fingerprinting approach (T-RFLP) that is providing a quick scan of the composition of selected bacterial groups. This project is only in its beginning stages, but large differences have been found between the compositions of periphyton communities taken from impacted and non-impacted sites. These preliminary data will aid in focusing our research toward potential indicator groups.

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The Potential for Filter Feeding Sponges to Control Phytoplankton Blooms in Florida Bay

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An unprecedented series of ecological disturbances has been recurring within Florida Bay (USA) since the summer of 1987. The most dramatic perturbation to this system has been the widespread mortality of turtlegrass, *Thalassia testudinum*, which has resulted in elevated inorganic and organic nutrient levels in the normally oligotrophic waters of Florida Bay and in increased turbidity in areas of exposed, easily resuspended sediments. The indirect eutrophication and increased turbidity resulting from the demise of *T. testudinum* have caused a general deterioration of the Florida Bay ecosystem, as evidenced by persistent and widespread phytoplankton and cyanobacteria blooms. These blooms have been responsible for a continued decline in seagrass communities as a result of increased light attenuation in the water column, and coincided with the large scale decimation of sponge communities.

Since the initial seagrass die-off, blooms have swept over extensive portions of the bay north of the middle Keys and have persisted for months at a time. The proliferation of the cyanobacterium *Synechococcus* and diatom *Rhizosolenia* blooms in the only region of the continental United States containing sensitive coral reef ecosystems has caused widespread concern among scientists and water managers. These blooms have the potential for disrupting the ecology of the bay through associated anoxia, toxin production and the reduction of light availability for benthic plant communities. Some regions of Florida Bay exhibit high levels of algal and/or non-algal suspended solids resulting in low light penetration. One factor which may be contributing to this unprecedented seagrass die-off is the reduction in light availability caused by high phytoplankton standing crops. One hypothesis is that the large scale loss of suspension feeding sponges has rendered the Florida Bay ecosystem susceptible to these recurring phytoplankton blooms.

Sponges are a particularly dominant structural feature of Florida Bay seagrass and hardbottom habitats, functioning as efficient filters of small (< 5 µm) planktonic particles. Previous studies have illustrated that the grazing pressure of filter feeding bivalves may control phytoplankton abundance. These studies generated great interest in the role that filter feeding bivalves have on phytoplankton growth dynamics and biomass. However, the influence that suspension feeding sponges have on phytoplankton biomass is relatively unknown. If the presence of sponges increases light availability to the benthic plant communities, then sponges may play an important role in reducing the shading effects of phytoplankton blooms, and the loss of this organism in Florida Bay may have cascading effects on the associated seagrass community.

A stratified random sampling design was used to identify 224 sites throughout the extent of the Florida Bay. This presentation will present data on current densities and biomass abundances of sponges at these sites. In addition, *in situ* grazing rates of the two sponge species which accounted for a dominant portion (69%) of total sponge community biomass prior to the sponge die-off (*Spheciospongia vesparia*, loggerhead sponge and *Ircinia campana*, vase sponge) will be used to assess the impact of the large scale mortality of sponges that has occurred in Florida Bay. We will speculate if the system-wide trophic dysfunction, a consequence of the documented sponge die-off, has potentially contributed to the magnitude of the nuisance blooms and if the loss of these organisms can explain why this system remains susceptible to recurrent blooms of phytoplankton and cyanobacteria.

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Demonstrating the Destruction of the Habitat of the Cape Sable Seaside Sparrow

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Countries differ in the vigor to which they protect biodiversity and in the particular laws they pass to do so. In the United States of America, one of the more effective laws is the Endangered Species Act. It prohibits direct take — the killing or harming — of Federally-listed endangered species. From its inception there has also been the implication that it prohibits take indirectly — through the destruction of the ecosystems on which species depend. That provision was challenged in a legal case, Sweet Home versus Babbitt, argued in front of the Supreme Court of the United States, on February 17th 1995. In the particular context of the Spotted Owl, an Oregon group challenged the responsible cabinet member, Secretary of the Interior Babbitt, arguing that only direct take violated the law and not habitat destruction. In a brief of Amici Curiae scientists, one of us (Pimm) among others (Cairns et al. 1995) argued that habitat destruction is most often the cause of species endangerment and extinction.

The Supreme Court agreed with the Babbitt's position and of this publication. In doing so, they raise a scientific question that transcends national boundaries: how are we to demonstrate that human actions harm the habitat on which a species depends? In the case of the owl, the action — extensive logging of the old growth forests on which the birds depend — was obvious. Of course, it need not be.

Our particular concern is the federally listed Cape Sable seaside sparrow, a bird found only within the seasonally flooded marshes in the Everglades of South Florida. In previous publications, we demonstrated that the unnatural flooding of its breeding habitat directly caused its precipitous decline in the western half of its range (Curnutt et al. 1998, Nott et al. 1998). The flooding resulted from the diversion of the area’s drainage, Shark River Slough, from its natural path towards the west and a change in the timing of its seasonal ebb and flow. Concomitant with those changes, areas in the east became over-drained and more susceptible to anthropogenic fires. Those fires also harm the birds directly.
We left open the possibility that flooding and fires also damaged the habitat directly and so the birds as a consequence. Here, we demonstrate that flooding has indeed altered the habitat, done so in a way to preclude the bird’s use of the habitat, and over a period of years longer than the flooding itself.

The paper proceeds in two stages. The first explains how we predict sparrow habitat. In brief, by precisely locating the nests of sparrows during the breeding season, we identify the "spectral signatures" of their territories on satellite images. (The signature of each pixel on an image is a six-element vector, each element representing a "color" -- a wavelength either within or beyond visual detection.) The combination of these spectral signatures for a sufficient sample of territories produces a prediction of the habitat available to the sparrows on the date of the satellite image.

The second stage is an evaluation of those predictions. It has three parts. The first explains how we can predict habitat in years before we began intensive fieldwork and thus have no nest locations. It includes both ecological reasons and empirical evidence supporting our methodology. The second is an analysis of the habitat predictions within each of the populations. It links water management decisions to their effects on the habitat. The third part is a detailed analysis of the errors we find in our predictions. We identify these errors using the annual range-wide surveys of the sparrow's abundance and distribution. We find that errors of the kind where we predict no habitat, but where there are sparrows, are few indeed. Often they are explicable in terms of birds remaining in the same place from one suitable year to the next unsuitable one. Errors of absence from predicted suitable habitat are more common. They are readily explainable by the bird's inability to re-colonize once-suitable habitat that in immediately preceding years became unsuitable because of fires or floods.

We will present two key results.

(1) Across the eight years of the study, large year-to-year fluctuations in predicted habitat confirm the culpability of water managers. Flooding in 1993 and 1995 greatly reduced the habitat predicted to be suitable for the sparrow compared to 1992. This is a formal, technical demonstration of the figures presented in Nott et al. 1998, inferring dry prairies in 1992 and extensively flooded prairies in 1993 and 1995, from the colors of the published images.

(2) The predicted suitable habitat west of Shark River Slough was at a low ebb in 1995 and has recovered slowly, but consistently, in the years from then until 1999. This formal, technical demonstration matches exactly the subjective opinion expressed by Bass and Pimm from their visual surveys. By 1999, the predicted suitable habitat had not yet recovered to its pre-flood state. The habitat is recovering faster than the bird populations. It is the repetition of precisely such a scenario that will lead to the species' extinction (Pimm and Bass, 2000).

Neither of these results will likely come as a surprise to readers of our previous papers. Nonetheless, we consider the results we shall now present in detail to be important in both a national and a broader context.

Importantly, our data conclude that water management practices have damaged huge areas of vegetation across Everglades National Park, have done so for extensive periods of time, and in a way that jeopardizes the survival of a Federally listed species. This constitutes a "take." Moreover, it is one that is independent of, and lasts longer than, the direct affects of flooding. Crucially, these data are independent of — and so additional to — all other conclusions that we have drawn in previous papers.

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Oral, Ecology and Ecological Modeling

Movements and Habitat Use by Florida Manatees in the Everglades Ecosystem

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A multi-year project has been initiated to develop the data and ecological models necessary to understand and predict the effects of hydrological restoration on Florida manatees (*Trichechus manatus latirostris*) in South Florida. Given the reliance of this endangered aquatic mammal on freshwater and aquatic vegetation, we expect that altered water management regimes and resulting environmental changes will affect manatee distribution, relative abundance, habitat use, and movement patterns. In order to test this hypothesis, and understand its implications, we are collecting information on the current distribution and status of the manatee population prior to implementation of restoration activities. Aerial surveys, satellite-based radio-telemetry, and field assessments of foraging areas are providing data on distribution, relative abundance, movement patterns, home range, and habitat use of manatees in this region.

Manatees inhabit the coastal zone, rivers, and canals of South Florida from the St. Lucie estuary on the Atlantic coast to Charlotte Harbor on the Gulf coast, and inland to Lake Okeechobee. The study area includes the coastal rivers, bays, and estuaries of the southwest coast from Flamingo to Marco Island, with a special focus on the Ten Thousand Islands area. The hydrologic restoration planned for the Southern Golden Gate Estates is predicted to reduce freshwater point flow discharges in the Faka Union canal by two orders of magnitude and to minimize the freshwater shock loads to the Ten Thousand Islands Estuary (Abbott and Nath 1996). We will use the implementation of this restoration effort as a large-scale experiment to assess the impacts of changes in freshwater inflow on manatee distribution, relative abundance, and habitat use in the Ten Thousand Islands region.

Aerial surveys in the Ten Thousand Islands are ongoing (see Doyle *et al*. this proceeding). Proposed radio tracking efforts include tagging up to 10 manatees each year for a period of three years. Radio tracking is accomplished through the use of conventional and satellite-based radio-telemetry systems. A floating radio-tag, attached by a flexible tether to a padded belt around the base of the tail, enables manatees to be tracked in saltwater environments. The tag incorporates both VHF (very high frequency) and ultrasonic transmitters for field tracking and tag recovery, and an Argos satellite-monitored transmitter for remote tracking. Location determination through Service Argos is relatively systematic, continuing day and night regardless of inclement weather or geographic location. The Argos data is the primary source for the determination of movements, home range, and habitat use of individual manatees. These tracking methods have been successfully applied throughout the manatee's range (Deutsch *et al*. 1998).

In a preliminary tracking study, three manatees were tagged and released on 22 June 2000 in Rookery Bay, near Marco Island. These individuals had been captured during the winter months expressing symptoms of exposure to red tide and held in captivity until release. Following release, one of the manatees, a subadult female named Keewi, made several trips between Marco Island and the Gordon River where the last satellite location was received on 07 July 2000. The other two, Poi (adult male) and Surfer (adult female) moved south to the Ten Thousand Islands/Everglades National Park. Poi made several trips between Marco Island and Port of the Islands/Faka Union canal during July and early August. During the period of 11-14 August, Poi moved out of the area and traveled north to the Caloosahatchee River in Lee County. His often rapid and erratic moves can be considered typical for an adult male manatee in search of estrus females. Surfer, however, took up residence in the vicinity of the Huston and Chatham rivers where she remained for over two months. Here she developed a pattern of feeding on offshore seagrass beds near Pavilion Key and traveling approximately 16 km every 3-5 days to Huston Bay, Last Huston Bay, and Chevelier Bay. Her movements suggest a preference for foraging in marine areas with brief travels up inland creeks, perhaps to drink fresh water. These movement patterns suggest that the availability of fresh water and spatial distribution of submerged aquatic vegetation may determine movement patterns of manatees within the Ten Thousand Islands. Hydrologic changes may result in a shift in spatial use of the area by manatees.

GIS technology has provided the capability of integrating telemetry point coverages on shoreline, seagrass, or bathymetry basemaps. While Argos data is valuable for comparison of spatial use patterns across large areas and over different temporal scales, fine-scale habitat analyses are limited by imprecision in the locations. The application of the NAVSTAR Global Positioning System (GPS) shows promise for determining detailed habitat use patterns. A datalogging GPS tag developed for manatees acquires and stores locations while deployed on the animal, primarily when the manatee is feeding or resting in shallow water. A two-week deployment of a GPS tag on Surfer in August 2000 demonstrated that fine-grained analyses of habitat use and better estimates of travel paths that are possible with GPS data.

Areas of tidal rivers with submerged aquatic vegetation (SAV) are important feeding and resting areas for manatees. Manatees also utilize nearshore grass beds on the southwest coast, primarily during the summer months (S. Snow, Everglades National Park, pers. comm.). Because there have been no systematic surveys of SAV along the southwest coast or in the inner bays, baseline conditions need to be established for both the SAV of estuarine bays and the seagrasses of the nearshore coastal waters prior to hydrological changes. Documentation of manatee foraging areas by tracking and aerial surveys will help to identify study sites for more intensive habitat characterization. These SAV assessments are part of a larger effort to evaluate restoration effects on estuarine communities of the southwest Florida coast, coordinated by Dr. Carole McIvor, U.S. Geological Survey.

This study will lead to improved understanding of both manatees and the aquatic vegetation upon which they depend, and the implications of changes to the region’s flow regime. It also provides valuable information on the environmental factors controlling manatee distribution in a relatively pristine, subtropical region where cold stress does not have a major influence on migratory and winter season behavior (see Runge *et al.* and Deutsch *et al*. this proceedings).

This study is a cooperative effort with federal, state, and private partners, including: the Everglades National Park, U.S. Fish and Wildlife Service, Big Cypress National Preserve, Rookery Bay National Estuarine Reserve, and Florida Marine Research Institute.

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Ecological Exchanges between a Mangrove Creek and Surrounding Wetlands in the Southern Everglades

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Hydrological restoration of the Everglades will result in increased freshwater flow to Florida Bay. The wetlands bordering Florida Bay are characterized by alternating flooding and prolonged draining. This variability results in sequential anareobic and aerobic conditions of the sediment surface that affects chemical transformations of nutrients and subsequently primary producers. Our objectives were to determine the trends in inorganic nutrient concentration and their flux to the photosynthetic components from adjacent wetlands into Taylor River. It is critical to determine the importance of relative effect of freshwater flow, rainfall, wind-driven and tidal forcing on water exchange and nutrient concentration for this area. Several 10-day intensive studies were conducted through out the period of June 1999 - May 2000. Total P concentration was variable (0.2 – 6.9 uM), and correlated with freshwater flow. TN concentration stayed relatively constant throughout rainy and dry season flow. Water exchange was influenced by freshwater flow and wind rather than by tide or local rainfall. Peak TP and TN export occurred during the beginning of the rainy season, while peak import was associated with wind-driven forcing. This salinity transition zone of the Everglades shows a high total and inorganic N:P ratios (51 – 373) give evidence for highly phosphorus-limited environment.

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USEPA–REMAP
Leaf Morphology and Tissue Nutrients of Two Everglades Macrophytes with Respect to Soil Physiochemistry

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Variation in leaf morphology can indicate changes in photosynthetic rates or other leaf functions. The leaf morphology of wetland plants is often highly variable, although most previous studies have explored only the influence of water on leaf morphology. Since plant nutrients are known to affect leaf development, we hypothesized that leaf morphology would be correlated with soil nutrients. We measured four parameters of *Cladium jamaicense* (number of leaves, length of leaf, leaf width, rhizome diameter) and four dimensions of *Sagittaria lancifolia* leaves (leaf base length, leaf petiole length, lamina length, and lamina width) on plants collected from randomly chosen locations throughout the Everglades ecosystem in both the wet and dry seasons. Principal component analysis on both plants from both collection periods distinguished variation in size of plants from variation in other characteristics (number vs. size of leaves for *C.jamaicense* and lamina width vs. petiole length for *S. lancifolia*). A nested analysis of variance revealed that most of the variation in plant morphology occurred between sites, as opposed to among plants within sites.

We also measured five soil characteristics (total phosphorus, alkaline phosphatase, mineral content, ash-free dry weight, and bulk density) at each site from which plants were collected. Principal component analysis distinguished physical characteristics (ash-free dry weight, mineral content, and bulk density) from those indicating phosphorus availability (total phosphorus, alkaline phosphatase). Larger *C. jamaicense* plants tended to occur in soils with a higher peat component. *Cladium jamaicense* plants with more leaves, but proportionately shorter and narrower leaves tended to occur on soils with more phosphorus. During the dry-season sampling, larger *S. lancifolia* plants tended to occur on sites with a higher peat component, but this was not observed during the wet season. During both seasons, larger plants, and plants with proportionately wider laminae and shorter petioles, tended to occur on soils with more phosphorus.

We also examined variation in %C, %N, and %P in leaf tissue of *S. lancifolia* collected during the dry season. Plants with higher leaf % N and % P occurred on soils with higher phosphorus availability and with higher bulk density. We found poor correlations between soil physical properties and *S. lancifolia* tissue nutrients. Plants with wider laminae and shorter petioles had higher values of %C, %N, and %P. These observations suggest that *S. lancifolia* nutrient uptake varies with soil nutrient availability and that leaf development, and thereby leaf morphology, varies with tissue nutrient levels. The observed variations in morphology may indicate modified growth strategies in response to soil phorphorus. Such morphological changes may lead to variation in leaf functions or in plant competitiveness under different soil nutrient conditions.

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USEPA–REMAP
Macrophyte Species Distributions and Community Structure across the Everglades Ecosystem

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A number of wetland plant communities have been identified in the Everglades and hypotheses advanced about the biotic and abiotic parameters that shape these communities. Previous studies, however, have frequently not been quantitative or have covered only a part of the historical Everglades watershed. In order to quantify species distributions and associations across the ecosystem and relate these to physicochemical parameters, we sampled 418 10m transects distributed randomly across the Everglades watershed from Lake Okeechobee south to Florida Bay. One hundred and seventy-eight transects from 120 sites were sampled during the 1999 dry season and 240 transects from 120 sites were sampled during the 1999 wet season. Species presence was recorded for 20 0.25 m^2 quadrats sampled from each transect in order to quantify species presence and abundance at each site. Cluster analysis was preformed on this plant census data to identify species associations and map these associations across the ecosystem. Principle component and correlation analyses were used to examine the correlations of these clusters to physicochemical parameters.

One hundred and sixty-one species were recorded, of which 136 were identified to species or as a single species within a genus. The number of species per transect ranged from 0 at a recently burned site to 30. The median and modal number of species per transect was 5 and the number of species per transect did not differ between the dry and wet season. Ninety-one percent of the species were found in fewer than 10% of the transects. The most common species was sawgrass, *Cladium jamaicense*, which was found in 74% of the transects. We recorded 5 exotic species, 6 endemics and an additional 121 native species.

We used UPGMA to group transects into 8 clusters based on the plant census data. Four of these clusters were relatively large, while 4 were small, representing 1 to 3 transects. The large clusters correspond to frequently recognized Everglades communities, while the small clusters recognize several unique associations. The 4 large clusters were a sawgrass cluster (55% of the transects), an *Eleocharis cellulosa*-*Utricularia purpurea*-sawgrass cluster (22% of the transects), a *Nymphaea odorata*-*Utricularia purpurea* cluster (17% of the transects), and a cattail (*Typha domingensis*) cluster (4% of the transects). The sawgrass cluster was distributed across the ecosystem, but the other clusters had different patterns of distribution that were correlated with variation in hydrologic and biogeochemical parameters.

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Population Modeling of the American Crocodile (*Crocodylus Acutus*) For Conservation and Management in South Florida

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An individual-based model of the American crocodile (*Crocodylus acutus*) in South Florida was constructed. This model is part of a larger modeling project, ATLSS (Across Trophic Level System Simulation), which attempts to predict the effects of restoration scenarios on the flora and fauna of the Florida Everglades. Altering the hydrology will result in altered salinity and water levels in estuaries areas, or core crocodile habitat. The crocodile modeling effort seeks to predict the effects of upstream hydrology on population size, population viability, breeding success and habitat utilization. The crocodile model utilizes a simulated spatial environment and incorporates information on individual movement, behavior, growth, and reproduction. The results of sensitivity analysis demonstrates the usefulness of such modeling techniques in the effective management and study of rare, endangered or otherwise difficult to study species.

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Oral, Ecology and Ecological Modeling

The Ecological Basis for A Phosphorus (P) Threshold in the Everglades: Directions for Sustaining Ecosystem Structure and Function

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Numerous studies have shown that the Everglades is a phosphorus-limited ecosystem. It was hypothesized that increases in phosphorus concentrations in the water column and the soils of the Everglades above the ecosystem's P assimilative capacity would result in significant imbalances in the structure and function of the Everglades ecosystem. Biotic responses at the algal, macrophyte, macroinvertebrate, as well as community and ecosystem level, were considered in the development of an integrated model of ecosystem imbalance. The classification and regression tree method (CART) was used to develop P threshold breakpoints for biological attributes at all trophic levels. A hierarchical analysis method was then used to integrate individual biotic responses into indices of imbalance at each trophic level.

The database used to develop the P threshold was based on a 6-year P dosing study in the northern Everglades and from a set of permanent P gradient plots analyzed over the past 10 years. The dosing and gradient research both provide strong evidence supporting a 20 µg/L TP threshold zone and range, which maintains ecosystem structure and function as well as a balance of flora and fauna in the Everglades. Our gradient research established that the Everglades have a phosphorus assimilation capacity above background P concentrations. A Bayesian modeling effort indicates the highest probability background total P distribution is near 20 µg/L and ranges from 18 ~ 25 µg/L.

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The Influence of Habitat on the Distribution and Abundance of Small Mammals in the Southwest Everglades

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The goals of this study were to describe the distribution and abundance of small mammals of the southwest Everglades, and to determine the influence of habitat on this distribution and abundance. Since the small mammal communities of the mangrove, marsh and mangrove-marsh ecotones within the southwest Everglades had not yet been described, it was important to gather baseline data using a mark-recapture technique. Baseline data included species richness and relative abundance, population structure, reproductive status, mass and size comparisons and presence or absence of ectoparasites. Habitat variables that were measured and compared to species richness and abundance included water level, salinity, elevation and vegetative structure (e.g, tree height and density).

Three independent study sites were set up along the Shark River salinity gradient and selected because I was able to obtain detailed hydrologic information from monitoring stations, location in reference to fresh water flow, powerboat accessibility, and suitability of mammalian habitat. Transect lines from each site were sampled on the same three consecutive days once a month from October 1998 to October 1999. Each transect line at each site contained nine trap stations with three traps per station. Trap stations were classified as mangrove, marsh or ecotone macrohabitat type, and 16 microhabitat variables were measured within each trap station's 10 m^2 area. Adjacent USGS hydrologic monitoring stations provided data on salinity and water depth.

Three native and one introduced rodent species were captured during the one-year study period: *Oryzomys palustris*, *Sigmodon hispidus*, *Peromyscus gossypinus* and *Rattus rattus.* Trapping results (2,919 trap nights) yielded 228 individuals with 249 recaptures for a grand total of 477 captures. *Sigmodon hispidus* and *R. rattus* had a negative correlation with water depth ($R = -0.731$, $P = 0.005$) and ($R = 0.684$, $P = .019$), respectively. *Oryzomys palustris* had a negative correlation with salinity ($R = -0.769$, $P = 0.004$). *Sigmodon hispidus* was captured most frequently in the ecotone, *O. palustris* was distributed almost evenly between the three macrohabitat types while *R. rattus* and *P. gossypinus* were captured most frequently in the mangroves.

In order to describe the microhabitat configuration for each species captured, Principal Components Analysis first ordinated the 16 microhabitat variables and then compared these axes against species distributions with regression analyses. Regression models indicated that the number of *O. palustris* can be predicted from the amount of herb, shrub, litter and elevation in an area ($R^2 = 0.772$, $P < 0.001$). *Sigmodon hispidus* can be determined from the amount of herb, shrub, litter, elevation and canopy ($R^2 = 0.704$, $P < 0.001$) and *Peromyscus gossypinus* from the amount of shrub litter and elevation ($R^2 = 0.486$, $P < 0.001$). *Rattus rattus* did not show a significant microhabitat selection, most likely because it is a habitat generalist and capable of adapting to many habitat types. This is also a possible explanation for *R. rattus's* success as an exotic species.

My research showed that macrohabitat type, surface water, salinity, elevation and vegetative structure had significant effects on small mammal distribution and abundance. If restoration efforts change salinity, water depth and ultimately vegetation type within the southwest Everglades, it is important to have baseline data on small mammals and their associated communities before these changes occur. Information from my study can be used for future comparison in order to evaluate the consequences of proposed hydrologic restoration, as well as to increase understanding of Everglades' faunal communities.

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Vegetation: Environment Relationships and Water Management in Shark Slough, Everglades National Park

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Vegetation in Shark Slough comprises a complex mosaic of marsh assemblages, spotted liberally with tree islands. Controls on this pattern are not completely understood, but hydrologic and edaphic variables, as well as disturbance history, are likely to play important roles. In this presentation, we use data from five cross-Slough transects sampled in 1998-99 to test and describe the association of marsh vegetation with several hydrologic parameters. By accounting for spatial autocorrelation, our analyses yielded estimates of both mean and variance in annual hydroperiod, mean water depth, and 30-day maximum water depth within each vegetation unit during the 1990's. We found clear and consistent differences in the hydrologic regime of three marsh vegetation types, in the direction expected based on the existing literature, i.e., hydroperiod and water depths increased in the order Tall Sawgrass Marsh < Sparse Sawgrass Marsh < Spikerush Marsh. Locally, these differences were quite subtle; within a single portion of Shark Slough, mean annual values for the two water depth parameters varied less than 15 cm among types, and hydroperiods varied by 65 days or less. More significantly, perhaps, regional variation equaled or exceeded the variation attributable to vegetation type within a small area. For instance, estimated hydroperiods for Tall Sawgrass in Western Shark Slough were longer than for Spikerush Marsh in any of the other Regions. Although some of this regional variation may reflect a natural gradient from the northern to southern Slough, we know that much is the result of management and compartmentalization of Northeast Shark Slough from Western Shark Slough. If hydroperiod or water depth are proximate causes of vegetation pattern within regions, as these data indicate, it seems likely that current water management will eventually result in large scale changes in landscape pattern within Shark Slough, or perhaps already has.

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An Overview of the Historical Everglades Ecosystem and Implications for Establishing Restoration Goals

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Using information in historical reports, data from measurements of peat and sediment cores, and flow modeling using the South Florida Water Management District's Natural System Model, we present a characterization of the historical Everglades Ecosystem. Available evidence shows that a natural phosphorus-enriched zone existed south of Lake Okeechobee that contained dense growths of pond apple and other upland species and an associated variety of birds and wildlife. Based on the bedrock profile and peat age, it is also believed that Lake Okeechobee covered a larger area, extending as far south as the current boundaries of Water Conservation Area 1. Because Lake Okeechobee was higher in nutrients than the areas south of it, this larger lake is believed to have had adjacent deposits that were enriched in phosphorus compared to areas of the Everglades further south.

The historical existence and ecological value of the enriched zone are pertinent to the restoration plans for the Everglades. A habitat characterized by nutrient levels above those seen in the most oligotrophic portions of the Everglades should be an explicit part of any restoration plan. Such a zone will be established in the northern parts of Water Conservation Areas 2A and 3A, by the outflow from Stormwater Treatment Areas that will be completed by 2003. Historical and current evidence indicate that this enriched zone, at current and planned inflows, will attain steady state rather than spread continually into the interior of the marsh. Additional phosphorus introduced to the area will be incorporated in greater depths of peat, and not an expanding front of higher soil and water concentrations. Use of the elevated nutrient zones to develop lost habitat types will facilitate a restoration that has the potential to provide the heterogeneity of habitat that was so vital to the health of the historical Everglades.

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Nutrient Cycling and Transport at the Florida Bay - Everglades Boundary

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

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

Nutrient exports are influenced by nutrient processing within the mangrove ecotone. In situ enclosures around mangrove islands within this wetland demonstrated that these islands are net sources of nitrate and nitrite throughout the year, indicating the importance of nitrification in the prop root system. This oxidized nitrogen may be readily denitrified within adjacent sediments.

Nutrient fluxes within benthic chambers demonstrated that mangrove pond sediments are a net sink for N, with nitrate and nitrite uptake and very low ammonium regeneration. Preliminary N_2 flux measurements found that these sediments have rapid rates of coupled nitrification and denitrification. Ammonium and P regeneration from sediments at nearby sites in Florida Bay were also very low, relative to dissolved oxygen uptake. Benthic nutrient regeneration does not appear to be strongly influenced by salinity levels. It appears that changing freshwater flow will not strongly change patterns of nutrient cycling and that the impact of increased nutrient inputs to the Everglades systems will be moderated because of the strong affinity of wetland and bay sediments for P and possibly because of N removal in the mangrove wetland.

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Using Adaptive Management to Assess Biotic Response to Environmental Change

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The hallmark of adaptive management is the desire to optimize management actions in the face of uncertainty about system dynamics, while in the process learning about the system and resolving such uncertainty. In any restoration effort, a critical uncertainty is how the plants and animals will respond to the management actions. If restoration actions are incremental, iterated, or replicated, there are opportunities to learn from earlier efforts and increase the effectiveness of later efforts. This process requires four fundamental elements: (1) a set of restoration strategies to choose from, (2) an explicit objective for management, (3) a predictive model of the system, including expression of uncertainty due to incomplete knowledge, and (4) a monitoring system to allow evaluation of the predictions and provide feedback to the next decision cycle. This fourth element is the key to making management adaptive—the appropriate monitoring needs to be anticipated and implemented in order to allow learning to take place.

As an example of the application of this approach to an issue relevant to wildlife in south Florida and the Everglades, we have developed a conceptual model for adaptive management of manatee use of warm-water effluents. Manatees have already shown a strong biotic response to environmental change, by using power plant effluents to extend their winter range northward. With the anticipated changes in the power industry brought about by deregulation, and the possible closing of a number of plants, there is increased concern about how manatees will respond to this new change in their environment. In particular, if their range contracts, will they become more reliant on south Florida and exterior portions of the Everglades? How would this change their population dynamics and status as an endangered species? In a sense, removal of thermal effluents is a restoration action, but it is not clear if it would be beneficial for manatees.

In the conceptual model we propose, the set of restoration strategies is all of the permutations of changes in existing warm water availability, both temporary and permanent, on the Atlantic coast of Florida, coupled with the potential creation of new thermal refuges. Changes in availability of thermal refuges represent environmental perturbations that are likely to affect manatees. We are uncertain about how manatee behavior might change in the future as a result of environmental change, but we can use current understanding of manatee biology to bracket a range of models. To the extent that warm water availability can be influenced by consideration of manatees, the objective of an adaptive management framework might be the minimization of manatee mortality. A suite of alternative management actions will be identified through analysis of past interruptions or terminations of warm water sources, data on manatee ecology, and information and data from power plants. Although management actions will not be under any central control, learning can take place provided that manatee response is monitored, using such techniques as aerial surveys, radio tracking, and photo-documentation of individual manatees at wintering sites. Further, in the event that the predictive models gain credibility, the various stakeholders may wish to begin taking actions that are identified as optimal.

The goal of management of this system is complex, and not necessarily shared among all interested parties. Even among those primarily interested in manatee conservation, there is not agreement about whether short-term mortality and contraction of winter range might be better in the long term. A formal decision process with predictive models allows these objectives to be discussed in a structured setting. The system model we envision would predict manatee winter mortality, site fidelity, and winter distribution as a function of thermal refuge availability across a grid of sites along the Atlantic coast, extending well into south Florida. Such a model can be developed from existing data on manatee use of thermal effluents in the winter.

Future development of this conceptual model will require collaboration among a large number of concerned agencies and stakeholders. Changes in manatee use of habitats in south Florida could have an influence on the management of other taxa, thus it is important that this issue be monitored closely and the ongoing learning conveyed to a larger audience. Finally, we hope that this example provides motivation for others to consider the advantages of taking an explicitly adaptive approach to restoration.

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Sensitivity and Uncertainty Analysis of a Spatial-Explicit Fish Population Model Applied to Everglades Restoration

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ALFISH is a spatially-explicit population level model for freshwater fish in the south Florida Everglades. The model divides the region into 500mx500m cells. The model's objective is to assess relative differences in fish biomass for wading birds under different hydrological scenarios associated with Everglades restoration. Determining model parameter sensitivity is critical to its reliability in assessing alternative scenarios. Two important model components are pond distribution and available lower trophic level resources. Pond distribution is important in providing fish refuges during periods when water level is low. Initial estimates indicated 34% of cells contained ponds with non-uniform spatial arrangements in some areas. ALFISH's sensitivity to pond distribution was assessed using alternative pond distributions and the same hydrologic data. Pond spatial distribution was varied to include a spatial Poisson, uniform and various clustered distributions. Pond density was also varied. Food resources for the fish were varied using constant maxima and minima across seasons as well as two alternative, seasonally varying cases. Results suggest that ALFISH is more sensitive to pond spatial distribution than pond density. Increasing lower trophic level resources leads to uniform spatial increases in fish density.

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USEPA - REMAP
Soil Subsidence and Soil Preservation in the Public Everglades

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Soil is a defining characteristic of an ecosystem, and soil preservation is an important aspect of ecosystem protection. The South Florida Ecosystem Restoration Task Force and the Comprehensive Everglades Restoration Program have adopted objectives and success indices in order to define restoration goals, track ecosystem status, and measure restoration effectiveness. Among these is restoring the natural balance of organic soil and marl soil accretion, and halting soil subsidence.

The United States Environmental Protection Agency South Florida Ecosystem Assessment Project is unique to South Florida in two aspects: its probability-based sampling approach permits quantitative statements about ecosystem health; its extensive spatial coverage is unprecedented. Ecological condition was consistently documented throughout 3000 square miles of the freshwater wetland portion of the Everglades and Big Cypress. About 500 marsh sites total were sampled in 1995-1996, and another 250 sites were sampled in 1999. Soil characteristics such as thickness, volume, bulk density, percent organic matter are presented for the public Everglades and Big Cypress. Change in soil thickness from 1946 to 1996 is documented. Soil characteristics are related to water regime and plant communities.

Soils to the west in Big Cypress Swamp were primarily sandy, while the wetland soils of the central Everglades were primarily Histosols and Inceptisols (organic peat). Marl was common to the shallower peripheral marshes of the Everglades subjected to shorter periods of surface water inundation. Since peat and marl soils are derived in wetlands from decaying plant matter, the origin and perpetuation of peat and marl soils is greatly dependent upon water depth and the duration of surface water inundation, and resulting wetland vegetative communities.

Soil thickness ranged from 0 feet to over 12 feet. The deepest soils were the peat deposits within LNWR with a mean soil thickness of over 9 feet. Mean soil thickness for other portions of the study area were 4.3 feet in WCA2, 1.5 feet in WCA3A north of Alligator Alley (I-75), 2.8 feet in WCA3 south of I-75, 1.3 feet in ENP, and 1.2 feet in BCNP. About 19% of the Everglades had a soil thickness less than one foot, while 40% had a soil thickness of over three feet. The deepest peat in the Everglades outside of the Refuge is within those portions of WCA2 and southern WCA3, which typically stay inundated year-round.

Soil subsidence within the Everglades Agricultural Area due to drainage and efforts to control it during the 1900s are well documented. In contrast, prior to the present study, subsidence of peat soils within the protected Everglades during the last 50 years was poorly documented. The portion of WCA3 north of I-75 lost 39% to 65% (2.0 to 6.0×10^8 m^3) of its soil. This area was reported to have 3 to 5 feet of peat in 1946, while in 1995-96 we found only 1 to 3 feet of soil, with less than

1 foot in some areas. WCA3B and Northeast Shark Slough may have lost up to 3 feet of soil, representing a 53% and a 42% loss of volume, respectively. Each of these three portions of the Everglades has been subjected to decreased surface water inundation since completion of the WCAs about 40 years ago. During the last 50 years the Everglades Protection Area has lost from 11% to 28% of its soil (5.4 to 17 x 10^8 m^3). No significant change was observed from 1996 to 1999.

Soil organic matter ranged from <1% to 97%. The highest organic matter content was found in the thick peat soils within LNWR with a mean of 92%. WCA2A and WCA3 south of I-75 also had soils exceeding 75% organic matter. Soils in the Park, which include the peat soils within the Shark Slough trough as well as the marl soils of adjacent shorter hydroperiod areas, had a mean organic content of 38%. Soil bulk density ranged from 0.05 to 1.50 g/cc. The highly organic peat soils of LNWR had the lowest bulk density with a mean 0.07 g/cc as compared to the mineral soils of BCNP, which had a mean of 0.77 g/cc. Bulk density in WCA3 north of I-75 had an average of 0.30 g/cc, the highest in the WCAs. Within the WCAs, this portion of northern WCA3 had the lowest organic matter content, the highest bulk density, and the greatest soil loss. All of these observations are suggestive of formerly deeper peat soils being subjected to drier conditions due to water management changes between 1946 and 1996. Surface water inundation has been reduced, soils have subsided, and the resulting surface soil has become less organic. Water management must be improved to maintain marsh soils if the plant communities and wildlife habitat of the public Everglades is to be preserved.

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Macroinvertebrate Response to Nutrient Enrichment in the Florida Everglades

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Extensive research has been conducted to document the environmental changes associated with nutrient enrichment in the northern Everglades. However, very little work has been done to identify the response of macroinvertebrates to nutrient related changes in this ecosystem. During 1997 and 1998, we sampled macroinvertebrates along a nutrient gradient, produced by urban and agricultural runoff in WCA 2A, to assess impacts associated with enrichment. Sampling was conducted quarterly in emergent macrophyte and slough habitats at13 permanent stations located 2 to 14 km downstream of canal inflow structures to document changes in invertebrate community diversity, taxonomic composition, and functional composition. Diversity was nearly constant along the nutrient gradient despite marked changes in vegetation structure and oxygen concentrations. Changes in taxonomic composition, however, were evident as species characteristic of the nutrient-poor marsh was replaced by species known to tolerate low dissolved oxygen in the enriched marsh. Among functional groups, deposit feeders and shredders were more abundant in the highly enriched sites along the nutrient gradient.

Invertebrate communities were compared in the emergent macrophytes and slough habitats in the unenriched marsh. Slough habitats supported higher animal densities and distinctly different taxonomic compositions than emergent macrophyte stands. Grazer abundance was also higher in the periphyton-rich slough habitats. Our findings indicate that Everglades invertebrate communities are sensitive to habitat structural changes caused by nutrient enrichment.

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Reintroduction of Brown-headed Nuthatches and Eastern Bluebirds to Everglades National Park

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The pine rockland ecosystem, dominated by the southern slash pine (*Pinus ellioti var. densa*) forest, is a critically endangered habitat in southern Florida. Along the Miami rock ridge, over 90% of this ecosystem was obliterated in the early 1900's from agricultural and residential development. The largest and only functional remaining tract is the 4,600 ha of pine forest in Long Pine Key, Everglades National Park. The most glaring losses to the pine rocklands has been the extirpation of four endemic bird species, all cavity-nesters: Brown-headed Nuthatch (*Sitta pussila*), Eastern Bluebird (*Sialia sialis*), Red-cockaded Woodpecker (*Picoides borealis*), and Southeastern American Kestrel (*Falco sparverius paulus*). A fifth cavity-nester, the Hairy Woodpecker (*Picoides villosus*) is extremely rare. Although habitat loss is a major factor in these extirpations, other contributing factors probably include altered fire regimes, effects associated with isolated small populations and the influence of a warming climate at the southernmost extent of these species' ranges. More importantly, however, the large distance between remaining isolated habitat islands from source populations has likely precluded recolonization by these species.

In 1997, a two-year experimental reintroduction project was initiated to develop and implement translocation techniques aimed at restoring viable populations of Brown-headed Nuthatches and Eastern Bluebirds. This project serves as one test of the progress made in restoring the rare pineland ecosystem represented by Long Pine Key. During this study, 20 nuthatches and 15 bluebirds (12 adults:3 juveniles) were released to Long Pine Key. Breeding and successful reproduction occurred in both years under natural conditions. At the end of the second breeding season, three nuthatch territories and two bluebird territories were established, which produced 12 and 6 juveniles, respectively. In general, hard-releases (1-3 days) from smaller cages were most effective for nuthatches, while soft-releases (1-3 weeks) from larger aviaries were effective for bluebirds. Moving bluebird pairs and their nestlings also proved to be an effective translocation technique. With effective translocation techniques developed, a long term reintroduction plan was developed.

The primary goal of the long-term reintroduction plan is to translocate approximately 100 individuals of each species to Long Pine Key. Because newly established populations are small and vulnerable the plan proposes moving 20 individuals of each species over a four-year period to increase population size as quickly as possible. During the first year, 14 nuthatches and 26 bluebirds (17 adults:9 juveniles) were released to Long Pine Key. At the end of the breeding season, 8 nuthatch and 4 bluebird territories had produced 22 and 16 juveniles respectively. Demographic, reproductive, and habitat use data from the reintroduced and donor population will be used to evaluate restoration of the pine rockland ecosystem in Long Pine Key and to test hypotheses concerning population biology.

In 1996, the South Florida Ecosystem Restoration Science Subgroup identified the loss of species from upland communities as a critical restoration issue and declared the investigation of reintroductions to restore biotic losses in upland communities as a critical information need.

Moreover, in the 1996 "Report of the Panel to Evaluate the Ecological Assessment of the 1994-1995 High Water Levels in the Southern Everglades" an independent panel noted that restoration efforts cannot concentrate only on the "River of Grass" while ignoring the remaining upland forest fragments. The panel specifically identified reintroduction of upland species lost from the Everglades as a necessary part of restoration. This ongoing project, thus, addresses a critical information need for South Florida Ecosystem Restoration, as stated by the Science Subgroup and implements the High Water Independent Panel's recommendations. Continued support of reintroductions of pineland species and other pineland projects will indicate that public officials are serious and committed to incorporating the endangered pine rockland ecosystem as part of the Greater Everglades Ecosystem Restoration effort.

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Restoration of Lake Okeechobee: Fixing the Headwaters of the Everglades

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Similar to other aquatic ecosystems in south Florida, Lake Okeechobee is threatened by three main problems: an excessive phosphorus load, unnatural hydrology, and the rapid spread of invasive species. The problems facing the lake have been recognized for decades, but the lake's condition has continued to deteriorate. Specifically, (1) external P loads to the lake continue to exceed the SWIM-mandated target, which has resulted in a doubling of the in-lake TP concentration; (2) high lake levels the past six years have contributed to the loss of submerged aquatic vegetation (SAV); and (3) torpedo grass (*Panicum repens*) has spread from less than 1000 acres in the 1970s to over 16,000 acres at present.

Two actions, in particular, during the past two years have rejuvenated the process to restore Lake Okeechobee. First, the Lake Okeechobee Issue Team, formed in 1998 by the South Florida Ecosystem Restoration Working Group, released an Action Plan. The issue team, which consisted of federal, state, and local interested parties, worked together to lay out a series of actions to meet both the phosphorus in-lake concentration and load reduction goals stated in the SWIM Act, as well as achieve further and more comprehensive Lake Okeechobee ecosystem restoration goals. Specifically, the Action Plan calls for building regional reservoir-assisted stormwater treatment areas, intensifying the control of P sources, controlling internal loading within the lake, controlling invasive plants, and minimizing the occurrence of damaging of high water levels. The second action of consequence was the passage of the Lake Okeechobee Protection Plan in the Florida Legislature. Sponsored by Rep. Pruitt in the House and Sen. Bronson in the Senate, this legislation includes a series of activities that are consistent with the Lake Okeechobee Action Plan, but are more detailed and include specific completion dates.

At present, an interagency agreement is being developed between the South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP), and Florida Department of Agriculture and Consumer Services (FDACS). This agreement will identify the process and partnerships involved in completing the elements required by the Lake Okeechobee Protection Plan.

The SFWMD has outlined a series of research, planning, and implementation projects, which will be undertaken over the next five years through both in-house efforts and in collaboration with a variety of partners, in an effort to restore Lake Okeechobee. These projects can be categorized according to their ability to address each of the major problems threatening the ecological status of the lake:

<u>Altered Hydrology:</u> Both excessive high and low water levels can cause ecological damage in Lake Okeechobee; our current focus is on the former because of the high lake stage the past six years. As a consequence, substantial amounts of SAV have disappeared from the near-shore regions of the lake. Our research is geared toward determining the effect of irradiance and lake level on SAV growth and germination in the hope of developing a "depth envelope", similar to the salinity envelopes proposed for the Caloosahatchee and St. Lucie estuaries.

Excessive P loads: Both internal (from the sediments) and external (from the watershed) loads are problematic in Lake Okeechobee. A series of complementary studies are being initiated to address the internal load question. A sediment removal feasibility study will examine the environmental, economic, and engineering implications of different approaches to minimize the internal P load from sediments within the lake. Coupled with this effort will be a pilot sediment-dredging study to evaluate the effectiveness of dredging from a relatively small area within the open water zone of the lake. In addition to the feasibility and pilot-dredging work, on-going efforts are directed toward the enhancement of water quality and hydrodynamic models in the lake. The linkage of these models will allow us to estimate the influence of meteorological conditions on wind/wave action, and in turn, its influence on water quality parameters in Lake Okeechobee.

External P load comes from a variety of mostly non-point sources. We are currently updating the major sources of P runoff in the watershed, as a function of land use changes over the past 10 years. In the meantime, a series of actions are taking place to better regulate, understand, and control the known sources. BMP research is taking place at Buck Island Ranch, using replicated pastures to examine the impact of beef cattle density on surface water runoff nutrient concentrations. In addition, a study at the Williamson Ranch is examining the effectiveness of soil amendments on binding P in replicated stargrass plots. Other activities include: (1) the evaluation and implementation of best available technologies on select dairy operations in the Lake Okeechobee watershed; and (2) research examining the impacts of residuals and chicken manure application on surface water nutrient runoff concentrations. A second set of treatments examines the effectiveness of alum additions to the residuals.

Phosphorus also can come from the heavily loaded tributaries in the watershed. A project is underway to evaluate the effectiveness of different sediment trap designs in a major tributary of the watershed. Also, we are updating the algorithms used to calculate assimilation of P as it travels downstream; in previous models, it was assumed that downstream nutrient transport followed a first-order decay function, regardless of tributary or drainage canal geomorphology or biology. This contract will re-examine and update these algorithms.

Finally, construction projects are underway to treat P and change the hydrology in the watershed. The Lake Okeechobee Water Detention/Phosphorus Retention Critical Project consists of two pilot STAs and ten wetland restoration sites in the watershed. As a part of CERP, stormwater treatment areas will be constructed in the four priority basins and an aboveground reservoir will be built with a 200,000 acre-ft capacity.

Invasive Species: Research is underway to determine what controls the spread of torpedo grass and what are the most effective approaches to treat it and maximize the likelihood of native plants returning to the treated areas. On-going efforts include evaluating the combination of fire and herbicide on torpedo grass control. This work also applies to the water level issue, as torpedo grass appears to spread more rapidly under dry than wet conditions; hence, extremely low water levels may negatively impact the lake because of the spread of invasive species.

Completion of these elements and their implementation in a fashion that also is sensitive to the fragile economy of the region will require substantial effort, patience, and resources. However, the process has begun and progress is now being made. With respect to the lake's three major issues: the problem of eutrophication is being addressed both at the sources and through public works projects; new operating criteria are being developed for the management of Lake Okeechobee, which will include more flexibility in operations to account for both in-lake and downstream environmental hydrologic needs; and finally, an intensive research and operational control program has begun to remove invasive species and return the habitat to natural vegetation. The overall restoration effort is a long-term process, but a pathway for success has been identified. It is now critical that progress be maintained so that these plans and efforts do not suffer the same fate as the failed initiatives that preceded them.

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The Effect of Fish Detritus on an Oligotrophic Everglades Marsh

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This study sought to quantify the effect of fish detritus on several ecosystem processes in the Everglades. The Everglades is a sub-tropical ecosystem characterized by wet and dry seasons. During dry season drawdown, fish congregation in pools can result in localized nutrient enrichment as the water evaporates. *Gambusia holbrookii*, with an average phosphorus content of 7.17 ± 1.46 mg/g wet weight, was selected for this study. There were 4 experimental treatments with three replicates; a control plus P added as fish to equal 40, 80 and 400 mg P m^{-2}. Previous studies have calculated the average amount of phosphorus tied into fish biomass to be 40 mg/g wet weight per m^2. Sites were dosed with dead fish in August of 1999 and April of 2000. A decomposition study has shown that fish decomposition rates at all times of the year are less than 1 week for *Gambusia*. Above and belowground biomass of *Cladium jamaicense* were measured. Soil and plant samples were analyzed for C, N, and P content. CO_2 and CH_4 production in soils was also monitored. CO_2 production followed seasonal patterns, whereas no methane production was noted. Belowground biomass of *Cladium jamaicense* is expected to increase by the first year and aboveground biomass by the second year post treatment. No significant changes in *Cladium jamaicense* aboveground biomass have been noted to date. To date, no significant effects due to treatment have been noted although patterns follow seasonal trends. In addition, a model has been developed to predict the results of this type of addition.

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USEPA–REMAP
Landscape Water Quality Gradients and Tissue Concentrations in the Everglades Ecosystem

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The US Environmental Protection Agency (EPA) Region 4 initiated a project in 1992 to assess the effects of mercury contamination on the South Florida Everglades Ecosystem. This project was designed around the EPA Ecological Risk Assessment Framework and implemented using a statistical survey design to conduct synoptic surveys during the wet and dry seasons from 1994-1996. During this first phase of the project soil, water and biota were sampled at about 500 sites throughout the 9600 km^2 marsh to assess the effects of hydropattern, phosphorus loading, habitat alteration and mercury contamination on the marsh ecosystem. The Phase I report (EPA 1998) found there were significant interactions among water depth, TOC, TP, and SO_4 concentrations, food web dynamics and fish mercury concentrations. These interactions exhibited different spatial patterns in the area north of Alligator Alley, between Alligator Alley and Tamiami Trial and south of Tamiami Trail in Everglades National Park. Three conceptual models were developed, one for each of these three areas, as part of the Phase I report to describe the pathways and interactions among factors affecting fish mercury concentration.

In 1999, EPA initiated Phase II of the Everglades Ecosystem Assessment Project which added parameters in pore water, floc, macrophyte tissue, and plant community sampling in addition to the constituents and media sampled in Phase I. Wet and dry season samples were collected at about 240 marsh sites in 1999. Six system wide synoptic surveys provide a spatial data base from which a full range of water depths can be compared with other key interacting variables. Selected variables (e.g., TOC, TP, SO^4, S^{2-}, HgT, MeHg, tissue Hg and BAF) will be presented to illustrate changes among wet and dry cycles, seven geographic subareas and system wide gradients which support the interactive conceptual models being developed to address the spatial changes in the system.

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USEPA–REMAP
Policy and Management Implications from the Everglades Ecosystem Assessment Project

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Ronald D. Jones
Florida International University, Miami, FL

Kent Thornton
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Seven management and policy-relevant questions have guided this project from the beginning. One of the primary objectives was to provide scientifically sound information to answer questions and contribute to management decisions on the Everglades ecosystem. Examples of some of the responses to the seven management questions will be presented to address the magnitude, extent, trends, associated factors, sources, risks and management alternatives which have been determined.

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USEPA–REMAP
Conceptual Models and Path Analysis - Analyzing Large Scale Patterns in the South Florida Everglades Ecosystem

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The US Environmental Protection Agency (EPA) Region 4 initiated a project in 1992 to assess the effects of mercury contamination on the South Florida Everglades Ecosystem. This project was designed around the EPA Ecological Risk Assessment Framework and implemented using a statistical survey design to conduct synoptic surveys during the wet and dry seasons from 1994-1996. During this first phase of the project, soil, water, and biota were sampled at about 500 sites throughout the 9600 km^2 marsh to assess the effects of hydropattern, phosphorus loading, habitat alteration and mercury contamination on the marsh ecosystem. The Phase I report (EPA 1998) found there were significant interactions among water depth, TOC, TP, and SO_4 concentrations, food web dynamics and fish mercury concentrations. These interactions exhibited different spatial patterns in the area north of Alligator Alley, between Alligator Alley and Tamiami Trail and south of Tamiami Trail in Everglades National Park. Three conceptual models were developed, one for each of these three areas, as part of the Phase I report to describe the pathways and interactions among factors affecting fish mercury concentration.

In 1999, EPA initiated Phase II of the South Florida Everglades Ecosystem project, which added pore water, floc, and plant community sampling in addition to the constituents and media sampled in Phase I. Wet and dry season samples were collected at about 200 sites in the marsh. As part of the Phase II analyses, path analysis or structural equation models were developed based on the conceptual models formulated during the Phase I sampling. Structural equation models are particularly applicable for survey-based data and have been used extensively in the socioeconomic sciences with statistical survey information. These structural equation models were tested using the Phase I and Phase II data to determine the strength of associations among the variables included in the conceptual models. In general, the survey data supported the pathways and interactions formulated in the conceptual models. There were significant differences in mercury pathways among the three areas identified during Phase I. North of Alligator Alley, chemical interactions were important in affecting mercury bioaccumulation, while south of Tamiami Trail, biological pathways were important in affecting fish mercury concentrations. In addition, water depth was noted as an important determinant of mercury concentrations in fish during Phase II. Additional analyses are continuing to investigate other conceptual models and to move from standardized to reduced form equations for use in projecting changes in fish mercury concentrations as a function of changes in stressor values.

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Hydrology and Fish Community Dynamics in the Florida Everglades: Perspectives from a 20-Year Study

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We examined a 20-year record of fish communities collected at a short and a long-hydroperiod site in the Florida Everglades to examine the persistent effects of extreme hydrological events. The data were gathered by use of a 1-m square throw trap, with monthly sampling between 1977 and 1985, followed by approximately bimonthly sampling through 1999. Small species, including poeciliids and fundulids, are sampled well by this technique and dominate the Everglades community. Larger species, such as centrarchids, were sampled mostly as juveniles. Of several physical variables measured throughout the study, annual minimum water depth was found to provide the most power in explaining fish absolute and relative abundance. Also, there was a lag of greater than 1 year in the recovery of community composition following a multi-year drought. Fish abundance was related to hydroperiod in a non-linear, decelerating, pattern at the long-hydroperiod site, possibly as a result of increasing piscivore density in multi-year periods lacking a regional dry-down. The presence of lags and multi-year responses to changing hydrology in this wetland ecosystem underscore the importance of community analysis over extended time periods. These results have important implications for the use of fishes as targets of long-term monitoring, and in modeling their response to management actions.

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The Utility of Mangrove Unit Models in the Greater Everglades Ecosystem Restoration Program

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As ecotones of continental margins in warm temperate to tropical climates, mangrove wetlands are one of the most susceptible ecosystems to climate and land use change. The land-margin ecosystems in southwest Florida represent a combination of different mangrove ecological types in mainland carbonate environments with gradients in amount of peat accumulation. Although there exist much published literature concerning the geology and forest structure of these ecosystems, along with analyses of food webs in these environments, the biogeochemistry and productivity have not been addressed. These ecological properties are important because potential changes in nutrients and hydrology in the upland watershed may have important impacts on the structure and function of mangroves in the coastal margin of southwest Florida. Initial studies of these specific types of mangroves indicate that they are sensitive to the availability of nutrients and type of hydroperiod. Thus changes in the water management of this coastal region could have significant ecological impacts on these mangrove ecosystems.

Restoration efforts in south Florida include issues of water management including projected impacts of fresh water diversions and nutrient enrichment on the Everglades and associated wetland ecosystems. However, the responses of mangroves to changes in water quality and the role of these land-margin ecosystems to mitigating nutrient enrichment in the coastal zone have received little attention. The biogeochemical properties of mangroves are the least understood of ecological processes along the transition from upland to coastal margin ecosystems. Thus the specific nature as to how the distribution of nutrients influences mangrove structure and productivity, and the role of mangroves in the fate of nutrients in sub-tropical estuaries, are poorly understood. Continued efforts monitoring these biogeochemical processes, together with further development of ecological models, will provide important information on the projected response of mangroves to changes in water management in this coastal watershed.

Ecological modeling is a powerful tool that can be used to describe, quantify, and forecast the response of mangroves ecosystems to different coastal management strategies. Potential impacts of coastal eutrophication and hydrological modifications on the structure and function of mangroves need to be evaluated in advance before implementing programs that modify regional land use, which can profoundly alter forcing functions controlling mangrove productivity.

We have developed three mangrove ecological unit models (FORMAN, HYMAN, and NUMAN) that can be used in the decision-making process to propose management scenarios for the Everglades Watershed. Resource competition theory can be utilized to model community development due to the shifts in nutrient resources and phytotoxin regulators across the land-margin coastal gradients of the south Florida mangrove region. The goal of this research program is to further develop these unit models to link community development and biogeochemistry of mangrove ecosystems in the south Florida region. These models can be applied to project the response of mangrove stands to changes in quantity and quality of discharge as part of the Everglades Restoration Program under the Critical Ecosystem Study Initiative (CESI).

FORMAN and NUMAN are designed to mimic ecological processes affected by water and nutrient delivery and the resultant patterns of forest development and nutrient distribution in coastal land-margin ecosystems of south Florida. The primary objective of the FORMAN model is to simulate the mechanistic effects of spatial gradients in soil characteristics and hydroperiod on the growth and development of mangrove wetlands. The FORMAN model is an individual-based mangrove succession model that simulates the influence of physical factors on species distribution and productivity on yearly basis. The HYMAN model is a hydrology model that simulates the mass balance of freshwater and tidal inputs, and calculates porewater and surface salinity. The NUMAN model was developed to simulate the availability of N and P in mangrove soil by coupling the simultaneous effect of productivity and allochthonous inputs of mineral sediment. Resource competition theory is utilized to model community development due to the shifts in nutrient pools and availability across the land-margin coastal gradients of the south Florida mangrove region. Task elements are designed to methodically calibrate model functions and parameter sets and to validate model behavior and results compatible with existing mangrove research programs of USGS, SFWMD, USCOE, FIU, and University of Miami to model the Everglades watershed. A large part of this effort will be to demonstrate to the various research and management groups associated with the Everglades restoration effort the utility of FORMAN in projecting the impacts of land use change on mangrove wetlands.

Results from our nitrogen and phosphorous cycling studies in mangrove forests show the regulatory nature of C:N:P ratios have on N and P transformations, particularly P and N immobilization. Model modifications will include explicit relationships of N and P transformations such as immobilization and mineralization. By adding mechanisms that describe the partition of C, N, and P exchange (atmosphere and water) and regeneration, we expect to increase our understanding of what processes control the flux of nutrients at the mangrove:coastal water boundary of south Florida land-margin ecosystem. The NUMAN model used a cohort analysis of mangrove soil formation. This initial modeling effort discovered some key parameters that need to be calibrated to understand the soil organic matter and nutrient pools along the estuary gradient in southwest Florida. One of these parameters is the allocation and turnover of above- and belowground biomass of mangrove wetlands related to soil conditions. Comparisons of organic matter production and decomposition will be evaluated among soil cohorts and compared to the input of mineral matter using Pb-210 techniques. Parameterization and calibration of the NUMAN model will have important applications to understanding the impacts of specific scenarios of CESI to the long-term sustainability of mangroves under conditions of present sea-level rise.

The goal of this research program is to further develop the FORMAN, HYMAN and NUMAN models to link community development and biogeochemistry of mangrove ecosystems in the south Florida region. These mangrove unit models can be used to understand how the restoration of ecological processes may influence patterns of forest development and nutrient distribution in coastal land-margin ecosystems of south Florida.

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Slough Macrophyte Community Changes in the Northern Everglades – Influence of P Enrichment and Hydrology

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Macrophyte species distribution in the slough areas of the northern Everglades were examined along a N-S gradient of altered phosphorus and hydrologic regime to characterize the effects of nutrient enrichment and hydrology on the macrophyte community changes in the Everglades ecosystem. Macrophyte species distribution and frequency examined at fifty-one sites located in the Water Conservation Area (WCA-2A) revealed distinct trends in species changes along the N-S gradient.

Trends in macrophyte species changes observed along the eutrophication gradient were also compared to the results obtained from the experimental P-dosed channels in the in-situ mesocosm study. Macrophyte density in the experimental channels was strongly influenced by P-enrichment as well as fluctuating water levels. Our experimental results suggest that the observed macrophyte species changes along the N-S gradient in WCA 2A have resulted from both enhanced P-input and altered hydrology.

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Encroachment by Cypress into Desiccated Areas with Historical Hydoperiods of Long Inundation and Deep Depths Is Not Reversed By Subsequent Rewatering

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The Big Cypress Seminole Indian Reservation, situated at a tripartite, natural boundary of water basins, geological formations and vegetation types, is considered “critical” to Everglades restoration by both state and federal agencies. In recognition of this important role, the Seminole Tribe of Florida and the U. S. Army Corps of Engineers have initiated a cooperative $49.3 million Water Conservation Plan (WCP) for the Reservation. A component of the WCP will be to rewater natural areas on and connected to the Reservation. To investigate the effects of desiccation and rewatering of forested wetlands, we created and ground-truthed a GIS base layer of current land cover for a 80 Ha diked area that has been rewatered for the past seven years and for outside reference sites that have been continually desiccated since the 1950’s. The base layer was generated from 1998 false-color infrared aerial photography. 1988 true color and 1953 black and white aerial photographs georeferenced by image-to-image rectification were used to generate historical land cover maps. Overlay analysis of land cover maps was used to assess changes in vegetation which may have occurred as a consequence of desiccation and rewatering. Our results show that desiccation leads to a significant encroachment of cypress *(Taxodium distichum)* trees into areas with historical hydoperiods of long inundation and deep depths and this encroachment is not reversed by subsequent rewatering. This historical pattern was also observed in a sample of 107 cypress domes located throughout the reservation. Furthermore, some native species not obligate to wetlands, such as laurel oak *(Quercus laurifolia)* , have reduced coverage coincident with re-establishment of the historical hydrology. In contrast, contrary to preliminary predictions, canopy coverage of non-indigenous invasive species did not decline with increased water depth and time of inundation. Such comparisons of composition and structure of different community types at different time intervals before and after rewatering is important for evaluating the basin-wide performance of the restoration effort.

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The Next 100 Years of Evolution of the Greater Everglades Ecosystem in Response to Anticipated Sea Level Rise: Nature, Extent and Causes

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The Past: During the past 2,400 years, our south Florida coastal and interior Everglades environments have evolved to their present character under the influence of a very slow relative rise in sea level. This rate averaged 4 cm per century, rising from about -1.2m to its present (1930) level during that period. In response, our beaches, barrier islands, and marl-levee coastlines stabilized and grew, and the vast mangrove swamps of the southwest Florida coast expanded over shoaling nearshore environments to take on their present character. These coastal deposits have formed a significant marginal impoundment to the interior freshwater Everglades helping to confine and direct the freshwater flow and encourage elevated water levels within the interior Everglades. This growth phase of our coastal environments is over.

The Present: A 23-cm (9-inch) rise of sea level has occurred in south Florida since 1930. This is equal to a rate of about 30 cm (12 inches) per century. This increased rate of rise has severely destabilized our sandy, mud, and mangrove coastlines and initiated dramatic changes in them. This rise has destabilized the coastal mangrove communities and resulted in significant transgression: storm erosion of mangrove coastlines (to 100 m), storm-initiated loss within mangrove forests, and landward expansion (to 1 km) of the red, black and white mangrove ecotones.

The Future: A further 60-cm (24-inch) relative sea level rise is projected for the next century in response to global warming. This rise will set into motion a near catastrophic evolution of the coastal environments of south Florida similar to that which occurred between 2,500 and 2,400 year before present. The types of changes that will occur to south Florida include: catastrophic loss of the coastal mangrove fringe, inundation of the marl levee coastline and of other low-lying topography, intrusion of saline water well into the surface and ground waters of the interior Everglades, and rise of the base level and decrease in gradient of the freshwater Everglades.

Future changes in south Florida's coastal and freshwater wetlands have been mapped using knowledge of coastal evolution during the past 4,000 years under known sea level conditions. Five principles form the foundation for this forecast mapping: 1) hurricanes initiate devastating changes to both the coastal margin and the interior of mangrove forests; 2) mangrove forest recovery or evolution is closely related to types of sediment substrate and rate of sea level rise; 3) landward mangrove migration is controlled by tidal (channel bound) and hurricane surge (not-channel bound) seeding; 4) freshwater drainage (non-channeled Everglades) and saline intrusion (channeled and non-channeled tidal waters) are closely tied to subtleties in the low-lying limestone topography and will dramatically change during rapidly rising sea level; and 5) different substrates have differing resistance to physical erosion and recycling during transgression. Substrates, from physically most to least resistant, are: Pleistocene limestone, coastal marl levee deposits, marine carbonate mudbank, mangrove peat, muddy sands, and sand. In addition, transgressed peat substrates, if not covered by other sediment, are prone to rapid erosion by burrowing and oxidation.

Mapping of the future patterns of coastal erosion, wetland evolution and upland inundation are made by interfacing these principles with mapped distributions of surface environments, substrate types and thicknesses, limestone topography/bathymetry, present surface topography, and differing rates of sea level rise.

In the scenario of a 60 cm relative sea level rise for the next 100 years, four critical changes emerge: 1) inundation of emergent topography decreasing the confining influences on interior Everglades flow; 2) formation of a major new outlet for Everglades drainage; 3) rapid erosion of both the coastal margin and the interior of the broad coastal mangrove wetlands of southwest and southeast Florida; 4) saline wetland intrusion well into the lower Everglades of southwest, south and southeast Florida; and 5) evolution of large areas of mangrove, transitional and freshwater wetland to marine and brackish ponds and lagoons.

A Closer Look at Mangrove Community Dynamics: A narrow to broad band of mangrove swamp forms south Florida's mainland coastline. This was largely destroyed by development on the borders of northern and central Biscayne Bay and along portions of the interior coastlines of Marco Island and Naples. Elsewhere it is largely preserved, and forms spectacular forests, 1 to 15 kilometers in width, along the southwest Florida coast between Flamingo and Naples. The red mangrove forests form in the intertidal zone and are the critical community coastal wetland community in assessing the future. Red mangroves have two important characteristics: over half of their biomass (living material) is in the subsurface root system; and the forests with larger red mangrove trees are decimated by major hurricanes (category 4 and 5 storms).

In conjunction with rising sea level, major storm events are not only devastating to mangrove forests in their own right, but can also to set into motion significant steps of erosive coastal evolution. Along the southwest Florida mangrove coast, hurricanes have caused about 100 meters of coastal erosion since 1930. Rising sea level has also caused as much as a one-kilometer landward expansion of the red, black and white mangrove communities into former marshlands. And within the mangrove forests, red mangroves are displacing blacks and whites, which live in the upper part of the intertidal. But this is only a small part of the change that has occurred.

The most serious historical loss to coastal mangrove communities, however, is the extensive degradation and loss **within** forest complexes. In each case, this interior degradation is initiated by a major (category 4 or 5) hurricane, which severely damages the taller mangrove forests. In areas with a dominantly red mangrove peat substrate, post-storm decay products commonly kill off surviving mangroves and severely inhibit the eventual recovery of the mangrove community in the area. Rapid subsidence of the decaying root-peat beneath the destroyed mangrove forest then lowers the substrate through the intertidal zone at 2-4 cm/year. Unless the damaged site is very well flushed by tidal waters, the interior intertidal mangrove community will not recover but evolve into subtidal ponds and bays. Interior mangrove forests behind Highland Beach, Big Sable Creek, Gopher Creek, Oyster Bay, and Whitewater Bay are in increasing stages of marine transgression from this storm initiated loss.

The forecast for the next 100 years is not good for the present mangrove forests. An additional 1-2 foot rise in sea level will lead to massive coastal erosion and interior degradation of our coastal mangrove forests. Although red mangroves can build a peat substrate at a rapid rate, interruption by hurricane events leaves the community unable to keep up with sea level rises greater than 4-5 inches per century. In addition, mangroves and associated tidal channels will move up the Shark River

Slough of the Everglades to the vicinity of Tamiami Trail, leaving the lower Everglades with a very different suite of habitats than today.

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Predicting Salinity in Florida Bay

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Biotic and chemical proxies for salinity in Florida Bay show that salinity values for the last century are strongly correlated with climate, specifically, rainfall (Brewster-Wingard and others, 1998; Cronin and others, 1998). Elemental chemistry of ostracode shells provides a methodology to discern salinity values of the past (Dwyer and Cronin, 1999). Adult tests of the ostracode *Loxoconcha matagordensis* are grown essentially instantaneously in the late Spring and Early Summer. For the purpose of this paper, salinity values derived from adult *Loxoconcha matagordensis*, generally grown between May and July each year serve as proxies for June salinities. Because *Loxoconcha matagordensis* growth shows a very tight normal distribution, population studies from one sample should provide us with data on salinity changes occurring at the beginning of the rainy season (usually June). The purpose of this study is to establish if a relationship exists between rainfall and Mg/Ca derived salinities, and if so, to mathematically express this relationship. In this initial attempt, the record from the Russell Bank Core (Brewster-Wingard and others, 1997) is utilized. Russell Bank has a long record and relatively abundant *Loxoconcha matagordensis*. Biotic indicators were analyzed from every other 2 cm sample and elemental chemistry of the ostracodes was performed from every sample. The calculated sedimentation rate of the core is 1.22 cm ± 0.05, so sampling represents approximately every 1.5 to 2 years.

The assumptions and values for the model:

January-May rainfall.—Monthly rainfall information is available from NOAA (www.ncdc.noaa.gov/onlineprod.drought.xmgr.html) dating back to 1895. The eastern portion of Florida Bay is influenced by rainfall and surface run-off. To compare rainfall to salinity values on a monthly basis, averages of the three southern districts (south west (Everglades), southeast coast, and Bay and Keys) were taken because rainfall to all three may influence salinity in Florida Bay. Because the focus is June salinity, rainfall from the five preceding months was examined to establish a relationship. During El Nino years, high winter rainfall is usually recorded in January; therefore, January rainfall is included in the data set to indicate the occurrence of these events.

June Salinities.—Mg/Ca derived salinities from the ostracode *Loxoconcha matagordensis* from Russell Bank Core as discussed above.

1955-1994.—Age models for specific cores can be very good for the latter half of the century because ^{210}Pb derived ages can be calibrated to the cesium spike of the early sixties caused by atmospheric nuclear testing. Some historical salinity data is available dating back to 1955. So for these two reasons, samples from 1955 to the date the core was taken (1994) were examined.

The Results:

1955-1970.—January-May total rainfall and Mg/Ca derived salinity values for a given calculated year correlate extremely well for the period 1955-1970, showing a strong negative correlation of –0.90. The regression line provides a formula for predicting salinity, given the Jan.-May rainfall for a specific year (fig. 1).

1971-1994.—January-May total rainfall shows little correlation to the Mg/Ca derived salinity values (fig. 1), in fact, the relationship is a weak positive correlation which is certainly counter-intuitive and suggests disruption. The core could possibly be mixed, but comparison to historical monthly salinity data compiled for the eastern zone of Florida Bay by Roblee (written commun., 2000) matches well the Mg/Ca derived salinities for June over this time span, suggesting that there is a strong disconnect between rainfall and salinity post-1971 compared to pre-1971.

Initial results are promising in that pre-1971 strong correlation between salinity and January-May rainfall provides a predicative tool for salinity that appears to represent a relationship prior to disruption of the system.

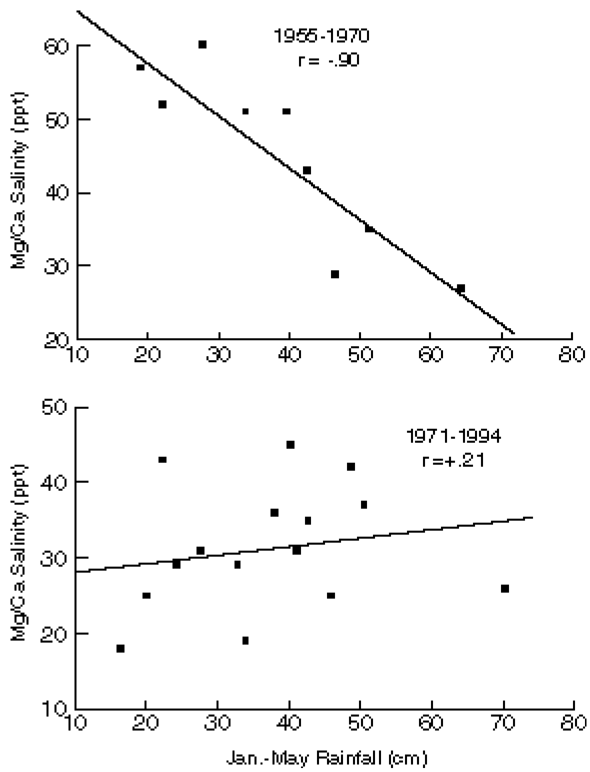

Figure 1.—Scatterplots of the relationship of Mg/Ca salinity derived from *Loxoconcha matagordensis* tests from the Russell Bank Core 19B and total average rainfall for January-May for South Florida for the years 1955-1970 and 1971-1994 including the least squared means correlation (regression) line and r value of correlation (Pearson correlation).

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Seedling Dynamics across a Mangrove – Sawgrass Ecotone in the Southwest Florida Everglades

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The extensive mangrove forests along the southwest coast of Everglades National Park form the saltwater wetland terminus of the Greater Everglades Ecosystem. Ecosystem dynamics in these forested wetlands can be expected to respond to three large scale factors. The first is global climate change as manifested in sea level rise. The second is to catastrophic disturbance, such as Hurricane Andrew (Smith et al 1994). Thirdly, is a response to the addition of freshwater to upstream areas and increased freshwater inflow to the downstream estuaries, which has been proposed as part of the greater Everglades restoration. It is also likely that interactions among these factors will occur.

Analysis of historical aerial photographs has revealed that the area of mangrove forested wetlands in the southeast and southwest Everglades has expanded in the past 40 years (Smith 1995, Ross et al 2000). This is presumably from a combination of decreased freshwater inflow to estuarine areas due to upstream water management and an increase in sea level (Maul and Martin 1993). In order for mangrove forests to expand aerial coverage, propagules from mangrove trees must be dispersed into adjacent upstream marshes. They must then become established and grow.

We have studied the dynamics of mangrove seedling establishment across a mangrove forest - sawgrass ecotone for three years. Eight one m^2 plots were established at each of five stations. The five stations were located along a 350 m. transect which started in a tall riverine mangrove forest and ended in a sawgrass prairie. Seedlings were classified as established or non-established. Established seedlings are those that are firmly rooted to the substrate and have at least two true leaves fully expanded. At each of the five stations we are sampling pore water conductivity at three different depths (Surface water, 30 cm., and 60 cm. below the surface). For the last three years pore water sampling has varied from weekly to bi-weekly sampling. During each seedling survey we counted non-established as well as tagged all established seedlings. We have collected seedlings survival data three times (October 1997, February 1999, and December 1999).

Non-established seedlings are essentially still in the dispersal phase of recruitment. Non-established seedlings differ significantly between samplings and stations. The overall patterns of non-established seedlings are dominated by the pattern of *Laguncularia racemosa* (L.) Gaertn. Non-established seedlings are most common 50 meters from the river (station 2). However, much of this is due to excessive non-established seedlings during the first sampling event. *Avicennia germinans* (L.) Sterns recruitment is low to not present in the surveys.

We have tagged and followed over 500 established seedlings during the three-year period. The total number of seedlings varied significantly between sampling stations with the majority of the seedlings being close to Harney River. Mortality also varied greatly between sampling stations, as did recruitment of the established seedlings. Mortality and recruitment of established seedlings also varied between sampling periods. Species specific recruitment patterns differed across the mangrove transitional zone. *Rhizophora mangle* L. was the most common established seedling species and Laguncularia was the most common non-established seedling. Avicennia was rarely present in either the non-established or established phase, in fact it is lacking completely in many of the samples. Ironically, this historically dominant species has the lowest recruitment into the system.

Pore water conductivity and percent vegetation coverage of the plot does not completely explain seedling patterns in the mangrove transitional zone. In the future, investigation of lags in productivity of the area and hydrological patterns need to be explored to help further understand seedling population dynamics.

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The Florida Everglades Ecosystem: Climatic and Anthropogenic Impacts over the Last Two Millennia

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We document the response of the Everglades ecosystem to climatic and environmental changes over the last two millennia using pollen records. Calibration of distinctive pollen assemblages with eight vegetation types from 170 sites throughout the Everglades allows interpretation of general hydroperiod and water depth, nutrient status, and salinity from down-core pollen assemblages. Such evidence from eight cores collected in Loxahatchee National Wildlife Refuge, Water Conservation Areas 2 and 3, and Everglades National Park indicate that marsh and slough vegetation characteristic of deeper water and longer hydroperiods than today dominated the region between 0 AD and 800 AD. Drier conditions between about 800 A.D. and 1200 A.D. resulted in shallower water depths and shorter, fluctuating hydroperiods in Everglades marshes as well as salinity increases near Florida Bay. After a recovery to deep-water conditions in the 14th century, slightly drier conditions are indicated from the 17th through 19th centuries. These climatically-induced periods of relative dryness are correlated with regional droughts during the intervals known as the Medieval Warm Period (9th -14th centuries) and Little Ice Age (15th -19th centuries). These data document the natural fluctuations in water depth and hydroperiod that occurred on centennial time scales and indicate that hydrologic conditions and Everglades vegetation were relatively stable from at least the 17th century until the early 20th century.

This interval of relative stablity contrasts with regional vegetational changes documented in Everglades wetlands by 1930. Our data indicate a shift at that time to much shorter hydroperiods and shallower water depths than characterized the last few centuries, even though regional precipitation increased concomitantly. Further, more localized changes occurred after 1960, when the Central & South Florida (C&SF) Project was completed. Among changes after that time are increased abundance of cattails at nutrient-enriched sites, drier conditions in Loxahatchee NWR, and salinity increases at some sites near Florida Bay, resulting in changes from brackish marshes to dwarf mangrove forests.

These data indicate that restoration goals of pre-C&SF Project hydrologic regimes are aimed at an already disrupted system; a more "natural" restoration target would be the 19th century Everglades, which had been stable for the past few centuries. The most recent land-use changes have resulted in localized rather than system-wide ecosystem responses, at least in part because of the fragmentation of the wetland. This artificially induced ecological heterogeneity makes prediction of future wetland responses to climatic changes problematic.

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Microbial Indicators of Phosphorus Enrichment in Everglades Soil

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The impacts of phosphorus loading to the Everglades are evident by increased detritus/soil P levels and/or changes in vegetation and periphyton communities. Soil microbial processes may be utilized as sensitive indicators of P enrichment and for the estimation of P impacts on wetland soil function. A variety of soil and microbial parameters were measured in detritus and soil from Water Conservation Areas 1, 2a, and 3a of the Everglades and in constructed mesocosms receiving various P loads. Soil and microbial parameters such as soil C, N, and P fractions, microbial biomass C, N, and P, microbial respiration rates, and extracellular enzyme activities were determined at various locations along P enrichment gradients and in constructed mesocosms. Phosphorus loading increased soil P parameters along the various transects and in mesocosms. Phosphorus loading generally increased the microbial biomass pool and activity. Alkaline phosphatase activity (APA) was significantly depressed by P loading or high soil P concentrations. Soils from transects and mesocosms in the various WCAs responded similarly to P loading. Some microbial processes, such as APA, appeared to be sensitive indicators of P enrichment.

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Poster Abstracts

Ecology and Ecological Modeling

Recent Patterns in the Vegetation of Taylor Slough

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Because of the combined influences of hydrologic and substrate conditions on wetland vegetation development, changes in hydroperiod can result in measurable shifts in community species composition, dominance, and spatial distribution. Taylor Slough has a long history of changing water management practices. Unfortunately, little data exists on the slough's past ecological systems that document its response to the effects of ecosystem management. The survey and analysis by Olmstead, Loope and Rintz (1980) provide a reliable but limited baseline for assessing changes in macrophyte vegetation patterns in the northern part of the slough. The present study builds upon their system of transects and sampling plots to determine whether the characteristics of the marsh vegetation of Taylor Slough have changed over time and whether these observed changes can be linked to hydropatterns and/or other environmental factors. Plant cover was estimated for all species occurring in 1 x $1m^2$ plots arranged in plots along three linear transects established across the slough. At each plot, elevations were measured using a rotating laser and soil depths were recorded. Sampling was conducted in 1992, 1995-1996, and has been compared with the 1980 data set. Preliminary analysis of the data shows that generally *Muhlenbergia filipes* (muhly grass) has decreased significantly with a concomitant increase in *Cladium jamaicense* (sawgrass) and *Eleocharis cellulosa* (spike rush). Some of the observed changes between 1992 and 1995/1996 are greater than those between 1980 and 1992, suggesting that vegetation response to environmental change, such as altered hydrological conditions, can be relatively rapid. The expectation is that restoration of historical hydropatterns in Taylor Slough will result in improved wetland hydroperiods favoring wetland community shifts back to former community composition and function.

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An Evaluation of Methyl-Mercury as an Endocrine Disruptor in Largemouth Bass and Freshwater Mussels.

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Previous contaminant assessments for the Greater Everglades Ecosystem have focused upon mercury as the primary contaminant of concern. Indeed, mercury levels for wildlife within this ecosystem are, in general, high and exposure assessments have indicated significant exposure and potential risks for multiple taxonomic groups including: birds, fish, reptiles, mammals and invertebrates. These exposures to mercury have been suggested as potential contributors to the documented declines of several species withing the Greater Everglades Ecosystem, including wading birds, fish and freshwater invertebrates. However, few efforts have examined, nor documented, non-lethal effects for mercury in these species. The current study evaluated the non-lethal effects of methyl-mercury in both largemouth bass and freshwater mussels under controlled laboratory conditions.

Adult largemouth bass (n= 240) were randomly distributed into four treatments: 0, 1.56, 3.12 and 6.25 mg methyl mercury chloride per kilogram of diet (30 male and 30 female per treatment). Prior to dosing, 10 fish (5 male and 5 female) were collected from each treatment tank for the collection of blood and tissue samples to determine baseline levels of mercury. Additional fish (n=10, 5 male and 5 female) were collected from each treatment biweekly. Blood samples were utilized for the analysis of sex steroid hormones (estradiol, testosterone and 11-keto-testosterone) and vitellogenin. Gonadal tissues were collected for histological evaluation of sex and reproductive status. Tissues were collected from each fish for mercury analyses. Plasma estradiol, testosterone and 11-ketotestosterone concentrations were not altered by the low dose (1.56 mg methyl mercury chloride/kg diet) treatment regardless of sex. However, plasma 11-ketotestosterone concentrations were decreased in male largemouth bass exposed to the 3.12 and 6.25 mg methyl mercury diets. Similarly, plasma estradiol concentrations in female bass were decreased following exposure to the 3.12 and 6.25 mg methyl mercury diets. Plasma vitellogenin concentrations were also decreased in female bass while unaltered in male bass. These results indicate that dietary exposure to methyl mercury affects plasma hormone concentrations in largemouth bass, and that mercury can act as an endocrine disruptor and potentially impair reproduction in fish.

Additional efforts examined freshwater mussels as potential vectors of acute methyl mercury exposure and bioaccumulation. *Elliptio buckleyi* were exposed to methyl mercury in the water column using a proportional diluter system and to methyl mercury via diet in a recirculating system. Water column exposures were 5.0 and 10 ng/L., whereas, dietary exposures utilized algae (*Selenastrum capricornutum*) which had been experimentally exposed at 1.0 and 10 ng/L. Mussels exposed in the water column were analyzed for methyl mercury at days 7, 21 and 32, while mussels with dietary exposure were analyzed at days 30, 60, and 90. Results indicate that *E. buckleyi* did not significantly bioaccumulate methyl mercury following water column exposure; however, dietary exposure to algae treated at 10 ng/L resulted in significant bioaccumulation. Little or no mortality was observed regardless of exposure dose or source. An analysis of mantle sex steroid concentrations indicated decreased estradiol and unaltered testosterone concentrations following dietary exposures of 10 ng/L These data indicate dietary sources for mercury exposure of freshwater mussels and suggest their potential utility as an ecological receptor to assess both exposure and effects.

In general, these results indicate the potential for altered reproductive and endocrine status for wildlife exposed to mercury. Future efforts will include the assessments of natural exposures to mercury and potential effects for wildlife within the Greater Everglades Ecosystem. These assessments are an essential component of current and future assessments of risks and potential effects of proposed and ongoing restoration efforts.

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Poster, Ecology and Ecological Modeling

Monitoring the Loss of Natural Cover in Southwest Florida (1973-1995) Using Landsat Data and a Hybrid Change Detection Technique

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South Florida has experienced dramatic landscape changes over the last 50 years as a result of various land and water use practices. Disturbance to the natural land cover of the region has resulted from many activities including the construction of an extensive network of canals and levees, urban expansion, agriculture and rangeland practices, and the introduction of exotic plant species. A plan to restore the south Florida landscape to a more natural condition with respect to surface water (flow and quality) and vegetation type is currently being implemented. A cost effective and timely procedure for detecting and characterizing landscape changes should be useful for managers and scientists involved in assessing historical landscape changes and/or monitoring the effectiveness of restoration activities for the region.

This study illustrates such a procedure by documenting the loss of natural cover in southwest Florida over a 22-year period (1973-1995). Landsat remote sensing images are used in a hybrid change detection processing technique to estimate the spatial-temporal loss of natural cover to developed lands in the vicinity of Naples, Florida. The procedure utilizes both categorical and radiometric change detection techniques. These landscape changes are estimated for three different time intervals: 1) 1973 to 1978; 2) 1978 to 1988; and 3) 1988 to 1995. Over the 22-year period, the total area of natural cover estimated to have been developed is 17,111 hectares.

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Mapping Invasive Plants in Florida with High-Resolution Spectroscopy

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Introduction

The Florida Department of Agriculture and Consumer Services, Division of Plant Industry regulates the introduction, release, and sale or distribution of noxious weeds within the State of Florida. This action, which is carried out by Rules established by the Department, regulates plants that are declared to be a public nuisance or a threat to the State's agricultural interests. Paragraph 5B-57.007, F. A. C., Noxious Weed List, declares *Lygodium microphyllum* (Cav.) R. Brown, Old World Climbing Fern, and *Oryza rufipogon* Griff. (Wild Red Rice) as noxious weeds that may directly or indirectly affect the plant life of the state. Additionally, *O. rufipogon* appears on the Federal Noxious Weed List, while *L. microphyllum* is described as a weed that is "…invading and disrupting native plant communities in Florida."

L. microphyllum was apparently introduced into Florida near the Loxahatchee River area and is now spreading widely throughout Southern Peninsular Florida in a wide range of habitats. The plant rapidly covers and out-competes native vegetation, and its dense vegetation carries fire up into the tree canopies. A variety of management programs are being evaluated, using herbicides and mechanical methods.

O. rufipogon was collected in Taylor Slough, Everglades National Park, Homestead, Florida, on 11/27/85 near the Royal Palm Visitor Center. Though reported in a number of other countries, the establishment of this perennial species has not been reported at any other location in the United States. Because this plant is one of the most destructive weeds in cultivated rice and poses a threat to aquatic and wetlands habitats, an eradication program was initiated in 1988.

Concepts of Hyperspectral Remote Sensing

Reflectance spectra of vegetation, gathered in the 400–2500 nm region of the electromagnetic spectrum, contain information on plant pigment concentration, leaf cellular structure, and leaf moisture content. This allows the remote discrimination and mapping of plant species or communities, the detection of their physiological condition and state of health, and the assessment of the amount of cover or biomass, based on the unique spectral properties of a vegetated surface.

Hyperspectral refers to the multidimensional character of remote-sensing spectral data. With imaging spectrometry, data can be acquired in hundreds of spectral bands simultaneously. Because of the increased information content, many more applications can be addressed by this remote sensing technique.

Field Investigations

Field spectra were collected at two sites on 7/18/00 and 7/19/00, west of Jupiter near the FL Turnpike and Highway 708, and near the Royal Palm Visitor Center in Everglades National Park. The field spectroradiometer was an ASD (Analytical Spectral Devices, Boulder, CO) FieldSpec FR with a spectral range of 380–2500 nm.

The primary objective at the Jupiter site was to measure the spectral reflectance of *L. microphyllum* and develop a reference spectrum that would characterize this plant. An independent reference spectrum was developed for *L. microphyllum* at Jonathan Dickinson State Park from spectra collected on 5/4/00. A reference spectrum could be used in subsequent *L. microphyllum* mapping experiments using airborne hyperspectral remote sensing data. The secondary objective was to establish the spectral separability of *L. microphyllum* and the surrounding vegetation.

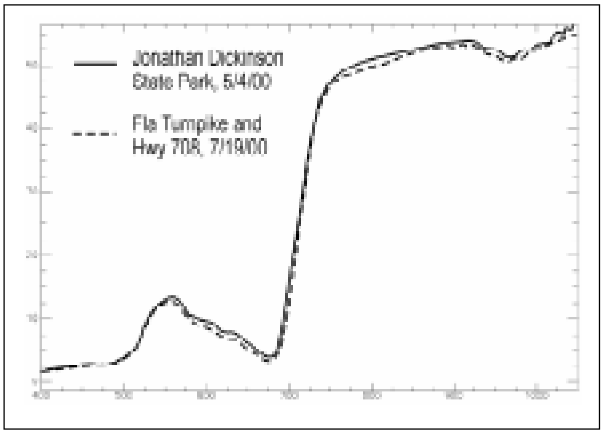

Figure 1 shows the visible/near-IR reference spectra for *L. microphyllum* from the Jupiter and Jonathan Dickinson State Park sites. Although the two sites were approximately 4 km apart and there were 75 days between the two sets of measurements, the two *L. microphyllum* reference spectra were essentially identical. Spectral consistency, both spatially and temporally, is important when applying spectral mapping techniques to airborne hyperspectral data.

The plants growing in the vicinity of the *L. microphyllum* at the Jupiter site (Table 1) were all spectrally unique. The spectral uniqueness suggested that *L. microphyllum* could be differentiated from other types of vegetation with airborne hyperspectral data. This could be an important technique for identifying unknown occurrences of *L. microphyllum* or determining the areal extent of known infestations.

The spectra of plants from Everglades National Park (Table 1), in addition to *L. microphyllum*, showed a level of separability similar to spectra from the Jupiter site. Spectral reflectance of *O. rufipogon*, measured in outdoor containers at the UF/IFAS, Fort Lauderdale Research and Education Center, was included in the analysis. The objective at the Everglades site was to determine the separability of *O. rufipogon*, *Phragmites australis* (Cav.) Trin. ex Steud., Common Reed, and *L. microphyllum*, from the naturally occurring vegetation (Table 1).

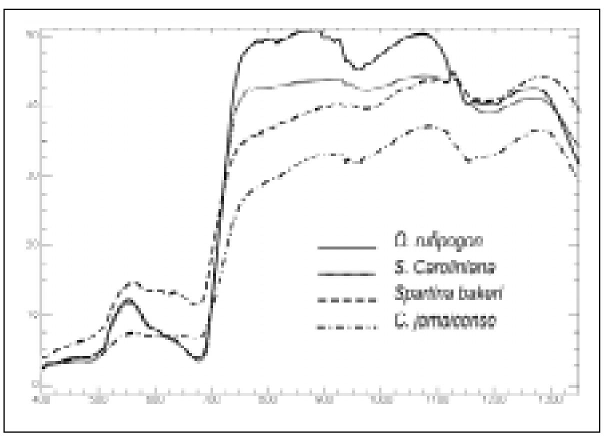

Figure 2 shows the spectra for *O. rufipogon* and several of the other plants. Although some parts of the spectrum are similar, such as *O. rufipogon* and *Salix Caroliniana* Michx, Carolina Willow, in the 400–700 nm range (visible spectrum), these similarities were clearly resolved in the 800–1200 nm range (near-IR). Similarly, with *P. australis* and *L. microphyllum*, broad spectral regions could be found where pronounced spectral differences were present.

Summary

This work demonstrated the potential of spectroscopy and hyperspectral remote sensing to identify and map invasive species such as *L. microphyllum*, *O. rufipogon*, and *P. australis*. Airborne hyperspectral imagery is routinely georeferenced, allowing easy integration into a Geographic Information System. Spaceborne hyperspectral systems, such as NEMO (scheduled for launch in early 2001), could be a cost effective, rapid method for identifying and measuring the extent of invasive plants.

Table 1. Field sites and plants used for spectral reflectance measurements

Site	Plants
Jupiter Turnpike and Highway 708)	Old World Climbing Fern, *Lygodium microphyllum* (west of FL (Cav.) R. Brown Brazilian Peppertree, *Schinus terebinthifolius* Raddi Southern Bayberry (Wax Myrtle), *Myrica cerifera* L. Cabbage Palm, *Sable palmetto* (Walt.) Lodd. ex J.S. Shult. and Shult. Slash Pine, *Pinus elliotii* Engelm. Coco Plum, *Chrysobalanus icaco* L.
Everglades National Park (Royal Palm Visitor Center)	Common Reed, *Phragmites australis* (Cav.) Trin. ex Steud. Pickerelweed, *Pontederia cordata* L. Pond Apple (Custard Apple), *Annona glabra* L. Sawgrass, *Cladium jamaicense* Crantz. Sand Cord Grass, *Spartina bakeri* Merr. Jointed Spikerush, *Eleocharis interstincta* (Vahl) R. & S. Carolina Willow, *Salix Caroliniana* Michx.

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Inventory, Monitoring, and Research at the Arthur R. Marshall Loxahatchee National Wildlife Refuge

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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 16 ha cypress swamp, and 821 ha of freshwater marsh impoundments. The refuge provides habitat for over 700 vertebrate species, 63 of which are considered as imperiled, and an unknown number of plant and invertebrate species. The mission of the National Wildlife System is "to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans". In support of that, 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. Currently underdevelopment is an Inventory, Monitoring, and Research Plan that will provide such a framework for future management. The plan will outline the inventory, monitoring, and research needs of the refuge and will discuss strategies for addressing those needs.

This poster will illustrate aspects of the plan including identification of key management related research issues and the rational for the selection of key species or groups for monitoring. Examples of current and planned inventory, monitoring and research projects will be presented. These projects include monitoring being conducted by refuge staff that address refuge, regional, and global issues; projects conducted in cooperation and collaboration with Universities and other agencies; and projects being conducted under Special Use Permits to qualified individuals.

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Molluscan Faunal Distribution in Florida Bay, Past and Present: An Integration of Down-Core and Modern Data

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Statistical comparison of modern molluscan fauna to down-core molluscan assemblages in four cores elucidates changes in the Florida Bay ecosystem since 1810. Fluctuations within molluscan faunal dominance and diversity patterns indicate an increase in salinity in the northern transitional zone, and possibly the eastern portion of Florida Bay. Distinctive faunal shifts recorded at Russell Bank occur approximately between 1910 and 1930 and at Bob Allen mudbank between approximately 1900 and 1910. The period from approximately 1930 to 1980 within these cores shows rapid and dramatic fluctuations in species dominance and faunal richness. Beginning around 1980, molluscan assemblages are dominated by euryhaline species that can tolerate diminished water quality.

While these fluctuations within assemblages are distinctive, they are not so profound that they represent a major shift in estuarine zonations within northern, eastern, and central Florida Bay during the past 100 to 200 years. The majority of the molluscan fauna that are present at the core sites today are generally present throughout the period of deposition. Changes that have occurred within the cores are fluctuations in patterns of dominance and diversity within a single assemblage, not complete replacement of the assemblage. For example, the *Turbo/Tegula/Columbella* assemblage indicative of more marine conditions has not existed at Bob Allen mudbank or at Russell Bank during the last 100-200 years. Nor has the northern transitional assemblage, typical of the Little Madeira Bay sites, dominated at Bob Allen or Russell Bank.

The changes indicated by shifts in dominance patterns and the appearance/ disappearance of critical indicator species, however, do suggest the influence of environmental factors on molluscan fauna in northern, eastern and central Florida Bay. The patterns in core T24 clearly demonstrate increasing salinity at the mouth of Taylor Creek. Freshwater outflow through Taylor Creek has been controlled by water management during the later half of this century. The change in salinity at this site may be due to water management practices, fluctuations in average annual precipitation, changes in sea level, or a combination of all of these. The record from Pass Key (core PK37) is not as clear, due in part to the rapid sedimentation rates at that site, but fluctuations in the abundance of *Anomalocardia auberiana* and other typical northern transition species at Pass Key probably reflect fluctuations in salinity. This conclusion is consistent with Lyons' findings (1996, 1998).

The age models for Russell Bank (core RB19B) and Bob Allen mudbank (core BA6A) allow us to compare changes in the molluscan fauna to historical data on human activities and rainfall. The changes that occur between 1910 and 1920 at Bob Allen and between 1910 and 1930 at Russell indicate a shift toward less stable conditions. The disappearance of *Anomalocardia auberiana* from Russell Bank after 1920 may indicate more saline conditions. During this time period, average rainfall did not fluctuate significantly in southern Florida, but substantial human alteration of the environment occurred with the construction of the Flagler Railroad in the Keys.

Between 1930 and 1980, the molluscan fauna at Bob Allen and Russell both went through a period of fairly rapid and dramatic fluctuations. These fluctuations correspond to a period of relatively dramatic shifts in regional rainfall and to a period of significant alteration of the terrestrial environment with the construction of canals, the implementation of water management practices, and a rapidly growing population. Beginning around 1980, *Brachidontes exustus* becomes the most dominant species at Russell and Bob Allen, and it increases in dominance in the upper portion of the cores from Pass Key and Taylor. *Brachidontes exustus* is a euryhaline species that can tolerate diminished water quality, and it is nearly ubiquitous at sites in central and eastern Florida Bay today. The concentration of this species in the upper portion of all the cores implies that salinity fluctuations have increased in the last 20 years, and/or water quality has diminished.

Understanding the dynamics of an ecosystem and the natural range of variation in the system over an extended period is a critical component of effective restoration. Analysis of the modern environment provides a means to interpret biological data preserved in cores, and to determine the physical and chemical variations in the environment indicated by the biota. Knowledge of the past provides the best insight to predicting the impact of future change on the environment.

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Applications of New Performance Measures for use with Everglades Restoration Hydrology Models

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As part of the Modified Water Deliveries to Everglades National Park Study, performance measures were developed in conjunction with the South Florida Water Management District and Everglades National Park. Multiple project plans were evaluated with the new performance measures. The performance measures were based upon various ecological, engineering or institutional criteria.

Performance measures are quantitative or qualitative indicators of how well (or poorly) an alternative meets a specific objective. Ideal performance measures are quantifiable, have a specific target, indicate when that target has been reached, or measure the degree of improvement toward the target when it has not been reached.

A multi-media, poster presentation will present the various performance measures of interest including:
-- Average weekly above ground storage
-- Days of continuous above ground inundation
-- Variations in flow to Florida Bay due to project implementation.
-- Weekly differences in heads, Base Year versus Alternatives
-- Distribution of Wetland types defined by hydroperiod and water depths
-- Percentage of area available for 60, 70, and 80 day breeding season for the Cape Sable Seaside Sparrow

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Demographical Analysis of a Spatially-Explicit Individual-Based Cape Sable Seaside Sparrow Model

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SIMSPAR (see P. Nott, 1998) is a spatially-explicit individual-based model for the Cape Sable Seaside Sparrow (Ammodramus maritimus mirabilis), an endangered species present in the Florida Everglades. It was developed as an evaluation and management tool for comparing the relative impacts of hydrological policies on the Cape Sable Seaside Sparrow, and parameterized for the western sub-population. As part of the model development, SIMSPAR has been migrated to an object oriented program to increase model run time performance, enhance output flexibility, allow for possible expansion to other subpopulations, and more fully integrate with other ATLSS component models. The model changes allow for direct analysis of the life history of each individual model sparrow, from which one can draw implications about the relative impacts of various environmental changes on population-level responses. For example, complete family trees can be extracted for demographical analysis and for possible extension to analysis of pedigrees for inclusion of genetics. This allows the examination of the derived life history parameters of the model for comparison to data and for use in sensitivity and uncertainty analysis. Notably, net reproductive rates, survivorship schedules, and causes of fledgling death are all statistics that can be explored. A comparison of these demographic parameters can then be made across various hydrological scenarios and models. (Nott P. Effects of Abiotic Factors on Population Dynamics of the Cape Sable Seaside Sparrow and Continental Patterns of Herpetological Species Richness: An Appropriately Scaled Landscape Approach [dissertation] .Knoxville(TN) : University of Tennessee; 1998)

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A Comparison of Everglades Alligator Production in Marsh and Canal Habitats

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Kenneth G. Rice
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Restoration planning is currently taking place for the Everglades under the Department of the Interior's South Florida Ecosystem Restoration project. Effects of landscape decompartmentalization on American alligator (*Alligator mississippiensis*) populations are largely not understood. No data exist on alligator nesting ecology with respect to canal habitat influences. Recent research has revealed that: (1) Influences of canals on adult alligators extend approximately 1 kilometer into the marsh. (2) Adult alligator densities are higher at canal habitats than those in the marsh interior. (3) Adult male alligator densities are higher at canal habitats than those in the marsh interior. (4) Adult alligators appear to have strong affinities for their home ranges within either canal or marsh habitats. (5) Adult body health condition may be better in canals than in the marsh. (6) Canal alligators appear to have a metabolic thermal advantage in some seasons.

Could it be that canals in the Everglades create sinks for alligator populations? That is, adults may survive well in canals, but not contribute reproductively to the population?

A complete understanding of alligator population ecology would require comparative information of production in all Everglades' habitats. With the immediacy of Everglades restoration efforts, critical is the relative production in canals and interior marsh in general. This study analyzes alligator nest success, nesting female physical condition, and hatchling survival at canal and marsh interior habitats in the Arthur R. Marshall Loxahatchee National Wildlife Refuge.

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Genetic Analysis of Introduced Predatory Asian Swamp Eels *(Synbranchidae)*

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Synbranchid eels referred to the Asian genus *Monopterus* on the basis of external morphology (some commonly known as Asian swamp or rice eels) have been found in aquatic habitats in several regions of the southeastern United States. 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 four known populations from the U.S., as well as samples from Malaysia, Indonesia, Vietnam, and two locations in China. We gathered nucleotide sequence data from an approximately 600 base pair region of the mitochondrial 16S rRNA gene to determine the pattern/level of mtDNA variation in introduced and native swamp eel populations to address the following questions: (1) What are the relationships among introduced populations? (2) What is (are) the source(s) of introduced populations? (3) What are the implications of (1) and (2) for understanding introduction history and planning future management/control**.**

Although introduced populations are similar in external morphology, our results indicate that there have been at least 3 independent introductions of genetically distinct forms. These independent introductions may be the result of the desirability of swamp eels as food items, as well as their appeal in the pet trade. Introduced populations in close proximity (approximately 30 miles) represent genetically distinct forms. 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 source of the Georgia population has not been identified.

While there is little mtDNA variation within introduced populations based on sampling to date, there is enormous mtDNA variation among populations. The amount of sequence difference among introduced populations is equivalent to that seen among closely related **families** of teleost fish for the same gene region. These genetically distinct introduced populations in all likelihood represent at least two and probably three species. These distinct forms may therefore be expected to vary in ecological or life history traits, representing different threats to the ecosystems where they have been introduced. The identification of source populations may prove helpful by giving us access to life history information available for these distinct forms in their native ranges, pointing out the advantage of sampling native as well as introduced ranges. These results indicate that studies of the ecology and life history of one introduced population may not necessarily apply to other populations.

Future directions include comparison of the mtDNA phylogeny with nuclear markers, further characterization of potential source populations, and development of multiple high-resolution genetic markers that will enable us to determine whether populations similar in mtDNA haplotypes represent separate introductions. In addition, high resolution markers such as microsatellites will allow us to determine population structure and to track the divergence, spread, mixing and potential hybridization of introduced populations, all of which are key parameters relevant to control and management, especially in the early stages of these introductions. The results of this work will be relevant to other situations involving introduced species, especially within morphologically conservative groups. The Southeastern U.S. has a swamp **eels** problem, not a swamp eel problem.

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A Simulation Model for Florida Panthers and White-tailed Deer in the Everglades and Big Cypress Landscapes

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The White-tailed Deer/Florida Panther Model was developed as one component of the Across Trophic Level System Simulation (ATLSS) family of models, with the overall goal of providing a total ecosystem approach to predicting the relative effects of restoration plans on the biotic components of the natural systems of South Florida. The Deer/Panther model was designed as a management and evaluation tool to analyze the relative effects of alternative water management scenarios on long-term population dynamics of the endangered Florida panther (Felis concolor coryi) and its primary prey species, the white-tailed deer (Odocoileus virginianus.)

The Deer/Panther model is a spatially-explicit, individual-based model which divides the landscape into a spatial grid of cells and tracks movements and behaviors of individual members of simulated deer and panther populations within this spatial grid. Each individual is described by a set of state variables which record information such as gender, age, body weight, reproductive status and current location on the landscape grid. Decision rules determine how individual animals move across the landscape, interact with one another and respond to their environment. Differences in individual states and stochastic components in decision-making produce variations in responses to local conditions of environmental variables such as water depth, habitat characteristics, and proximity to other animals. Individuals mate at different times, disperse varying distances from their natal ranges, and gain or lose weight depending on local forage and prey availability, individual bioenergetic status, and stochastic factors.

The four major interacting model components are hydrology, vegetation, deer, and panthers. Daily water level inputs, provided by scenario simulations of the ATLSS High Resolution Hydrology Model derived from the South Florida Water Management Hydrology Model, influence vegetation growth and restrict movement for deer and panthers. The vegetation component provides spatial and temporal variation in available forage for the deer herd. Deer selectively consume forage biomass and serve as prey for panthers. Panther predation is reflected through deer mortality. Two spatial scales, corresponding to strategic vs. tactical decision-making, are used in the model. The size of spatial cells for simulated animal movement is 500-m x 500-m; biomass generation and foraging behavior occur in 100-m x 100-m cells. Model events are simulated on a daily time step. The Deer/Panther Model is coupled to PV-WAVE, a software application for visual representation and statistical analysis of data. Model outputs can be displayed during execution, or states can be saved at specified times during a simulation for static display and analysis. Results are presented for alternative hydrologic scenarios derived as part of the Restudy.

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PanTrack: Analysis of Panther Locations and Movements through Time and Space

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The ATLSS PanTrack tool is a software application designed to display georeferenced spatial animal movement data and perform statistical analyses of spatial patterns. This tool has been specifically customized to study and interpret radio-telemetry observations collected for the Florida panther endangered species recovery project. Features include subsetting location observations for specific time periods, spatial locations, or groups of individuals (e.g. gender, age, genetic makeup, or cause of death); viewing and analyzing observations over relevant habitat and land use maps; and composing user-controlled animations of selected panther movement sets. PANTRACK has been used to extract spatial and temporal patterns from panther movement data to (1) define behavior rules for an individual-based panther model, a process which requires detailed information about individuals and about how they interact with each other and with their environment; (2) explore questions vital to panther survival and recovery, such as habitat use, dispersal at maturity, and reproductive isolation; and (3) suggest possible explanations for recent panther geographical distributions in South Florida. Links between monitoring observations and panther management decisions could be strengthened by the availability of such a customized, user-friendly tool to organize and present monitoring data. This tool could be also be used in an educational setting to increase public awareness and understanding of target species.

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Seasonal Movements, Migratory Behavior, and Site Fidelity of Radio-tagged West Indian Manatees in Southeastern Florida

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The West Indian manatee (*Trichechus manatus*) is endangered by human activities throughout its range, including the U.S. Atlantic coast where problems caused by increasing coastal development and watercraft collisions have been particularly severe. We radio-tagged and tracked 78 manatees along the east coast of Florida and Georgia over a 12-year period (1986-1998). Our goals were to characterize the seasonal movements, migratory behavior, and site fidelity of manatees in this region in order to provide managers with scientific information upon which effective conservation strategies could be developed. Most study animals were tracked remotely with the Argos satellite system, which yielded an average of nearly 4 locations per day. We also tracked manatees in the field an average of 2 days per week using VHF telemetry. The combined data collection effort yielded >93,000 locations over nearly 32,000 tag-days. The median duration of tracking was 8.3 months, but numerous manatees were tracked over multiple years (maximum = 6.8 years) by retagging or replacing tags in the water without recapturing the animal.

Most tagged manatees migrated seasonally over large geographic areas (median = 280 km, maximum = 830 km) between a northerly warm season range and a southerly winter range, but 12% of individuals were resident in a relatively small area (<50 km) year-round. Forty-one manatees were tracked south of the Sebastian River, which is thought to have been the northern limit of the species' historical winter range on the Atlantic coast. The vast majority of these individuals visited southeastern Florida (SE FL) only during the winter months, with the greatest concentration of use around the Port Everglades power plant and in northern Biscayne Bay. Most individuals that overwintered in SE FL spent the warm season in Brevard County (northern Indian and Banana Rivers) and some traveled further north to the lower St. Johns River and Georgia. The movements of one adult male spanned >2300 km of coastline between SE FL and Rhode Island. No study animals journeyed to the Gulf coast of Florida. A few tagged manatees were year-round residents of SE FL, including the upper Florida Keys. One adult female moved between northern Biscayne Bay and Port Everglades during the winter, but her warm season movements over a 5-month period were restricted entirely to the rivers and canal system around Miami; she moved as far inland as Homestead, 77 km by canal from the Miami River mouth.

Manatees summering in central Florida departed for southerly overwintering sites in early winter (mean ± SD = 12Dec ± 25 days) in response to cold fronts that dropped water temperatures by an average of 2.0 °C over the 24-hr period preceding departure to a mean temperature of 19 °C. Water temperature at departure from the warm season range was not related to body size or female reproductive status, but varied substantially among individuals (16 - 22 °C). Manatees overwintering in SE FL returned to their warm season range in the central region during late winter to early spring (16Mar ± 22 days). The presence of industrial warm-water effluents permitted many manatees to overwinter north of their historic winter range, and for some migrants this delayed fall migrations and facilitated earlier spring migrations. Southward fall and northward spring migrations between central and south Florida lasted an average of 10 ± 4 and 19 ± 10 days at mean rates of 36 ± 6 and 23 ± 6 km/day, respectively. Manatees spending the winter in SE FL often traveled north during periods of mild weather—sometimes reaching their warm season ranges—only to return south again with the next major cold front. The highest documented rate of sustained travel during migration was 87 km/day (3.6 km/hr over 32 hr) during winter.

Manatees showed strong fidelity to their seasonal movement patterns, including warm season and winter ranges. Cluster analysis usually identified only 1 or 2 core use areas for each individual within a season, indicating strong within-year fidelity to particular ranges. Site fidelity across years was also strong: the median distance between location clusters within a region from one year to the next was 3.4 and 4.8 km for the winter and warm seasons, respectively. Most manatees with multiple years of tracking data returned faithfully to the same seasonal ranges, which in winter were typically centered around warm-water refugia. Seasonal movements of 4 immature manatees that were tracked with their mothers as dependent calves and then after weaning as independent subadults provided evidence for strong natal philopatry to specific warm season and winter ranges, as well as migratory patterns.

Seasonal movement patterns of manatees along the Atlantic coast were largely driven by changes in temperature and influenced by strong fidelity to seasonal ranges and warm-water refugia. This study has revealed a high degree of variation in seasonal movement patterns, annual range, and apparent cold tolerance among individuals. Migratory patterns and fidelity to particular areas may be transmitted from mother to offspring, and this mechanism could maintain the observed inter-individual variation across generations.

Historical patterns of manatee movement prior to the establishment of industrial warm-water sources probably included seasonal migrations between a winter range in SE FL and a summer range in central or northern Florida or Georgia, as well as year-round residence in southern Florida. Deregulation of the electric utility industry may result in the loss or unreliable operation of thermal effluents from coastal power plants that manatees have become dependent on. Under this scenario, SE FL would become even more important as an overwintering area for manatees. Long-term viability of the Atlantic coast subpopulation will require the maintenance of healthy seagrass communities in the intracoastal waters of SE FL, which can be achieved through actions to improve water quality. Monitoring programs should be established to determine the effect of planned changes in freshwater flows into Biscayne Bay on manatees and their habitat.

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Evaluation of Strip-transect Aerial Surveys for Monitoring Manatee Population Trends in the Ten Thousand Islands Region

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Although strip-transect aerial surveys have been used extensively in Australia to estimate trends in offshore dugong populations (Marsh and Sinclair 1989; Marsh 1995), their use in estimating manatee population size and trend 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 ultimate objective 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.

The objective of this pilot study is to test the feasibility of strip-transect surveys in the Ten Thousand Islands. If successful, a series of surveys will be conducted during the warm season of 2001, and repeated following restoration of the Southern Golden Gate Estates. Strip-transect surveys will also be designed and for other portions of the southwestern coast, in cooperation with the Everglades National Park.

The first survey was conducted on 25 July 2000; at least two more will be conducted in August and September 2000. The survey design is similar to that described by Miller *et al*. 1998. The study area is 166 km², of which approximately 100 km² is water. We established 20 parallel transects, 1 km apart, with a survey strip width of approximately 250 m. Water area within the strips is 28 km². Transects are oriented perpendicular to shore, between Palm Bay and the Ferguson River, to maintain homogeneity of the sampling units. Manatee locations are plotted on topographic maps, and flight paths are recorded on a Trimble Basic Plus GPS. Surveys are conducted from a Cessna 172 at an altitude of 153 m, travelling at approximately 120-140 km per h. Perception bias, which occurs when some of the manatees visible within a strip transect are missed by an observer, will be estimated for as many flights as possible through the use of a second observer.

A total of 14 manatees in 8 groups were seen on 7 transects in the first survey: 5 groups by both observers, 2 by the right front observer, and 1 by the right rear observer. The estimated number of groups available, after correction for perception bias, was 8.4. Mean group size was 1.75 (SD=1.16). The corrected number of manatees seen was 14.7 (8.4 X 1.75). The estimated number of manatees in the study area was 52 (14.7 X 100/28), or 0.52 per km².

Population estimates in the Banana River, an important area for manatees on the Atlantic coast in the warm season, ranged from 112 to 209, or approximately 0.67 to 1.26 per km² (Miller *et al*. 1998). The high CV (66%) associated with mean group size in the single Ten Thousand Islands survey exceeded any of those observed for the 15 Banana River surveys (range=14 to 32%), and mean group size (1.75) was lower than all but one of the 15 Banana River surveys. Group size was ≥ 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 in and smaller observed group size.

The distribution of sightings, on transects 6-9 and 11-13, was spatially clumped. Transects 1-8 are southeast of the Faka Union canal, 9 starts at the mouth of the canal, and 10-20 are northwest of the canal. Thus, sightings in this survey were made on transects that bracket the entrance to the canal, although manatees have been sighted throughout the Ten Thousand Islands chain in earlier, non-transect surveys. The 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 future surveys, the canal will be added to the survey route as a separate “high density” stratum. Manatee counts from this stratum will be added to the study area estimate, consistent with methods used by Marsh and Sinclair (1989) and Miller *et al*. (1998).

Based upon these preliminary findings, we decided to increase the number of transects surveyed from 20 to 30, which will increase the total survey time from 1.5 to 2.25 h. Surveys will be timed to coincide with high tide to the extent possible, as tide stage may influence the accessibility to manatees of many portions of the study area. Similar strip-transect surveys will be designed for other areas of the southwest coast.

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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 is 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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Mycorrhizae Required for Native Plant Growth on Pine Rockland Soils

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Arbuscular mycorrhizal fungi (AMF) are reported in the roots of many common and rare plants, that are native to the pine rockland vegetation of southeastern Florida. The neutral to slightly alkaline soils are sandy and shallow on a base of oolitic limestone. Available minerals are very low, especially phosphorous which ranges from 5-15 ppm.

Greenhouse experiments using potted seedlings growing on steam-pasteurized native soil show that the growth of the following species (some strictly pine rockland and others at the margin of hammocks) is promoted by addition of AMF inoculum:

1) Common dicotyledons: *Hamelia patens, Nectandra coriacea, Picramnia pentandra, Psychotria nervosa, Rhus copallina*;
2) Palms: *Serenoa repens, Sabal palmetto, Coccothrinax argentata*; and
3) Endangered species: *Amorpha crenulata, Jacquemontia reclinata.*

For several species, addition of PO_4 to the control has a similar growth effect as addition of AMF to control soil. There is increased phosphorus uptake by plants that are colonized by AMF. Although these findings are not unusual and are expected in a natural terrestrial ecosystem, the requirement for AMF by native plants has important implications for restoration ecology and the recovery efforts for endangered plant species. Restoration or augmentation of pine rockland communities and the endangered species that inhabit these communities require the presence of AMF. On naturally low phosphorus soils, these plants will only flourish with AMF or addition of phosphorus containing fertilizers, which will pollute. Our results are also significant to the potentially large-scale production of nursery-grown plants used in future efforts at restoration of upland habitats of the greater Everglades. Early introduction of AMF may be required for economical and successful outplanting.

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Protection of Florida's Native Bromeliads byBiocontrol of *Metamasius callizona* (a Mexican Weevil)

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Florida's rarest native bromeliads *Catopsis berteroniana, C. floribunda, C. nutans, Guzmania monostachia, Tillandsia pruinosa*, and *T. flexuosa* are in imminent danger as populations of an invasive adventive weevil encroach on the Everglades area. Florida populations of *Tillandsia utriculata*, which was common and widespread, have been so devastated that this species and *T. fasciculata* have been placed on the Florida list of endangered species. At least 11 of the 16 species of Florida native bromeliads are in great danger, and all but one of these 11 are now listed as threatened or endangered (Florida Administrative Code, 1998). The only realistic way of controlling the weevil populations is by biological control.

This weevil, *Metamasius callizona*, is native to southern Mexico and Central America, was detected in a nursery in Broward County, Florida in 1989, and became feral in that county. By natural dispersal and by careless human transport of infested plants it had spread by 1991 to three more counties, by August 1997 to at least twelve, and by April 1999 to 16: Brevard, Broward, Charlotte, Collier, Dade, DeSoto, Glades, Hendry, Highlands, Indian River, Lee, Manatee, Martin, Palm Beach, St. Lucie, and Sarasota (Fig. 1). It has invaded the Sebastian, St. Lucie, Loxahatchee, Caloosahatchee, Peace, Myakka, and Manatee river systems, attacking what once were dense populations of bromeliads epiphytic in riverine trees. It has devastated bromeliad populations in Broward County parks and in the Savannas State Preserve (St. Lucie County), is destroying bromeliad populations in Highlands Hammock State Park, and is on the verge of the Big Cypress National Preserve and the Fakahatchee Strand State Preserve (Collier County).

Damage is caused mainly by the weevil larvae which mine the meristematic tissue of these plants to kill them and decimate populations. Although the weevil may be a specialist of the larger *Tillandsia* species (whose larger specimens provide enough plant tissue for development of several larvae), it also attacks *Catopsis* and *Guzmania*.

By selectively destroying the larger plants, which take years to develop, it kills them before they have opportunity to reproduce by seed. Because the adults are long-lived and persist in areas where large plants have been destroyed, the weevil continues to decimate the pre-breeding bromeliad population, thus preventing seedling replacement and driving populations toward extinction.

Research into biological control is in progress at the University of Florida, but adequate funding to complete research and implementation has not been committed. A potential biological control agent (a specialist parasitoid fly of the family Tachinidae) has been discovered in Honduras, and research is in progress toward its use as a biological control agent. The Florida Council of Bromeliad Societies (FCBS) is planning a program to collect, record, and germinate seed of native bromeliads, and to replace seedlings in nature when the risk to bromeliads diminishes after biological control begins to take effect.

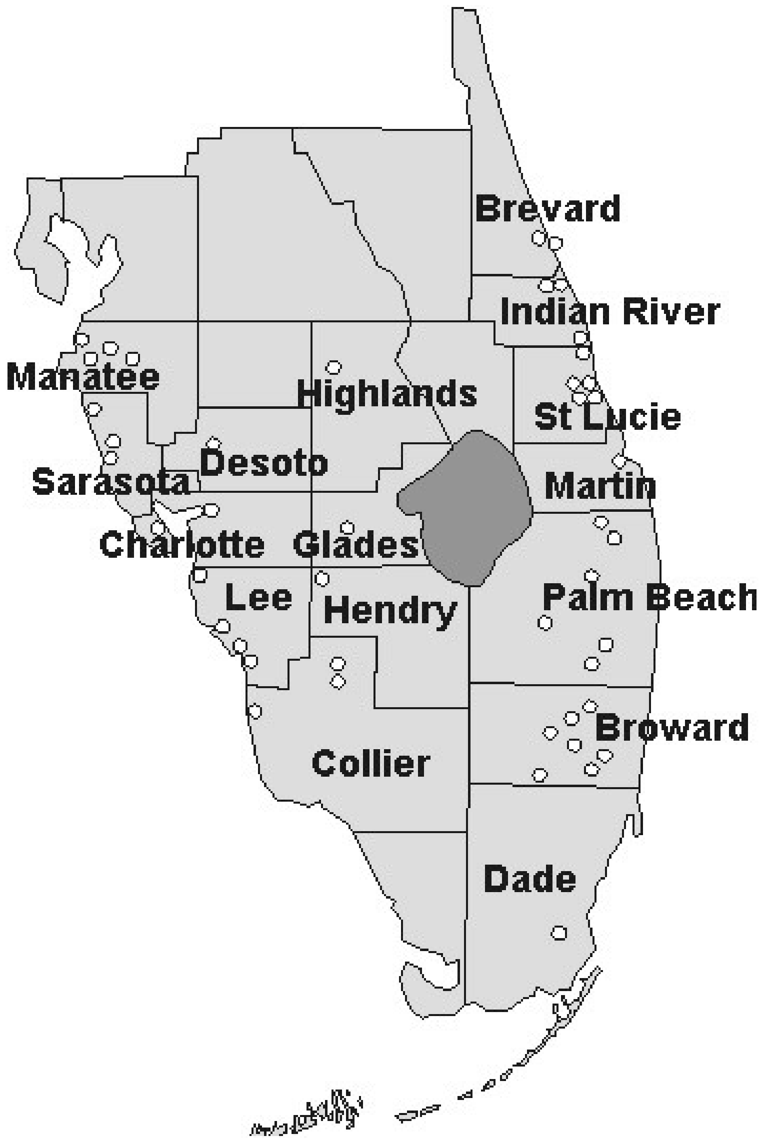

Fig. 1. Sites where *M. callizona* has been found in 16 south Florida counties.

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The plight of Florida's native bromeliads has been publicized by a website (http://www.ifas.ufl.edu/~frank/danger.htm); FCBS (http://www.fcbs.org); the Bromeliad Society of South Florida (BSSF) (http://www.seflin.org/bssf/); The Bromeliad Society International (BSI) (various issues of Journal of the Bromeliad Society); and the Florida Native Plant Society (http://www.fnps.org/ and the winter 99-2000 issue of its newsletter The Palmetto). Verbal encouragement and cooperation for the project have come from Florida Division of Recreation and Parks; Broward County Parks and Recreation Division; Miami-Dade Parks; the Florida Endangered Plant Advisory Council; and the Research Department of Everglades National Park. Funding support has been received not only from FCBS (and various of its member societies including BSSF), BSI, and FDACS (Division of Plant Industry and the Florida Plant Conservation Program, Division of Forestry); however, funding levels are still low and and with uncertain future.

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The Demography of Sargent's Cherry Palm (*Pseudophoenix sargentii* ssp. *sargentii*) on Elliott Key (Biscayne National Park)

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Palms of the genus *Pseudophoenix* (4-6 spp.) occur in coastal habitats throughout the northern Caribbean basin. *Pseudophoenix sargentii* ssp. *sargentii* (Sargent's cherry palm or buccaneer palm) is the only species of this genus found in North America and is the rarest Florida native palm. It is currently classified as endangered by the State of Florida, ranked as critically imperiled by the Florida Natural Areas Inventory, and is included in the 1997 IUCN Red List of Threatened Plants as a Florida endangered species. Decline of the Sargent's cherry palm in Florida is attributed to habitat loss due to coastal development, over-exploitation for use as an ornamental palm and poaching/collecting. The species is also threatened with extinction throughout its northern Caribbean range by coastal development and commercial exploitation. Sargent's cherry palm historically occurred on Elliott, Sands and Long Keys. Elliott and Sands Keys are now a part of Biscayne National Park, and Long Key, an island fifty miles southwest of Elliott Key, is one of three state parks in the Keys. No wild palms are known to occur on Sands or Long Keys.

In 1886, the year of its discovery in southern Florida, more than 200 adult Sargent's cherry palms occurred in the Florida Keys. Today, Biscayne National Park contains the last wild population of the Sargent's cherry palm in North America. Twelve reproductively mature trees, 18 juvenile palms, and seedlings are all that remain of this wild population.

Natural factors in the environment pose additional threats to the survival, growth and reproduction of the Sargent's cherry palm. These threats may include tropical storms and hurricanes, salt water intrusion, old age, and disease. Populations of Sargent's cherry palm were severely affected by Hurricanes Donna and Andrew, which hit Long and Elliott Keys in 1960 and 1992, respectively. Hurricane Andrew killed nineteen reproductively mature trees on Elliott Key or 58 percent of the population. Hurricane Donna's impact on the palm population was not studied.

Fairchild Tropical Garden, Biscayne National Park, and the Florida Department of Environmental Protection, Recreation and Parks, District V are leading conservation efforts to restore Sargent's cherry palm to its former range in the Florida Keys. A permanent *ex situ* conservation collection of the species was established and is being maintained by the Garden. This collection is used for germplasm storage and conservation research, to augment the wild population, and in the case of native habitat destruction, as insurance against extinction and loss of genetic diversity.

Fairchild Tropical Garden, in collaboration with Biscayne National Park and the Florida Department of Environmental Protection, restocked the single wild population of Sargent's cherry palm on Elliott Key and reintroduced new populations on Long and Sands Keys. Some 250 seedlings were planted on the three sites. These plants were grown from seed collected from tagged and mapped wild palms on Elliott Key. Individual palms in the reintroduced and wild populations were mapped using GIS/GPS technology. To date, the survival of the translocated seedlings on Elliott and Long Keys is 33% and 61%, respectively. None of the three palms translocated to Sands Key survived. Mortality of translocated seedlings on Elliott Key was attributed to herbivory, but this has not been confirmed by field research. Mortality of the translocated seedlings on Long Key is also attributed primarily to heavy grazing by a herbivore. Marsh rabbits have been suspected, but this supposition has not been confirmed by field research. Protective caging, placed around individual palms on Long Key, was effective in guarding seedlings from herbivores.

The restoration of Sargent's cherry palm has been hindered by our lack of knowledge of this species' natural ecology and biology. Baseline site data, including vegetation, soils, elevation, precipitation, and canopy cover, is needed to describe the habitat in which this palm grows in the wild. In addition, few established seedlings are found around adult palms in the wild population. This suggests that predation of seed and seedlings may be high; conditions may rarely be favorable for germination and/or seedling establishment; or seeds may be non-viable. Heavy predation upon the seeds and seedlings by wildlife and infrequent production of viable seeds may prevent new recruitment, but this has not been well studied.

Fairchild Tropical Garden has initiated a formal demographic survey of the wild population of Sargent's cherry palm on Elliott Key to record the proportions and spatial distribution of adults, juveniles and seedlings. In 2000, all individual palms were remapped, newly discovered seedlings were tagged and mapped, and the sizes of all individual palms were measured. The results are a quantitative description of the population structure.

Fairchild Tropical Garden is overseeing a long-term plan to monitor the wild population of Sargent's cherry palm on Elliott Key. Palms are being monitored to record changes in the population over time. The palms will be revisited at least two times per year to re-measure individual plant sizes and record fecundity, mortality, and the appearance of new plants. Baseline habitat data will be collected to describe the habitat in which Sargent's cherry palm grows. The results will be a record of the pattern of changes that occur in a natural population and the ecological context of these changes. Accumulated data will be analyzed to correlate the varying fates of individual palms to habitat variables. Information about the dynamics of the natural population of Sargent's cherry palm on Elliott Key will be used to assess and strengthen our conservation efforts to restore this endangered palm to its former range in the Florida Keys.

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The Effects of Prey Availability on the Feeding Tactics of Wading Birds

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A noticeable decline in several wading bird populations since the 1930s was one of the first signs that the Everglades ecosystem was being degraded. The relationship between hydrologic properties and wading bird nesting has helped define how the Everglades functions, and wading bird population levels are now being used as performance measures to monitor the progress of restoration. One common explanation for the population declines is that changes in hydrologic properties of the Everglades have reduced the amount of prey available to wading birds. An under appreciated point is that not all species have declined at the same rate, or perhaps even declined at all, even though they often nest and feed in the same locations. Furthermore, prey availability is not equivalent to prey density because availability may be affected by prey vulnerability to capture. In wetlands the influence of prey vulnerability may be particularly important for wading birds because they forage in an ecosystem with widely fluctuating water levels that influence the distribution, behavior, and vulnerability of prey. There currently is no mechanistic understanding of how prey become available to wading birds in a wetland, nor is there an understanding of how individual species in a wading bird assemblage respond to fluctuations in prey availability.

In 1996, I manipulated prey density and water depth in 12, 0.2-ha ponds to determine their relative effects on the feeding tactics of eight species of free-ranging wading birds. The experiment was conducted in a constructed wetland adjacent to, and west of, the northern tip of the remnant Everglades, in Palm Beach County, Florida. Each pond was set to one of three water depths (10 cm, 19 cm, or 28 cm) and stocked with golden shiners at a density of either 3 fish/m^2 or 10 fish/m^2.

Total bird use (all treatments pooled) increased from day 1 (day after stocking) to day 6, stabilized for several days at approximately 280 birds, and then decreased until day 16 when bird use nearly ceased. Fish were depleted most rapidly in the shallow and least rapidly in the deep treatment. Giving-up-density of prey (GUD), which is a measure of energetic foraging costs, increased with increasing water depth. In the deepest treatment, the White Ibis, Wood Stork, and Snowy Egret, had higher GUDs than did the Glossy Ibis, Great Egret, Tricolored Heron, Great Blue Heron, and Little Blue Heron. Also, the first 3 species were affected by both prey density and water depth whereas the latter 5 species showed a decidedly weaker response to one or the other component of food availability. The first three species never occurred in large numbers in the deep treatment and they abandoned the study site before other species reached their maximum levels. Their feeding strategy was to search for new high quality food patches (i.e., searchers) rather than stay and exploit food patches that were declining in quality (i.e., exploiters). Species that used a searching strategy also have shown the most severe population declines since the 1930s, suggesting that the loss of high-quality feeding sites may have resulted in the population changes. Based on the concordance between the experimental results and long-term population data, I hypothesize that what has changed in the ecosystem is the simultaneous occurrence of both high prey densities and shallow water (i.e., high quality patches), either in overall frequency, or the spatial and temporal pattern of their occurrence. This is distinct from the suggestion that average prey availability levels have declined or overall prey population levels have decreased because it only addresses the highest quality patches. In the natural system, high-quality patches contain shallow water and high fish densities.

They mainly occur as a result of a strong seasonal water level recession, often preceded by several years of wet conditions, which increase fish populations. These processes are not mutually exclusive and indeed an increase in overall fish population size coupled with a seasonal recession would produce the highest quality patches. High prey-density patches produce by a seasonal recession are fundamentally different from fish population increases solely as a result of increased hydroperiod or nutrient inputs because season recessions produce small-scale patches (1-20 m) that are clumped at any one time and moving across the landscape. Only one component of those patches (i.e., high prey density or shallow water) needs to have changed to produce a reduction the simultaneous occurrence of shallow water and high prey density, suggesting a delicate balance between them.

When water depths are deeper than optimal, species with higher GUDs (searchers), like Wood Storks, White Ibises, and Snowy Egrets, require a larger spatial extent of marsh to provide suitable feeding conditions than do the other species. These spatial requirements support the notion that overall loss of spatial extent could have contributed to population declines and it provides an explanation for why those declines would differ among species. Because differences in GUDs were only apparent in deep water, the loss of short hydroperiod wetlands, which are used by wading birds early in the dry season when adults are building energy reserves for nesting and during very wet years, may have had particularly serious consequences. The encouraging news from this experiment is that if hydrologic conditions that produce high-quality feeding sites at a landscape scale are restored, the species that will benefit most, the searchers, are those that are currently most impacted.

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Omnivory and Periphyton Mats: Uncoupling Consumption and Consumer-Mediated Stimulatory Effects

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The role of omnivores in structuring communities through consumption or stimulatory effects (e.g., nutrient recycling, physical stimulation) is poorly understood. We studied the effects of two abundant omnivores, the riverine grass shrimp (*Palaemonetes paludosus*) and eastern mosquitofish (*Gambusia holbrooki*), on periphyton biomass in the Florida Everglades. We performed field experiments to assess consumptive (i.e., grazing) and stimulatory effects on periphyton, using a nested experimental design that permitted uncoupling of these effects. Omnivores and periphyton were maintained in field cages, with a fraction of the periphyton held in grazer-exclusion bags that allowed passage of nutrients but prohibited grazing by the omnivores. Grass shrimp and mosquitofish consumed periphyton, but in many instances, periphyton wet weight, chlorophyll a, and ash-free dry mass (AFDM) increased significantly with increasing omnivore density. The net balance of consumption and stimulation varied among experiments. These omnivorous macrograzers, in addition to consuming periphyton, enhanced it mainly through trophic cascades and nutrient regeneration. Omnivores may have provided a nutrient subsidy to periphyton by mobilizing nutrients from ingested animal prey.

Periphyton mat structure and the arrangement of palatable algae in a matrix of unpalatable ones (associational resistance), combined with calcification and low nutritional value, may have reduced herbivory. In a laboratory feeding experiment, mosquitofish consumed more green algae and diatoms in treatments with disrupted mat structure than in those with intact mats, consistent with the associational resistance hypothesis. No difference in diet was observed for grass shrimp in this feeding experiment.

Studies that fail to differentiate between consumptive and stimulatory effects may misinterpret the implications of finding no net grazer effects. This is particularly a concern with omnivores that can provide nutrient subsidies to primary producers, potentially compensating for direct consumption. Our study underscores the complexity of consumer-periphyton interactions in which periphyton edibility affects herbivory, and consumers influence periphyton mats through multiple routes that cannot be fully appreciated in experiments that only investigate net effects.

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USDA - Wetland Reserve Program in the Everglades Region

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The Wetland Reserve Program (WRP) is the nation's premier wetland restoration program on agricultural lands. The WRP provides voluntary incentives for landowners to restore, enhance, and protect wetlands impacted from agricultural activities. Natural Resources Conservation Service (NRCS), in partnership with the U.S. Fish and Wildlife Service (FWS), provides technical and financial assistance to landowners that engage in wetland restoration, enhancement, and protection. Incentive payments are paid to landowners wishing to establish long-term conservation easements on property entered into WRP. Advances in agricultural development over the centuries in America have led to the creation of one of the greatest food producing systems in the world. Less than 2 percent of our nation's population is engaged in the actual production of the food we consume, allowing the rest of our population to pursue other interests. One (1) farmer in the United States provides enough food for 129 people. Private lands provide 75 percent of the nation's wildlife habitat. Advances in agricultural productivity and efficiency over the last 200 years did not occur without a price to the environment. The 1996 Farm Bill instituted the strongest package of private land wildlife habitat restoration opportunities ever assembled. The WRP along with other important Farm Bill programs is currently being implemented in south Florida and contributing to the ecological restoration of the Everglades. The WRP is restoring and enhancing freshwater marshes, wet prairies, hydric flatwoods, wetland hardwood hammocks, and cypress wetlands with the primary mission of wildlife habitat throughout the Everglades region. The Florida panther, Audubon's crested caracara, Everglades snail kite, wood stork, red-cockaded woodpecker, and the eastern indigo snake are some of the endangered and threatened wildlife species that are expected to be benefited by the ecological contributions of the WRP in south Florida.

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A 2D Graphical Visualization System for Integrated ATLSS Hydrology, Fish, and Wading Bird Simulation Data

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An output data-graphical/visualization interface is critical to the presentation of voluminous Across Trophic Levels System Simulation (ATLSS) results in a form interpretable by decision makers as well as scientists and engineers. A prototype 2D graphical visualization interface has been designed and implemented for integrated hydrology, fish, and wading bird ATLSS data. The system is characterized by the following features: 1) water depth, fish biomass density, and wading bird population are color-coded, where the differential visual intensity of the color assigned to a data type indicates gradation of data with respect to other cells of the same data type, 2) data are shown spatially with respect to the Everglades landscape, and the data representations can be superimposed on one another to allow a composite view of data, which facilitates easy comparison between the spatial distribution patterns of fish biomass and bird population, 3) temporal progression of simulation data are presented in a "slide show" fashion that is controlled by the user, 4) restoration and non-restoration scenarios are shown side-by-side for easy comparison, 5) the user of the visualization can view the entire Everglades landscape at once or "zoom in" on a particular region for a more detailed view, and 6) various composite statistics and information are made available to the user outside of the scope of the graphical display.

The system is implemented via Java applet running within a web browser, and so is portable between common PC systems. The system reads numerical data from files on the fly and generates the graphical display dynamically based on the data contained in those files. In addition to the controls given to the user within the visualization itself, many useful program parameters may be altered through modification of the webpage that runs the applet, making it as dynamic and flexible as possible. While the system is not "statistically rigorous," it is open-ended and can accommodate modules that provide more in-depth statistical information. As the system stands, however, it can be a useful tool for surface-validation of simulation output, and for the development of intuition concerning model/simulation behavior on a gross scale.

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South Florida Multi-Species Recovery Plan: A Species Plan, An Ecosystem Approach

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In 1995, the U.S. Fish and Wildlife Service (FWS) was directed to prepare a comprehensive, ecosystem-wide recovery strategy to help fulfill two objectives of the South Florida Ecosystem Restoration Initiative: to recover threatened and endangered species, and to restore and maintain the biodiversity of native plants and animals in the upland, wetland, estuarine, and marine communities of the South Florida Ecosystem. This strategy, now completed, is known as the South Florida Multi-Species Recovery Plan.

The Multi-Species Recovery Plan contains information on the biology, ecology, status, trends, management, and recovery actions for 68 federally-listed species that occur in South Florida, as well as the ecology and restoration needs of 23 natural communities in this region. It is one of the first recovery strategies specifically designed to meet the needs of multiple species that do not occupy similar habitats. To make certain the greatest diversity of species found in South Florida benefit from the management actions of the FWS and our partners, the Recovery Plan also includes candidates for Federal listing, State-listed species, migratory birds, and other species of concern. This recovery strategy is intended to serve as a blueprint to be used by the Federal agencies, State agencies, Tribal governments and other partners who are committed to the restoration of the South Florida Ecosystem. It is also designed to meet the information needs of the agencies involved in the South Florida Ecosystem Restoration Initiative as they prepare NEPA compliance documents, go through regulatory permitting processes, or engage in endangered species consultations with the FWS. This nearly 2,200-page document must be flexible enough to accommodate the changes identified through ongoing and planned research, and be compatible with adaptive management strategies.

Implementation of the Recovery Plan will require multiple stakeholder participation. In November 1999, a Multi-species/Ecosystem Recovery Implementation Team (MERIT) was appointed with the purpose of overseeing this objective. MERIT includes 36 members representing Federal, State and local governmental agencies, two Tribal governments, academia, industry, and the private sector. The focus of MERIT will be on developing a conservation strategy for South Florida to prioritize the recovery and restoration actions as identified in the Multi-Species Recovery Plan, and on recommending and funding on-the-ground recovery and restoration activities. Additional goals of this team will be to coordinate government, non-government and private efforts to recover species and restore habitats in South Florida, exchange information among the various Working Group efforts to recover species and restore the ecosystem, promote outreach to involve the public in species recovery and community restoration, and evaluate restoration success through species and ecological community monitoring and adaptive management. This implementation process is an integral component in meeting the goals of the Administration's restoration plan for South Florida.

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Analysis and Synthesis of Existing Information on Higher Trophic Levels: Factors Affecting the Abundance of Fishes and Macro-invertebrates in Florida Bay

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A data base was assembled for Florida Bay that integrates six independent forage fish and macro-invertebrate studies from 1974-1997, creel census data, and information on major forcing functions: ambient and lagged data on rainfall, water discharges, salinity, tidal amplitude, sea level, wind, El Nino events, bathymetry, and habitat (seagrass vegetation type and density). Sogard and Matheson collected throw trap data at overlapping stations on banks during the 1980's and 1990's, while Robblee provided data for Johnson Key banks and basins (1983-1999). Trawl data was provided by Schmidt (1970's), Thayer and Powell (1980's and 1990's), and Colvocoresses (1990's). Seine data was provided by Schmidt (1970's) and Colvocoresses (1990's). For each sample, number of species per sample were interpolated to density per hectare. Creel census data (1983-1999) from Everglades National Park was used to evaluate adult fish populations.

The data base was used to examine the dynamics of key species selected by consensus by researchers who had conducted fishery studies within Florida Bay. General additive models were used to determine which major forcing functions are controlling the abundance of key species within the Bay. The data base was also used to examine spatial and temporal changes in fish densities intraannually (seasonal), interannually (between years), and to examine decadal trends.

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Development of a GIS Tool to Visualize and Analyze ATLSS Models Result for Resource Managers

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For the past several years, the U.S. Geological Survey (USGS) and other agencies have worked on a modeling approach, the Across Trophic Level System Simulation (ATLSS), to predict the responses of a suite of higher trophic level species to different alterations in the Everglades/Big Cypress hydrology regime. The ATLSS project has produced many scenarios for the Everglades/Big Cypress region of south Florida to represent the biotic community and various factors affecting this community. ATLSS is also being used to view different hydrologic scenarios in relation to the south Florida landscape. A tremendous amount of digital data has resulted from running these scenarios. This project concerns the development of a customized ESRI-ArcView based spatial query and visualization tool that provides capabilities of loading ATLSS models data and showing alternative water management changes and their effects on numerous species modeled in ATLSS, as opposed to one species, and compare numerous scenarios for one species. Model index values can be averaged spatially and temporally, and displayed as maps or tables. This tool integrates the results of running ATLSS models with spatial and no-spatial data from different sources, allows users to extract statistic information for defined areas, and generates simple outputs in form of maps, time series graphs, summarized tables, and reports. Most of the outputs generated by the system can be saved to files using standard exporting formats for text, graphic, and table documents.
Particular attention has been devoted in defining final users common tasks and implementing procedures that perform those tasks. Particular emphasis has also been given in designing a graphical user interface that assures product usability for not highly trained GIS users.
This tool will be used as prototype server application for a future Internet based visualization system.

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Vegetation Pattern and Process in Tree Islands of the Southern Everglades and Adjacent Areas

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The tree islands of the southern Everglades area, including adjacent interior and coastal areas, are classified based on species composition and environmental factors controlling tree island distribution and structure. Tree islands occur on various substrates within surrounding habitats that may be freshwater or coastal wetlands, or rockland pine forest of the Atlantic Coastal Ridge. Eight tree island groupings within seven subregions are defined by cluster analysis of data from the literature and previously unpublished studies. Most of the types are dominated by native, tropical species found in the continental United States only in southern Florida. A total of 164 woody species occur naturally many of which are rare or highly restricted in distribution. All 135 tropical species have distribution ranges centered in the West Indies where most occur in calcareous, dry sites, frequently as invaders of disturbed habitats.

Hurricanes, drainage, excessive burning, spread of non-native species and logging have differentially affected all types and few undisturbed tree islands exist even within federally preserved lands. Collectively, the types occur along local and regional elevation gradients, with associated vulnerability to flooding and fires. Marked differences exist in the response of tree islands to protracted flooding that are consistent with their location in the landscape. Thus bayhead swamps, which occur as part of freshwater slough tree islands and are comprised mostly of temperate swamp forest species, have been inundated up to 10 months/yr in the past several decades, while tropical hardwood hammocks on the same tree islands were inundated for 0 to 22% of the year. Elevational profiles with species distributions and flooding frequencies are presented for several tree island types to illustrate the diversity of communities and the range of conditions that can support tree islands.

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Seasonal Variation in Habitat use by Decapods and Fishes in the Northern Everglades

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I characterized seasonal variation in the spatial ecology of decapods and fishes within the Arthur R. Marshall Loxahatchee National Wildlife Refuge. This research revealed a wealth of information concerning the basic ecology of freshwater wetlands and aquatic macrofaunal assemblages.

First, factors that vary over a large scale (e.g., gradients in hydroperiod and nutrient enrichment) play a significant role in determining the abundance of decapods and small fishes, and these factors are likely mediated through bottom-up (i.e., resource availability) and top-down (i.e., risk of predation) food web processes.

Second, local variation in water depth and accumulation of plant biomass (i.e., habitat complexity) also profoundly affect population demographics, and are driven by more localized versions of top-down and bottom-up food web processes. There are distinct patterns of habitat use by prawns, crayfish, and most fishes, and these patterns of nonrandom habitat use translate into habitat-specific assemblage structure.

Third, seasonal changes in water levels result in shifts in the relative quality of adjacent habitats, which leads to shifts in patterns of habitat use by decapods and fishes. This seasonal shift is most extreme during severe marsh drawdowns, when most fishes and prawns are congregated into deep, dry-season refugia (i.e., sloughs and alligator holes in the northern Everglades). In contrast, crayfish apparently respond to drought conditions by burrowing into the peat substrate.

Fourth, the relative abundance of small fishes and large invertebrates is about equal in the northern Everglades. This suggests that a rich diversity of size-structured interactions is possible, including a reversal of the typical vertebrate predator-invertebrate prey relationship. Small-scale experiments were used to assess the strength of such interactions.

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Food Web Responses to Enhancement of the Altered Kissimmee River Ecosystem

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Historically, the Kissimmee River meandered from Lake Kissimmee southward across extensive floodplain wetlands and into Lake Okeechobee. Between 1961 and 1972, the river was transformed into a 90-km long, 100 meter wide, 9 meter deep canal. Channelization drained 2/3 of the floodplain, eliminated water level fluctuation and flow, and profoundly altered fish community structure within this unique Florida ecosystem. Concern over loss of this ecosystem led to a "restoration experiment," which involved enhancing water level fluctuation, in-channel flow, and natural plant communities within Pool B of the river.

In this paper, we compare the diets of predatory fishes collected from enhanced (Pool B) and non-enhanced portions (Pools A and C) of the Kissimmee River to determine whether food web structure was positively affected by the restoration experiment. Diets were reconstructed for similar numbers of black crappie, bowfin, chain pickerel, Florida gar, and largemouth bass. Collectively, our univariate and multivariate analyses indicate that prey eaten by large predatory fishes in the enhanced portion of the Kissimmee River were quantitatively and qualitatively different from prey eaten by the same species in non-enhanced portions of the river. Predators in the enhanced portion of the river had fewer empty stomachs, more prey items per individual, more prey types per individual, greater overall diversity of prey, and a multivariate suite of prey distinct from predators in non-enhanced portions of the river. These results suggest that restoration of hydrologic linkages between the main channel and floodplain habitats will also positively affect food web structure and ecosystem function in the Kissimmee River.

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Development of Monitoring Protocols for Freshwater Fish Assemblages of the Rocky Glades, Everglades National Park

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Fish monitoring efforts in Everglades National Park 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 of eastern Everglades National Park. Presently, we are sampling fishes within multiple habitats of the Rocky Glades, relating aspects of the fish assemblage to hydroperiod, and evaluating sampling techniques for use within the diverse Rocky Glades habitats. We sampled monthly from June 1999 to the present using minnow traps, and collected 17 species of fishes (13 native and 4 exotic) at nine Rocky Glades sites. The mean total biomass of all fishes caught per unit effort in Rocky Glades habitats was positively related to hydroperiod. Understanding how aspects of fish assemblage structure relate to hydroperiod is important for predicting the effects of increasing hydroperiod on short-hydroperiod areas. Future directions for investigation include examining fish assemblages in dry season refuge habitats and mortality associated with below-ground water elevations, expanding the areas and habitats sampled, and relating aspects of fish assemblage structure to habitat and hydroperiod within Rocky Glades marshes.

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Vegetation Density Mapping From Multispectral and SAR Imagery Using Artificial Neural Network Techniques

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Vegetation cover information was determined for the S. FL Everglades using unsupervised and artificial neural network based supervised classification techniques applied to multisensor, multispectral and RADAR imagery. The main objective was to develop and demonstrate an automated, supervised classification process for mapping vegetation type and density from moderate spatial resolution (30-m) Landsat Thematic Mapper (TM) multispectral imagery, integrated with higher spatial resolution synthetic aperature RADAR (SAR) data of the European Space Agency satellite.

Unique to this mapping requirement, the defined land cover classes can be mixtures of homogenous cover types. For example, within the 30-m -by- 30-m ground projected instantaneous field of view (GIFOV) of the TM multispectral sensor, the cover for the low density sawgrass class includes open water and sparse sawgrass. Consequently the spectal signal is a mixture instead of pure as for a homogeneous area on the ground. Mixed pixels also occur when boundaries between homogenous cover types are within the GIFOV; for example the boundary between dense, homogeneous sawgrass and open water. The accurate classification of mixed pixels is difficult to obtain from multispectral imagery with the often used parametric maximum likelihood classification techniques applied on a per pixel basis. Spectral unmixing techniques offer an alternative to the classification of mixed pixels but there are other problems such as the requirement for reference, or end-member spectra for each class (Foody, et al, 1997).

The application of multilayer NN techniques for the supervised classification of mixed pixels has been reported, for example by Foody, et al, 1997. The vegetation density mapping described here used a hybrid classification process that combined unsupervised, fuzzy clustering with supervised NN classification techniques. The overall process is thus NN based classification, and fusion of fuzzy-clustered, preprocessed multisensor data. For this vegetation density mapping requirement, the individual NN outputs represent class, (e.g., vegetation type) while their output levels represent the fuzzy categories of low, medium and high density vegetation. With training, the NN learns to produce the three output levels that denote the respective density classes. This learned classification is optimal in the sense that the training process attempts to minimize the square error between the NN learned output level for class and the true level. It provides an automated method for mapping the image feature data into class; in this case into the fuzzy (i.e., low, medium and high) density classes. A class cover map results from hard thresholding the output values.

Input data for training was obtained by a two step process. First, clusters were found by an iterative fuzzy clustering process (Fuzzy Learning Vector Quantization) (Bezdek, 1993) applied to the feature data derived from preprocessed multispectral (XS) and SAR imagery. XS and SAR data were each clustered separately using ten and eight clusters, respectively; simply more clusters than classes were used.

NN input values for each class-labeled feature vector used for training were the respective fuzzy-memberships (a continuous value, proportional to the distance to the cluster) between the feature vector and all clusters. This may be contrasted to hard clustering where the input feature data is associated only in a binary sense and with only one cluster. Information related to the other clusters is lost.

Preprocessing and feature extraction techniques were developed and applied to the TM and SAR data before clustering in order to improve classification results, and this work reported in conference proceedings. New techniques were developed for the resolution enhancement of TM 120-m thermal infrared data in order to improve classification results (Lemeshewsky, 1998, 2000). Also, a discrete wavelet transform (DWT) based technique for the fusion of TM and higher spatial resolution panchromatic imagery (Lemeshewsky, 1999) was developed in order to produce several false color image, 1:24000 scale photo image maps. SAR speckle noise was reduced using the reported discrete wavelet transform (DWT) based soft-thresholding technique of Donohoe, and implemented with shift-invariant DWT (Lemeshewsky, 1999). To improve the classification accuracy of TM mixed pixels, especially where the GIFOV contains boundaries between cover types, a reported (Wu and Schowengerdt, 1993) 'partial restoration' preprocessing technique was applied to the TM spectral band data, excluding the thermal band. The TM pixel feature data vector used in clustering included TM bands 2, 4, 5, and 7 after 'partial restoration' preprocessing, resolution enhanced band 6 thermal data, and normalized difference vegetation index (NDVI) computed from partial restoration processed bands 3 and 4. Local mean and variance features were derived from the denoised SAR imagey.

A vegetation type-density image map was produced for the SICS area and several 1:24,000 scale image photomap examples printed. Classification results are promising and further study of this technique applied to higher spatial resolution hyperspectral imagery is suggested.

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Testing the Effects of Changes in Water Quality on Coral Survivorship

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Changes in historic hydrological patterns as a result of the redistribution of fresh water flows into the South Florida landscape by the construction of the C&SF Project have caused significant modifications in water quality and health of coastal habitats. The massive die-off of *Thalassia testudinum* documented in Florida Bay starting in 1987 is considered to be one of the best documented examples of the effects of changes in water quality possibly associated with the C&SF Project. Similarly, the outflow of low-quality Florida Bay water has been correlated recently with coral mortality and loss of species richness along the Florida Reef Tract.

In response to concerns over declining coral health we developed a project to evaluate the potential impacts of modifications in water delivery patterns on the growth and survivorship of hard coral populations within Biscayne Bay. Considering the location of these coral populations directly downstream of a massive Everglades restoration effort as well as their known susceptibility to water quality declines, these populations have been selected for evaluation as early warning indicators of environmental changes.

Here we report on our research on the most abundant coral species within Biscayne Bay, *Siderastrea radians*. Field surveys of coral distribution, survivorship, recruitment, and growth were incorporated into a spatially-explicit dynamic population model for this species. At present, we are conducting microcosm exposure experiments to evaluate the effects of changes in salinity, nutrient concentrations, and sedimentation on the survivorship and growth of *S. radians* at our microcosm facility housed at the Rosenstiel School of Marine and Atmospheric Science in Miami. Based on our findings, we will develop response models to determine the potential effects of changes in water quality.

Simulation models allow the projection of population parameters over time scales that go beyond those examined by monitoring programs. In addition, by modifying model parameters, it is possible to simulate a range of environmental conditions to produce testable, long-term hypotheses of the potential effects of multiple stressors on coral populations. The potential effects of different water management scenarios on the condition of coral populations within Biscayne Bay will be evaluated using output from our Biscayne Bay hydrodynamics model under different water management scenarios (e.g., 95Base, D13R). The integration of these models will provide important tools to predict the potential effects of different restoration scenarios on coral health, as well as a tool to assess restoration success.

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Trophic Patterns of an Everglades Freshwater Fish Community across Habitats and Seasons

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As part of a study to examine the relationship between mercury bioaccumulation and the trophic positions of fishes in the southern Everglades, we studied the stomach contents of small- and large-bodied fishes from natural wetland habitats. We began by analyzing the gut contents of the 26 native and 6 introduced fish species in this community. Information on the diets of most Everglades fishes had never been published. We expanded the scope of the fish diet segment beyond that required for the mercury work to include gut samples from pond, spikerush, and sawgrass marsh at high and low-water periods. This allowed us to compare trophic patterns in the Everglades fish community with results from tropical fish communities. Major food types included algae for species like the sailfin molly (*Poecilia latipinna*) and sheepshead minnow (*Cyprinodon variegatus*), detrital/algal conglomerate for the flagfish (*Jordanella floridae*) and spotted tilapia (*Tilapia mariae*), small invertebrates for the killifishes and livebearers, and larger aquatic insects and decapods for most sunfishes and catfish. The top of the piscine food web was occupied by bowfin (*Amia calva*), Florida gar (*Lepisosteus platyrhincus*), largemouth bass (*Micropterus salmoides*), and pike killifish (*Belonesox belizanus*). Based on the volumetric contributions of prey in the guts, we grouped the fish species quantitatively into five functional guilds of herbivore, omnivore-highly herbivorous, omnivore, omnivore-highly carnivorous, and carnivore. Independently derived estimates of fish trophic position from stable-isotope measurements, and from a multivariate ordination (NMDS), agreed well with the results of the gut analyses.

We compared patterns of food resource use among habitats and water level in the Everglades fish community to those reported for tropical seasonal wetlands. The native Everglades community exhibited patterns similar to tropical communities, including higher levels of feeding at high water, movements among habitats with water-level changes, and reduced feeding and some diet switching at the height of the dry season. However, the seasonal diet changes that are so marked in many tropical communities appeared to be weaker in the Everglades fauna. Dietary overlap within and among seasons was relatively low. The majority of Everglades fishes were omnivorous. There were few of the dietary specializations that characterize tropical communities, and only a few species were strictly herbivorous, detritivorous, or piscivorous. This may reflect the temperate origin of the native fauna, in which specialized herbivores and detritivores are uncommon. The introduced species included three herbivores/detritivores, two omnivores, and a piscivore.

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Ecology and Conservation of the American Crocodile in Florida

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The American crocodile (*Crocodylus acutus*) is primarily a coastal crocodilian that occurs in parts of Mexico, Central and South America, the Caribbean, and at the northern end of its range in southern Florida. As for other species of crocodilians, hunting, for hides, meat, collections, and fear, and habitat loss (direct and/or due to degradation) have made the American crocodile endangered throughout its range. In Florida, habitat loss from human development in the rapidly growing coastal areas of Palm Beach, Broward, Dade, and Monroe Counties has been the primary factor in endangering the United States 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. At that time most of the remaining crocodiles (about 75% of known nests) were in Florida Bay in Everglades National Park. When crocodiles were declared endangered in 1975 (Federal Register 40:44149) scant data were available for making informed management decisions. Field and laboratory data that were available suggested that low nest success, combined with high hatchling mortality, provided a dim prognosis for survival of crocodiles. Results of intensive studies conducted by the National Park Service, Florida Game and Fresh Water Fish Commission, and Florida Power and Light Company resulted in a more optimistic outlook for crocodiles in Florida. Largely based on these studies and recovery efforts by the U.S. Fish and Wildlife Service, the U.S. National Park Service established a crocodile sanctuary in northeastern Florida Bay in 1980, Crocodile Lakes National Wildlife Refuge was created, and Florida Power and Light Company began a long term management and monitoring program. Crocodiles have continued to respond positively to these activities.

Currently, new issues face crocodiles in Florida. Florida Bay has undergone a number of changes that have caused a great deal of concern for the ecological health of this ecosystem. Efforts have been, and continue to be, made to improve Florida Bay and Biscayne Bay. Monitoring and research studies also have continued on crocodiles with the dual purposes of assessing the status of the population and evaluating ecosystem restoration efforts. An important aspect of evaluating ecosystem restoration efforts has been increasing our understanding of hydrological relations of crocodiles. Conspicuously, more crocodiles have been discovered in more places now than even ten years ago.

Crocodiles are now known from Biscayne Bay, Broward County, and in several areas in Southwest Florida, between Shark River to Sanibel Island. However, virtually nothing is known about the population structure, distribution, and habitat use of crocodiles in these areas. Once again we lack data for making informed management decisions. In these locations negative impacts of projected land uses, the positive potential of restoration efforts, and an increasing number of human/crocodile encounters will likely be the most important factors affecting crocodiles.

In South Florida we have the unique opportunity to integrate endangered species conservation with ecosystem restoration and management. Certainly this is not always the case, and we are fortunate here. American crocodiles thrive in healthy estuarine environments, and in particular are dependent on freshwater deliveries. In this regard crocodiles can be used to evaluate restoration alternatives, and set success criteria for Florida and Biscayne Bays. Crocodiles also can be used as an indicator of negative impacts of freshwater diversion due to coastal development in Dade, Collier, and Lee Counties.

Perhaps even more importantly, we have an opportunity to reevaluate the status of the American crocodile. This naturally provides an excellent opportunity to spotlight the success of an endangered species recovery effort. Continued research and monitoring will be an essential component of this effort.

Recovery of the American crocodile in Florida will require an integration of habitat enhancement for an endangered species with environmental education. As crocodiles benefit from a restored freshwater flow into estuaries, their numbers will increase. It is important to recognize that an increase in the presence of crocodiles will exacerbate a growing problem concerning interactions between humans and crocodiles. The challenge of integrating a recovering population of the American crocodile with an ever increasing use of coastal areas by humans will require a proactive education program and will be the final challenge in the successful recovery of this once critically endangered species.

The objectives of this project are to determine the relative abundance, distribution, and habitat relations of crocodiles in Florida; to monitor the nesting ecology, growth and survival of crocodiles in Florida; and to develop an educational program to increase the appreciation of crocodiles as an exciting natural history benefit and decrease the perception of them as a problem or nuisance.

In all areas population surveys and monitoring include nesting effort and success, growth and survival of crocodiles. In areas with recently observed crocodile activity, additional survey effort will be expanded to determine population structure, relative abundance and habitat relations. Crocodile nesting effort and success is determined by searching known and potential nesting habitat during April and May (effort), and July and August (success) for activity (tail drags, digging or scraping) or the presence of eggs or hatchlings. When nests are located their vegetation, substrate, distance from shore, dimensions (lxwxh), and salinity of adjacent waters are recorded. Hatched eggshells or hatchling crocodiles are evidence of successful nests. The number and cause of egg failure are noted whenever possible. Distribution, growth, survival, relative abundance, and habitat relations of crocodiles are assessed by quarterly survey and capture efforts.

The educational program will focus on the status and recovery of this endangered species (a success story in progress), the natural history of the American crocodile (especially its mild manner), and the appropriate behavior towards crocodiles (don’t feed them).

For the first time since its discovery in Florida the American crocodile is being studied throughout its US range. The results of this study will be used to reevaluate the status and distribution of the American crocodile in Florida, and will become the foundation for the reassessment of the listing status of this species. This project continues to monitor the response of crocodiles to habitat alterations from ecosystem restoration or commercial development. This study will provide a rationale for evaluating restoration alternatives and for setting restoration success criteria. A new brochure “The American Crocodile: Recovering an Endangered Species in an Endangered Ecosystem” will be premiered at the GEER Conference.

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Historical Ecology of the American Alligator in Greater Everglades Ecosystems

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Introduction

USGS-BRD and its cooperators are using a system of empirical data collection and simulation modeling to apply information on wildlife community patterns in guiding the restoration process. Evaluating long-term trends and developing population models require a large amount of data collected over a number of years and a number of locations. Information on alligator densities, nesting, and growth have been collected in south Florida since the 1950s by rangers and researchers in Everglades National Park and Big Cypress National Preserve, Florida Game and Fresh Water Fish Commission personnel, University researchers, and private consultants. Many of the most critical data sets (those having the largest amount of data or those from particular areas or years) are not accessible for use in evaluating restoration alternatives or developing models. The data are not available in a centralized, easily accessible, well documented database. Further, the size and scope of these data sets are not fully known. Certainly, thousands of individual records need to be evaluated, compiled, and entered into an appropriate database.

It is critical that these data sets are accessible to establish restoration targets for alligator populations, develop models, and design short and long-term monitoring tools for evaluating restoration success.

The primary objective of this project is to compile and make accessible the three most important data sets for alligators in Greater Everglades Ecosystems. Other objectives of this project include: developing a standardized format for collecting and managing data on alligators, and producing a digital library of historic reports. An immediate application of historical data assembled above will be to develop a method and to compare body condition among alligator populations in south Florida both spatially and temporally.

Methods

Historical Data Sets. -- A list of historic and current alligator projects and data sets will be compiled by sending a questionnaire to FFWCC, NPS, USFWS, University researchers, and private consultants who are conducting or have conducted research on alligators in south Florida. The three most important data sets will be obtained and compiled during the first year. This may involve physically retrieving field notes from locations outside of south Florida, entering data from field notes, reading data from old tapes, converting computerized data sets into a form usable by our chosen database housing software (ORACLE, ACCESS), and reviewing data sets with the PIs.

Guidelines for establishing standardized databases for the types of alligator research projects will be developed. This will include metadata requirements. Metadata guidelines will be consistent with federal metadata standards. These guidelines will be distributed to all researchers working on alligators in south Florida so that data currently being collected can be easily combined with historic data sets.

Condition. -- The definition of a reasonable “condition factor” is not trivial. This is true in part because our informal evaluations are often normative. For example, we proclaim that one animal is in good condition; another, we say, looks terrible. Even when applied to individuals within one population these terms are not objectively informative. In crocodilians we tend to believe that fat is good. Amongst crocodilians it is probably true that fatter females do produce larger clutches in a given year; however we have no strong evidence that their lifetime productivity is higher. Furthermore, even when our condition-assessments have been value-free, they have usually been qualitative rather than quantitative. So long as our definitions of condition remain unquantified, we shall confront serious difficulties when we attempt to compare across populations. The preliminary problem is to define the condition of an individual animal. The more complex objective is to establish a protocol for comparison across populations.

Study areas include sampled sites from each major compartment in the Everglades: A.R.M. Loxahatchee NWR, Water Conservation Area 2, Water Conservation Area 3, Everglades National Park, and Big Cypress National Preserve. Animals were captured by cable nooses from airboats at night. For each animal, we measured total length (TL), snout-vent length (SVL), tailgirth, chestgirth, neckgirth (all in cm), and mass (kg). We also determined the sex of each alligator, and we noted any deformities, particularly the loss of tail tips. Because condition among small alligators appears to be unstable over short time periods, we included only animals with SVL > 50cm.

Results and Significance

Interviews, questionnaires, and discussions with crocodilian biologists and managers in South Florida have been used to identify, locate, and assess availability of historical data sets.

We have conducted alligator capture and measurements for current alligator condition throughout the Everglades Ecosystem. Animals have been captured from A.R.M. Loxahatchee NWR, WCA 2A, WCA 2B, WCA 3A North, WCA 3A South, Everglades National Park (Shark Slough and estuarine areas), and Big Cypress National Preserve and we have developed an initial condition model for comparison of current alligator condition to historical information in the collected data sets.

This study provides access to data required for develpping evaluative tools used during adaptive implementation of the Comprehensive Ecosystem Restoration Plan. We also provide other timely investigations involving comparisons of condition of alligator populations in the Everglades. The alligator is both a keystone and indicator species in the Everglades ecosystem. Therefore, it is critical to understand the effects of restoration alternatives on this species and to include the alligator in restoration alternative selection, evaluation, and monitoring. This study allows access to historical data required for ecological modeling and assessment of current and future status of alligator populations that would be otherwise inaccessible.

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A Multi-Species/Habitat Ecological Evaluation of Alternative Everglades Restoration Plans

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Introduction

The protection of biological diversity has been identified at the global, national, state, and local level as a critical component of protecting native ecosystems. Major goals of the South Florida Everglades Restoration Initiative are to restore and maintain the native biological diversity of South Florida, and to recover threatened and endangered species. The first step to doing this is to conduct an ecological inventory of existing biological resources. To conserve biological diversity, we must have knowledge on what species will be found in what habitats and the patterns of distribution of habitats and communities in relation to environmental parameters. This information can be used as a base for monitoring, a base for developing models that predict amounts and locations of habitat types under different land use/management plans, and a base for the development of scientifically based conservation plans. Being able to model the potential effects of changes in land use allows us to decrease uncertainty when making management decisions.

Gap analysis has been developed as a landscape scale approach to biological diversity planning at the national scale. Gap analysis consists of mapping the vegetation of each state, developing databases on species habitat affinities, linking species to the mapped vegetation, overlaying the boundaries of existing and proposed conservation lands, and looking for areas of high species richness that are not in areas designated for conservation. These spatially referenced data layers are managed in a Geographic Information System (GIS) that allows large amounts of data to be presented in a format that is easily assimilated by decision makers.

In Florida, it was recognized from the onset of the gap analysis project, that it was important to develop products that were compatible with national efforts, but also could be used within the state to address in more detail ecosystem management issues. Data layers completed to date in conjunction with the gap project include: a vegetation map of South Florida consisting of 70 vegetation types (60 are natural and the rest are urban and agriculture) developed from 30m resolution 1993/94 satellite imagery, databases on the habitat affinities of terrestrial mammals, breeding birds, wintering birds, reptiles, amphibians, ants, butterflies and skippers. These layers provide the information that can be used to address questions on the current status of critical habitats, to develop hypotheses on the effects of different landscape configuration on future biological diversity, to provide direction for the development of restoration plans, and set priorities for restoration projects.

In the tasks below, "potential habitat" is defined as areas that have been identified as having plant communities and, in some cases, other attributes that a specific species will use for its habitat. The particular species may or may not be currently present in that "potential" habitat.

This project provides direct integration of South Florida wide data layers on species richness and potential habitats developed through the USGS gap analysis project with questions on how to protect and conserve threatened and endangered species and the biological diversity of South Florida. It provides a scientifically based ecological evaluation procedure for assessing the potential effects of alternative restoration plans. It can be used to examine how restoration plans for one species may impact available potential habitat for other species and for developing habitat management plans that optimize the benefits to the greatest number of species on a regional scale.

The objectives of this project are to provide a comprehensive assessment of the effects of restoration alternatives on the amount and configuration of ecosystem types and potential habitats of endangered and threatened vertebrates and to evaluate the effectiveness of threatened and endangered species habitat protection for protection of overall South Florida biological diversity.

Tasks

Task 1. Ensure that the existing data layers for vegetation and species correspond with other data layers developed by FWS for the multi-species recovery plan. Update species/habitat models for listed species.

Task 2. Quantify existing potential habitat for terrestrial vertebrates and examine patterns of distribution of potential habitat for threatened and endangered in relation to overall vertebrate species richness.

Task 3. Forecast the amounts and locations of potential habitats for threatened and endangered species under different scenarios for land cover change and hydrological conditions.

Task 4. Develop a user friendly ArcView interface for easy access to all data layers and models developed in this project.

Significance

This project is the only study to evaluate the effects of restoration alternatives on biological diversity and ecological integrity throughout the Greater Everglades/South Florida region. The tasks in this proposal provide a consistent, structured methodology for the integration of multiple spatial data themes and the evaluation of region-wide habitat changes throughout South Florida. The proposed structured methodology will facilitate the presentation and exploration of resulting recommendations. Conveying the information and decisions to the public will be substantially enhanced. These tasks also will provide a multi-species evaluation procedure that is complimentary to other ongoing efforts for selected species. Additionally, the results can be compared to other assessment methods to add robustness to decisions made regarding importance and protection of habitats and will provide a flexible tool that can be used to monitor and evaluate potential impacts. This project meets a critical science information need of local governments for integrating land-use decision making with ecosystem restoration.

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Fish and Aquatic Invertebrate Assemblages in Everglades National Park in Relation to Changes in Hydrology

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Restoration programs should increase the magnitude and alter the timing and duration of discharges to Everglades National Park with the intent of more closely matching predrainage hydropatterns. This increase in inflow will affect the physical structure (e.g., vegetation) and water quality (e.g., nutrients, dissolved oxygen) within the basins. Fish and invertebrate assemblages should respond to these changes in physical structure and water quality with changes in relative abundance and species composition. In order to document these changes, we are quantifying the existing fish and invertebrate assemblages by habitat type. We are developing biomonitoring metrics and sampling procedures to quantify any changes in the fish and invertebrate assemblages by habitats as a result of the restoration of hydropatterns. We are associating aquatic invertebrate species with hydrological and habitat variables to develop a set of indicator species. Information gathered will be used to further refine fish abundance prediction models (e. g., ATLSS-ALFISH) and provide performance measures for evaluating restoration plans (such as the Comprehensive Everglades Restoration Plan (CERP) and the Lower East Coast Water Supply Plan). Monitoring will be focused primarily in Shark River and Taylor Sloughs, with an emphasis on increased sampling in the shallower edges of the basins (e.g., Rocky Glades, margins of Shark River Slough) where increased hydrologic flow is expected to have the greatest effects on biotic communities. Fixed sites are located to represent the longitudinal and spatial diversity of fish and habitats within Shark River and Taylor Sloughs. Site locations will follow a nested hierarchy with habitat types (e.g., marl prairie, sawgrass, *Eleocharis* slough, or alligator ponds) within locations (e.g., upper slough, middle slough, lower slough) within regions (e.g., Rocky Glades, northeast Shark River Slough) within basins (e.g., Shark River Slough and Taylor Slough). Sampling periods are in conjunction with the seasonal hydroperiods (e.g., wet season, dry season, transitions between the wet and dry seasons). Analysis of fish data collected from 1985 to 2000 suggest that hydroperiod duration may be the primary factor determining fish assemblages in *Eleocharis* sloughs.

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Influence of Hydrology on Life History Parameters of Common Freshwater Fishes in Southern Florida

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Fishes are essential to the successful functioning of wetland food webs in southern Florida through their roles as prey and predators. In particular, fishes are important food items for most wading birds. Any changes that reduce the population sizes, community composition, or availability of aquatic animals will affect all facets of the ecology of these wetlands. For this reason, fishes have been recognized as key indicators by which to measure restoration success. However, gaps in baseline knowledge remain. Basic demographic information, termed life-history parameters (i.e., growth rate, age at maturation, fecundity and life expectancy), is needed to make predictions about their resilience under alternative management scenarios. To date, most basic life-history parameters remain to be characterized, even for abundant fishes. Adding to the challenge, life-history characteristics of important Everglades species are known to be plastic in response to environmental conditions and survivorship and recruitment schedules are certain to be influenced by variation in hydroperiod. This project looks at the effect of hydroperiod on recruitment, size/age structure, growth, and fecundity, which, in turn, determine fish population dynamics. Resulting life-history information will help explain patterns of fluctuations over time and space. Accurate life-history data are also very important in building credible simulation models like ATLSS. Without empirical life-history data from a range of environments, the model will be simplistic and inadequate.

Study Design: To document the life history parameters of Everglades fishes, we divided target fishes into small- and large-bodied fishes. Small-bodied fishes are typically short-lived and are most common in shallow marsh habitats. Large-bodied fishes are generally long-lived and are common in canal habitats and other deepwater areas. The present study takes advantage of existing or newly funded fish studies in south Florida. These include the throw-trap program for small-fish monitoring, and an electrofishing study of larger native and introduced species in canals.

The present work involves counts of daily rings on otoliths from small fishes and of annual rings on otoliths from large fishes, as well as size-frequency analyses of all target fishes. Ultimately, the results will allow us to create an age-at-size table for each species, and to estimate growth in two different seasons. Furthermore, we will be able to construct life-tables for the species under different conditions in the Everglades. In addition to our own field fish collections, we will analyze past data from extensive spatial and temporal marsh and canal study collections for reproductive analyses of fecundity, size at maturity, seasonality of reproduction, and sex ratios.

Small Fishes: Investigations on small fishes began in Winter 2000. For small-bodied species, we are establishing age-to-size relationships for three marsh fishes not yet studied: sailfin molly (*Poecilia latipinna*); flagfish (*Jordanella floridae*); and spotted sunfish (*Lepomis punctatus*). These relationships will be estimated at one representative short (at Shark Valley) and one representative long hydroperiod location (at Shark River Slough).

For small fishes, we are conducting experimental rearing of each species to a known age in field cages in anticipation of otolith removal and interpretation. In past efforts, this approach has demonstrated a very high fidelity of daily ring deposition in sailfin mollies up to the age of 21 days. This result needs to be repeated and expanded to other species. In addition, we are documenting reproductive phenology and output in six marsh fish species: least killifish (*Heterandria formosa*); bluefin killifish (*Lucania goodei*); golden topminnow (*Fundulus chrysotus*); eastern mosquitofish (*Gambusia holbrooki*); sailfin molly; and flagfish.

Large Fishes: For large-bodied fishes, we are establishing age-to-size frequencies and reproductive phenology for five target species, including one non-indigenous fish, the spotted tilapia (*Tilapia mariae*), and four native fishes, Florida gar (*Lepisosteus platyrhincus*), yellow bullhead (*Ameiurus natalis*), warmouth (C*haenobyttus gulosus*), and spotted sunfish (*Lepomis punctatus*). All five species are common to abundant in many south Florida freshwater habitats and most are predators that prey on other fishes and various crustaceans (i.e., crayfish and shrimp).

Preliminary sampling of canal fishes began in 1999 with intensive quarterly sampling beginning in January 2000. To date, the focus has been on sites in three major south Florida waterways: Canal L-31W, Tamiami Canal (C-4), and Snake Creek Canal (C-9). Reaches sampled in the first two canals have direct surface water connections to adjacent marsh habitats. The C-9 reach is located in a heavily disturbed urban area and is not associated with a natural marsh. Each of the three study sites sampled encompasses four linear kilometers. During the first of three quarterly samples of year 2000 (January, April, and July), we have taken 3,377 target fishes. In addition, we have carried out supplemental sampling between quarters. Phase II and Phase III of the project involves dietary analysis, food-web dynamics, fecundity, and seasonality of reproduction within and among study sites.

Applications: By applying the fish models to restoration alternatives and predicting fish-community responses, we can choose the alternatives that result in biotic characteristics that approximate historical conditions. The iterative process of evaluating and testing the fish-community simulation model in ATLSS also helps identify important data gaps to guide future research. One of the most obvious gaps is the absence of good life-history data, critical to model performance, for most of the fishes. The benefits to restoration include having more confidence in improved tools, like the ATLSS models and performance measures from conceptual models, that are used to evaluate alternatives for ecological effects of the Central and Southern Florida Project Restudy, C-111 Project, and Modified Water Deliveries Plan to Shark Slough. In addition to the application of the life-history data to modeling and to interpretation of the data time-series, these data represent new information about the adaptations of many of these species in wetland habitats that form the southern extent of their geographic ranges. These also represent the first life-history data for some of the most abundant introduced species in Florida, and may identify vulnerable life stages for controlling these species. The publications resulting from this work will be scientifically significant for those reasons.

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Poster, Ecology and Ecological Modeling

The Asian Swamp Eel: A Recent Invader in Peninsular Florida

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During the past four years, three separate populations of the Asian swamp eel (family: Synbranchidae, genus: *Monopterus*) have been discovered in peninsular Florida. Specimens taken from a drainage system of Tampa Bay during September 1997 represented the first record of this foreign fish in the state. In October 1997, a second and much larger population was found in an extensive canal network in the North Miami area. In December 1999, a third and genetically distinct population was found in a canal system near Homestead close to the eastern boundary of Everglades National Park. Our field data demonstrated that the species is reproducing and is locally common or abundant at all three locations. We have gathered data on the size-structure, reproductive phenology and fecundity, and predator-prey interactions of this fish in the field and in mesocosms. Based on the literature and our findings, the eel appears to have the potential to colonize and negatively affect the natural wetlands of the Everglades and other systems of the southeastern U.S. The swamp eel shares ecological and life-history attributes common to other highly successful invaders found in the southeastern United States: parental care of eggs and young, a generalized diet, ability to breathe air and survive drought, and broad environmental tolerances. Assessing the effects of this new invader on native species is complicated by the disturbed nature of aquatic environments in developed areas of peninsular Florida, many of which are already occupied by other introduced fishes. Unlike most other foreign fishes introduced to peninsular Florida, in its native range**,** the Swamp Eel is not restricted to tropical areas. Given sufficient time, the eel potentially may colonize much of Florida and many other regions of the country.

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Adaptive Management Strategies for the Construction and Engineering Phase of the Hole-in-the-Donut Wetland Restoration and Mitigation Program - Everglades National Park

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A major site of exotic plant invasion within Everglades National Park (ENP) is an area of former freshwater prairie and upland pine and hardwood forest known as the Hole-in-the-Donut (HID). This area of about 4,050 ha of abandoned farmland has within it an area of about 2,400 ha dominated by a stand of a single exotic woody species, Brazilian pepper (*Schinus terebinthifolius*).

Farming began in the HID in 1916. Agricultural methods used at that time primarily consisted on land clearing and crude mechanical soil preparation. In 1934 Congress authorized the establishment of ENP but excluded the privately owned HID agricultural lands. In the early 1950's rock plowing was developed. Rock plowing crushed the natural oolitic limestone rock into a growth medium better suited for row crop production than did prior soil preparation techniques. Rock plowing continued in the HID through June 30, 1975. This disturbance changed the substrate from consolidated rock land or parent material characterized by low nutrient and anaerobic conditions to very coarse textured soil material characterized by higher nutrient and aerobic conditions. This artificial soil development process increased the susceptibility of the HID to invasion by exotic plant species.

Once all land in the HID was acquired by the National Park Service and farming ceased, the Park Service was confronted with a dual problem; how to reestablish native vegetation and at the same time prevent the invasion of exotic species, particularly *Schinus*. At the same time of abandonment, there was little scientifically based information available regarding the successional trends on abandoned rock plowed farmland in south Florida. Attempts to define and describe old field succession were undertaken by several researchers. Research showed that *Schinus* invasion proceeded from low densities in a mosaic of herbaceous vegetation five to ten years after abandonment through extremely high densities ten to twenty years after abandonment to self sustaining *Schinus* stands after twenty years since abandonment. Research also showed that for disturbed soil within the Hole-in-the-Donut, proximity to seed source, seed rain intensity, and local distribution were primary causes for *Schinus* expansion in and around the HID.

Research was also conducted on ways to restore the HID. Various projects included: 1) planting pine seedling and saplings; 2) seeding with pine and several species of hardwoods and grasses; 3) transplanting native grasses sedges; 4) mowing; 5) disking; 6) bulldozing and other mechanical techniques to remove *Schinus*; 7) substrate removal; 8) planting hardwood saplings; and 9) chemical control. Although constant mowing and disking prevented *Schinus* reestablishment, both are cost prohibitive and once stopped, succession will proceed to *Schinus*. The only method that successfully restored a portion of the HID was substrate removal. The net result of substrate removal was elimination of the effects of disturbed substrate and increased hydroperiod.

The objectives of the HID Wetland Restoration and Mitigation Program are 1) restoration of wetland habitat; 2) removal and control of exotic plants, especially *Schinus terebinthifolius*; 3) restoration of a wetland community that resembles natural Everglades wetlands in species composition and dynamics.

As originally, proposed in the Scope of Work, there are minimum technical requirements for engineering and construction. In the engineering and construction section of the request for proposals the following tasks were proposed: 1) survey and control sheets; 2) permanent concrete bench marks; 3) prior to clearing an area, a vegetation survey to identify remnant vegetation features worth protecting; 4) vegetation clearing and burning; 5) substrate nutrient analysis; 6) substrate removal; 7) substrate disposal; 8) hydrologic well installation; 9) project management; 10) minimizing consequence to Park operations and visitors; and 11) GIS mapping.

As originally proposed, about 7.64 million cubic meters of material (disturbed substrate and associated vegetation) from about 2,400 hectares within the HID would have been cut, excavated, and removed from the park over a 20 to 30 year period. This cut and excavated material would have been deposited in nonjurisdictional wetlands east of the C-111 canal, this proposal originally included the Frog Pond, but since acquisition of the Frog Pond by the South Florida Water Management District it no longer does.

The original proposal assumes about one truck trip every 4.6 minutes, 10 hours each day, six days per week for 5 to 6 months during soil hauling operations (December through May). This comes to 6,553 truck trips for each 50 ha of material removed. Once the project increased to 100 to 150 ha per year the number of truck trips would increase to between 13,000 to 16,000 during each construction period. The construction period (December through May) coincides with the peak of the Park's visitor season.

Recent changes in overall hydrological restoration and water delivery models indicate a long-term increase in water levels in the Taylor and Shark Slough Basins. After review of this issue and its possible impact on Park roads, a determination was made that the park roads, including the main park road could not withstand repeated heavy traffic due to the HID soil hauling. Estimates ranged between less than one month to one year until the roads would be unusable and need to be completely rebuilt. Considering the amount of truck traffic the 11 miles of road between the HID and Main Park Entrance will need to be replaced.

The Park is also concerned with safety considerations and liability relating to this high level of truck use on public roads, attendant road damage, and how the project will affect visitor and employee use of the Park and Park facilities near the project. Specific concerns have been raised pertaining to the trucks using the same roads as visitors to the Royal Palm area and employees using the Daniel Beard Center and Iori office facilities. While this has always been a concern, more recent and accurate assessments of truck volume increases have heightened the Park's awareness and apprehension of the haulage and off-site disposal task in the original scope of work. Consideration was given to whether or not the heavy truck use would prevent visitor use and enjoyment of the Royal Palm area, both by excluding visitor traffic during high activity periods of the project and by imposing noise levels in the area that visitors might find intrusive. While the magnitude of these disruptions to park visitors and employees are uncertain, and the project, as originally proposed, devotes substantial resources to traffic control and enforcement, the Park has determined that the original HID Wetland Restoration and Mitigation Program is no longer workable and alternatives to off-site disposal and associated long haulage distances must be considered. The alternatives to be considered are 1) on-site disposal, 2) off-site disposal, 3) combination of on-site and off-site disposal, and 4) temporary on-site disposal.

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A Method for Successful Wetland Restoration on Former Farmlands Dominated by Brazilian Pepper in the Hole in the Donut of Everglades National Park

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When Everglades National Park was established in 1947, farming was allowed to continue on in-holdings called the Hole-in-the-Donut (HID). More than 60% of the farmed areas were originally short hydroperiod prairies with marl soil, with the remainder occurring primarily on low-lying pine savannahs. Farming ended in 1975 and the land was incorporated into Everglades National Park. Initial attempts to control colonization by the exotic pest plant Brazilian pepper (*Schinus terebinthifolius*) and promote colonization by native plants included prescribed burning, mowing, herbicides, and planting of desirable native plants, either alone or in combination with each other. These early efforts were either unsuccessful in controlling exotic plants or were cost prohibitive. Within 7 to 10 years, Brazilian pepper formed a closed-canopy forest over most of the former farmlands. Preliminary findings in the Rocky Glades region of the eastern Everglades, and in the HID indicated that mechanical removal of all vegetation and scraping out the rock plowed materials down to bedrock resulted in a longer hydroperiod. This facilitated natural recolonization by wetland plants and prevented re-establishment by Brazilian pepper. Allowing even a portion of the altered soil to remain did not prevent re-establishment by Brazilian pepper, since the soil contained mycorhizal fungi that was absent in undisturbed marl soils. These findings led to a cooperative effort between Miami-Dade County, FL and Everglades National Park to establish a wetland mitigation bank to restore former farmlands in the HID.

Each year, since 1997, an area of approximately 80 ha in the HID had the Brazilian pepper removed and all rock plowed substrate removed down to bedrock. Re-vegetation occurred by natural recruitment and did not involve any planting or seeding. The areas were monitored for both plant and animal use and colonization patterns.

Vegetation on restored sites, natural short-hydroperiod prairie, and unmitigated Brazilian pepper was surveyed each fall in permanent plots, established using a stratified random sampling design. All species in each plot were identified and an estimate of coverage in different height classes was made using a modification of the Braun-Blanquet sampling method. Two different sizes of plots were used, to effectively address different hypothesis. Large plots (10 m x 10 m) were used to characterize broad patterns of species richness. Small plots (1 m x 1 m) were used to relate species occurrence to variation in ground surface elevation and soil depth. A survey marker was placed near the center of each small plot and its location and elevation were determined using traditional surveying techniques. Additionally, 20 random soil depths were measured in each small plot to determine the average soil depth in each small plot.

An estimate of plant species richness in natural vegetation (~130 species) was higher than on the restored sites. However, the restored sites reach approximately 80% of the species richness observed in natural vegetation within 15 months. More importantly, between 61% and 73% of the plant species and total vegetative cover on the restored sites were wetland associated species (i.e. either "Obligate" or "Facultative Wetland"). By comparison, 66% of the species in adjacent natural vegetation and 27% of the species in unmitigated Brazilian pepper were wetland associated species. While many of the species that initially colonized the restored sites were native, wetland species, they tended to occur at a higher coverage on the restored sites than in undisturbed, natural areas. However, the 18 ha pilot site, restored in 1989, showed increased coverage by desirable native, wetland species typical of the surrounding short-hydroperiod prairies (e.g. sawgrass (*Cladium jamaicense*), muhly grass (*Muhlenbergia capillaris*), southern beaksedge (*Rhynchospora microcarpa*)). Newer restored sites were showing even more rapid colonization by these species since the new sites always had at least one edge adjacent to natural vegetation.

Remnant tree islands that persisted in the Brazilian pepper were left intact during preparation of the restored sites. However, in comparison to undisturbed tree islands in the natural vegetation, there were fewer tree species on the remnant tree islands on the restored sites, and the understory often harbored a number of non-native pest plant species. The preservation of at least some tree islands within areas to be cleared seems desirable because of the many wildlife habitat functions they perform, as well as for aesthetic purposes. But the number and size of the islands to be retained must be balanced against the costs associated with effectively removing any non-native pest plant species.

Wildlife using restored sites was also monitored. Methods included surveys for apple snail egg masses dip netting for selected aquatic macro-invertebrates (e.g. crayfish, grass shrimp) and fishes, drift fencing for selected aquatic macro-invertebrates, fishes and herptiles, surveys for birds, and track surveys for mammals.

During the first three years of the study, 198 species of vertebrates were observed. There were 22 species of fishes, 15 species of amphibians, 27 species of reptiles, 123 species of birds, and 11 species of mammals. Unmitigated Brazilian pepper had the lowest cumulative total (48 species) and the restored sites had the highest totals (range of 91 to 143). Natural vegetation had 110 species (includes both graminoid and thicket vegetation). Higher species richness of restored sites was primarily due to higher number of birds.

The restored sites have a higher abundances of fishes and selected aquatic macro-invertebrates (e.g. crayfish, grass shrimp) than undisturbed natural vegetation. This higher prey base on the restored sites supported higher numbers of wading birds and grassland associated species (meadowlarks, bitterns). The sites were also regularly used by 15 – 18 White-tailed deer, which attracted Florida panther, a federally endangered species, during the dry season. Raccoon, marsh rice rat, marsh rabbit, and bobcat were also frequently noted.

Intrinsic attributes of sites chosen for restoration include elevation, adjacency to natural areas, and the presence of tree islands and depressions. These attributes vary from site to site, and may affect the wetland community that develops on a site. Adjacency to natural areas facilitates colonization by wetland plant species, and animals that are unable to disperse over dry land (fishes, salamanders). Remnant tree islands preserved on the restoration sites provided roosting and resting sites for herptiles, birds, and mammals.

There appears to be a trade-off on the construction procedures required to eradicate Brazilian pepper. The rocked plowed soils must be removed because they foster Brazilian pepper and do not foster colonization by preferred sedges and grasses. But at the same time, the soil removal dictates that a lag time for colonization by these preferred species occurs. The trade-off is acceptable if in the time after clearing, ecological succession is dominated by taxa that are predominantly native, wetland taxa, and help establish soil conditions to promote the desired wetland community composition. All of these conditions appear to be met by the current methodology.

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ATLSS American Alligator Production Index Model

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The American Alligator (Alligator mississippiensis) is a keystone species of the South Florida Ecosystem. Although other endangered and keystone species occur within the ecosystem, the American Alligator's role as a top predator and its effect on the structuring of plant communities and associated aquatic animals make it an indicator of ecosystem health. The ATLSS American Alligator Production Index (API) Model is a spatially explicit species index model for estimating the yearly productivity potential (probability of producing nests and offspring successfully) based upon local habitat and hydrological conditions.

The spatial resolution for the model is 500 meters by 500 meters since historical observations suggest that this roughly correspond to the home-range of nesting female alligators. The temporal resolution for the model is one day for all water data (height above mean sea level and current standing water depth) and is static for the vegetation habitat types. The model produces a single yearly value for each spatial cell that takes account of the daily water data affecting the nesting and offspring production during that year. This yearly index value indicates the relative (on a ranking of 0.0 to 1.0) capacity for the cell to provide high alligator productivity.

Water levels encountered during the period ranging from May 16 of the current nesting year to April 15 of the previous year are used as an indicator of the probability of breeding occurrence in an area. The mean water depth during the peak of the mating season from April 16 through May 15 is used as an indicator of the probability that mating and nest construction will occur in a given area. The probability of a nest being flooding is calculated from a combination of the mean water level during nest construction and the maximum water level during egg incubation. A static ranking of the dominant vegetation type within each spatial cell is used as a measure of habitat quality. Lastly, the overall API is calculated as a weighted product of the above described model components. The API model has been applied to a variety of hydrologic plans derived for the Restudy to evaluate the relative affects of alternative plans on potential alligator productivity across the Restudy area.

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Estimating Suspended Solids Concentrations in Estuarine Environments Using Acoustic Instruments

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As part of a cooperative study between the South Florida Water Management District (SFWMD) and the U.S. Geological Survey (USGS), acoustic Doppler instruments were installed at three sites with within the St. Lucie River Estuary system (fig. 1). These sites present information on flow, salinity, water-quality, and channel cross-section characteristics.

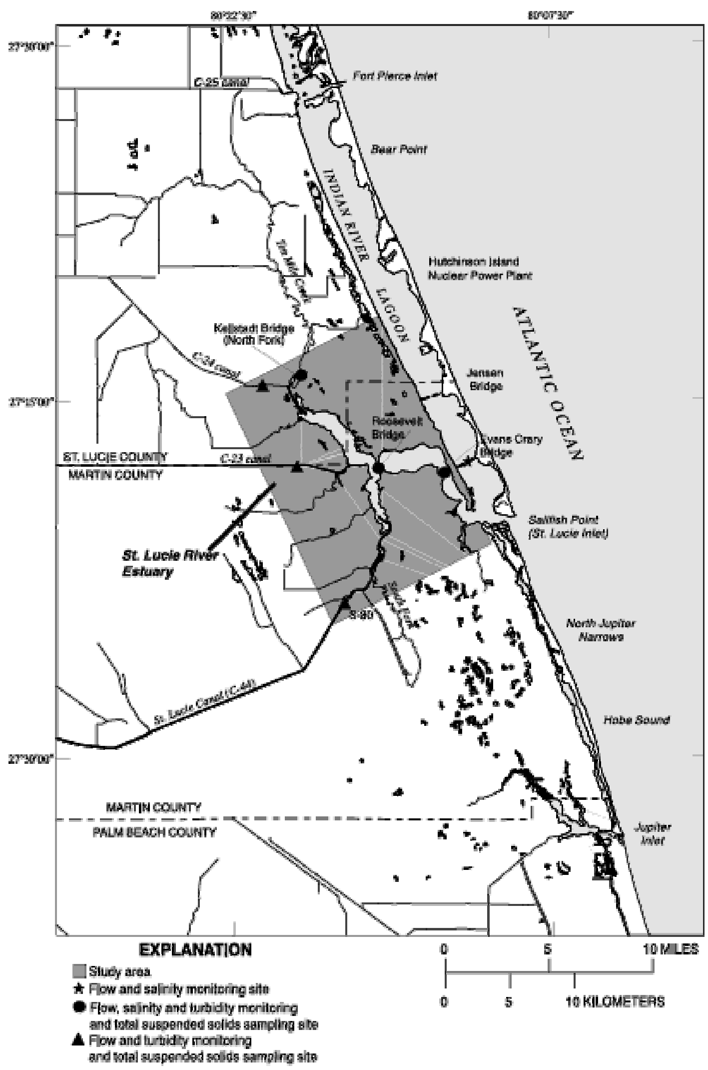

Figure 1. Location of monitoring sites within the St. Lucie River Estuary.

The Doppler instruments were installed to measure an index of the mean water velocity at surface-water monitoring sites. These instruments also record information related to the received strength of the velocity signal, acoustic backscatter (ABS), a parameter affected primarily by the amount of material in suspension. This study involves the development of total suspended solids (TSS) to ABS relations in order to estimate time-series records of TSS concentrations for the monitored sites. In addition to the suspended solids, the water density also has an effect on the strength of acoustic signals traveling through it. Therefore, salinity and temperature data are also collected at the monitoring sites and used as secondary variables in the estimation model for suspended solids. Sediment samples are collected using a point sampler lowered between the probes that measure water quality and near the Doppler face (fig. 2). The samples are analyzed for TSS and volatile suspended solids (VSS) at the U.S. Geological Survey laboratory in Ocala, Fla.

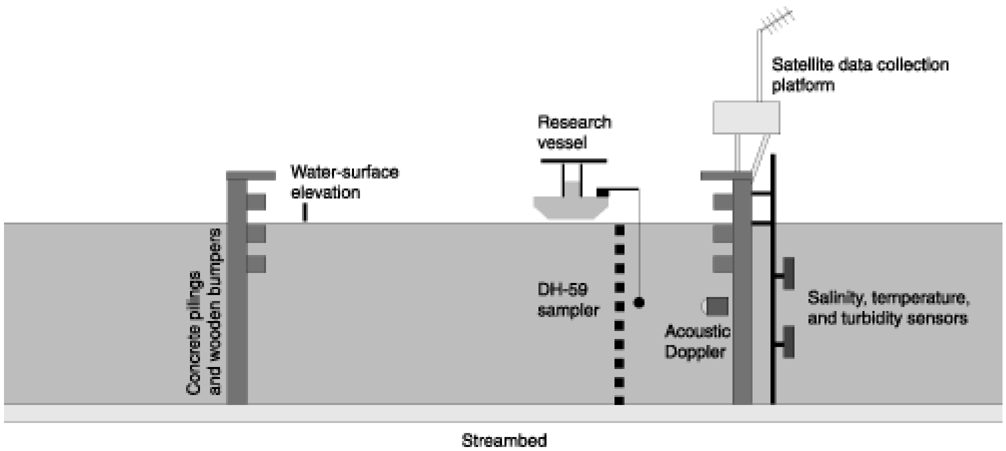

Figure 2. Instrument setup for monitoring sites at the St. Lucie River Estuary.

The results are very promising for use of this technique in environments with high organic content in the suspended material. At all of the study sites, measured TSS concentrations ranged from 3 to 23 milligrams per liter with an organic content of between 50 and 70 percent, temperature varied from about 18 to 32 degrees Celsius, and salinities ranged from less than 1 to about 25 parts per thousand. At the North Fork site, TSS concentrations ranged from 3 to 18 milligrams per liter, and salinities ranged from greater than 1 to 15 parts per thousand. The resultant equation currently used for estimating TSS concentrations represents a relation in the “local” space (point samples collected near the instruments). The relation for the North Fork monitoring station is as follows:

$$TSS = 10^{\{ABS[0.06232 + 0.00118*\log(sal) - 0.02212*\log(temp)] -1.32321\}}$$

R^2 (correlation coefficient) = 0.86

The relation of estimated to measured TSS concentrations is shown in figure 3. Measured concentrations used in the regression analysis for the development of the estimating equation and verification measurements are presented.

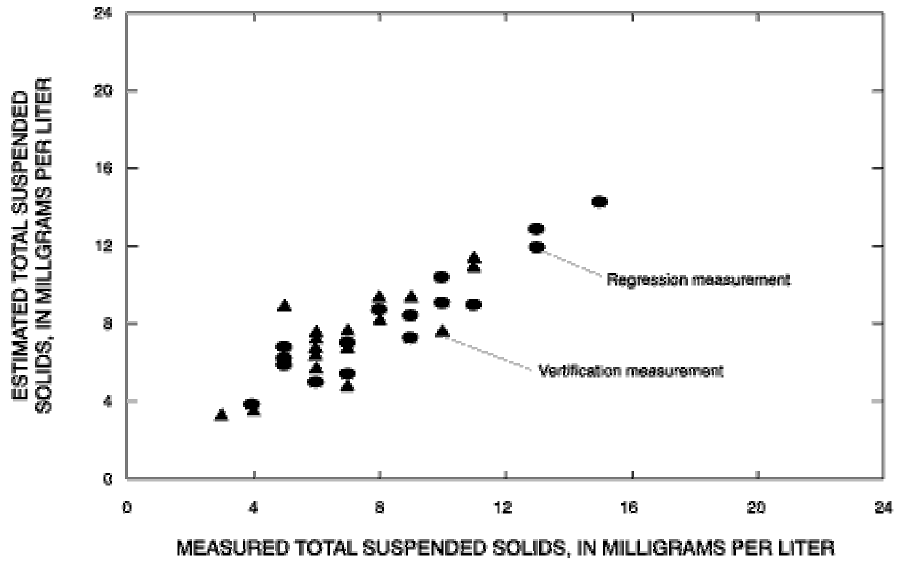

Figure 3. Measured to estimated total suspended solids concentrations comparison at the North Fork site.

At present time, this project includes an expansion of the "local" TSS to ABS relation to represent a relation to the mean cross-sectional concentrations at monitoring sites. Preliminary data suggest that results similar to the local relation will be possible in the future. At that time, TSS fluxes will be calculated.

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Thermal Regulation of the American alligator (*Alligator mississippiensis*) in the Everglades

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In an attempt to rectify a century of hydrologic alterations to the everglades, a massive restoration effort is underway. Restoration managers are using a spatially explicit, individually-based model, the Across Trophic Level System Simulation (ATLSS), to predict the response of native flora and fauna, including the American alligator (*Alligator mississippiensis*), to alternative water management scenarios. Despite the prominence of the alligator within the ecosystem and elsewhere within its range, many important biological and ecological questions about the species remain unanswered. It is not only a top consumer and a keystone species in the Everglades, but also physically influences the system through construction and maintenance of gator holes and trails. The Everglades is believed to be a harsh environment for alligators and Everglades alligators' weight, maximum length, and sexual maturity are less than elsewhere. A combination of low food availability and high temperatures are currently suspected as the reason for this poor condition.

We initiated a study on thermoregulation, and body temperature patterns of alligators both in Shark Slough in Everglades National Park and in Water Conservation Area 3A North. A total of 66 alligators were captured and surgically implanted with radio-transmitters. A subset of 29 of these also were implanted with disk shaped temperature data loggers (diameter = 3.0 cm and thickness = 1.5 cm). Each device was capable of recording 7944 temperature readings from a range of -5 to 37° C with an accuracy of +/- 0.2° C. Data loggers were programmed to record core body temperature (T_b) every 72 minutes, allowing 396 days of continuous data collection. . Environmental temperatures were recorded in the marsh near the home ranges of implanted alligators. A total of 15 functioning data loggers were retrieved from animals recaptured after one year.

Alligators exhibited distinct patterns of T_b within the annual temperature cycle. T_b was more variable in spring than in any other season. Importantly, the normally limited prey base in the Everglades becomes concentrated in pools during the dry season, which peaks in spring. The increased activity of spring reflects the importance of this season in the ecology of alligators in the Everglades. The high temperatures of summer increase the metabolic cost to alligators in the Everglades. When combined with low food availability resulting from the high water levels of the renewed wet season, summer appears to be a time of negative energy balance. Fall T_bs declined with the declining ambient temperatures. Alligators were apparently avoiding metabolically active temperatures in fall since prey is dispersed. Although low T_bs were maintained during the winter

months, they were occasionally raised to activity levels. These heating events were not synchronized as would be expected if environmental factors alone were inducing basking behavior. We speculate higher T_bs in winter may be necessary for excretion of metabolic wastes. Everglades' alligators are adapted to fluctuating hydropatterns. While low water levels decrease their ability to thermoregulate, they also concentrate prey in an otherwise nutrient poor system. Without a food base to support the resulting high metabolic rate, a high stable T_b would be detrimental.

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Restoring Crayfish Populations in the Stressed Wetlands of Eastern Everglades National Park

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The impacts of hydropattern disturbance have been most severe on the habitats and biotic communities of the seasonally-flooded marl prairie wetlands of eastern Everglades National Park. To assess the effects of hydrological stress on the aquatic faunal community, we used the Everglades crayfish *Procambarus alleni* as a model to study the association between hydrology, habitat, and population dynamics in this critical habitat. To classify crayfish habitat as sources or sinks, regression analysis was used to evaluate the association between crayfish density and vegetation community structure from GIS habitat maps. We then used a spatially-explicit stage-structured population model to assess crayfish response to simulated habitat changes that may occur from hydrological restoration. Under the current habitat and hydroperiod conditions, the crayfish population size continued to decline slowly over a 50 yr period. Following the simulated change in habitat from shorter-hydroperiod *Muhlenbergia*-dominated to longer-hydroperiod *Cladium*-dominated habitat, crayfish density rapidly increased ten-fold. The model indicated that several functional effects are possible from the restoration of historical hydroperiods in marl prairie wetlands: 1. the areal extent of crayfish population sinks will shrink to isolated patches, whereas source habitats will expand; 2. the crayfish population size will increase several-fold; 3. crayfish population viability and persistence will stabilize over time. Restoration of historical hydroperiods in the marl prairie may consequently have cascading positive effects throughout the Everglades aquatic food web.

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Trace Metal Concentrations in Osprey Populations in Everglades National Park: A Pilot Study

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A project funded by the National Park Service is being conducted for an assessment of trace metal concentrations in the Florida Bay area of Everglades National Park. Birds that consume only fish (obligate piscavores) are often used as a bioindicator species for monitoring xenobiotics in an ecosystem. Tissues, (feathers and blood), of these species are utilized by quantitatively measuring the amount of contaminants that accumulate in them. This pilot study will measure concentrations of metals in tissues of adult and juvenile osprey, and will compare the variation of inorganics displayed in this species. Geographical trends exhibited by metal contaminants will be plotted, utilizing ospreys' tissue as a type of bioindicator for metal concentrations in East and West Florida Bay.

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Home Range and Movement of the Alligator in the Everglades

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Over the last one hundred years the hydrology of the Everglades has been greatly altered by mankind. Efforts to repair the functioning of the ecosystem are using a multicomponent model, the Across Trophic Level System Simulation (ATLSS), to predict the response of native flora and fauna to alterative water delivery scenarios. This study was designed to provide information on the natural history and population functioning of the American alligator in the Everglades for construction of an ATLSS American alligator population model and to investigate restoration needs and status of the alligator in the Everglades ecosystem. Specifically, we initiated a 5-yr study on the effects of hydrology and habitat on home range, daily movement, and habitat use of alligators in the Everglades.

Two study sites were chosen from within the Everglades ecosystem. Water Conservation Area 3A North (WCA) represented a drier and more dynamic hydropattern while Shark Slough, Everglades National Park (ENP) typified the more stable conditions of the central drainage of the Everglades ecosystem.

Alligators were captured at night from airboats using snares or toggle darts. The location was recorded using GPS along with time of capture and a description of the habitat. Alligators were transported to the University of Florida Fort Lauderdale Research and Education Center in Davie, Florida. The total length, snout-vent length, head length, hind foot length, tail girth, mass, and sex were recorded. Alligators were anesthetized using a combination of medetomindine and isoflurine (T.S. Gross, USGS, unpublished data). Two sterilized radio transmitters (AVM model SB2 transmitter in the 166-170 MHz range) were then implanted between the peritoneum and the muscle layer on each side of the alligator. After incisions were sutured, the medetomindine was reversed using atipamezole hydrochloride and the alligators were monitored for signs of ill health. The alligators were then released within 24 hours at the exact capture location.

Key Results

During this study, 79 alligators were captured and surgically implanted with radio transmitters. A total of 66 alligators were subsequently radio tracked for a sufficient period of time for inclusion in home range, movement, and habitat use analyses. These analyses include 31 animals from Shark Slough, Everglades National Park and 35 from Water Conservation Area 3A North.

Home range size and daily movement for alligators located in WCA and ENP were not significantly different. Mean seasonal alligator home ranges successively decreased from spring (39.17 ha) to summer (31.77 ha) to fall (27.52 ha) to winter (14.08 ha). Mean annual home range size for male alligators (122.04 ha) was significantly greater than females (35.92 ha).

Mean seasonal daily movements successively decreased from spring (406 m/24-hr) to summer (261 m/24-hr) to fall (154 m/24-hr) to winter (100 m/24-hr). Male alligators (167.19 m/24-hr) moved significantly more than female alligators (70.05 m/24-hr).

Three distinct groups of radio-tagged alligators existed according to habitat availability. Marsh alligators located in WCA, slough alligators located in ENP, and canal alligators located in both WCA and ENP. Radio-tagged marsh alligators located in WCA primarily used cattail, water lily, mixed marsh potholes, and holes. ENP slough alligators used spike rush, holes, and shrub more than their availability would suggest. Canal alligators primarily used canal and hole habitats.

Home range size and shape and daily movement varied according to gender, temperature, reproductive efforts, habitat and water level. Male alligators had much larger home ranges and moved more on a daily basis than did females. Home range size and daily movement were positively correlated with temperature. However, the spring breeding season promoted greater home range sizes and daily movements than were observed during the summer. Limited summer movements were probably due to the passing of the breeding season, high temperatures, and for females, the onset of the nesting season. Increased movements in the spring may also have been a result of increased feeding opportunities as air temperatures increased and water levels decreased pooling aquatic prey.

An alligator's location in the landscape of the Everglades affected their movements. Canal alligators had larger home range length and area in certain seasons than alligators located in marsh habitats. However, marsh alligators regularly used a higher proportion of their home range on a regular basis. Canal habitats were considered to be prime habitats for adult animals due to the consistently deep water and apparent abundance of prey. Canals offered open water travel corridors than tended to increase home range size by promoting long-distance movements of short duration, whereas, marsh habitats tended to limit these movements. However, it must be noted that while adult animals did prefer canal habitats for thermal refugia and feeding, these animals did not occupy and maintain alligator holes in the marsh. These holes are extremely important to other species (wading birds, fish species, etc..) as well as juvenile alligators. Further, canals offer little or no brood habitat for hatchling alligators and, as such, little production presumably results from nesting of canal animals. Cannibalism and predation certainly accounts for a high proportion of alligator production in canal habitats. An extension of this study will examine the relative reproductive contribution of alligators by marsh and canal habitats in 2000 and 2001.

Water level effected home range sizes and daily movements. Alligators moved less and had smaller home ranges in portions of the marsh that experienced near-dry conditions. Alligators located in canals and sloughs, where water was more abundant, were less affected. Alligators in the marsh where water levels were lowest spent the majority of their time in holes, depression potholes, and airboat trails where pools of water remained.

Alligators were found to have 1 or more preferred gator holes or depression potholes within their home range. Regular movements were observed for alligators within their respective home ranges and daily movements were often from one preferred hole to another. These movements were most often initiated at dusk and commenced prior to dawn. Everglades alligators in the marsh are dependent upon hole habitats. Alligators can survive during high water conditions without holes, however, the regular use of hole habitats throughout the year suggests that these are prime alligator habitats regardless of season, temperature or water level variation.

Everglades alligators may live in an adverse environment, but have adapted accordingly. Adult alligators establish a home range that encompasses several habitat types that allow them to access the basic requirements of food, water, shelter, and reproductive opportunities. Of these natural habitats, traditional gator holes and depression potholes are the most critical.

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An Assessment of Contaminant Exposures and Effects for Freshwater Mussels in the Greater Everglades Ecosystem

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Approximately 2 million acres of the Everglades drainage system contain sediments and biota with elevated mercury and other contaminants related to human activities. The current study examined species diversity, health, and reproductive status of freshwater mussels in South Florida in relation to habitat alteration and contaminants. Mussels were present in only 10 of the 33 sites examined. Although species diversity and abundance widely varied between sites, two species *Elliptio buckleyi* and *Utterbackia imbecillis* were each present at multiple sites. Approximately 25 adult mussels of each of the two species were collected per site and health assessed using: soft tissue, mantle, total gill and shell wet weights; shell length, shell width, and mantle glycogen concentrations. A body weight to length ratio was calculated as a body condition index (BCI). Histological analyses were utilized to determine sex and reproductive stage. Contaminant analyses indicated significant bioaccumulations of mercury, organochlorine pesticide residues and PCB's which varied widely between sites. Foot biopsy tissues were analyzed for sex steroid concentrations (estradiol, testosterone and progesterone) to assess reproductive status and potential contaminant related endocrine disruption. Health assessments indicated decreased body condition indices and mantle glycogen concentrations for mussels from sites with elevated mercury and organochlorine pesticide exposures. Likewise, endocrine analyses indicated decreased estradiol for females and decreased testosterone concentrations for males from sites with increased mercury and pesticide exposures. Exposure differences were also correlated to differing reproductive status. These data are among the first to indicate potential endocrine disrupting effects of contaminants in invertebrates. Overall, these data indicate that both habitat degradation and elevated contaminant levels from anthropogenic sources are probable causes of mussel declines.

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Predictive Spatial Models of Wading Bird Distribution in Everglades National Park

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We present predictive spatial models of the foraging distribution of each of seven wading bird species during their primary nesting period (the 'dry season', December–May) in Everglades National Park. The data upon which the models are based are from the Systematic Reconnaissance Flights (SRF), monthly aerial surveys of both birds and surface water condition. The models estimate the probability that birds will be observed in a particular cell during a survey identical to that of the SRF. Thus, just like the SRF data themselves, the models provide estimates of the *relative* distribution of the birds.

As explanatory variables, the models contain only time and various measures of water condition and dynamics at different spatial scales. Depending upon species, these variables explain from 50% to 75% of the month-to-month variation in total observed area occupied by foraging wading birds. They also predict quite accurately the spatial distribution of birds.

These models could, in principle, be used to predict the effects of future water management regimes on wading bird foraging patterns, which are correlated closely with nesting success. (Such future predictions depend upon our ability to translate water management models into estimated SRF surface water observations.)

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An Assessment of Potential Contaminant Exposures and Effects for Largemouth bass in the Greater Everglades Ecosystem

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Altered reproductive and endocrine function has been suggested for largemouth bass from contaminated sites in Central Florida. These results indicate a complex process involving reclamation/restoration and the exposure of adult fish persistent contaminants (i.e. pesticides), which can lead to reproductive/endocrine dysfunction and developmental toxicity. The current study assessed both exposure to and the potential effects of environmental contaminants for largemouth bass in the greater Everglades ecosystem. Adult large mouth bass (n=10 to 20 per site) were collected from multiple sites within several restoration related sites: Everglades National Park, Loxahatchie National Wildlife Refuge, Big Cypress National Preserve, and Water Conservation Areas 1, 2 and 3. Fish were sacrificed upon capture for the collection of blood, liver and gonadal tissues, as well as for whole body analysis of contaminants. Contaminant analyses included 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 assessments of endocrine status (sex steroids and thyroid function). Gonadal and liver tissues were also examined histologically for an evaluation of reproductive status and liver toxicity. Initial results demonstrate significant, site specific, exposures to pesticides and mercury. These results also indicate altered endocrine status in response to contaminant exposures. The assessment of exposures for fish within the Greater Everglades Ecosystem is an essential component of current and future assessments of risks and potential effects of proposed and ongoing restoration efforts.

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Estimation and Population-Based Simulation Modeling of American Alligator Populations in Support of ATLSS

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A map-driven spatial simulation model for alligator population densities in the Everglades is introduced. Supporting the ATLSS (Across Trophic Level System Simulation) model of the USGS-BRD, this simulation model uses GIS maps of land elevation, habitat types, and daily water levels from a 3,000 km^2 section of the Everglades. Its purpose is to simulate the south Florida ecosystem, and estimate alligator population densities and spatial distributions under varying management strategies.

The age-structured alligator population is represented as a 3-dimensional array, $N(i, j, k)$, indexing the number in age group k at spatial location (i, j). This array interacts with the habitat, elevation and water level maps, and other inputs such as fish density and alligator life-table data to determine growth rates, reproduction and survival of the alligators, and the production of “alligator holes”: deep pools of water created by alligators that trap water and fish during times of low water level.

Dispersal of alligators is performed with discrete spatial convolution, where a dispersal probability density function (pdf) known as a dispersal kernel interacts with the population density map to ‘spread out’ the existing population. This process is similar to a ‘blur filter’ applied to a 2-d image in a photo editing computer program, except we are able to specify the precise attributes of the filter. It is possible to apply different dispersal kernels to specific areas on the map, depending on existing geologic and climatic conditions.

As part of this project, we will use water management structure maps to develop spatially varying dispersal patterns. In particular we will examine the habitat with & without canals and dikes in various locations in order to assess the effect on alligator population growth and survival under different management options. The finite rate of increase, λ, will be mapped and compared under different management scenarios, and the alligator response will be judged on both spatial distribution and total abundance criteria.

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Effects of Above-ground and Below-ground Fire on Soil Properties and Cattail Seedling Growth Potential in a Northern Everglades Marsh

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The effects of surface- and muck-fire on soils from a hydrologically-altered Everglades marsh were investigated by chemical analysis and bioassay. Muck fire resulted in losses of total carbon, nitrogen, and organic forms of phosphorus (P) while inorganic P and calcium (Ca) were significantly elevated. Muck fire also resulted in greatly increased vertical heterogeneity in concentrations of Ca, total P, and inorganic P between the upper (0-2 cm) and lower (2-10 cm) soil layers. In contrast, surface-fire had only a minor enrichment effect with respect to soil P fractions and little effect on other elements. In terms of fire-related concentration changes, calcium was used as a conservative tracer to estimate soil reduction during muck burning. In this way, physical and chemical transformations could be resolved. To address potential ecological effects of such fire events, cattail (Typha domingensis) seedlings were planted in muck-, surface, and non-burned soils collected from the area. Plant biomass and tissue P concentrations were significantly higher in plants grown in muck-burned soils indicating that P availability, in addition to concentration, is an important factor regulating cattail invasion and expansion in the Everglades. Additionally, wetlands with shortened hydroperiods and, consequently, an increased probability of muck fire may be susceptible to invasion by opportunistic species that are adapted to high nutrient availability.

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Reintroduction of the Florida Wild Turkey to Everglades National Park

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The pine rockland ecosystem, dominated by the southern slash pine (*Pinus ellioti var. densa*) forest, is a critically endangered habitat in southern Florida. Along the Miami rock ridge, over 90% of this ecosystem was obliterated in the early 1900's for agricultural and residential development. The largest and only remaining functional tract is the 4,600 ha of pine forest in the Long Pine Key Region of Everglades National Park. A pineland associate, the Florida Wild Turkey (*Meleagris gallopavo osceola*) disappeared by the late 1950's. The Wild Turkey while primarily residing in pinelands, also inhabits cypress swamps and hardwood hammocks in southern Florida.

Although habitat loss is a major factor in the disappearance of the Wild Turkey, they were also heavily impacted by unrestricted hunting, even after Everglades National Park was created in 1947; the last in-holdings were transferred to Everglades National Park ownership in 1976. Other contributing factors probably include altered fire regimes and effects associated with isolated small populations. More importantly, however, the large distance between remaining isolated habitat islands from source populations has likely precluded recolonization by these species.

An attempt was made to reintroduce wild turkeys to the Long Pine Key area in 1971 and possibly in the early 1960s as well. It is believed most birds were hunted by farm workers from private inholdings. With the removal of unregulated hunting, the restoration of natural fire regimes, and the maturation of pine forests in Long Pine Key, a new attempt to reintroduce turkeys was attempted in 2000. The reintroduction of turkeys, and other extirpated pineland species, can be viewed as a test of the progress made to restore this rare pineland ecosystem.

Between 3 - 8 January 2000, 7 males (6 adults:1 juvenile) and 22 females (18adults:4 juveniles) were released to Long Pine Key several hundred meters south of the campground amphitheater. All turkeys were wild-caught birds from south-central Florida and ten were attached with radio transmitters. A monitoring program was developed to determine the survival, reproduction, and habitat use by the radio-tagged birds.

After release, radio-tagged turkeys spread out widely and many favored the *Schinus* thickets in the Hole-in-the-Donut area during the dry season. Five of the radio-tagged turkeys have died, of which one was a juvenile. Evidence suggests that several deaths were a result of predation. Reproduction was not expected to occur in the first year and no signs of reproduction have been observed. We report on home range size and habitat use by radio-tagged individuals in relation to Wild Turkey in other areas in Florida. Finally, we discuss future reintroduction efforts for the Wild Turkey in Long Pine Key.

In 1996, the South Florida Ecosystem Restoration Science Subgroup identified the loss of species from upland communities as a critical restoration issue and declared the investigation of reintroductions to restore biotic losses in upland communities as a critical information need. Moreover, in the 1996 "Report of the Panel to Evaluate the Ecological Assessment of the 1994-1995 High Water Levels in the Southern Everglades" an independent panel noted that restoration efforts cannot concentrate only on the "River of Grass" while ignoring the remaining upland forest fragments. The panel specifically identified reintroduction of upland species lost from the Everglades as a necessary part of restoration. This ongoing project, thus, addresses a critical information need for South Florida Ecosystem Restoration, as stated by the Science Subgroup and implements the High Water Independent Panel's recommendations. Continued support of reintroductions of pineland species and other pineland projects will indicate that public officials are serious and committed to incorporating the endangered pine rockland ecosystem as part of the Greater Everglades Ecosystem Restoration effort.

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Long-term Experimental Study of Fire Regimes in South Florida Pinelands

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South Florida slash pine forests represent one of the region's most fire-dependent and imperiled ecosystems. Some 65 vascular plant taxa are endemic to southern Florida and more than half are herbs and low shrubs restricted to pine forests. These species are quickly shaded out in the absence of fire. The fire regime that created this system is not fully known. While lightning-ignited fires during the May to July period surely burned substantial areas before the arrival of Europeans, the indigenous people had most likely been burning at other seasons for thousands of years. Even in large natural areas like Everglades National Park, a lightning-driven fire regime cannot be allowed to operate because of human health and safety concerns. Prescribed fire will be required to restore and maintain South Florida pinelands. While restoring the natural fire regime is frequently posed as a restoration goal, a more realistic goal may be to use prescribed fire to restore and maintain the desired species composition and structure of South Florida ecosystems.

This long-term study will document the ecological effects of a wide range of potential fire management strategies on South Florida pinelands. The main objective of the current project is to establish the baseline conditions and begin the experimental treatments for a long-term study of season and frequency of burning in South Florida pinelands. The research will provide detailed data on vegetation responses (such as changes in species composition, biomass, and demography of pines) to different burning regimes that will be considered along with wildlife, public safety, and other management concerns in refining prescribed burning programs on Department of Interior lands in South Florida. Because many of the effects of fire regime will not become evident until after several repetitions of the experimental treatments, this study must be treated as a long-term ecological study. Specific objectives for the initial phase of the long-term study include: 1) describing the vascular plant communities of all treatment units to document initial conditions, 2) conducting all the initial experimental burning treatments, 3) documenting the short-term effects (<1 year) of season of burning and fire intensity on selected vegetation parameters, and 4) institutionalizing burning and data collection schedules and protocols for study of long-term effects of season and frequency of burning.

The experimental study has been set up in eastern Big Cypress National Preserve, where the most extensive unlogged stands of South Florida slash pine (*Pinus elliottii* var. *densa*) remain. The pinelands exist as a mosaic of slightly elevated "islands" within a matrix of cypress domes and dwarf cypress prairies. The substrate is a shallow layer of sand over limestone bedrock, making these pinelands transitional between the true rockland pine forests of the Miami Rock Ridge and the widespread pine flatwoods to the north. The study site of 2573 ha surrounds the Raccoon Point oil field and is divided into 18 experimental burn units. Each burn unit includes at least 50 ha of pine forest. Within each unit, three permanent 1.0 ha tree plots were established. In each plot, trees with diameter at breast height (dbh) >5.0 cm are tagged and mapped. Smaller 0.1 ha vegetation plots are located in the center of each tree plot and at two additional locations in each unit to sample herbaceous and shrubby vegetation. There are a total of 54 tree plots and 90 vegetation plots. The tree plots (containing a total of 16,370 trees) show the Raccoon Point pinelands to have average stand densities (trees/ha) of 227 pines, 53 cabbage palms, and 24 cypress. All but five of the tree plots contain at least one cypress tree, indicating the hydric nature of these pinelands. The understory vegetation also is frequently dominated by wetland indicators.

The experimental treatments consist of burning at three seasons (spring, or early wet season, when the largest human-caused or lightning-caused wildfires occur; summer, or mid wet season when there are frequent, but generally small, lightning-ignited fires; and winter, or mid dry season when conditions are frequently favorable for prescribed burning) and two frequencies (every 3 years and every 6 years) for a total of six treatment combinations. Each treatment is replicated three times, with one replicate being burned per year for three years. The project is a cooperative effort of the USGS and the NPS and all the experimental prescribed burns are conducted by the Big Cypress National Preserve Fire Management Division. Beginning in 1996, two units have been burned at each season, representing both short- and long-frequency treatments. Some treatment burns have been postponed to subsequent years because of abnormally wet conditions or because of state-wide burning bans brought on by drought conditions. By spring 2000, all 18 of the initial experimental prescribed burns were completed and the second cycle of burns of the 3-year treatments was begun.

The severity of each burn is quantified several ways, because fire behavior may vary significantly within a given treatment. Fuel consumption is measured by collecting 50 fuel samples before and after each burn. Fire temperature is measured by placing in the plots 148 small steel plates with spots of temperature-sensitive paints. And lastly, the proportion of scorched needles and the height of bark charring on the stem of each pine tree is measured after the burn. Tree mortality is evaluated one year after burning.

Based on the data from the first 16 burns, fuel loadings average 1055 g/m^2. Fine litter, dominated by pine needles, comprised 78% of the mass consumed while herbs, palms, and coarse litter (>0.6 cm and <2.5 cm in diameter) each made up 5 to 10%. Fuel consumption averaged 717 g/m^2 and was lowest during the mid wet-season burns. Fire temperatures were relatively mild, with means ranging from a low of 212^oC during mid wet-season burns to a high of 222^oC after early wet-season burns. Mortality of pine trees >5 cm diameter in the first year after the burns was very low, including trees in which all the needles were scorched. The greatest number of trees (2.9%) died after mid wet-season burns. South Florida slash pine is extremely resistant to fire at any season. Patterns of mortality are often associated with localized fuel conditions rather than season of burning. Results to date do not support the argument that all prescribed burning should be done during the lightning-fire season.

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Automated Vegetation Mapping and Change Detection Using Remotely-Acquired Spectral Imagery

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Introduction: Restoration of the Everglades will require monitoring of the ecosystem on micro and macro scales. While targeted monitoring of indicator species and areas will be performed on the ground, there is much to be gained from remote sensing from space based and aerial platforms. The basic monitoring classes need to include hydrology, various land, aquatic and near-shore vegetation with special focus on endangered native species and exotics, various benthic fauna communities, and specific endangered species habitat areas. Of particular interest will be remote sensing detection and tracking of changes in the spatial extent and density of the exotic and native vegetative species that will be used as indicators of restoration success. Given the large spatial extent of the Everglades ecosystem, the number of species of interest and the need for high-resolution monitoring, large amounts of data will be collected and analyzed. In order for the analysis process to be efficient, new tools will be required enabling rapid extraction and interpretation of collected information. This paper discusses some proprietary new tools and methods that automate many of the collection and interpretation steps.

Background: Hyperspectral and multispectral imagery (HSI and MSI) are increasingly available and affordable. While such imagery offers new opportunities to identify materials remotely, with 10’s to 100’s of bands of information it is even more overwhelming with respect to data volume than any current imaging system. For these kinds of data to be successfully integrated into a realistic environmental monitoring approach, they must be rapidly and automatically screened for critical information, both to cue other resources and to free scientists to concentrate on relevant data.

Manual analysis of spectral imagery data is extremely time-consuming and requires extensive training and expertise. However, the quantitative nature of the data lends itself to automated computer processing. While automated analysis of spectral imagery is not a new concept, most methods result in complex products that are difficult to interpret and frequently miss critical information. A real solution to these problems is one that not only processes data automatically, but also produces readily interpretable results.

Approach: Our approach to this problem is to automate the implementation of physically realistic models for analyzing spectral imagery. Key among these is spectral mixture analysis (SMA)[*Adams et al.*, 1993; *Mustard and Sunshine*, 1999], which models each pixel in a spectral image as a linear combination of its major compositional components or “endmembers” (including shade, a key constituent of most scenes). The direct results of SMA are by themselves extremely useful, and as a basis for more detailed analysis become even more powerful. One direct result is a series of GIS-compatible information layers that show the distribution and abundance of each of the background materials within a scene. Another direct result, derived from the RMS error image, is a map of all materials that do not spectrally match the natural background (typically manmade objects, pollutants, etc.). Finally, because SMA’s shade endmember renders these products independent of variations in illumination geometry (not true for the original HSI data), images acquired at different times can be directly compared, and any change between them can be automatically detected, identified, and quantified.

Vegetation Mapping: Our experience suggests that SMA based approaches will be the most useful and most stable for spectral imagery-based vegetation mapping. MSI data allow the accurate segregation of basic background materials, such as green vegetation, non-photosynthetic vegetation, shade, and soil. HSI data include sufficient spectral information to resolve multiple constituents within these major background classes. However, to accurately segment HSI data, an adaptive approach is required (see "Advanced Tools" below).

Change Detection: Identifying changes from one collection to the next based on compositional information is one of the most relevant methods for highlighting areas of potential concern. Change detection applications are particularly useful in that they allow for broad area searches and provide a framework for efficient cueing of additional more focused data collections. Conceptually, change detection is extremely straightforward. However, actual implementation in real world situations is complex and has yet to be well demonstrated, particularly using hyperspectral systems.

In principle, change between two data collections should be revealed by simply differencing two images or map products derived from spectral data. However, in reality the process is hindered by variations in lighting, time of day, atmospheric conditions (including differences in cloud cover), spatial coverage, spatial geometry, and instrumental effects. Of the many exploitation tools available, SMA offers the most promise for overcoming the complexities involved in actual implementation of change detection. Under SMA, each pixel is represented by the fractional abundances of a small number of endmembers. For change detection, endmembers for subsequent data collections can be chosen from the same spatial areas, or from a canonical set of endmember spectra. Using the endmembers as a fixed compositional framework and allowing for variations in scene conditions to be accommodated with changes in the abundance of shade/shadow (through the use of a shade endmember), SMA overcomes many of the complexities preventing change detection from being a practical tool for remote sensing.

Advanced Tools: While the benefits of SMA are clear, for successful results one must first find the correct endmembers. We have developed a tool (called Abacus™) which finds these endmembers automatically and intelligently, providing easily interpreted and believable results. The goal of the Abacus™ approach is not unique, but its methodology is. Most current automated processes derive endmembers by statistical methods, which frequently lead to results that are mathematically correct but physically impossible. The Abacus™ tool combines statistical techniques with a knowledge-based system, making use of unique spectral information to find the most physically realistic endmembers with which to model the background. In addition, Abacus™ endmembers are used adaptively so that multiple endmembers from a single class of interest (*e.g.*, multiple vegetation types) can be supported. Abacus™ endmembers derived from airborne HSI data have been evaluated at Brown University through the NASA Stennis Affiliated Research Center (ARC) Program and have been found to be comparable to manually-derived, academic research-quality results [*Sunshine et al.*, 1999].

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Vegetation on Elevated Tree Islands in the Central Everglades Water Conservation Areas, Broward and Dade Counties, Florida

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Tree islands occupy a small but distinctive portion of the Everglades landscape. They are enclaves of plant species diversity and provide nesting habitat and wet-season refuges for a variety of wetland and upland animal species. Tree islands in the central Everglades have been dramatically altered by human activity during the past century, with drought, wildfire and prolonged high water identified as principle causes of damage to island vegetation and soils. However, our ability to specify the conditions that can lead to restoration of tree islands is currently hampered by a lack of baseline ecological and physical data. Here we describe results of an ongoing field investigation of plant community variation among the elevated "heads" of tree islands in the central Everglades Water Conservation Areas 3A and 3B. The project objectives are to obtain a comprehensive baseline description of tree island vegetation, to identify hydrologic correlates of vegetation that might serve as predictors of the response of vegetation to future changes in water management, and to identify candidate variables for vegetation monitoring. We present here a description of variability among tree island plant communities within a large sample of elevated tree islands in Water Conservation Areas 3A and 3B. Associations between vegetation, hydrologic variation, and human disturbance are identified and discussed in light of restoration requirements for Everglades tree islands.

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Landscape Analysis of Fish Communities in the Florida Everglades

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We have monitored the abundance of small fishes (<8cm) from 17 locations across the Florida Everglades from 1997 to the present to examine their relationship to management activities over that period. Several of the study sites correspond to locations where similar data were gathered in the 1980's, permitting a multi-term perspective to the analysis. These fishes include many species and size classes that are important food items for wading birds. Fish were collected with a 1-m^2 throw trap, and environmental data at the study site was gathered simultaneously.

Several patterns have emerged that have implications for future management of the Everglades ecosystem. The total density of small fish displays a non-linear relationship with hydroperiod, reaching a maximum at sites with hydroperiods around 300 days. When juveniles are excluded, the relationship of small-fish density to hydroperiod can be modal, actually declining at hydroperiods exceeding approximately 300 days. When coupled with data on large-fish (>8cm), it appears that the shape of this relationship is determined by environmental fluctuation from dry-season mortality in short-hydroperiod marshes, and biotic interactions and predation in long-hydroperiod marshes. Thus, hydrological pattern and management may shape variation in small fish abundance at regional spatial scales, where marshes in Shark River Slough tend to have the highest density, Taylor Slough the least, and southern WCA-3A and intermediate density. Our study was conducted over 2 relatively wet years, 1997 and 1998, followed by drier years. Intermediate and short-hydroperiod marshes went dry in 1989. The abundance and community composition of small fishes at sites that went dry in 1989 were regained in approximately 1 year.

Our study sites also include habitats experiencing a range of levels of nutrient availability and local productivity. Fish density increased with increases in measures of local phosphorus availability across the range experienced at our study sites (soil total phosphorus: 75 – 590 ug/g TP). Hydroperiod and soil TP varied together in our data, though hydroperiod explained more total variance in small-fish density if two nutrient-enriched sites were excluded. Emergent vascular-plant stem density and floating mat volume (mostly periphyton and *Utricularia*) varied with hydroperiod and soil TP, and fish density was mostly correlated with emergent stem density. We found evidence that the highest nutrient-enriched sites yielded stem density and floating mat volume so dense that fish density declined, probably from a loss of habitat to plant biomass.

The data from this study will be used to improve study designs for future monitoring of fish communities in the Everglades. We have examined patterns of optimal sampling frequency and effort, and are collaborating with modelers in developing tools for predicting the response of fish communities to projected management options. The results support the conclusion that hydrological management has critical short and long-term impacts on small-fish communities.

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Preliminary Differences in Abundance and Sex-Size Distribution of Pig Frog *Rana Grylio* Populations from South Florida Wetlands

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Anthropogenic modifications of the greater Everglades Ecosystem watershed, have disrupted the natural hydrologic regime. Restoration efforts intend to increase the hydroperiod and water depth to parts of south Florida Everglades. These changes will have a dramatic effect on the herpetological assemblages in these freshwater ecosystems (Duellman and Schwartz 1958 and Dalrymple 1988). The herpetofauna of the Everglades and Big Cypress is a critical trophic level of these systems, yet are understudied (ATLSS 1997). Amphibians are ideal organisms to study due to their bi-phasic life cycle and quick response to hydrological changes. We are investigating the population dynamics of the pig frog, *Rana grylio*, a common aquatic frog of freshwater marshes and forested wetlands throughout south Florida. They have a role as an intermediate link in the Everglades food web, consuming a variety of insects, reptiles, amphibians, and birds; and are a source of prey for wading birds and raptors, snakes, fish, and alligators (Ligas 1960 and ATLSS 1997). Despite its abundance and ecological role, little data has been published on this frog. Most accounts on these frogs include incidental harvest tales, anecdotal data, and unpublished reports (Duellman 1958, Craighead 1968, Ligas 1960). Consequently, there is a general lack of information on the ecology and population dynamics of *Rana grylio* in South Florida.

I am presenting a preliminary comparison of abundance, sex ratios, and size distributions, between harvested *R. grylio* populations and protected *R. grylio* populations, under different hydrological regimes in south Florida. These population parameters are believed to respond to harvest pressure and hydrology and thus will allow us to assess how long term changes may affect these populations. Three areas which contain both long and medium hydroperiod wetlands have been selected to assess these population parameters: Water Conservation Areas 3A and 3B and in Shark River Slough. As part of a pilot study, time constrained searches and frogs were collected randomly from Water Conservation Areas 3A and 3 B in spring of 1999, and summer 2000 and in Shark River Slough in spring and summer of 2000. These samples have been used to assess size distributions of adults and juveniles among harvested and protected areas.

We found more juveniles in WCA3A than in 3B in March and May 1999. There was temporal variation in the size distributions within 3B, with smaller females being present later in May. Sex-size of individuals did not differ between WCA3B and Shark River Slough in May, 1999-2000. Overall, there were more frogs observed in SRS than in WCA 3B. August samples from all three sites showed a larger proportion of juveniles and fewer adult males in harvested areas. WCA 3A tends to have smaller individuals than in WCA3B and SRS. This could suggest stronger harvest pressure in WCA 3A than 3B. The deeper water and longer hydroperiod than 3B will be used as a covariate to assess differences between sites.

A two-year study will assess these preliminary observations. We will use double observer techniques on a monthly basis when sampling fifteen one km line transects. This will estimate abundance between the three areas (Nichols pers comm.). Sex ratios and mean sizes of juvenile, and adult male and female frogs will be compared using time constrained searches of 30 minutes. Mark recapture techniques will also be implemented starting in September, 2000 to assess recruitment and survival rates.

The information obtained during this study will be used to construct a population simulation model that will examine responses to harvest and hydrological pattern. Model parameterization and form will be developed using the first year of data and will be validated from the second year of data.

Given the lack of information on the aquatic fauna of the greater Everglades region, this project will provide new information on a common aquatic species. By attempting to correlate population parameters such as abundance, mean adult and juvenile size distribution, and other factors to water level and harvest this will be useful for the ATLSS model. This study will bring understanding a component of the ecosystem about which we know almost nothing about.

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Amphibian Inventory of Everglades and Big Cypress National Parks

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Amphibians are an important part of the assemblage of vertebrates in the Everglades. They represent a large portion of the animal biomass in the area, and are an important part of the Everglades food web. Because of their sensitivity to contaminants and to hydrological changes, they are also considered good indicators of ecosystem health. The ecology and status of most of the amphibian species in South Florida is poorly known. Little more than a species list exists, with only a few intensive studies as exceptions. This project seeks to create a georeferenced inventory of all of the amphibian species in Everglades National Park (ENP) and Big Cypress National Preserve (BCNP). In addition, long-term monitoring sites will be established which will allow us to follow changes in the relative abundance of amphibian species across seasons and over time. This project will provide real baseline data on which the effects of proposed hydrological changes and restoration efforts could be judged. Additionally, these data will serve ecological modelers attempting to understand how ecosystem processes affect this important component of the Everglades fauna.

ENP and BCNP represent a contiguous expanse of 2.2 million acres. This landscape, unique in the United States, is a diverse array of different wetland and upland habitats. The amphibian fauna of the Everglades / Big Cypress region is comprised of 16 native species, all derived from the temperate zone, and two non-indigenous species from the tropics. This surprising lack of species richness is due in part to the young geological age of South Florida and the difficulty amphibians face when dispersing to the end of the peninsula. Although some historical survey and inventory studies have been done on the DOI lands of South Florida, there is still a need for a current inventory of the amphibians of ENP and BCNP. The proposed project will provide critical information on the distribution, abundance, and current status of amphibians in South Florida.

The primary goal of this project is to inventory the amphibians of ENP and BCNP. This will provide information on the status and distribution of the species of amphibians on these DOI lands. In addition, nine permanent monitoring sites will be established to provide the baseline data necessary to detect population trends. Monitoring will be designed so that it will be repeatable and comparable over time, and data will be collected on the health of individuals, which will aid in determining the causes of declines should they be discovered.

Study sites will be established in a manner that allows for estimates of the status of amphibians within the boundaries of ENP/BCNP. This will provide baseline data to detect changes in the abundance and distribution of amphibian species. Research will be conducted to develop sampling protocols and appropriate methods to analyze data, detect trends, and make predictions concerning status. Ancillary biological and physical data will be collected so that possible causes of changes in abundance and distribution can be determined. Should emergency situations be detected, such as the presence of disease or malformations, research will assist in the determination of cause and methods of containment. In this regard, research and field personnel will work closely with the USGS National Wildlife Health Center. Data collection will be coordinated within USGS, among DOI and other federal agencies to ensure that datasets are comparable with respect to the larger goals of the

DOI's Declining Amphibian Task Force. Finally, information will be made available to cooperating agencies, the scientific community, and the public.

1. Create a georeferenced inventory of the amphibians of ENP, BCNP, and VINP.

2. Measure the abundance of amphibian species at several locations as baseline data for long-term amphibian monitoring.

3. Estimate variation in species richness through time and among different sites and habitats.

Amphibian inventory and monitoring in this project will be accomplished using standard survey methods across the three parks. The project will be divided into two types of surveys, extensive surveys and intensive monitoring. Extensive surveys will be designed to efficiently sample for the presence of all species of amphibians in an area in a short time so that many areas can be sampled in each park. This will provide distribution information but will not effectively quantify the abundance of amphibian species. The intensive monitoring portion of this project will be designed to provide information on the species richness and abundance at a few specific areas. These monitoring sites will be sampled in a repeatable way to provide comparable data for comparison during the course of this one-year study. They will also be set up as the basis for long-term amphibian monitoring in the parks. The search methods used will include time-constrained searches, visual encounter surveys (VES), litter plots, call counts, and opportunistic collecting. Capture methods like drift fences, coverboards, PVC traps, and permanent VES transects will add the ability to get abundance estimates of some species.

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Introduction to Paleoecological Studies of South Florida and the Implications to Land Management Decisions

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The Florida Everglades developed from the interplay of sea level and climate. The subtle balance of these two factors over the last two millennia is important to understanding restoration strategies. During the Medieval Warm Period and the Little Ice Age, the Everglades show a general drying trend. The Medieval Warm Period trend is due to a significant decrease in annual precipitation while sea level was rising. The Little Ice Age trend is due to the combined effect of reduced precipitation and the slowing in the relative rate of sea level rise, failing to keep base level with Everglades sediment and peat accumulation, yielding shorter hydroperiods and dryer conditions. Sea level has been steadily rising over the last century and should be considered in water flow modeling. Land use and water management practices over the last century have greatly partitioned the Everglades compounding its ability to respond ecosystem-wide in predictable ways to climate and sea level change.

Salinity in Florida Bay is affected by marine circulation, climate (rainfall) and runoff. Marine circulation was reduced in the early 20th century by intense construction connecting the Keys. Rainfall and runoff appeared coupled until the late 1960's. A restoration goal should be to couple rainfall and runoff again. Salinity in central, western and southern (Atlantic transitional) zones of the Bay is influenced by direct rainfall; salinity in the northern (northern transitional) and eastern zones is influenced to a large extent by runoff. These latter zones need to be monitored to ascertain that rainfall and runoff are indeed coupled to the degree that they have been in the past. [This abstract is from the volume “Paleoecology Studies of South Florida” edited by Bruce R. Wardlaw, American Bulletin of Paleontology, in press].

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Trends in Tree-Island Development in the Florida Everglades

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Tree-island formation and development are influenced by a number of environmental factors, including hydrologic regime, nutrient influx, and underlying geologic structure. Design of management strategies to maximize the health of tree islands and the Everglades wetland as a whole requires an understanding of how changes in these parameters affect the diverse plant and animal communities on these features. To determine how tree-island communities have responded to past climatic and environmental changes, we have collected transects of sediment cores from tree islands in the Everglades to determine: the timing of tree-island formation throughout the region; underlying controls on tree-island formation; patterns of vegetational development on tree islands; nutrient trends on and around tree islands; and the use of sediment phsophorus as a tracer of historic bird populations in the Everglades.

To date, we have collected sediment cores on sixteen tree islands: two in Arthur R. Marshall Loxahatchee National Wildlife Refuge, one in WCA 2A, eleven in WCA 3A, and two in WCA 3B. Sediments in these cores are described lithologically, dated using radiometric techniques (^{14}C and ^{210}Pb), and analyzed palynologically and geochemically. Integration of these data with field evidence for peat/sediment thickness and elevation, bedrock elevation, and existing vegetation are being used develop models of tree island formation and development.

Palynological and geochemical analyses of cores collected on the head, near tail, far tail, and adjacent wetland have been completed for two tree islands in WCA 3B, Gumbo Limbo island and Nuthouse island. Both are elongate, teardrop-shaped tree islands, with trees clustered at the north end of the island on the head and a tapering tail to the south with shrubs and thick marsh vegetation. Sediment cores collected in transects across the head and along the length of both islands contain records of the last 4.3 ka and predate tree island formation. We have identified three stages of tree-island development from both cores. Prior to tree-island formation, sites on the tree island were covered by sawgrass marsh vegetation with common weedy annuals, indicating moderate water depths and hydroperiods with periodic intervals of drought. In the wetlands adjacent to the head, however, slough vegetation, characteristic of deeper water depths and longer hydroperiods grew concomittantly. In the early stage of tree-island development (beginning at 1200 BC on Gumbo Limbo and 300 AD on Nuthouse), ferns, trees, and shrubs became more abundant; this stage persisted for 1,000 to 2,000 years. Mature tree-island vegetation is indicated in the pollen record by strong dominance of fern spores and increased abundance of tree and shrub pollen. Such vegetation has been in place on Gumbo Limbo island since 800 AD and on Nuthouse island since 1500 AD. Thus, these features are geologically old, with formation occurring as long ago as 1200 BC, early tree-island vegetation lasting 1,000 to 2,000 years, and mature tree-island vegetation persisting for the last 500-1200 years.

Vegetational reconstructions from transects along the length of these tree islands indicate that sites on the island were drier than the surrounding wetlands throughout their histories, with shallowest water depths on the heads and progressive deepening of water depths with increasing distance along the tail. Thus, relatively localized hydrologic conditions appear to have played a major role in determining where tree islands formed; ongoing research on topography and lithology of the underlying limestone should clarify the roles of climate and geologic framework in influencing tree-island formation. The impact of artifically altered water depths on tree-islands is illustrated by preliminary results from a "drowned" tree island in WCA 2A. Vegetational reconstructions indicate an abrupt change from vegetation characteristic of a tree-island head to that similar to a far tail site, with much deeper water. Based on the current age model, this change occurred within the last fifty years, after high water levels were maintained for more than a decade. Thus, a tree island that had existed for about 2,000 years was altered to an unprecedented degree over a span of a few decades, highlighting the sensitivity of tree islands to extreme hydrologic change.

Sediments collected on these tree island heads are characterized by extremely high phosphorus content, both before and after tree-island formation. Sediments from the surrounding wetlands, in contrast, have relatively low phosphorus content, similar to marshes elsewhere in the Everglades. In tree-island tails, phosphorus levels were low prior to tree-island formation and increased after formation, when water depths decreased. We hypothesize that these phosphorus records may be a tracer of historic bird populations in the Everglades and are analyzing additional cores from rookeries to establish the validity of this hypothesis.

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Oral Abstracts

Hydrology and Hydrological Modeling

Sensitivity of the Comprehensive Everglades Restoration Plan to Individual Project Components

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Sensitivity of the Comprehensive Everglades Restoration Plan (CERP) to individual project components was evaluated by sequentially removing major components from the preferred alternative (D13R) modeled using the SFWMM. Components removed included aquifer storage and recovery, surface and in-ground storage and wastewater reuse. Results of these simulations were compared with the preferred alternative and the effects of removing the components on environmental and water supply performance were evaluated.

Although much of this information is contained in the Final Integrated Feasibility Report and Programmatic Environmental Impact Statement, the summary presented here provides a means to easily compare the relative merits of each component in terms of hydrologic performance. Furthermore, additional sensitivity analyses undertaken subsequent to the final report are also included in this summary.

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Oral, Hydrology and Hydrological Modeling

Concepts and Algorithms for an Integrated Surface Water/Groundwater Model for Natural Areas

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As part of South Florida Regional Simulation Model (SFRSM), the Hydrologic Simulation Engine (HSE) primarily simulates two-dimensional flow in areas where inertia forces can be considered negligible. HSE is an integrated surface water/groundwater model that performs continuous simulation using a variable mesh discretization. This presentation primarily discusses the concepts and algorithms in the HSE as they apply to natural areas.

Hydrologic processes modeled in the HSE include rainfall, evapotranspiration, infiltration, surface water/groundwater flow, channel and structure flow, and levee seepage. Most of the algorithms and procedures in the HSE were inherited from the South Florida Water Management Model. However, key algorithms were vastly improved to make the simulation more realistic, accurate and numerically efficient. Using the finite volume method, the model solves an implicit formulation of the governing two-dimensional diffusion flow in arbitrary shaped areas. The model is ideal for simulating South Florida conditions because of its ability to handle (1) wetting and drying; (2) flow thorough structures and (3) canal-wetland-aquifer interaction.

The HSE was, and still is, being developed using recent advances in computer technology such as object-oriented model development. A few test cases were completed and more testing is required before the HSE can be combined with the more comprehensive SFRSM.

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Operational Planning for Everglades Restoration

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The South Florida Water Management District (SFWMD) manages the water resources of South Florida for the benefit of the region, balancing the needs of present and future generations. The complexity of the system and the coexistence of competing water needs, such as flood control, water supply and water for environmental needs, necessitate the use of appropriate water management decision tools. The operational planning project uses different concepts and approaches to plan for the short-term operation of the system. The SFWMD has developed a set of tools and methods to serve this purpose. Among these are the use of regional hydrologic simulation models, the technique of Position Analysis and methods of incorporating climate outlooks into the operational planning of the system. The application of these techniques to restoration efforts in south Florida is also presented.

In Position Analysis, a regional hydrologic simulation model for the SFWMD is reinitialized to historical or known conditions, for a given date in every year in the simulation period. Each simulated year represents the system's response to different historical hydro-meteorological inputs under the same initial conditions. Model results are post processed and presented as time series of percentile traces. Conditional Position Analysis results are presented as time series of percentile traces shifted according to the Climate Prediction Center's seasonal climate outlooks for south Florida.

Within recent restoration and planning projects, such as CERP (Comprehensive Everglades Restoration Project) and the LECRWSP (Lower East Coast Water Supply Plan), different operational recommendations have been identified to ensure that the optimum balance among the competing water resources needs is obtained. One of these recommendations, which is highly related to operational planning, is the so-called Everglades Rainfall Driven Operations. Rainfall Driven Operations seek the short-term operation of the system in such a way that natural system-like targets for the Everglades hydrology are achieved. The conceptual framework in which the SFWMD expects to develop the Everglades Rainfall Driven Operations is also discussed.

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Effect of Water Management in the Everglades Nutrient Removal Area (ENR) on Hydrologic Interactions with Groundwater

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Successful management of constructed wetlands for water treatment in the Everglades requires better understanding of interactions between surface water and groundwater. Those interactions not only affect the hydrologic budget of constructed wetlands, but also affect the transport and fate of environmental contaminants. In order to identify and quantify the key relationships, we investigated surface water and groundwater interactions in the Everglades Nutrient Removal project (ENR), a 1544 hectare constructed wetland built as a prototype to evaluate the effectiveness of constructed wetlands in removing nutrients from agricultural drainage. We determined groundwater recharge and discharge using a combined water and solute mass balance approach (Choi and Harvey, *2000*). Over a 4-year period (1994 through 1998), groundwater recharge averaged 0.9 cm/day, which is approximately 31% of surface water pumped into the ENR for treatment. In contrast, groundwater discharge was much smaller (0.09 cm/day or 2.8% of water input to ENR for treatment). Using a water balance approach alone only allowed net groundwater exchange (discharge - recharge) to be estimated (-0.78 ± 0.16 cm/day). Discharge and recharge were individually determined by combining a chloride mass balance with the water balance. For a variety of reasons the groundwater discharge estimated by the combined mass balance approach was not reliable (0.09 ± 2.4 cm/day). As a result, groundwater interactions could only be reliably estimated by comparing the mass-balance results with other independent approaches, including direct seepage-meter measurements (Harvey et al., 2000) and previous estimates using groundwater modeling (Guardo and Prymas, 1998; Hutcheon Engineers, 1996). All three independent approaches provided similar estimates of average groundwater recharge, ranging from 0.84 to 0.9 cm/day. There was also relatively good agreement between groundwater discharge estimates for the mass balance and seepage meter methods, 0.09 and 0.06 cm/day, respectively. However, groundwater-flow modeling provided an average discharge estimate that was approximately a factor of four higher (0.35 cm/day) than the other two methods. In order to determine the control which managers have over the extent of groundwater recharge, our estimate of groundwater recharge was compared with the rate of surface-water inflow by pumping from the supply canal. Recharge was positively correlated with the pumping rate of surface water from the supply canal into ENR. This demonstrates that the relatively high surface-water inputs to this constructed wetland have the unintended effect of increasing recharge of surface water. A considerable portion of the recharged groundwater (73%) was collected and returned to the ENR by a seepage collection canal. Additional recharge that was not captured by the seepage canal only occurred when pumped inflow rates to ENR (and ENR water levels) were relatively high. In conclusion, we have shown how management of surface water in the northern Everglades increases interactions with groundwater. The increased groundwater recharge causes environmental contaminants in surface water to migrate to groundwater, and possibly to be discharged back to surface water outside of the treatment wetland. Consequently, a detailed understanding of wetland and groundwater interactions will be necessary to improve the operational efficiency of these treatment wetlands.

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Topography of the Florida Everglades

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One of the major issues facing ecosystem restoration and management in South Florida 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 continues to grow (Light and Dineen, 1994). The natural systems of the Kissimmee-Okeechobee-Everglades watershed compete for water resources primarily with the tourism and agricultural industries, and urbanization. Therefore, surface-water flow modeling studies, as well as ecological modeling studies, are an important means of providing scientific information needed for ecosystem restoration and modeling. Hydrologic and ecological models provide much needed predictive capabilities for evaluating management options for parks and refuges, land acquisition planning, and for understanding the impacts of land management practices in surrounding areas. These models require a variety of input data, however, including elevation data that defines the topography of the Florida Everglades.

Sheet flow and water surface levels in South Florida are very sensitive to any changes in topography due to the region's expansive and extremely flat terrain. Therefore, hydrologic models require very accurate elevation data for input 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 most accurate elevation data available to achieve meaningful simulation results. Therefore, elevation data points are being collected every 400 meters in a grid pattern to meet the requirements of hydrologic models of various cell resolutions. The vertical accuracy specification for the elevation data being collected in support of these modeling efforts is 15 centimeters (6 inches), and are referenced to the North American Vertical Datum of 1988 (NAVD88).

Because traditional methods for collecting these data for the Everglades are impractical or too costly, a feasibility study was conducted in late 1994 and early 1995 to determine if state-of-the-art techniques using the Global Positioning System (GPS) could be employed to meet the stringent vertical accuracy specifications of the elevation data. GPS is an all-weather, 24-hour worldwide three-dimensional satellite positioning system developed by the U.S. Department of Defense (DOD). Its primary purpose has been to provide a Precise Positioning Service (PPS) to the military and other authorized users. PPS was extended to the rest of the civil community in April 2000, when DOD turned off Selective Availability, an encryption code that limited the accuracy of GPS positioning.

The feasibility study successfully demonstrated that differential GPS techniques, using airboats to navigate transects, could meet the vertical data accuracy requirement. The land surface being surveyed in the Everglades is typically under water and obscured by vegetation, which precludes the use of other elevation data producing methods such as photogrammetry and alternative remote sensing technologies. Therefore, topographic surveys over such a large area of the Everglades with such a stringent accuracy specification can only be efficiently accomplished by using GPS. This is especially the case in an inaccessible wilderness environment.

Because the Everglades are so expansive and remote, and include environmentally sensitive areas, impenetrable vegetation, or other areas unapproachable by airboat, access to many areas is possible only by helicopter. To solve this accessibility problem, the U.S. Geological Survey developed a helicopter-based instrument, known as the Airborne Height Finder (AHF), that is able to measure the terrain surface elevation in a non-invasive, non-destructive manner. Accuracy tests have shown that the AHF system can consistently measure elevation points to within 3 to 5 centimeters. An accuracy test was performed in May 2000, where 17 National Geodetic Survey (NGS) benchmarks were measured twice with the AHF. The average difference between the AHF measured elevations and the NGS published data sheet values was 3.3 centimeters. These accuracy test results provide confidence that the elevation dataset being produced meets the 15-centimeter vertical accuracy specification.

To date, thousands of elevation data points covering significant portions of the Florida Everglades have been collected and processed using differential GPS methods, from both airboats and helicopters. These data are organized by USGS 7.5 minute quadrangles and are available from the South Florida Information Access website at http://sofia.usgs.gov. Data collection will continue, with emphasis on providing coverage of the TIME (Tides and Inflows in the Mangroves of the Everglades) Model Domain (http://keylime.er.usgs.gov/), and completing coverage of Water Conservation Area 3.

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The ATLSS High Resolution Topology and High Resolution Hydrology Models

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There are many factors affecting individual growth and reproduction and population dynamics in South Florida (SF). The influence of hydrology upon the fauna and flora is among the more significant factors. Hydrology has a wide range of effects upon these species, including the creation and loss of suitable habitat, modifying the availability of food resources and influencing mating success. The range of effect and number of species influenced by hydrology makes it a critical part of the Across Trophic Level System Simulation (ATLSS) models. An important part of these models is their spatially explicit nature and particularly the fine spatial resolution at which they simulate biological processes. Many of the models simulate processes at a 500x500 meter or a 100x100 meter resolution. The accepted hydrology data for most of SF, the South Florida Water Management Model (SFWMM), provides hydrology at a much coarser 2x2 mile resolution. To bridge the gap between the SFWMM hydrology data and the ATLSS models, the ATLSS High Resolution Topography (HRT) model and High Resolution Hydrology (HRH) model have been created. These models modify SFWMM hydrology to provide spatial variation in water depths at sub-2x2 mile resolutions, in particular they provide spatial variation at both a 500x500 meter and 100x100 meter resolution.

The HRT model is the basic element in the operation of the HRH model. The HRT model generates elevation values at resolutions as fine as 28.5x28.5 meters. It does this by combining habitat type information for each locale across the landscape, hydrology data for the landscape, and expected hyroperiod values for the habitat types. The main assumption is that plant associations are located in places where the elevation provides suitable range of hydroperiods. Currently the habitat type data is provided by the Florida GAP analysis map (FGAP v2.1), the hydrology data is provided by the Calibration/Validation run of the SFWMM and the hydroperiod values are drawn from available literature. The hydrology data is processed into a hydroperiod histogram which provides the number of days the water surface is at or above a certain elevation as a function of elevation. The HRT model can be used to create elevation maps at any resolution from 28.5x28.5 meters to 2x2 miles. These maps are collectively referred to as ATLSS HRT maps.

The ATLSS HRH model is used to create hydrology at resolutions which are appropriate for the various ATLSS models. The HRH model modifies local water depths across the landscape by redistributing the SFWMD water depth values over an ATLSS HRT map. The redistribution process is carried out on a cell by cell basis at the 2x2 mile resolution and preserves the volume of water in each 2x2 mile cell for each day.

The USGS has initiated a High Accuracy Elevation Data (HEAD) collection program aimed at collecting elevation data for SF at a high spatial resolution and with a high degree of vertical accuracy. This data is available for a number of regions, eleven of which are covered by the ATLSS HRT model. The data from the HEAD project has been compared to the ATLSS HRT model output. These comparisons have demonstrated a number of strengths and weaknesses in the ATLSS HRT maps. At a regional scale the ATLSS HRT model generates elevation means and variations which are similar to the USGS HEAD data. At a local scale the current ATLSS HRT model does not accurately predict ground surface elevations.

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Regional Evaluation of Evapotranspiration In The Everglades

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Nine sites in the Florida Everglades were selected and instrumented for collection of data necessary for evapotranspiration (ET) determination using the Bowen-ratio energy-budget method. The sites were selected to represent the sawgrass or cattail marshes, wet prairie, and open-water areas that comprise most of the natural Everglades system. Site characteristics are given in the following table.

Site number	Community	Latitude-Longitude	Comments
1	Cattails	263910 0802432	Never dry
2	Open water	263740 0802612	Never dry
3	Open water	263120 0802013	Never dry
4	Dense sawgrass	261900 0802307	Dry part of most years
5	Medium sawgrass	261541 0804356	Dry part of some years
6	Medium sawgrass	254450 0803007	Never dry
7	Sparse sawgrass	253655 0804211	Never dry
8	Sparse rushes	252112 0803807	Dry part of every year
9	Sparse sawgrass	252135 0804600	Dry part of every year

At each site, measurements necessary for ET calculation and modeling were automatically made and stored on-site at 15- or 30-minute intervals. Data collected included air temperature, humidity, wind speed and direction, incoming solar radiation, net solar radiation, water level and temperature, soil moisture content, soil temperature, soil heat flux, and rainfall. Data are available for 8 of the 9 sites for January 1996 through December 1997, and for one site January-December 1997. Four sites were continued through September 1999 and 2 sites are still being operated in May 2000. Plans are to install additional sites in the summer of 2000 in Shark Valley Slough, to provide ET and meteorological data for development of hydrologic models, and to confirm regional models of ET developed using data from the original network of 9 ET sites.

Modified Priestley-Taylor models of latent heat (ET) as a function of selected independent variables were developed at each of the 9 sites, using data for January 1996 through December 1997. These models were used to fill in periods of missing latent-heat measurement, and to develop a regional model of the entire Everglades region. The individual site models were combined and used to formulate regional models of ET that may be used to estimate ET in wet prairie, sawgrass or cattail marsh, and open-water portions of the natural Everglades system. The models are not applicable to forested areas or to the brackish areas adjacent to Florida Bay.

Two types of regional models were developed. One type of model uses measurements of the energy budget at a site, together with incoming solar energy and water depth, to estimate ET for 30-minute intervals. This energy-based model requires site data for net radiation, water heat storage, and soil heat flux, as well as data for incoming solar radiation and water depth. A second type of model was developed that does not require site energy-budget data and uses only incoming solar energy, air temperature, and water depth data to provide estimates of ET at 30-minute intervals. The second model thus uses data that are more readily available than the data required for the available-energy model, but does not give as precise an estimate ET as the model using energy-budget measurement.

Precision of the site models and the regional models was evaluated for each site. Precision of the individual site models is only slightly better than the regional model based on energy-budget measurement. The difference in precision of the two types of regional models is most noticeable for 30-minute ET totals. For 30-minute ET totals, the energy-based model has a standard error of about 32 percent and the non-energy-based model has a standard error of about 58 percent. For monthly ET totals, both types of models are much more precise, and have standard errors of about 7 percent for the energy-based model and about 9 percent for the non-energy-based model.

Computed ET mean annual totals for all nine sites for the 1996-97 period range from 42.4 inches per year at Site 9, where the water level is below land surface for several months each year to 57.4 inches per year at Site 2, an open-water with no emergent vegetation. The variation in ET follows a seasonal pattern, with lowest monthly ET totals occurring in December through February, and highest ET occurring in May through August. The monthly total ET among all nine sites for the 2-year period ranged from 1.81 inches in December 1997 to 6.84 inches in July 1996.

Although the density of photosynthetically-active plant leaves has been shown to relate directly to ET in some studies, it does not appear to relate directly to ET in the Everglades, based on comparison of annual ET data with leaf-area index data from satellite imagery (NDVI). In fact, NDVI and ET appear to be inversely related in the Everglades. The greatest ET rates occurred at open-water sites where the NDVI data indicated the lowest leaf-area index. Among the remaining vegetated sites, there is no clear relation between ET and NDVI, though the highest ET rate (Site 2) corresponded to the lowest NDVI and one of the lowest ET rates (Site 1) corresponded to the highest NDVI value.

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Quantity, Timing, and Distribution of Freshwater Flows into Northeastern Florida Bay

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A major Everglades restoration goal is to provide the wetland with the right amount of water at the right time, “getting the water right.” The need for accurate information on the quantity, timing, and distribution of water flows through the Everglades and into Florida Bay is paramount for successful water management relating to restoration issues. Hydrologic models and biological research are dependent upon accurate outflow data to calibrate and verify boundary conditions and establish flux parameters. With this information, water-management practices can be monitored and decisions can be made to restore the Everglades to its natural system.

In October 1994, the U.S. Geological Survey, as part of its South Florida Place-Based Studies Program, began a study to measure water flow, stage, and salinity at five instrumented sites and water flow at four noninstrumented sites entering northeastern Florida Bay to calculate freshwater discharge. The five instrumented sites, from east to west, are: West Highway Creek, Trout Creek, Mud Creek, Taylor River, and McCormick Creek. Data are collected continuously on a 15-minute interval and transmitted by way of satellite every 4 hours to the U.S. Geological Survey Miami office. The noninstrumented sites, from east to west, are: East Highway Creek, Oregon Creek, Stillwater Creek, and East Creek. In 1999, the study was expanded to look at distribution of flows in Joe Bay and the upstream flow characteristics of Taylor River. Four deployable salinity probes were installed within creeks along the northern coast of Joe Bay, and an instrumented site was installed in upstream Taylor River.

The quantity of water moving through the Taylor Slough and C-111 Basin, including rainfall and evaporative losses, can be measured as total outflow volume in acre-feet from the creeks. Outflow over the Buttonwood Embankment as sheetflow into northeastern Florida Bay is considered negligible due to the higher elevations of the embankment. The impact of strong storms, such as Hurricane Irene in October 1999, even causes water levels to drop rapidly after the storm surge and positive flow (flow into the bay) is constrained to the creeks. Stage, discharge, and salinity characteristics from Trout Creek indicate that the highest water levels correspond to negative flows during the hurricane, and positive “freshwater” outflows occur at lowered water levels after the effects of wind from the storm have subsided.

The timing of flows is directly related to the wet/dry season with more than 80 percent of the total freshwater entering northeastern Florida Bay from June through November. Negative flows are prominent during the dry season, and lower water levels in the wetland accompanied by wind forcing cause saltwater to intrude upstream and into the backcountry subembayments, such as Joe Bay and upstream Taylor River.

An accurate representation of surface-water flow paths (distribution), from the Everglades into northeastern Florida Bay, is needed to calibrate and validate hydrologic models. Water-level, discharge, and salinity data collected along the coast are used as boundary conditions for models, and the distribution of outflow can be determined and compared to modeled output. Because of the complex drainage system of the southeastern Everglades and the flat topography, small changes in water level can cause changes in flow distribution that would not be observed without directly computing discharge at the creeks. Discharge computation and salinity observations at the creeks and subembayments have led to the interpretation of the following flow distribution results: (1) Trout Creek carries about 50 percent of the freshwater outflow to northeastern Florida Bay, including the gaged and ungaged creeks; (2) West Highway Creek rarely has net-negative flow on a monthly basis; (3) McCormick Creek had net-negative flow for water year 1998, following the El Nino event; (4) flow exchange between Joe Bay and Long Sound does occur, and direction of flow is dependent upon water levels in the Taylor Slough and the C-111 Basin; and (5) northeastern Joe Bay shows a direct connection with outflows from S-18C.

The accurate measurements of quantity, timing, and distribution of freshwater flows into northeastern Florida Bay can assist water managers in their endeavors to restore the Everglades to its natural state. Direct field observations accompanied by model predictions will invariably facilitate understanding of the diverse Everglades ecosystem.

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Determination of Resistance Coefficients for Flow through Submersed and Emergent Vegetation in the Florida Everglades

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Indoor flume experiments and field surveys have been conducted to yield unique data sets describing flow through submersed and emergent vegetation at low Reynolds numbers (Lee and Carter, 1999; Lee and Carter, 1997). Hydraulic measurements were conducted concurrently with vegetation sampling surveys to provide the data needed to determine the correlation between frictional resistance and vegetative characteristics (Carter et al., 1999; Rybicki et al., 1999). In addition, an innovative method for measuring the extremely small water-surface slope has been developed (Lee et al., 2000). The objectives of the present effort are as follows: 1) to determine the flow resistance due to vegetation for each of the plant communities sampled in the laboratory and field surveys; 2) to derive equivalent Manning's n functions to quantify frictional resistance for the specific vegetation types surveyed; and 3) to examine the role of upscaling on the derived Manning's n values. Future USGS research will correlate the flow resistance to specific physical characteristics of the plants. This future work will permit flow resistance to be predicted from generalized functions, rather than requiring physical surveys in each plant community.

Fluid moving through an array of erect objects is commonly characterized by the "stem" Reynolds number, $Re_D = DV/\nu$, where D is the average spacing of the objects, V is the discharge velocity, and ν is the kinematic viscosity. Preliminary analyses indicate that the laboratory and field data have stem Reynolds numbers in the range 10 to 400. Let us consider what is known about the flow regime in this range (Churchill, 1982): For an isolated erect cylinder in a horizontal flow field, flow is laminar for $Re_D < 150$; For $6 < Re_D < 44$, separation occurs behind the cylinder creating a recirculation zone in the lee of the object; For $44 < Re_D < 150$, organized vortex shedding is observed; For $150 < Re_D < 30000$, a turbulent wake forms. In a multi-cylinder array, the limits of these different regimes are different because of wake interference, sheltering, and tortuosity. Nonetheless, the range of Re_D experienced in the Everglades data suggests that the flow regime varies from laminar to transitional, but does not become fully developed turbulent flow, as is commonly assumed for open channel flow. Other researchers suggest that laminar flow in a multi-cylinder array occurs for $Re_D < 200$ (Nepf, 1999).

The conceptual model of a multi-cylinder array is useful for advancing the analysis of flow through submersed and emergent vegetation to a certain point. Yet the vegetation array is much more complex. The vertical variation of the plant form and the vertical variation of the plant population density affect the flow field. The velocity profiles observed in the laboratory and field studies are very different than what is typical for open channel flows, and than what has been suggested for uniform multi-cylinder arrays. These observations indicate that the historical use of Manning's n to describe the flow resistance of heavily vegetated environments is inappropriate. One goal of this work is to identify a simple and useful function for specifying the resistance factor for each plant community sampled in the field survey. Resistance coefficients such as the Darcy-Weisbach friction factor or the average stem drag coefficient may be more suitable than Manning's n for this purpose. An approximation of Manning's n for use in Everglades hydraulic routing models can be derived for either of these.

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Uncertainty Analysis of Regional Simulation Models

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Parameter uncertainty, combined with input uncertainty and algorithm uncertainty are responsible for total model uncertainty. Regional hydrologic models for South Florida use large numbers of distributed parameters such as ET crop coefficients and flow roughness which change with local natural conditions that cannot be determined with precision. Model outputs also depend on topographic elevations, river widths, detention depths and other features that are not precisely known. Total model uncertainty is an important component needed in project risk analysis or project return analysis.

In a regional model, the spatial variability of input and parameters add to the complexity of the evaluation of total model uncertainty. Rainfall and land use type are two of the variables that are extremely variable spatially, specially in urbanized settings of South Florida. Traditional methods using linearized approaches may not be the most suitable under these conditions. Methods such as the first order method, the Rosenblueth method and the Latin Hypercube sampling (LHS) method have limitations when used as lumped parameters. The paper describes some of the methods useful in carrying out model uncertainty analysis.

Since the use of complex computer models directly in a project is not a simple task, indicator regions and indicator periods have become first useful tools in extracting information from hydrological models before used in design and evaluation. Indicator regions defined for South Florida have helped to simplify complexities associated with spatial and temporal variabilities in model solutions, and their uncertainties. The discussion includes implications of using such regions.

In addition to the uncertainty analysis of hydrologic models, uncertainty analysis of the association of hydrology to conditions such as flood damage, ecology and species survival are also important in project design. These have to be determined by experts in the respective disciplines. Performance measures developed for various indicator regions in South Florida have become useful in fulfilling few of these functions needed for risk analysis. As mentioned earlier, since project design and evaluation also depend on uncertainties associated with ecology, plant growth, species survival, etc., more extensive and sophisticated use of performance measures is needed to take into account the overall risk or return of a project. The paper includes suggestions to improve some of the available methods.

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Ground-Water Discharge to Biscayne Bay

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One of the main goals of Everglades restoration is to "get the water right" by modifying the existing canal network and management operations. There is concern that the modifications could adversely affect salinities in Biscayne Bay, which hosts a wide range of estuarine organisms. To evaluate the effects of the modifications on Biscayne Bay, the U.S. Army Corps of Engineers is constructing a hydrodynamic circulation model. To achieve a reasonable calibration, the model requires the accurate specification of freshwater discharges to the bay. The two most important mechanisms for freshwater discharge to Biscayne Bay are thought to be canal discharges and submarine ground-water discharge from the Biscayne aquifer. Canal discharges are routinely measured and recorded, but few studies have attempted to quantify the rates and patterns of submarine ground-water discharge. In 1996, the U.S. Geological Survey initiated a project, in cooperation with the U.S. Army Corps of Engineers, to quantify the rates and patterns of submarine ground-water discharge to Biscayne Bay. These rates have been incorporated into the circulation model, which is currently under development by the Corps.

To quantify rates and patterns of submarine ground-water discharge, field studies were combined with numerical modeling techniques. The field studies were performed at three transects: Coconut Grove, Cutler Ridge, and Mowry Canal. At each transect, monitoring wells were installed inland and offshore to characterize the interface between fresh and saline ground water. Data from the offshore monitoring wells indicate that ground water beneath Biscayne Bay has relatively low salinity values along the coast. At distances of about 300 to 500 meters from shore, however, ground-water salinities are nearly equal to seawater salinities. This suggests that most of the ground-water discharge is confined to a narrow band along the coast. The salinity data also support the conceptual model of cyclic ground-water flow within the freshwater/saltwater interface being driven by density variations.

Ground-water discharge rates to Biscayne Bay were quantified by constructing variable-density ground-water flow models that use the assumption of an equivalent porous medium. The models were developed with a code called SEAWAT, which is a combination of MODFLOW and MT3D. The numerical models were constructed at the local and regional scales. Local-scale models were developed and calibrated using the field data collected at the Coconut Grove and Cutler Ridge transects. Results from the local-scale models were used to guide the development and calibration of the larger, regional-scale model. The regional-scale model covers most of Miami-Dade County and represents the period from January 1989 to October 1998. The model includes the following hydrologic stresses: recharge, evapotranspiration, canal interaction, interaction with surface water in the Everglades, municipal well fields, and ground-water discharge to Biscayne Bay.

Results from the regional-scale model provide important information about the rates and patterns of ground-water discharge to Biscayne Bay. The model results suggest that ground-water discharge rates are probably 3 to 10 percent of the total discharge from the coastal canals. The results also suggest that most of the ground-water discharge to Biscayne Bay occurs along the northern half of the coast, where the Atlantic Coastal Ridge is directly adjacent to the bay. Ground-water discharge rates for southern Biscayne Bay are nearly zero because the low-lying areas prevent the water table from rising more than a few tenths of a meter above sea level. The importance of tidal canals also was highlighted by the model. Simulated ground-water discharges to the tidal portions of the Miami, Coral Gables, and Snapper Creek Canals are similar in magnitude to submarine ground-water discharge.

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Five-Year Incremental Analysis of Lower East Coast Regional Water Supply Plan

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The Lower East Coast (LEC) planning area covers much of South Florida including (a) the heavily urbanized areas of Miami-Dade, Broward, and Palm Beach counties; (b) Lake Okeechobee Service Area (LOSA) which includes the Everglades Agricultural Area (EAA), Caloosahatchee River and St. Lucie River watersheds, and other basins around Lake Okeechobee; and (c) the remaining natural areas of the original Everglades including the Water Conservation Areas and the Everglades National Park. The region covered by the LEC planning area faces many challenges to provide adequate water supply for meeting growing urban demands, changing agricultural demands, and needs of the environment through the year 2020. The Lower East Coast Water Supply Plan (LECRWSP) was developed through an extensive process lasting many years and involved stakeholder participation and computer modeling of numerous alternatives. It is integrated with many other plans, and in particular, the Comprehensive Everglades Restoration Project (CERP) including the Water Preserve Areas (WPA). Structural and operational components of the CERP formed the foundation for the development of the LEC Regional Water Supply Plan.

Extensive hydrologic modeling of the planning alternatives was conducted using the South Florida Water Management Model (SFWMM). As one of the final tasks of the plan development, an analysis was made to understand how the entire LEC system performed in the interim period between now and 2020. Incremental snapshots in 2005, 2010, and 2015 were selected and simulated to determine the performance of the plan with partial completion of the CERP and LECRWSP projects every five years. Each snapshot, developed using the components that were scheduled to be complete and fully operational by the end of each five-year period selected, was modeled using the SFWMM, and an extensive set of performance measures were evaluated. These performance measures address restoration goals, minimum flows and levels, and the water supply planning criteria specified in the state legislation enacted recently.

The analysis demonstrated the problems that could be created by the increase in demands prior to the complete implementation of CERP and other LECRWSP components. Possible alternatives to address such problems during the early period of the 20-year planning horizon were suggested and analyzed. The analysis also led to several improvements that should be considered in the future implementation of projects associated with the CERP.

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Sound-bite Hydrology

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Throughout the process of developing an Everglades Restoration Plan, many sound-bites have been used to promote a certain point of view. Sound-bites are often simplistic and may accurately characterize a particular aspect of the plan. Unfortunately, some sound-bites – while effective – is also grossly inaccurate from a hydrologic standpoint. Examples of some common sound-bites, as applied to the Comprehensive Everglades Restoration Project, will be provided and evaluated for accuracy. Some new sound-bites will be presented.

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A Retrospective and Critical Review of Aquifer Storage and Recovery Sites and Conceptual Frameworks of the Upper Floridan Aquifer in Southern Florida

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Regional aquifer storage and recovery (ASR) in southern Florida is proposed as a cost-effective water-supply alternative that can help meet needs of agricultural, municipal, and recreational users and help provide Everglades ecosystem restoration. The Restudy of the Central and South Florida Project plans to utilize about 300 ASR wells in southern Florida. ASR technology has been tested and implemented in some areas of southern Florida; ASR wells have been constructed at 24 sites in an area that extends southward from Charlotte, DeSoto, Glades, Okeechobee, and St. Lucie Counties, and wells are planned (or are in the permitting process) at five additional sites. A pilot ASR facility currently is under construction by the South Florida Water Management District on the Hillsboro Canal in southeastern Palm Beach County. Three ASR facilities are operational.

Existing and historical ASR sites in southern Florida have mostly been located along the east and west coast. At most of these sites, the recovered water is being used, or planned to be used, as additional water supply for local municipalities. However, the Restudy plans to locate wells in more inland area such as around Lake Okeechobee, in central Palm Beach County, and along the Caloosahatchee River in Lee, Glades, and Hendry Counties; the recovered water will be used for additional purposes including maintaining water levels in wetland areas. The source water planned for the Restudy ASR program is untreated or minimally treated ground water or surface water. The injection interval being used at most sites is the Upper Floridan aquifer, which is in the Floridan aquifer system, and is underlain by the middle confining unit and Lower Floridan aquifer.

Few regional investigations of the Floridan aquifer system hydrogeology in southern Florida have been conducted, and the focus of those studies often addressed separate and unrelated issues. Lacking a regional ASR framework to aid the decision-making process, ASR well sites in southern Florida have been primarily located based on factors such as land availability, source-water quality, and source-water proximity (preexisting surface-water canal systems or surficial aquifer system well fields). Little effort has been made to link information collected from each site into a regional hydrogeologic analysis. Additional tools and data are needed to make informed decisions that incorporate constraining hydrogeologic factors in the placement and construction of ASR facilities in southern Florida.

Important hydrogeologic and construction related attributes are being determined for each ASR site, and these attributes are being plotted on maps for the purpose of a comparative analysis of differences between the ASR sites. Hydrogeologic attributes include aquifer transmissivity and degree of confinement, native ground-water salinity, and the structural setting of the site. Construction related attributes include placement of the injection zone relative to the top of aquifer and the diameter and thickness of the injection zone, which in most cases, is an open hole interval below the final casing. Published hydrogeologic frameworks of the Floridan aquifer system in southern Florida are being reviewed and refined in order to relate ASR well sites to a regional scale.

Historical and current data on ASR cycle testing at each site are being assembled, and the recovery efficiency, if not clearly defined or substantiated in a report, will be evaluated. The recovery efficiency will be related to the hydrogeologic and construction related attributes listed above to identify common threads, technical issues, or potential problems that have been encountered and that influence the level of success of ASR. Data collected so far indicate that some important problems are injection zones with a transmissivity that is too high due to fractured dolomite, transmissivity that is too low, ambient ground-water salinity that is too high, and casing that has been set too deep within the aquifer resulting in the loss of injected water. Sites that are located in structural depressions could also be problematic.

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USDA- Everglades Agro-hydrology Computer Model- Interaction of Surface and Subsurface Water Flow

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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. Over 23,000 people are directly involved in the county's highly efficient agriculture. Agricultural production in south Florida is very vulnerable to flooding. For instance, during Tropical Storm Gordon in 1994, it was estimated that about 17 percent of the agricultural area was adversely affected by flooding with an estimated $89 million lost due to the storm (Moseley, 1990). Seepage and surface runoff from agricultural areas may contain nutrients, pesticides and other chemicals, and non-point source water pollutants resulting from agricultural areas have been implicated as a source of water quality degradation in southern Biscayne Bay. In 1996, the United States Environmental Protection Agency published an interim report on South Florida Ecosystem Assessment (EPA, 1996). The report stated that the nutrient loading from agricultural and urban areas had significantly increased nutrient concentrations, particularly phosphorus at the ENP. They further reported that discharging phosphorus at the current control target of 50ppb would continue to allow eutrophication of over 95% of the Everglades marshes (EPA, 1996). Nutrient-enriched waters from agricultural runoff affects vegetation types and patterns of plant growth.

A farm scale, deterministic model called the Everglades Agro-Hydrology Model (EAHM) is currently under development for south Florida. This model is process-based and deterministic, and will simulate processes such as evapotranspiration (ET), percolation, plant growth, infiltration, soil erosion, and the movement of agricultural chemicals within the soil profile. The EAHM will enable land users and regulatory agencies to evaluate, predict, and extrapolate possible hydrologic impacts on agricultural production resulting from the proposed Everglades Restoration Plan. The EAHM will be an upgrade from the United States Department of Agriculture (USDA)-Water Erosion Prediction Project (WEPP) model (USDA, 1995). This upgrade will include the addition of 1) fate and transport of agrochemicals; 2) plant growth stress, due to nutrient deficiencies and flooding; 3) EAHM and regional model linkage using GIS; 4) improved rainfall/runoff relationships; and 5) simulated effects of upward flux from the shallow groundwater table that exists in the region. The water balance of the model including the upward flux routine was tested using soil water and evapotranspiration data from agricultural area near the Everglades National Park.

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Quantification of Ground-Water Seepage beneath Levee 31N, Miami-Dade County, Florida

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A method to quantify the exchange of water between surface-water channels and the ground-water aquifer based on the concept of reach transmissivity was evaluated for use in numerical models. Linking ground-water and surface-water models to each other is frequently problematic because the two models use different sets of governing equations; additionally, the time-scale of interest is often significantly longer for ground-water modeling than for surface-water modeling.

Currently, the formulation of the most common method used for leakage calculations assumes vertical flow of water through a low permeability layer at the bottom of the surface-water channel. The mathematical formulation of this relationship is based on Darcy's law and may be expressed as follows:

$$q = \frac{k'}{b'} B(Z - h) \qquad (1)$$

where

- q is leakage to the aquifer from the channel (volume of water per unit channel length per unit time),
- k' is hydraulic conductivity of the low permeability layer of the channel bottom,
- b' is thickness of the low permeability layer of the channel bottom,
- B is top width of the channel,
- Z is surface-water elevation in the channel,
- h is piezometric head directly beneath the channel bed.

In the reach transmissivity leakage relationship, the flow resistance is based on the transmissivity of the aquifer, and the reference ground-water head is measured at points located a distance *L* from the center of the channel:

$$q = \frac{T_R\left(Z - h_R\right)}{L_R - \frac{B}{2}} + \frac{T_L\left(Z - h_L\right)}{L_L - \frac{B}{2}} \qquad (2)$$

where *T* is the transmissivity of the aquifer and the subscripts *L* and *R* designate the left and right sides of the channel, respectively.

Differences between the vertical flow and reach transmissivity relationships were examined. The input parameters required for the reach transmissivity relationship are easier to obtain from published sources than those required for the vertical flow relationship, which must be established through model calibration or site-specific sampling. The reach transmissivity relationship also calculates leakage to each side of the channel separately, and its parameters are less dependent on model grid spacing.

The derivation of a form of the reach transmissivity relationship that is suitable for use in numerical modeling relies on the following assumptions: steady state conditions, full penetration of the aquifer by the channel, and the Dupuit-Forcheimer assumption. These assumptions may preclude use of the reach transmissivity relationship in certain conditions, such as when very short time steps are used in a numerical model. Methods were developed to quantify the error associated with use of the reach transmissivity relationship to simulate both periodic and aperiodic transient conditions; these methods can be used to evaluate the suitability of the reach transmissivity relationship for a particular application. Leakage calculations based on the reach transmissivity relationship were compared to measured leakage on the L-31N Canal; differences between the calculated and measured data had approximately the same magnitude as measurement errors in the gaging data. In addition, leakage calculated using the reach transmissivity relationship matched the measured data better than leakage calculated using the vertical flow relationship.

The equations associated with the reach transmissivity relationship were developed in finite-difference form and incorporated into a modified version of MODBRANCH, a numerical flow model that couples a ground-water model (MODFLOW) and surface-water model (BRANCH). The modified program was then tested and judged to have functioned satisfactorily for three problems with analytical solutions and one problem that had previously been solved with the original version of MODBRANCH. Additionally, the modified model required only about 60 percent as many iterations as the original model.

A model using both the vertical flow and reach transmissivity versions of MODBRANCH was developed for a region centered on Levee 31. The model grid consisted of 49 rows, 58 columns, and 6 layers. Row and column spacing was 500 ft near the center of the study area and 1,000 ft elsewhere. The top layer was assigned a hydraulic conductivity of 3,000,000 ft/d to simulate the wetlands environment; the hydraulic conductivities of the other layers were based on geologic properties of the surficial aquifer. The model was run to simulate transient conditions throughout a calendar year. Ground-water boundary conditions consisted of interpolated heads obtained from the perimeter of the study area; initial conditions were obtained by interpolation, using an inverse distance method, of measured heads at the beginning of the simulation. Evapotranspiration and recharge were obtained from measured data. Potential evapotranspiration was constant throughout the model area, and the extinction depth was specified as 20 ft, based on previous research. Recharge was obtained from three rain gages within the study site and was spatially variable. A 6-mi reach of the L-31N Canal was simulated by BRANCH; boundary conditions consisted of specified head and discharge at the upstream and downstream ends of the channel, respectively.

The computer model of the Levee 31N area was first run using the existing version of MODBRANCH (with the vertical flow relationship) and calibrated by varying aquifer hydraulic conductivity and the vertical flow leakage coefficient. Calibration was based on data from the 1996 calendar year. The model was found to be more sensitive to changes in the aquifer hydraulic conductivity than in the leakage coefficient. The overall transmissivity of the surficial aquifer was calibrated to 1.4×10^6 ft/d, and the vertical flow leakage coefficient was established as 0.0009 s^{-1}; both results were similar to those of previous studies.

The version of MODBRANCH modified to use the reach transmissivity relationship was then calibrated with the aquifer hydraulic conductivities previously obtained using the vertical flow relationship. There were no large differences between results modeled using the vertical flow and reach transmissivity leakage relationships. The mean annual modeled ground-water heads differed by only 0.02 ft, and the mean yearly modeled canal discharges varied less than 1.0 ft^3/s. The vertical flow and reach transmissivity models' output provided coefficients of determination (R^2) values within 0.03 of one another for mean ground-water head, canal stage, and canal discharge within the study area. The reach transmissivity version of MODBRANCH, however, reached a solution in about 40 percent fewer iterations.

An estimation of seepage beneath Levee 31N was obtained by summing the MODFLOW cell-by-cell flow terms for all layers of model cells directly west of the levee. These values were converted to a seepage rate per foot of distance along the levee, yielding mean values of 198.9 ft^3/s and 179.1 ft^3/s per foot of levee for 1996 and 1997, respectively.

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Development of Numerical Tools for Defining Wetland Hydrologic Processes: SICS and TIME

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To delineate the hydrologic processes that control the results of restoration efforts, the local information derived from field studies is integrated using a numerical model that provides a mathematical evaluation of the flow regime. The SWIFT2D hydrodynamic model, as applied to the interface between the southeastern Everglades and Florida Bay, is referred to as the Southern Inland and Coastal Systems (SICS) model. The model domain was chosen to correspond with the coastal area of Florida Bay that is the focus of restoration efforts and intensive hydrologic field studies that, in part, involve the parameterization of controlling processes. Another application is currently under development for a much larger area, incorporating most of Everglades National Park (ENP). This application is referred to as the Tides and Inflow in the Mangrove Ecotone (TIME) model. The expanded TIME model will also include a ground-water model with a dynamic link to the surface-water model.

One of the most impressive qualities of the SICS model is that the field process studies are extensive enough to provide nearly the entire input data set. In most cases of model development, calibration is necessitated by the absence of field information. In the SICS model, an unprecedented amount of input information has reduced the calibration need to a minimum. The SWIFT2D code was modified to allow the computation of evapotranspiration rates for each model cell. A study of evapotranspiration in various wetland environments indicates that it is possible to regionally defining the Priestly-Taylor α coefficient as a function of solar radiation and water depth. Using this formulation of α and a least square fit of α, water depth, and solar radiation to field measured evapotranspiration, the SICS model computes cell-by-cell evapotranspiration rates using only regional solar radiation data as input. Although approximated by the least squares fit, this computation of evapotranspiration provides a robust and practical method for defining an important parameter that can be difficult to quantify.

The frictional resistance coefficient is a crucial surface-water parameter, and is usually estimated or used as a calibration tool. This is because little real data usually exists to determine friction effects. However, in the SICS model area, where frictional resistance in wetland flow is a function of vegetation type, airborne and ground methods were used to delineate vegetation types in the study area. Another study used a laboratory flume and field measurements to relate vegetation type to frictional resistance. Thus, frictional resistance terms are defined spatially in the model without any calibration effort. Through the variety of vegetation types, the average Manning's *n* values are all near 0.4 for typical flow depths.

Because the large-scale topography is so flat, small variations in land-surface elevation can substantially affect the wetlands flow regime. An extensive data set of land surface elevations was collected in the SICS area by the U.S. Geological Survey Mapping Division. In addition, research projects have yielded data for wind friction effects on flow, distributions of ground-water inflows, salinity boundaries, coastal creek outflows, and wetland flow velocities.

The initial SICS model simulation period was 3 weeks. The model performed well, successfully matching measured coastal creek flows and unit discharges measured by mobile velocity meters in the wetlands. This success indicates that the input parameters developed from the process studies were probably accurate and correctly defined their hydrodynamic effects. In particular, the simulation demonstrates how wind can cause flow reversals at the coastal creeks.

The next simulation period was from August 1, 1996 to February 28, 1997, which allowed for a more extensive 7-month prediction of coastal flows and coastal salinities. This run also indicated the ability to match measured water levels at stations in the wetlands. An uncertainty analysis was performed on this run, and the coastal creek frictional resistances were identified as having the greatest uncertainty, followed by wind friction terms and ground-water inflows. These findings have motivated further efforts: multiple stage and flow stations on Taylor River to compute the creek frictional coefficient; laboratory research on wind friction in wetlands with emergent vegetation; and the coupling of SWIFT2D with the ground-water flow and transport model SEAWAT. Thus, the model is developed with field information, and the model results guide further data collection.

The 7-month simulation also is useful for testing management scenarios for restoration. The model-produced effects of increasing flow at Taylor Slough Bridge by 50 percent. The model results indicate that the volumes from local rainfall have a greater effect on water levels than do flows at Taylor Slough Bridge. For this particular scenario, the effects of Taylor Slough Bridge flows on water levels are only significant in the northern areas, where there is a noticeable shift in the location of the 1.0-foot water level contour.

To develop a model for observing long-term phenomena, the 7-month run was extended to 2 years. This longer time span allows: (1) adequate output data to supply water-level data for the Across Trophic Levels System Simulation (ATLSS) model of biological processes in the Everglades, and (2) improved tracking of waters entering the study area to their destinations.

The TIME model will include the area shown extending to the western coast. The western areas have received far less field study and hydrologic data collection than the SICS study area. New data collection for the western area includes: continuous acoustic measurements of coastal flows and wetland flow velocity; airborne mapping of topography; and collection of ground-water levels and salinity. The SWIFT2D model is being linked explicitly to the SEAWAT variant of MODFLOW, which allows for density-dependent transport of constituents. This coupled model is referred to as Flow and Transport Linked Overland-Aquifer Density-Dependent Simulator (FTLOADDS); it simulates flow and salinity exchange between the surface water and ground water. The explicit linkage requires that either the exchange of ground-water heads generated by SEAWAT to SWIFT2D or leakages generated by SWIFT2D to SEAWAT be lagged in time. Given the likelihood that leakages vary on a more rapid basis than ground-water heads, it was decided to compute leakages in SWIFT2D based on ground-water heads from the previous time stress period. With the expanded model area, the ground-water/surface-water coupling, and the expanded field data, the TIME model will improve on the SICS model's ability to answer restoration questions.

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Long-Term Daily Evapotranspiration Estimation in South Florida

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Hydrologic models have been, and will continue to be, used extensively to evaluate the effects of different Everglades restoration alternatives. Hydrologic models applied to the greater Everglades region of southern Florida are particularly sensitive to rainfall and evapotranspiration inputs to the models. The Penman-Monteith method has been widely used to estimate daily reference evapotranspiration in South Florida. Limitations in the availability of long-term meteorological data, needed in the Penman-Monteith method, have necessitated the use of surrogate data such as cloud cover in lieu of measured solar radiation and the use of average data where data are missing.

Data and methods used to estimate the 31 year (1965-1995) daily record of reference evapotranspiration, used in several hydrological modeling applications in southern Florida including the South Florida Water Management Model and the Natural System Model are documented. Application of the Hargreaves and Samani (1982) and Allen (1997) methods to estimate solar radiation from extra-terrestrial radiation and air temperature are shown to illustrate their potential to improve surrogate date used in Penman-Monteith long term daily evapotranspiration estimates.

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Simulation of the Anthropogenic Impacts to the Regional Climatic Patterns of Central and Southern Florida

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Abstract

Recent atmospheric simulations indicate that artificial microclimates have been induced by anthropogenic landscape modifications. In many areas the local "heat island" circulations have overtaken the larger scale trade wind/sea breeze weather regime. These heat islands create aberrant surface wind convergence patterns which concentrate rainfall along strong, artificial horizontal gradients in surface heat and soil moisture. Thus, the mesoscale rain and water transport cycles have been drastically interrupted. A significant portion of the rainfall has shifted offshore with a rapid decline in rainfall occurring over the Florida peninsula in the past decades. It remains to be seen whether the damage that mankind has inflicted upon this delicate ecosystem can be reversed through macro-scale engineering projects and urban planning in time to save it.

The Center for Analysis and Prediction of Storms' (CAPS) Advanced Regional Prediction System (ARPS) cloud-/mesoscale atmospheric numerical weather prediction model has been applied to simulate persistent, locally-forced weather regimes which generate thunderstorm complexes over the Everglades and coastal areas. These micro-scale systems account for roughly one-third of Florida's annual rainfall. The atmospheric model's moisture physics and surface energy parameterizations allow the prediction of precipitation, temperature, evapotranspiration at high resolution. A valuable capability of the ARPS model is its ability to generate detailed horizontal maps of evaporation - at the ground surface, from the fraction of foliage covered by intercepted rainfall, and from transpiration by leaves. Its two soil-layer force/restore surface energy parameterization, which includes multiple categories of soil and vegetation/land use, allows the prediction of evaporation as a by-product of the calculation of radiation/temperature and the vertical flux of water vapor, the latter being a function of the wind speed and surface-to-air moisture gradients. By selectively reverting isolated areas of urbanization and drainage to their "natural system" (circa 1900) state, then comparing the results of the atmospheric simulations against their "present day" counterparts, distinctive microclimates (urban heat islands and associated shifts in the rainfall distribution) which have emerged over the past century can be identified. The impact of proposed restoration modifications to the surface sheetwater/groundwater flows (such as more evenly spreading the water over the Water Conservation Areas to create a more natural overland flow southward) and the future urbanization/development of pristine areas can also be simulated and quantified.

One of the most intriguing potential applications of this numerical modeling approach is the prediction of the environment's response to alternative anthropogenic planning actions. These may include development/urbanization of pristine areas and the restoration of natural habitats. It is well known, from previous meteorological modeling studies, that landscape discontinuities can generate strong mesoscale circulations which alter the spatial and temporal distribution of regional scale rainfall. South Florida's

quiescent, sensitive tropical climate is dominated by locally-forced (sea/land/lake breeze) weather regimes. Horizontal variations in vegetation can profoundly impact the water cycle through evapotranspiration.

The drainage and cultivation of the Everglades Agricultural Area (EAA) south of Lake Okeechobee for growing sugar cane may seem like an innocuous, even appropriate, use of the land. However, the replacement of standing water within the EAA allows for the rapid soil heating and drying of the soil. This has created a "hot spot" at the ground surface that causes abrupt divergent deflections of the winds over the lake. The maximum rainfall associated with lake breeze thunderstorms, has shifted from its natural position, east of Lake Okeechobee, to its modern day location at the lake's southern shore. Thus, decisions to drain the Florida Everglades' "muck" soil (which tends to resist evaporation and heating due to its high water retention and strong capillary forces) must be made carefully under scientific guidance, with consideration for landscape features nearby. Otherwise, unintended microclimates might be generated that can shift the evaporation/precipitation patterns to other geographical locations. If a significant fraction of the rainfall is diverted offshore by coastal development, as recent studies indicate, then the ecosystem is depleted of valuable fresh water. If this disturbing trend continues, there will be little excess storm water over the Florida peninsula to pump into underground storage aquifers, as is called for in the Florida Everglades Restoration Program.

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Establishing Minimum Water Levels for the Everglades

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This report documents the methods and technical criteria used by staff of the South Florida Water Management District (SFWMD) to develop proposed Minimum Flows and Levels (MFLs) for the Everglades. The "Everglades" includes the Water Conservation Areas, the Holeyland and Rotenberger Wildlife Management Areas, and the freshwater regions of Everglades National Park.

Section 373.042 (1), F.S., defines the minimum level as the "...level of ground water within an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area..." Water resource functions protected under Chapter 373 are broad and include flood control, water quality protection, water supply and storage, fish and wildlife protection, navigation, and recreation. Passage of additional MFL legislation in 1997 added the requirements to consider changes and structural alterations, allow exclusions, and require development of a recovery strategy for water bodies that are not expected to meet the proposed criteria. During development of MFL criteria for the Everglades, a number of structural changes or alterations were considered, along with the constraints such changes have placed on regional hydrology.

Surface water management and consumptive use permitting regulatory programs must prevent **harm** to the water resource. The hydrological criteria include level, duration, and frequency components and are used to define the amount of water that can be allocated from the resource. For purposes of establishing MFLs, **significant harm** is defined as loss of water resource functions that takes multiple years to recover, which result from a change in surface water or ground water hydrology. Water shortage declarations are designed to prevent **serious harm,** interpreted as long-term, irreversible, or permanent impacts, from occurring to water resources.

MFL criteria and definitions of significant harm were developed based on the water resource functions of and technical relationships of these functions to water levels. The SFWMD was directed to use the best available information to establish a minimum flow or minimum level and define significant harm (Section 373.042, F.S.).

The Everglades is an internationally recognized ecosystem and is the largest subtropical wetland in the United States. Today's Everglades is comprised of five Water Conservation Areas (WCAs), the Holey Land and Rotenberger Wildlife Management Areas (WMAs) and Everglades National Park. Minimum level criteria and definition of significant harm for the Everglades were based on protecting six water resource functions: a) providing recharge to protect the Biscayne aquifer, b) supporting Everglades ecosystems, c) providing natural biological filtering and nutrient cycling, d) providing refugia for aquatic wildlife, e) preventing invasion by undesirable species, and f) maintaining desired salinities in coastal estuaries. Everglades water levels are managed based on regulation schedules in the WCAs and a rainfall based water delivery plan for Everglades National Park.

Minimum water level criteria for the Everglades were based on results of a literature review, historical water level and fire data, and data from a mathematical computer model. Technical relationships for the Everglades included analysis of the effects of water levels on hydric soils, plant and wildlife communities, and frequency and severity of fires. Everglades "no harm" standards were derived from model simulations for the year 2020 that included implementation of the Comprehensive Everglades Restoration Plan. Impacts associated with significant harm include increased peat oxidation, frequency of severe fires, soil subsidence, loss of aquatic refugia, loss of tree islands; and long-term changes in vegetation or wildlife. The proposed minimum water level criteria for the Everglades considered the two dominant soil types as follows:

Water levels within wetlands overlying **organic peat soils** within the WCAs, Rotenberger and Holey Land WMAs, and Shark River Slough (Everglades National Park) should not fall 1.0 feet or more below ground level for more than 30 days, at specific return frequencies for different areas, as identified in this report.

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, at specific return frequencies for different areas, as identified in this report.

Research programs proposed for the Everglades include studies of soils, peat accretion, nutrient thresholds, plant and animal communities, and methods to improve regional models. Additional research is needed in Florida Bay to study sediments, salinity, seagrass and plankton models, and fish communities.

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Object-Oriented hydrologic simulation models for South Florida

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An effort is underway to develop new hydrologic simulation models using modern technologies such as Object Oriented programming with high-level languages like C++. Some goals of this effort are to produce reusable code modules, enable faster modifications, and to isolate components from unwanted side-effects and dependencies. Traditionally, many hydrologic analysis models have been written using a monolithic procedural approach to structuring the code. There are a number of problems associated with this strategy including strong coupling between different code modules, and an inability to comprehend portions of the code in isolation.

Our experience with Object Oriented Programming have shown some of the desired benefits, but also highlighted a number of hurdles to overcome. As one of the benefits, it has become possible to couple various models much easier than previously thought, because new object oriented design methods make it possible to do so. As hurdles, institutional inertia in resisting change, and retaining skilled personnel are just two. A large amount of long term planning is also required at the beginning of a project. The paper discusses about some of the object oriented design concepts that are found to be most valuable in designing models for South Florida.

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Using a Salinity Model for Biscayne Bay to Assess Salinity Variations Resulting from Alterations in Freshwater Inflows

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The restoration of the Everglades is linked to an extensive reevaluation of the management of surface and groundwater in South Florida from the Kissimmee River Basin and south. A number of objectives have been proposed for a modified water management plan for south Florida, many of which are competitive in nature, such as providing more water to Shark River and Taylor sloughs, assuring water supply needs well into the twenty-first century, maintaining flood control, and enhancing the distribution and quantities of flow to estuarine environments including Biscayne Bay.

Situated between the terrestrial Everglades system and the unique offshore coral reefs, Biscayne Bay interacts with and links these systems. In recognition of its ecological values and its economic importance to the south Florida population, Biscayne Bay was designated an aquatic preserve and more recently a national park to afford long term protection to its delicate ecosystems, especially its primary communities: the mangrove fringe, the seagrass beds and the hard bottoms. The health and function of these communities are sensitive to salinity and its variability and therefore to changes in the freshwater inflows.

A numerical hydrodynamic model has been developed and calibrated to predict salinities in Biscayne Bay from freshwater inflows arriving as canal discharge, surface sheetflow, groundwater, and effective rainfall (precipitation minus evaporation). The model numerically solves the vertically integrated 2-dimensional equations of motion coupled with the advection-diffusion equation for salt and an approximate equation of state used to derive density from salinity. A finite element method using linear triangular elements is used. The total number of elements and nodes in the grid are 6364 and 3407 respectively yielding a variable resolution with a minimum grid point separation of approximately 300 m. Numerical stability constrains the model time step to 45 sec.

In addition to the freshwater inflows, the model is forced by tides and wind. The best available data for the simulation period of 1965 to 1995 were recorded at Miami International Airport (MIA). Additional wind records were obtained from the Fowey Rocks CMAN station (FR) for 1995 to 1999. Analysis of the records for the overlapping period of 1995 showed the winds at the two stations to be highly coherent (> 0.8) at all important periods greater than approximately 2 days, with MIA lagging FR only slightly. Wind speeds at FR are significantly higher than at MIA, by as much as 50%, except the diurnal seabreeze is more pronounced at MIA.

Prior to the implementation of the SFWMD's telemetering monitoring network, ca 1994, canal discharge records had frequent and large gaps. Hence, model calibration was carried out for the 4-year period 1995 to 1998 for which fairly reliable data were available. External conditions of tides, wind, and freshwater inflows were prescribed from observations or hydrologic model results. The model-computed salinities were compared to monthly observations at 54 stations distributed within the bay.

To evaluate the effects of proposed restoration alternatives, results from the Water Management Model (WMM) of the South Florida Water Management District (SFWMD) were obtained for two scenarios: the 95 Base case which used the meteorological conditions observed from 1965 to 1995 and assumed the physical configuration and operating procedures existing in 1995; and the scenario known as D13R4, which includes extensive modifications to both operational rules and physical characteristics. Canal discharges obtained from the WMM can be compared to observed discharges however, the groundwater and sheetflow components have never been directly observed and are therefore difficult to validate. Because of the simplifying assumptions in the model regarding the physical characteristics at the shoreline, the model-computed quantities of groundwater and sheetflow to the bay are associated with sizable uncertainties. The results of the salinity model indicate that the WMM model groundwater flows may be as much as an order of magnitude too large, whereas the sheetflow component appears to be in a reasonable range. The results of the model simulations are presented in the form of seasonal mean salinity fields and coefficient of variation and a number of statistical measures are used to gage the salinities resulting from the scenarios and their differences.

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Spatial Simulations of Tree Islands as Ecosystem Indices for Everglades Restoration

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The Florida Everglades is a vast wetland dotted with diverse tree islands. It is a uniquely difficult wetland to manage due to competing urban, agricultural and environmental water demands. Tree islands in certain sections of the Everglades have experienced altered hydroperiod due to water management practices. This altered hydroperiod has at times caused tree island vegetation to die. This study investigates whether an observed trend in tree island loss is reversible and if tree islands can be used as performance measures or ecological indicators for the success of Everglades restoration actions. The Everglades Landscape Vegetation Model (ELVM) was developed and designed to be a tool to understand the spatial and temporal interactions among vegetation, water, fire, and nutrients. Simulation results from this model indicate that hydroperiod is a major factor contributing to tree island development and stability in the Everglades. The model suggests that Everglades fires occurring under dry hydrological conditions may cause peat fires, which can cause the loss of tree island in some areas. The model also suggests that ponding water depths greater than 30 cm and hydroperiods longer than 150 days could have an impact on tree island survival. Hence, tree island restoration will depend on water depth and hydroperiod. According to the model, about 60% of lost tree islands could potentially recover naturally or through assisted recovery projects in several decades by restoring the natural hydrological regimes. As a result, tree island health could be used as an indicator to evaluate the effectiveness of various hydrological restoration alternatives in the Everglades.

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Poster Abstracts

Hydrology and Hydrological Modeling

A Spatial Analysis of Seasonal Surface, Soil and Groundwater Salinity Variations from April 1997 to April 2000 Across the Coastal Mangrove-Freshwater Marsh Ecotone, near the Harney River in Everglades National Park

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The hydrodynamics of the tidal cycle, freshwater inflows and local rainfall are the principal physical forces that determine the marsh-mangrove interface or ecotone in the southwestern coastal region of Everglades National Park. The effects of these physical parameters can be evaluated by measuring water salinity at the ecotone. Our study evaluates salinity variations across the mangrove-marsh ecotone near the Harney River. A 300m boardwalk was constructed to bisect the mangrove-marsh ecotone without significantly impacting the soil and vegetation. Hydrology gauging stations, S4 near the river (30 m) and S5 located in the freshwater sawgrass marsh were installed to continuously monitor surface, soil and groundwater levels (shallow wells) and salinity (specific conductance in *mS*). Along the 300m boardwalk, five regularly spaced, soil pore water sampling sites (SW1-5) were placed. Pore water sites SW1-3 were located near the river bank (SW1) outwardly through the mangrove fringe forest, site SW4 was set in the sawgrass-mangrove interface and site SW5 was placed in the marsh, near site S5. At each soil porewater sampling site, three replicate tubes were installed to sample pore water at 30 cm and 60 cm depths. The pore water has been pumped and evaluated for salinity and temperature every week for the first year and then biweekly for the next two years. Sampling began in April 1997. Here, we report on data through April 2000. Ancillary salinity data was provided by Everglades National Park Harney River stage gaging station (HR), located in the Harney River nearby the transect.

The seasonal variation of water salinity in the Harney River estuary and along the mangrove-marsh transect is primarily caused by diurnal tidal exchange, lunar spring overbank flooding, local rainfall and overland flows across the coastal islands. The salinity data from the seven sites was summarized into monthly averaged salinity values and analyzed with the GIS software, *Arc View*. The monthly averaged salinity data was entered in the GIS software to create a series of grid contours of the transect region for 36 months. Grid contours were created for four data categories: Surface water Salinity using sites HR, S4, S5, and soil sites SW1-5, if surface water was present (n<=7); Groundwater Salinity used S4 and S5 and HR for a salinity contour boundary (n<=3); 30 cm soil water included soil sites SW1-5 , S4, S5 and HR (n<=7); and 60 cm soil water used soil sites SW1-5 and (n<=6). These spatial salinity contour images were created to provide a synoptic picture of the salinity gradients across the ecotone. The contour grid boundaries were set at the riverbank and excluded the river from the transect contouring. The width of the contour was set by the actual transect width to create a narrow contoured corridor. After the contour were created, they were exported in a .jpeg format files and imported into *Microsoft PowerPoint* to create a 36 image slideshow for each of the four salinity groups (142 contour images).

The analysis of the salinity data using the grid contouring for three years indicated several interesting seasonal and spatial patterns and correlations between sites and water types. Foremost, it clearly indicates the seasonal salinity variation follows the Wet (June-October) and Dry (Nov-May) weather pattern of the Everglades. Typically, Harney River salinity rises to 35 *mS* (~ 23 PPT) in April-May and fall to 5-10 *mS* (~ 3-6 PPT) by mid-summer. The greatest salinity value for any of the sites was 45 *mS* (~ 29 PPT) was observed in the 30 cm soil pore water in April-May, 1997. The lowest salinity value of 1.6 *mS* (~ 1 PPT) occurred in Oct 1999. Rainfall of 89 cm (HR) occurred during Sept-Oct, 1999 caused by Tropical Storm Harvey and Hurricane Irene significantly reduced river salinity. Site SW1-3 30 cm and S4 generally correlated well with each other and with HR. HR correlated with SW4-30 cm (R= 0.51), but significantly less with SW4-60 cm (R= 0.25). Site SW5-30 cm indicated a (R=0.39), and no significant correlation SW5-60 cm and HR (R= -0.11). Site S4 surface, groundwater and soil salinities were highly correlated (R=0.99) to each other. HR salinities also strongly correlated to S4 (R=0.86). However, Site SW 1, located between S4 and HR did not correlate as well (HR/SW1-30 cm, R=0.61; HR/SW1-60 cm, R=0.39) as site SW2 with either HR or S4, (HR/SW2-30 cm, R=0.75; HR/SW2-60 cm, R=0.49). Site S5 surface, and soil salinities indicated a (R=0.68), and (R=0.43) respectively to S5 groundwater salinity. Site S5 had a (R= -0.52) correlation with local (HR) rain data.

The use of GIS grid contouring provides a useful interactive analysis tool to evaluate the hydrodynamics of surface, ground and pore water salinity across the mangrove-marsh ectone; especially when used in an animated times-series.

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Interrelation of Everglades Hydrology and Florida Bay Dynamics to Ecosystem Processes and Restoration in South Florida: Regional Simulation of Inundation Patterns in the South Florida Everglades

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The ability to quantify changes in water-surface elevations and hence water depths in the southern Everglades, throughout space and time, is fundamental to evaluating both the historical and current hydrologic behavior of the ecosystem and the success of restoration efforts. The low topographic relief yields very small water-surface gradients that produce large fluctuations in the spatial extent of inundation making the ecosystem highly sensitive to regulatory controls. A time series of daily water depths has been generated for the region of the southern Everglades encompassing the Taylor Slough and C-111 wetlands to analyze changes in seasonal inundation patterns and hydroperiods and to evaluate and correlate the response of wetland water levels to local precipitation and regulated structure flows. The time series can be used to validate the performance of flow models guiding restoration efforts and to investigate how wetland sheet flows have been affected by anthropogenic influences.

A land-surface elevation grid was interpolated from topographic data collected by the U.S. Geological Survey (USGS), National Mapping Division, using differential global positioning system technology. Water-level data, from 1995 to present, obtained from the South Florida Water Management District (SFWMD), the National Park Service (NPS) Everglades National Park, and from within the USGS are used to interpolate daily water-surface elevation grids. The water-surface elevations are then subtracted from the topographic surface to produce daily grids of computed water depths. Structure releases and precipitation data were obtained from the NPS, SFWMD, and USGS to aid in the analyses.

Water-depth accuracy is directly correlated to the spatial distribution of hydrologic monitoring stations and to the spatial resolution and accuracy of the topographic data. The spatial resolution of the topographic data is 400 meters and the stated vertical accuracy is 15 cm; however, tests against elevation values published by the National Geodetic Survey for 17 benchmark monuments resulted in an Root Mean Square Error of 4.1 cm. To estimate water-depth accuracy, computed depths were subtracted from depths measured in the wetlands adjacent to the C-111 canal and in Taylor Slough in 1997 and 1999. The standard deviation of the differences between measured and computed water depths was found to be 12 cm.

The simulated time series of regional inundation patterns is used to compare historical and current water depths and hydroperiods in order to isolate temporal changes, particularly as these may have been affected by anthropogenic influences such as the management of control structure releases and the re-engineering of canals. Further analysis is focused on quantifying the response of water-depth to precipitation and control structure releases. Several time series and sample water-depth maps are available at the Tides and Inflows in the Mangroves of the Everglades (TIME) website (http://time.er.usgs.gov).

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Using Time-Series Satellite Imaging Radar Data to Monitor Inundation Patterns and Hydroperiod in Herbaceous Wetlands of Southern Florida

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Knowledge of the components of the hydrologic cycle, including spatial and temporal distribution of water, is critical for regional hydrologic applications. However, at a regional scale, the variations of hydrologic condition are often too great to be easily quantified with ground-based observations alone. The goal of our project was to use remote sensing data to advance techniques for monitoring changes in hydrologic condition of regional scale wetland ecosystems in the south Florida region. Satellite imaging radar data have been shown to be sensitive to soil moisture variations and to flood conditions in a variety of wetland ecosystems. Initial observations of south Florida imagery from the European Space Agency's C-band microwave sensor onboard the European Remote Sensing Satellite (ERS) showed dynamic variations in backscatter between wet and dry seasons. Further studies revealed how fluctuations in water level influenced ERS radar backscatter for several different herbaceous vegetation cover types. Unfortunately, the C-band wavelength is incapable of penetrating dense forested canopies, thus, our project was focused on the vast herbaceous wetland ecosystems of southern Florida. The ERS synthetic aperture radar (SAR) sensor is a C-band, 5.7 cm wavelength imaging radar with vertical transmit and receive polarization (C-VV). It has a fixed antenna with an incidence angle of 23° to the swath center. The ERS sensor has a resolution of 30 m and a footprint of 100 by 100 km. SARs have the unique capability to collect data independent of cloud cover and illumination. This provides an advantage in areas typically covered by clouds such as tropical and sub-tropical regions

In this study, several techniques were developed to utilize SAR data to detect, monitor, and map spatial and temporal changes in wetland hydrology. This study shows that radar imagery can be used to create hydropattern maps of relative soil moisture and flooding in herbaceous wetlands. Using C-band SAR imagery collected between 1997 and 1999, hydropattern maps were created at approximately bi-monthly periods for the south Florida region. In addition, a methodology for creating hydroperiod (the length of water inundation) maps was developed and an example based on 14 months worth of imagery is presented. Several image analysis techniques were evaluated for wetland monitoring. An unsupervised classification of the principal component images offered the best spatial and temporal hydropattern information for the region.

To obtain our goal we first conducted empirical and theoretical research to better understand the relationships between ERS SAR backscatter and wetland ecosystem parameters such as flood condition, vegetation stem density, vegetation height, and biomass. We then built upon the initial research to develop techniques for using single date and time-series SAR imagery to map spatial and temporal patterns of flooding in the herbaceous wetlands of southern Florida.

We set up sites to collect field measurements and installed data loggers in 1997 to measure water level continuously. We obtained rain gauge data and water level data from local government agencies to supplement our database. Our study area included portions of Big Cypress National Preserve, Everglades National Park, and Water Conservation Area 3A. Several study sites were selected for installation of automatic data loggers to measure water level at half hour increments. Using this method, we obtained water level measurements at all sites coincident with each (1997-1999) ERS SAR overpass. Sites were installed in pairs within a vegetation cover type: one upgradient from a water control structure (canal and dike), and another downgradient. This design allows for continuous monitoring of the impacts of anthropogenic structures on the local hydrology. The major vegetation cover types encompassed by the study sites were Marl Prairie wetlands, Cypress Dome Wetlands, Cypress Prairie Wetlands, Sawgrass Marsh, and Pine Flatwoods

Unsupervised classifications of ERS imagery were conducted to obtain maps of hydropattern. The classified images were assessed for accuracy using *in situ* measurements of water level from a variety of herbaceous wetlands in the Big Cypress/Everglades region (http://esg.erimint.com/terrestrial/wetlands_management.html). Because these hydropattern maps use field data on water depths at sites throughout the image, spatial heterogeneity of the relative levels of inundation and soil moisture could be determined. In some of our hydropattern maps, dry areas and inundated areas both exhibit low backscatter and are sometimes confused. Thus, some dry areas are mapped as flooded. This anomaly does not occur in the wet season imagery, and we are currently conducting further research to rectify the confusion classes.

Once the hydropattern maps were created, our research focused on the ability to monitor temporal variations in hydrologic condition, specifically hydroperiod. While a time series of imagery allows assessment of temporal variation in land cover condition, it is often cumbersome to deal with the large number of images. Interpretation of 14 single images can be difficult. Various methods of combining time series SAR imagery have been investigated to better interpret the factors influencing the large variation observed in ERS backscatter from the South Florida wetlands in wet versus dry seasons (Bourgeau-Chavez et al 1996, Kasischke and Bourgeau-Chavez et al. 1997, Smith et al. 2000). Principal component analysis (PCA) was performed on the temporal data set, which consisted of 14 ERS SAR images from June of 1997 to July of 1998. One negative characteristic of SAR imagery is image speckle that results from the coherent image formation process. PCA is a multi-variate statistical technique that is used to identify the dominant spatial and temporal backscatter signatures of a landscape. The PCA technique reduces speckle noise in the first component image and it becomes progressively greater in the subsequent component images, with speckle dominating PCs greater than 4. Thus, these first few component images are useful for analyzing 14 months worth of data. In fact, the first 3 component images represent 76% of the variability in our 14 input images. We focused on the first 4 component images (PC-1 to PC-4) for our analyses.

PC-1 showed areas of little to no change. PC-2 differentiated between forested and herbaceous site. A plot of the PC-2 loadings for each image date over time appears strongly correlated with rainfall patterns. The rainfall data from 5 gauges within the scene were summed by month and then averaged to obtain monthly average rainfall for the entire SAR scene. Since rainfall drives the hydrologic regime, the PC-2 loadings are likely correlated with hydroperiod. The next step was to conduct an unsupervised classification on the first 4 principal component images to create a map of relative hydroperiod (short to very long). The accuracy of the 1997-1998 hydroperiod map was conducted using water level data from the Big Cypress National Preserve and our field data. Based on our testing sites, the hydroperiod map has high (100% for the testing sites) accuracy.

While the preliminary maps developed in this study need further refinement and further validation, they demonstrate the utility of SAR data for monitoring hydrologic condition in regional wetland ecsosytems.

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Modeling Evolution of Topography and Hydrology of the Greater Everglades Ecosystem

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The Everglades Landscape has evolved to its current status through a series of changes in water management and soil distribution. Lowered water tables exposed peat soils, leading to higher rates of oxidation and subsidence. However, subsidence rates decrease as the soil surface approaches the water table. In order to understand the hydrology of the pre-drainage Everglades, a map of the topography of the pre-drainage Everglades is needed. Clues to the pre-drainage landscape can be gleaned from current features. Historical data are available for a few areas from a variety of sources for various time periods, but no detailed map is available for the entire pre-drainage system. We are integrating historical elevation data, previous studies on Everglades peat soil oxidation and records of hydrologic conditions to construct a model that will de-evolve the current landscape to create a map of pre-drainage Everglades topography. The model is calibrated with historical data and uses modeled and measured water levels to determine soil deposition and oxidation rates. This model will be integrated with a fully coupled model of groundwater and surface water hydrology each decade in order to refine both the hydrologic model and the soils model.

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Poster, Hydrology and Hydrological Modeling

Estero Bay Watershed Integrated Surface Water Ground Water Model

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The Estero Bay Watershed is located in southwest Florida in an area roughly described as south of Fort Myers and North of Naples and between Bonita Springs and Immokalee (see Figure 1). The area is prone to periodic flooding and drought events. Urban land use in the watershed is primarily located in the western developed corridor. The major wetland and associated upland systems are located in the center and eastern parts of the watershed, while the agricultural uses are located on the boundaries and between the large wetland systems. The watershed contains seven major public water supply wellfields that withdraw water from the surficial and intermediate aquifer systems. The eastern and southern portions of the watershed contain numerous agricultural operations that utilize ground and surface water resources. Approximately 36 permitted golf course communities are within the watershed placing additional demands on the limited water resources of the watershed. The rapid growth of the Estero Bay area during the past decades with its increased population and accompanying urban and agricultural development has stimulated significant concerns regarding the water and environmental resources of the region. There is concern that the scale of urban and agricultural development will affect the ecological integrity of the region, as well as the environmentally sensitive Corkscrew Audubon sanctuary within the watershed.

The natural surface water flow patterns in the Estero Bay region have undergone drastic changes due to the evolution of urban and agricultural development. Historic flow-ways in the region followed the natural drainage features emanating from the Immokalee highlands through a series of strands, sloughs and more broadly as surface sheetflows to the tidal passes of the Gulf of Mexico. These natural features consisted of a series of flat wetlands or swamps connected by shallow drainage ways or sloughs, and were divided by low ridges that were dry for a portion of the year, and overtopped by water in periods of seasonal high rainfall. Characteristic of natural strands, the historic water flows were extremely slow and penetrating due to vegetation and physical geography. Pre-development hydroperiods extended well into the winter/spring dry season (Johnson Eng. et.al., 1988).The Estero Bay watershed receives water from runoff from the watershed and through baseflow from the Surficial Aquifer System. The characteristics of the hydrologic system of the Estero Bay Watershed (flat topography, sandy soils, high water table, and a highly developed canal system) cause significant interactions between ground water and surface water systems. Interaction processes include infiltration, evapotranspiration (ET), runoff, and exchange of flow (seepage) between canals and ground water. Simulation of these interaction processes by either a surface water model or a ground water model alone can produce inaccurate results. This is because surface water models generally oversimplify ground water movement and ground water models generally oversimplify surface water movement.

Previous attempts to characterize the region have used separate models to characterize the sheet-flow areas east of I-75, and the urban areas west of I-75. And the groundwater system was modeled separately using modflow. The study presented an integrated surface water and ground water modeling system for improved characterization surface water and ground water interaction. The model used in this study is an integrated model including a suite of components simulating overland flow, river/canal flow, flow in the unsaturated and saturated zone, evapotranspiration losses to the atmosphere and irrigation water use and its distribution.

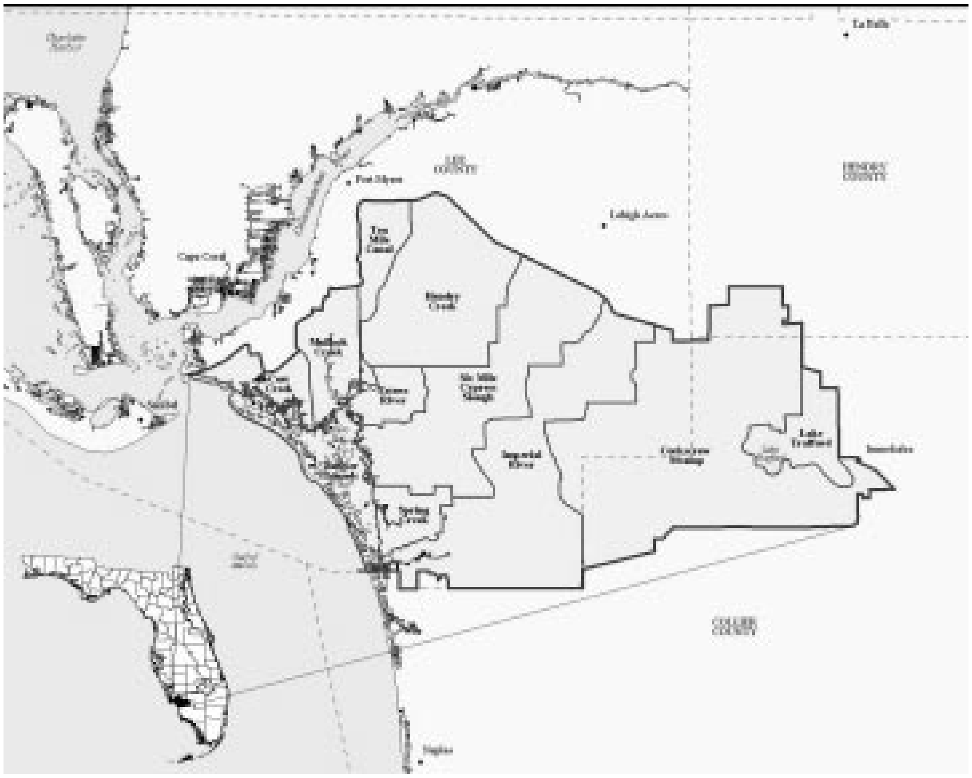

Figure 1 Estero Bay Watershed

A fully dynamic and integrated hydrological model incorporating all major flow processes was developed for the Estero Bay watershed. The model is based on a comprehensive database assembled for this project including rainfall, evapotranspiration, soil physics, hydrogeology, canal geometry including hydraulic control structures, land use, crop, irrigation and municipal wellfield withdrawals. The modeling system is comprehensive and so are the input data requirements. Through calibration and verification it was demonstrated that the model is capable of simulating flood level and duration. The calibrated model is a useful tool in the analysis of the impacts of various proposed water management alternatives.

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The Atlantic Multidecadal Oscillation and its Relationship to Rainfall and River Flows in the Continental U.S.

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An Atlantic Multidecadal Oscillation (AMO) has recently been identified that may have had a large impact on European and American climates in the 19th and 20th centuries and may be driven by the Atlantic thermohaline circulation (Schlesinger and Ramankutty, 1994; Enfield and Mestas-Nuñez, 1999; Kerr, 2000; Delworth and Mann, 2000). As an index of the oceanic expression of the AMO, we have computed the 10-year running means of North Atlantic SST anomaly (SSTA) from the Kaplan et al. (1998) SSTA analysis (1856–1999). In agreement with other studies we find AMO maxima (positive SSTA) during 1860–1880 and 1940–1960, and minima during 1905–1925 and 1970–1990, with periods ranging from 65 to 80 years. We find a significant (95%) correlation of the AMO with monthly precipitation for many of the climate divisions of the continental U.S. (1895–1992). We use a Monte Carlo approach with frequency-domain phase randomization of the serially correlated data to judge the significance. Over much of the Mississippi River Basin the significant correlations are negative, as is the integrated rainfall over the basin.

Strong negative correlations are also found in the northern Rocky Mountains. Positive correlations are limited to two small regions: South-Central Florida and in the Pacific Northwest east of the Cascades. As hydrological checks we also find a significant negative correlation with the directly measured Mississippi River outflow, and a significant positive correlation with the inflow into Lake Okeechobee (South-Central Florida). To diagnose the relationships, we construct composite averages (for recent contrasting phases of the AMO) of tropospheric NCEP/NCAR reanalysis variables (1950-present). We also examine the strength of ENSO-rainfall correlations for both phases of the AMO.

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Canal Operations and Alternative Plans: Computer Simulations using MODBRANCH

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A numerical model of the hydrology of south Dade County was developed as a tool to determine impacts of canals, structures, and general water use. Due to the complex interaction between the Biscayne Aquifer and various drainage canals in south Florida, the MODBRANCH model was found to be applicable for recent studies. The U.S. Geological Survey's (USGS) MODBRANCH couples MODFLOW, a pseudo-three-dimensional groundwater flow model, with BRANCH, a one-dimensional canal routing model. The model code has been further modified to accurately represent the operational criteria of the South Dade Conveyance System control structures.

Ground water and overland flow are simulated by the MODFLOW portion of MODBRANCH. Canal hydrodynamics are simulated by the BRANCH portion of MODBRANCH via a network of canals and structures. Structures operated within the model include gated and ungated culverts, pump stations, and gated spillways. The structure operations are set via an operating rules file which can specify times of operation, operation by specific season or day, and water level or flow criteria. These rules can be easily modified to simulate changes in operational scenarios.

The South Dade Model is useful in determining operational scenarios of the South Dade Conveyance System and its associated impacts on the Everglades ecosystem.

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Summary of Ground-Water Related Geophysical Investigations in Everglades National Park

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Over the past six years a series of geophysical investigations have been carried out to obtain information needed to construct ground-water models of the southern portions of Everglades National Park and adjacent areas. Because of the inaccessible nature of the region and the extreme difficulty of drilling except on established roads, geophysical measurements from the air, and on the ground, are the only way of obtaining information on geologic and hydrologic boundaries needed for model development. Hydrologic models are a very important tool for resource management and ecosystem restoration planning. Inadequate or insufficient data with which to construct these models reduces their reliability. Geophysical data have provided information on three factors critical to ground-water model construction: 1) the extent of saltwater intrusion in the surficial aquifer, 2) the depth to the base of the Biscayne aquifer, and 3) evidence refuting the existence of fresh ground-water flows to Florida Bay.

Helicopter electromagnetic (HEM) surveys and transient electromagnetic (TEM) soundings have been used to estimate formation resistivity throughout the study area. Formation resistivity is influenced by the resistivity of pore water in the formation and the formation porosity. If the formation porosity and geology vary slowly spatial, then the formation resistivity is a direct measure of pore-water quality. Borehole measurements of formation resistivity and pore-water specific conductance (SC) are used to establish a relationship between these parameters, allowing SC to be estimated from the formation resistivity derived from the HEM and TEM data. Finally, an empirical relationship between SC and salinity, which has been established for the region, is used to estimate aquifer salinity. The result is a three-dimensional estimate of water quality.

The HEM surveys provide closely spaced samples (10 m along flight line with 400 m flight line spacing). The HEM data are interpreted as layered earth models at each measurement point and displayed as formation-resistivity maps at selected depths. The TEM soundings provide greater depth of exploration and better model resolution than the HEM data, however, the sampling interval is much coarser (one sounding per 25 km^2). The TEM data are also interpreted as layered earth models. Comparison of the results of these methods show good agreement.

The HEM data show a clear transition from freshwater to saltwater saturated regimes, which occurs from 8 to 20 km inland from the coast. The presence of tidal rivers, as found to the west of Taylor Slough, results in a jagged transition boundary whose landward extent corresponds to the terminus of the rivers. In Taylor Slough and eastward across the region draining toward Florida Bay and Barnes Sound, the interface is smooth because of the absence of tidal drainages into the area. The lack of significant drainages to the east of Taylor Slough is due to the bedrock ridge that parallels the coast and forms a barrier to large stream formation. Other features visible in the HEM data include: 1) a deep resistive zone in the middle of Taylor Slough where fresh-water flow recharges the underlying aquifer, 2) variations in resistivity near raised roadways reflecting their influence on surface-water flow and aquifer recharge, 3) fresh-water zones associated with infiltration from canals due to control structures and flow through cuts in the canals, and 4) historic saline water transport along a canal, formerly open to Florida Bay, adjacent to old Ingraham Highway.

The TEM soundings also locate the transition from fresh-water to salt-water saturated zones. TEM interpreted formation resistivities fall into two groups: 1) a fresh-water saturated zone with resistivities in the range of 18-300 ohm-m, and 2) a salt-water saturated zone with resistivities of 2-7 ohm-m. On this basis the location of the fresh-water/salt-water interface is mapped. The result agrees well with the HEM results, but lacks the spatial detail of the HEM data because of the much coarser sampling interval.

The geophysical data also provide some insight on the issue of whether fresh ground-water is flowing to Florida Bay. If flows are present, we would expect to see a high resistivity zone leading to Florida Bay. Five to ten kilometers landward of Florida Bay the HEM resistivity depth-slice maps show a uniformly low resistivity (1-2 ohm-m) zone from the surface down to a depth of at least 24 m. The base of the Biscayne aquifer, as mapped by drilling, is less than 24 m deep at locations where geophysical data are available. The low observed resistivities are indicative of saltwater saturation of the Biscayne aquifer. Similarly, the TEM results do not show the presence of a high resistivity zone in the Biscayne. While the geophysical models do not indicate the presence of a fresh-water zone, thin resistive zones (1-2 m thick), that are not detectable and do not degrade the fit of the model to the data, could be embedded in the models. The likelihood of such zones existing over extended distances and being isolated hydrologically from the surrounding salt-water intruded aquifer is not considered to be of significance. Therefore, we conclude that there is no evidence of fresh, groundwater flowing to Florida Bay from the surficial aquifer

The results of this project are of immediate value to managers who are responsible for restoration decisions because they provide information about the impact of natural and human activities on saltwater intrusion and the hydrologic regime. This work also provides a baseline for long-term monitoring of changes in the ground-water regime. Future geophysical surveys can be used to look for changes in subsurface conditions associated with planned modification of water deliveries to Everglades National Park.

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Hydrogeology of the Northern Everglades

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The principal goal of the Everglades restoration is to deliver the right amount of water, of the right quality, to the right places, at the right time. To help achieve this goal, water will be stored in more than 217,000 acres of new reservoirs and wetlands-based treatment areas. To better understand the groundwater/surface water fluxes and preferential flow paths in the restoration and water storage and treatment areas, knowledge of the subsurface conditions are needed to predict the movement of groundwater.

Over a period of three years, more than 50 groundwater monitor wells were installed at 20 locations in two study areas which included Water Conservation Area 2A (WCA-2A), the Everglades Nutrient Removal (ENR) site, and the area surrounding the ENR. These wells ranged in depth from 15 to 180 feet with multiple wells at the same site screened at different depths. In order to obtain data from specific zones, the well screens utilized were all one or two feet in length except for one 15-foot screen in a zone of low permeability. Geophysical logs (caliper, natural gamma, neutron, and resistivity) were run in the deep boreholes at seven of the locations. Split spoon and/or core samples were obtained from the deepest borehole at each location. The core samples were analyzed to determine grain size, porosity, and vertical and horizontal hydraulic conductivity. Sieve analyses were used to estimate horizontal hydraulic conductivity. Slug tests (drawdown) were completed at each well to estimate the composite hydraulic conductivity of the screened interval. Water quality samples were collected from the wells and nearby surface water to determine the chemical constituents of the water, as well as any spatial or seasonal variations.

Our data indicate that preferential flow paths that facilitate horizontal and vertical flow and the transport of nutrients and other solutes exist throughout the study area. This was demonstrated by the results of the core and sieve analyses, slug tests, geophysical logs, water quality sampling, and vertical and horizontal hydraulic gradients as calculated from the head differences between wells in the study area. At three sites, core samples from the aquitard and the layer under the aquitard were analyzed. The vertical conductivities of the lower layer were found to be larger by four to five orders of magnitude. Sieve analysis results generally show several 2-foot thick layers with horizontal hydraulic conductivities that are one or two orders of magnitude larger than the average value for that borehole. The depth of these layers of increased hydraulic conductivity varies across the study area. The neutron log run in well S10-C in WCA-2A shows a number of brief deflections suggesting a number of thin layers with lower water content throughout the length of the well. Slug tests were performed to discern the insitu hydraulic conductivity of the formation at the screen interval. The horizontal hydraulic conductivity values determined through slug tests vary from 1 foot per day to 1261 feet per day. These values were highest for the sites in WCA-2A. These varying layers of higher and lower hydraulic conductivity indicate preferential flow is occurring in selected zones.

The neutron logs of the wells in and around the ENR show deflections at very shallow levels that suggest areas of lower water content. This occurs at elevations of 10.6 feet to –12.6 feet NGVD and could indicate a zone of low permeability. Horizontal hydraulic conductivities determined by sieve analyses, core analyses, and slug tests showed significant variations in this layer ranging from 0.03 feet per day to 77.00 feet per day. The overall results show a very shallow, non-continuous layer that functions, with spatial differences, as an aquitard. Where this layer is intact, vertical flow is restricted. However, where this layer does not exist, vertical flow can be significant.

The natural gamma logs and analyses of the cores and unconsolidated sediments indicate the presence of secondary depositional crusts, at depth, throughout the aquifer. An earlier study in Palm Beach County demonstrated that secondary depositional crusts generally exhibit elevated levels of chemical constituents such as Ca, Mg, Al, Sr, and Fe which can affect water quality and inhibit the flow of water.

The results of the sieve analyses were used to calculate uniformity and gradation coefficients for each sample. The ENR samples show generally well sorted sands while S10-C in WCA2-A shows generally poorly sorted sands. This indicates different depositional environments. One result of the different depositional environments may be different hydraulic conductivity values. Our data shows consistently higher horizontal hydraulic conductivity values from the boreholes in WCA-2A.

Our study found significant variations in the strata that produce changes in vertical and horizontal hydraulic conductivity by as many as four or five orders of magnitude. Subsurface conditions can affect the quality and residence time of surface water because the heterogeneous strata underlies the entire area of this study.

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Hydrologic Interactions between Surface Water and Ground Water in Taylor Slough, Everglades National Park

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Determining the extent of hydrologic interactions between wetland surface water and groundwater in Taylor Slough is important because the balance of freshwater flow in the lower part of the Slough is uncertain. Although freshwater flows through Taylor Slough are quite small in comparison to Shark Slough (the larger of the two major sloughs in Everglades National Park), flows through Taylor Slough are especially important to the ecology of estuarine mangrove embayments of northeastern Florida Bay. The extent of wetland and ground-water interactions also must also be known before their role in affecting water quality can be determined. For example, ground-water discharge is a potential source of solutes to Taylor Slough whereas ground-water recharge could potentially store solutes, including contaminants, for long periods of time.

Taylor Slough is the smaller of two major freshwater sloughs in Everglades National Park. It is from separated from Shark Slough by the a series of low-lying uplands referred to as Long Pine Key, and by an area of relatively high-elevation wetlands called the Rocky Glades. Historically, Taylor Slough received water from precipitation as well as surface overflow from Shark Slough across the Rocky Glades. It is also likely that Taylor Slough received groundwater discharge from the coastal ridge system. Presently, Taylor Slough receives much of its input as surface flow from water releases from the L31-W canal. The inputs occur as pumped flow at the S332 pumping structure, which often functions as the northern terminus of Taylor Slough, and from the southern end of the L31-W canal (about 4 miles to the south), as determined by releases from the S175 water-control structure.

Multiple independent approaches were used to investigate wetland and ground water interactions in Taylor Slough. Taylor Slough is underlain by organic wetland peat that varies in depth and in the content of calcitic mud. Under the peat is a highly permeable sand and limestone aquifer (Biscayne aquifer). We estimated hydraulic conductivity in the peat by the piezometer slug test method. Those estimates were combined with measurements of vertical hydraulic gradient in order to compute vertical water fluxes through the peat using Darcy's law. A second method to compute discharge used measurements of water balance fluxes, including precipitation, evapotranspiration, and surface-flow velocity, and measurements of chloride in surface water and ground water.

The research was conducted during seven primary measurement periods between September 1997 and September 1999. Our results are discussed with reference to four reaches of Taylor Slough. The first reach is between structure S332 and Taylor Slough Bridge. A net loss of surface flow from Taylor Slough by recharge to ground water is evident in that reach, based on the substantially lower flow measured at Taylor Slough Bridge compared to the S332 structure. During some periods recharge could account for as much as 80% of the pumped input in reach 1. In reach 2 (directly south of Taylor Slough Bridge) there is only minor dilution of chloride in surface water, suggesting that discharge of ground water with lower chloride concentration is minor. The slight decrease in chloride concentration with distance could usually be accounted for by considering the effect of precipitation and evapotranspiration. In reach 3 there is a significant decrease in chloride concentration that cannot be explained by precipitation and evapotranspiration. Substantial discharge of ground water into Taylor Slough in reach 3 was evident for all data collection periods in both wet and dry seasons. As an example we show results of a calculation for November, 1997, when ground-water discharge in reach 3 may have been as large as 3 cm/day (expressed on a per area basis), which represents a very significant input of water to Taylor Slough because it is and order of magnitude higher than evapotranspiration. Results for reach 4 are less certain, because chloride concentration generally increased, possibly because tidal mixing was transporting chloride against the direction of freshwater runoff. Tidal mixing of salt is not accounted for in out model and therefore our chloride balance is inconclusive about groundwater discharge in reach 4.

The source of discharging ground water detected by the chloride balance is chemically dilute ground water that enters the Slough in shallow flow paths from the western side. Ground water has relatively low chloride concentrations on the western side of Taylor Slough near the location where Ingraham Highway changes direction from southwest to west. The ultimate source of dilute ground water is probably recharge of precipitation on Long Pine Key. We also have observed that the highway impedes surface water flow and therefore causes surface water to be ponded at higher elevations on the northwestern side of Ingraham Highway. During wet periods input of water to Taylor Slough sometimes occurs as sheet flow across the top of Ingraham Highway. In a few places surface water behind the highway has also been observed to flow directly beneath the highway through the porous limestone foundation of the road bed. These 'surface water' inputs to Taylor Slough are similar in concentration to chloride in shallow ground water, and therefore cannot be separated definitively from deeper ground-water discharge. We therefore refer to all of the input delineated by chloride as 'shallow ground-water discharge to Taylor Slough'.

Vertical discharge of ground water from directly beneath Taylor Slough cannot be detected by the chloride balance because of its similarity in chloride concentration to Taylor Slough surface water. Our best estimate of vertical ground water comes from combining measured vertical hydraulic gradients with estimated hydraulic conductivity in the peat. Measured hydraulic gradients in peat indicate the potential for upward flow. The resulting estimate of discharge from beneath Taylor Slough is 0.06 cm/day, which is more than an order of magnitude lower than the estimate of shallow ground-water discharge detected from the chloride balance. Vertical discharge from directly beneath the Slough therefore appears to be relatively minor component of ground-water discharge in comparison with shallow groundwater discharge on the western side of the Slough.

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Water Budget Analysis for Stormwater Treatment Area 6, Section 1

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This paper presents a water budget for the area known as Stormwater Treatment Area (STA) 6, Section 1. It covers the period of operations from January 1, 1998, through December 31, 1999. STA 6, Section 1, was the first of six stormwater treatment areas to be built and operated following the success of the prototype Everglades Nutrient Removal (ENR) project started in August 1994. The STA started full operation on December 9, 1997. Its principal purpose is to reduce phosphorous concentrations in runoff from U.S. Sugar Corporation's (USSC) Unit 2 development (approximately 10,400 acres) north of the STA.

STA 6 is in the southwestern corner of the Everglades Agricultural Area (EAA). It is comprised of two treatment cells, Cell 3 and Cell 5, with a total effective treatment area of 870 acres (245 acres and 625 acres, respectively). Under typical operating conditions, the cells are designed to have depths of 0.5 to 4.5 ft. The long-term design operating depth is 2.0 ft. Water enters the STA at the northwest corner using up to five 100 cubic feet per second (cfs) pumps at station G600_P. It flows from west to east across the cells and eventually discharges to the L4 canal at the southern end of the STA.

Over the two-year period studied, STA 6 received 128,287 ac-ft of water from pumping operations at G600_P. An additional 9065 ac-ft was input to the STA via rainfall; 8063 ac-ft was lost through evapotranspiration. Seepage was 24,440 ac-ft. Outflow from the STA at G606 was 75.8 percent of the flow entering the STA at G600_P or 97,250 ac-ft. This volume entered the L4 canal via the G607 culverts. The amount of water stored in STA 6 was reduced by 665 ac-ft in two years. The error in the biannual water budget was 8,265 ac-ft or 5.99 percent. Cell 3 retained water an average of 4.2 days in 1998 and 1999. The average retention time in Cell 5 was 8.79 days.

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A Pipe Manometer for the Determination of Very Small Water-Surface Slopes in the Florida Everglades

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Restoration and management decisions regarding the south Florida ecosystem are based in part on the results of numerical surface-water flow models. These model results are sensitive, in turn, to the expressions used to account for the resistance effects of vegetation on flow and to the values of the coefficients that appear in those expressions. U.S. Geological Survey (USGS) hydrologists and ecologists are conducting studies to quantify vegetative flow resistance in order to improve the models.

Expressions for vegetative flow resistance include coefficients that must be evaluated in terms of measurable parameters that describe the flow conditions and the vegetation characteristics. These parameters include the flow velocity through the vegetation, water depth, slope of the water surface, and the type, physical characteristics, and density of the vegetation. Water-surface slope is perhaps the most difficult of the flow-resistance parameters to measure in the Everglades due to the very low-gradient characteristics of the topography and flow. Conventional surveying methods do not provide the level of precision needed to accurately determine water-surface slopes in such wetland environments. A unique pipe manometer has been developed by the authors to evaluate these very small water-surface slopes that are typically on the order of 1 cm per 1 km (10^{-5}).

The pipe manometer is a 2.4-m-long, 7.6-cm-diameter PVC pipe with a short elbow of the same internal diameter at one end. In application, the pipe is positioned fully submerged near the water surface with its long axis parallel to the direction of flow. It is oriented with the elbow opening downward at the upstream end of the pipe. For low Reynolds number flow, water velocity in the pipe is theoretically a function of only the pipe geometry, water viscosity and the head difference between the ends of the pipe (e.g. Streeter and Wylie, 1979). The relationship, either theoretical or empirical, between the flow velocity in the pipe and the head difference can be used as a surrogate for measurement of the water-surface slope. It is under this assumption that the pipe manometer is developed to determine water-surface slope.

A series of steady-state controlled flows, conducted in the tilting flume at the USGS Hydrologic Instrumentation Facility at Stennis Space Center in Bay St. Louis, Mississippi during February and March of 1999, were used to establish the relationship between the pipe-centerline velocity and water-surface slope. During this time period, eleven separate flow conditions were replicated, representing a variety of water depths and slopes. Each controlled condition consisted of two water-surface slope measurements and approximately twenty pipe-centerline velocity measurements.

A single water-surface slope was calculated from six independent stage measurements collected using hook gages equipped with digital calipers at each of five locations along a side of the 60-m-long, 2-m-wide flume. Pipe-centerline velocity was measured by inserting the side-looking probe of an acoustic Doppler velocity meter into the downstream end of the pipe manometer at five locations along each side of the flume.

Analyses of the observations collected under the controlled flow conditions show a strong empirical relationship between pipe-centerline velocity and water-surface slope. The relationship between pipe-centerline velocity and the square root of water-surface slope is nearly linear within the range of flow conditions observed in the Everglades. Efforts are currently underway to reconcile the observations with pipe flow theory in order to establish design criteria for pipe manometers with geometries different than the pipe manometer used in this study.

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The Derivation of Land Cover Characteristics for Hydrologic Research in the Everglades

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Research into the measurement and modeling of water movement and other hydrologic processes has been identified as a primary scientific need in support of Everglades restoration. To accurately simulate surface water hydrology in South Florida, scientists must understand the variation in vegetation cover and the role vegetation plays in surface water flow, surface water removal, and water quality.

Numerous efforts to map vegetation type and/or associations have been recently completed recently in the South Florida region (e.g., Welch and others, 1999). However, we need to account for the effect vegetation has on surface water flows, so additional vegetation characterization has been necessary to meet the needs of hydrodynamic models being developed for the Everglades. Field and flume experiments are measuring the importance of vegetation structure and amount on resistance to flow (see Lee and others, this volume). Therefore, two objectives of this remote sensing effort are the creation of land cover maps to which resistance coefficients can be assigned (Carter and others, 1999) and the derivation of biomass or density maps for dominant vegetation types, such as sawgrass (Jones, 2000). By combining information extracted from the literature and field experience with a unique combination of satellite image data, we have generated a nine-class map of vegetation types to which preliminary vegetation flow resistance values have been assigned. The resultant flow resistance information has been used successfully in the hydrodynamic modeling of the Southern Inland Coastal System (Swain, 1999).

Although logistical constraints, variable water levels, and changing vegetation conditions present great challenges, we are continually augmenting a set of ground truth data points for use in accuracy assessment. In this heterogeneous environment, however, comparison of point characterizations of land cover with variables derived from satellite imagery is problematic. Spatial analysis of high-resolution airborne imagery collected for this project indicates that the scale lengths over which sawgrass densities are strongly related are extremely short–with statistically significant relationships ending at lengths of approximately 30 meters. Thematic mapper (TM) resolution is therefore at the limit required to capture inter-patch dynamics and represent the average distribution of sawgrass over large areas. Intra-patch dynamics are not resolved through conventional classification of TM pixels into nominal density classes. The importance of variation at these short scale lengths remains in question, given a planned hydrodynamic model resolution of 500 m. None the less, subpixel classification of satellite data presents one possible means of characterizing sub-30 m heterogeneity. Spectral un-mixing is being investigated for the estimation of fractions of cover type within TM pixels or the generation of continuous fields of vegetation density for use in model parameterization. These results will be compared with neural network based classification techniques also being developed through this project and detailed elsewhere in this volume (see Lemeshewsky).

The characterization of other surface features is important for process modeling in the Everglades. The important role that periphyton composition plays in mercury cycling has been recently discovered (Cleckner and others, 1999). Its composition and placement in the water column vary in time and space – making it both an attractive target for and a complicating factor in remote sensing activities. For example, on an event timescale, it can separate from the soil substrate and form mats that float on the water surface. The result can be a drastically different canopy substrate as imaged by the remote sensing instrument. Although limited in temporal and spatial extent, hyperspectral imagery collected from airplane platforms may provide data of sufficient spatial and spectral resolution to develop effective techniques for mapping periphyton characteristics. A spectral library is being assembled using reflectance spectra collected in the field over various vegetation canopies, water, bedrock, and other surfaces. In May of 2000, reflectance spectra were collected in the field using a hand-held spectroradiometer within 24 hours of the collection of airborne hyperspectral remote sensing data. Periphyton field spectra collected at this time compare well with spectra drawn from calibrated imagery. These and other hyperspectral data are being used to develop periphyton mapping methods.

Measurement of evapotranspiration (ET), a dominant component of the Everglades water balance, has been under way at nine locations for several years (German, 1996). While the importance of the role of vegetation in wetland evaporation remains a source of controversy (Allen and others, 1997), results from these sites suggest that, as in many environments, available energy and water levels are the first-order variables (see German, this volume). Therefore, remotely sensed data have been used to empirically derive spatially distributed fields of ET for selected image dates. Although this technique provides a glimpse of spatially distributed ET, its application is limited to the clear-sky dates for which both imagery and sufficient ET point estimates are available. Therefore, a simple, more widely applicable technique has been developed, in which the spectral characteristics of the regions immediately surrounding each ET monitoring site are used to generate ET regions under various water level conditions. ET values from ET site measurements or from the models developed from them are then used to provide spatially distributed values of ET.

The overall objective of this research is to develop and apply innovative remote sensing and geographic information system techniques to map and characterize vegetation and related hydrologic variables, such as evapotranspiration, through space and over time. The effective use of in situ measurements and the use of remotely sensed data from multiple systems allows us to derive regional fields of information about the land surface that are not possible through any other means. Continued hydrodynamic model development and water quality research will assess the value of biophysical fields generated through these techniques.

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Quantifying Hydrologic Exchange Between Surface and Ground Water in the Florida Everglades, WCA-2a

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In areas of the Florida Everglades receiving agricultural runoff, concentrations of dissolved nutrients are elevated in surface water and in sediments. This nutrient loading has been linked to changes in plant community distributions and to increases in peat accumulation rates. Elevated nutrient levels in the surface and subsurface are directly linked, and remediation efforts to decrease surface water nutrient concentrations will promote a release of nutrients that have built-up in ground water and sediments. In order to anticipate this release, we must increase our understanding of the exchange of water and chemicals between the surface and subsurface.

Exchange rates are slow in the Everglades and difficult to quantify with direct methods. We can overcome this limitation by employing naturally occurring isotopes of radium and radon. Radium isotopes are continually produced in the sediments from decay of their particle-bound thorium parents. The radium desorbs from the particles to surrounding pore water, and moves into surface waters via exchange processes (advection and diffusion). Determining the production rates of radium isotopes in the sediments and the radium concentrations in the surface water will allow us to quantify these exchange processes.

While the particle reactivity of radium is less than that of its thorium-parent, it is not a negligible effect. Radium is therefore transported through the subsurface more slowly than the water, due to its interaction with sediment particles. As an independent tracer of hydrologic exchange, we can use ^{222}Rn, the short-lived daughter of ^{226}Ra. Whereas radium occurs as a dissolved solid, radon occurs as a dissolved noble gas and has negligible particle reactivity. One disadvantage to using ^{222}Rn is that it readily degasses from surface waters, and this effect must be estimated independently.

Plans call for a rigorous sampling effort across the nutrient gradient in Water Conservation Area 2A, collecting sediment, ground water and surface water samples for radium, radon, and dissolved nutrients. Using radium and radon as independent tracers, we will determine the hydrologic exchange between the surface and subsurface water, and will also ascertain the relative merits of each tracer.

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Southwest Coast of Everglades National Park Broad, Harney, and Shark River Hydrodynamics and Discharges during 1999

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The analysis of 1999 discharge data provides information on annual discharge characteristics and the effects of weather systems on discharges for the Broad, Harney, and Shark Rivers. As a part of the U.S. Geological Survey South Florida Ecosystems Initiative and Placed Based Systems programs, these three estuarine-river sites were selected using the criterion that a large amount of the water that flows through Shark River Slough, sometimes referred to as the "Heart of the Everglades", must pass by these sites. This study's data will be used, in conjunction with data from other ongoing studies, to determine the effects changes in water deliveries to Everglades National Park (ENP) have on the southwest estuaries and Florida Bay ecosystems. Each station was equipped with a vertically oriented acoustic-velocity sensor, water level pressure transducer, bottom water-temperature thermister, and specific conductance four-electrode sensor.

Discharges from the Broad, Harney, and Shark Rivers are influenced by semi-diurnal tides, wind events, and freshwater inflow. All three rivers are well mixed, with a difference in specific conductance from top to bottom usually no greater than 500 microSiemens per centimeter during flood and ebb tides. Discharge is one-dimensional except for brief (less than 20 minutes) periods during slack water (between flood and ebb tide) when flow is vertically bi-directional (moving upstream and downstream). The flood discharges (water moving upstream, denoted as negative values) are usually of greater magnitude and shorter duration than the ebb discharges (water moving downstream, denoted as positive values).

Instantaneous and residual discharges for the three stations were calculated for the 1999 calendar year. During 1999, the Broad River instantaneous discharges ranged from –2,400 to +3,500 cubic feet per second (cfs), while the Harney and Shark River instantaneous discharges ranged from –15,600 to +12,900 cfs and –10,100 to +10,500 cfs, respectively. The instantaneous discharges values were processed using a 9^{th} order Butterworth low-pass filter to remove semidiurnal tidal frequencies that eliminates bias associated with lunar cycles when computing daily, weekly, monthly, or yearly mean or median residual (filtered) discharge values. The residual discharges for the Broad, Harney, and Shark River stations ranged from –900 to +2,500 cfs, -3600 to +5,700 cfs, and –2300 to +4,400 cfs, respectively. The Broad River station is the furthest upstream from the Gulf of Mexico (9.3 river miles) and exhibits lesser magnitudes of instantaneous and residual discharges than the other two stations and longer duration positive discharges than the Harney (4.4 river miles upstream) or Shark (6.2 river miles upstream) River stations.

Mean annual residual discharges were computed for the Broad and Shark River stations and estimated for the Harney River station. Discharge data were missing for the Harney River from April 4 to June 11, 1999 due to erroneous index-velocity data. This period coincided with prolonged minimum residual discharges recorded at the Broad and Shark River stations. The mean annual residual discharge for the Broad and Shark River stations, using the complete 1999 record were computed as +400 and +440 cfs respectively. Excluding the period of missing discharge data for the Harney River station, the mean annual residual discharges for the Broad, Harney, and Shark River stations were +520 cfs, +580 cfs, and +550 cfs, respectively. Applying the same difference of approximately 100 cfs between mean annual residual discharges for the Broad and Shark River stations, the Harney River station mean annual residual discharge for 1999 was estimated to be approximately +470 cfs. The mean annual residual discharges reflect the net downstream flows with minimal errors associated with water storage.

Wind events such as cold fronts, tropical storms, and hurricanes can amplify, attenuate, or completely overwhelm the tidal forces that normally dominate flow patterns in the estuaries along the southwest coast of ENP. Four strong cold fronts occurred between January and March 1999 that significantly affected short-term discharges (less than a few days) for the Broad, Harney, and Shark Rivers. The lowest water levels for the Broad, Harney, and Shark Rivers occurred during the passage of strong cold fronts in February and March 1999, when mean water levels were lower than in the late summer and early fall. The most significant effects on maximum water level and discharge occurred during the passages of Tropical Storm Harvey and Hurricane Irene in September and October 1999. The two storms had different effects on the water levels and discharges during their movement towards and away from the southwest coast.

Tropical Storm Harvey approached the Broad, Harney, and Shark Rivers from the northwest and moved to the east with maximum sustained winds of 60 miles per hour (mph). The winds associated with Harvey forced water into the mangrove forests of the southwest coast to water levels of approximately 1.81 feet above mean water levels at the Broad River station, 3.30 feet above mean water level at the Harney River station, and 2.96 feet above mean water level at the Shark River station. Some pulsations in water level and discharge not attributable to semi-diurnal tidal forcing preceded the storm by two to three days. The center storm surge caused a prolonged flood flow that lasted almost 24 hours; then as the winds shifted and abated, the stored water flowed back out to the Gulf of Mexico for approximately 24 hours with no tidal flow reversal. The maximum positive and negative instantaneous and residual discharges for the Harney and Shark River stations were recorded on September 21, 1999 as Tropical Storm Harvey made landfall. The Broad River discharges exhibited similar patterns but a lesser magnitude than the Harney and Shark River stations due to the location of the station and the storm track.

Hurricane Irene caused a different response at the three river stations because of the storm path and wind strength. Hurricane Irene approached from the southwest and moved to the northeast on October 15, 1999 with maximum sustained winds of 85 mph. The winds associated with Irene forced water out of the mangrove forests and the return seiche was less in magnitude than during Tropical Storm Harvey. Water levels during Irene decreased and caused a rapid increase in ebb flow (towards the Gulf of Mexico) that lasted approximately 24 hours with no flow reversals during the 24-hour period. The Broad River instantaneous and residual discharges reached maximum values of +3,500 and +2,500 cfs respectively during the passage of Hurricane Irene.

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The Environmental Science and Technology Academy at Forest Hill Community High School, West Palm Beach, FL

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The Environmental Science and Technology Academy at Forest Hill Community High School in West Palm Beach represents a new and innovative approach to environmental education. The Academy uses an integrated curriculum that incorporates all subject matter (geography, english, social studies, chemistry, etc.) except formal mathematics into their environmental science program. The curriculum uses learning assignments that are self-paced and encourage independent thinking skills and use of various sources of information including the Internet. Grades 9 through 12 are all located in the same room and share facilities. The Academy is heavily computer based and the large classroom is fitted with computer kiosks rather than seats arranged as in a typical classroom. Field trips, on the job training, mentoring, science fair projects, research activities and special projects are all a part of the magnet program. The intention of the Academy is to prepare students for real work in the environmental field. The Academy has recently acquired a full-operational weather station that is part of the South Florida climate monitoring network. The Academy has purchased a Hydrolab environmental monitoring unit for water quality studies of the Lake Worth Lagoon; this is a state of the art piece of equipment that is currently used by environmental professionals. The Academy uses a "Friends" organization of local businesses and government agencies to help support activities such as a part time person to function as a research director for the students. The Academy is currently engaging in a Sister Project with the Tzahar region of Israel in order to study a wetlands problem there similar to the Everglades of South Florida.

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Avoiding Incremental Losses of Short Hydroperiod Marl-Forming Wetlands in the Greater Everglades Ecosystem

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Marl-forming wetlands have been identified by the South Florida Ecosystem Restoration Working Group as a landscape remnant that has been lost or greatly diminished in the Everglades landscape. These wetlands occur primarily along the transition zones between uplands and sloughs and are the prime habitat for a diverse population of aquatic and terrestrial species, including the endangered Wood Stork and Cape Sable Seaside Sparrow. These unique transitional wetlands are particularly vulnerable to changes in water management strategies, due to the narrow window of hydrologic conditions they require. As Everglades restoration proceeds, new canals and levees will be built and the operations of existing structures will change to allow for higher water levels in the sloughs while providing lower water levels to accommodate agricultural and residential uses in neighboring upland landscapes. The short-hydroperiod wetland exists in the interface of these landscapes. Without careful scrutiny and vigilance these critical habitats will be lost. This will be especially true if small losses on a project level are allowed to occur without identifying an equivalent amount of acreage where these wetlands will be restored.

Under current wetland regulations, distinct wetland types are not protected. For the analysis of the 8.5 Square Mile Area mitigation plan for Modified Water Deliveries to Everglades National Park we developed methods to translate hydrologic modeling results to predict the spatial distribution of short hydroperiod wetlands. The locations of the modeled existing marl-forming wetlands generally coincided with the observed existing marl-forming wetlands. Under the Corps' preferred plan for the 8.5 Square Mile Area, 1,309 acres of marl-forming wetlands are lost and 108 acres of marl-forming wetlands are created – a net loss of 1200 acres out of the 1885 acres of existing marl-forming wetlands in the study area. For this project, retention or expansion of marl-forming wetlands was considered as a secondary objective and therefore did not carry as much weight as the mandatory objectives to restore hydroperiods in Everglades National Park and protect the 8.5 Square Mile Area from flooding. The Corps and the Fish and Wildlife Service determined that the loss of marl-forming wetlands was offset by the gains in long hydroperiod wetlands. Additional model runs, using the D13R restoration model for boundary conditions and including the effect of the C-111 project, indicate further losses of marl-forming wetlands could occur. These modeling exercises demonstrate that the effect of restoring sloughs and using canals to maintain a sharp gradient between upland and slough is inherently destructive to marl-forming wetlands. In order to avoid these losses, the timing and distribution of water deliveries should be adjusted to balance the trade-offs between maintaining existing agricultural and residential use, restoration of deep water sloughs, and preservation of the marl-forming wetland landscape.

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Quantifying Internal Canal Flows in Southern Florida

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Historical changes in water-management practices to accommodate a large and rapidly growing urban population along the Atlantic Coast of southern Florida, as well as intensive agricultural activities, have resulted in a highly managed hydrologic system with canals, levees, and pumping stations. These structures have altered the hydrology of the Everglades ecosystem on coastal and interior lands. Surface-water flows south of Lake Okeechobee have been regulated by an extensive canal network, begun in the 1940's, to provide for drainage, flood control, saltwater intrusion control, agricultural requirements, and various environmental needs. Much of the development and subsequent monitoring of canal and river discharge south of Lake Okeechobee have traditionally focused on the eastern coastal areas of Florida. Recently, increased emphasis has been placed on providing a more accurate accounting of canal flows in the interior.

As part of its Place-Based Studies Program, the U.S. Geological Survey is presently conducting a study to: (1) evaluate approaches for quantifying freshwater flows to and from Native American Lands, and (2) provide various hydrologic data to support various other Federal, State, and Tribal hydrologic investigations. The implementation and development of strategically placed streamflow and water-quality gaging sites in the interior have provided vital information for determining future surface-water flow requirements in the internal canal system. Subsequent studies, based on accurate flow determinations resulting from these sites, have been used for computation of nutrient loadings in the canal system. Providing continuous-flow data from selected impact points for internal basins complements the data from the eastern flow canal discharge network. This has resulted in increased accuracy for timed water deliveries to specific locations.

During 1996-97, the U.S. Geological Survey constructed, instrumented, and calibrated three streamflow monitoring sites south of Lake Okeechobee in an effort to accurately gage flows in canals entering and exiting Tribal Lands, Big Cypress National Preserve, and Water Conservation Area 3A in southern Florida. The L-28U site is used to monitor freshwater flows to and from Seminole and Miccosukee Indian Tribal Lands. The L-28IN site is used to monitor freshwater flows from Seminole Indian Tribal lands to Big Cypress National Preserve and ultimately to Miccosukee Tribal Lands. The L-28IS site, discontinued in September 1999, was used to monitor flows from Seminole Indian Tribal Lands and Big Cypress National Preserve to Miccosukee Indian Tribal Lands. This site also was instrumental in bracketing and quality assuring the flow calibration conditions for the upstream L-28IN site.

Acoustic instrumentation, in lieu of standard methods for field data collection and flow computations, is used to gage flows in the canals. With the acoustic velocity meter (AVM) and the acoustic Doppler current profiler (ADCP), it is possible to more accurately gage flows in this type of environment because they can quickly measure low or rapidly changing water velocities. The ADCP calibration of the *in situ* acoustic velocity meter indexes is ongoing. A sum of least squares regression has been developed for data processing at all sites and continues to be refined. Velocity data collected during the dry season have displayed a phenomenon known as acoustic refraction or ray bending. This is produced by thermal stratification in the water column during extended periods of very slow flow. At one site, a point velocity electromagnetic velocity meter and associated velocity index were established in conjunction with the AVM to verify periods when these episodes occur.

Average annual runoff of 70,100 acre-feet was recorded during 1997-99 at L-28U. This represents about twice the inflow amount determined by the South Florida Water Management District at their upstream U.S. Sugar Outflow (USSO) site located on the northwestern border of the Seminole Indian Tribal Lands. An average annual runoff of 53,770 acre-feet has been recorded at L-28IN since its inception in 1997, and an average annual runoff of 49,070 acre-feet was recorded during 1997-99 at L-28IS. The lesser discharge recorded at the more southerly site of the two on the Intercepter canal was likely due to the heavy influence of the S-140 pump station where losses could be attributed to heavy operational pumping periods.

These flows also are being monitored as part of a multiagency effort to calculate nutrient loads in the canals that cross or border Tribal Lands. The South Florida Water Management District installed flow-weighted samplers at the gaging sites for nutrient analysis in conjunction with the streamflow monitoring; the flow-weighted samplers have been serviced by the Seminole and Miccosukee Indian Tribes, respectively. Real-time telemetry programming assistance and phosphorus and nitrogen load calculations have been provided by the South Florida Water Management District. The nutrient load data from all three sites is used by water managers for resource planning and management.

The implementation of strategically placed streamflow and water-quality gaging sites in the interior of southern Florida - in conjunction with four entities to collect, analyze, and distribute information for water managers useful to determine future surface-water flow requirements in the interior canal system - has been a success. Ongoing flow-weighted nutrient loads require accurate flow data collection combined with a highly coordinated nutrient collection and analysis procedure. This collaborative product has been documented in five semiannual progress reports presented to the South Florida Water Management District/Seminole Working Group. The South Florida Water Management District is in the process of documenting the protocol used for collection, computation, and processing of "flow-weighted" nutrient loads in the interior canal system, and a future quality assurance/quality control document is forthcoming. Another future effort is being considered to co-locate an *in situ* side-looking, acoustic Doppler, continuous recording flowmeter with the existing AVM at the L-28IN site to more accurately monitor flows along with the potential ability to provide auxiliary nutrient information at little cost.

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A Geochemical Investigation of Groundwater Flow in Everglades National Park

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Water flow is an important component of the Everglades, and although surface water flow has been extensively monitored, little is known about the subsurface groundwater flow component. A direct connection between surface water and groundwater has always been assumed, with surface water levels equating to groundwater levels. However, the flux of groundwater flow within the Everglades has never been quantified. In light of the ongoing Everglades Restoration effort, interactions between groundwater and surface water should be known in order to evaluated the overall effects of the project. The aim of this project was to use chemical and isotopic data to constrain the estimates of groundwater flow within Everglades National Park (ENP).

Groundwater and surface water chemistry was investigated within four major areas of ENP: Shark Slough, Rocky Glades, Taylor Slough, and south of the C-111 canal. A total of 47 groundwater wells were sampled from various depths within the Surficial Aquifer, and one well from the top of the underlying Hawthorn formation. A total of 23 surface waters stations representing canal water and Everglades' surface water were also sampled. Both groundwater and surface waters were collected on a monthly basis from January 1997 to September 1999 for the following constituents: stable isotopes of oxygen and hydrogen; major ion chemistry (calcium, magnesium, sodium, potassium, chloride, sulfate, and alkalinity) and field parameters (conductivity, salinity, temperature, and pH). In addition, groundwater samples were collected once a year (1997, 1998, 1999) for tritium, helium isotopes and CFCs (CFC-11 and CFC-12). The apparent age of the groundwater from each well was estimated using $^3H/^3He$ and CFC age dating techniques assuming a groundwater recharge temperature of 26 degrees Celcius. With the age of the groundwater known, then groundwater flow rates were determined. Rainfall was collected monthly at four locations for stable isotopes of oxygen and hydrogen.

Stable isotopic composition of $\delta^{18}O$ and δD provided insight into the source of water that recharged the Surficial Aquifer. The weighted-mean values of $\delta^{18}O$ and δD of rainfall was -2.8 and -10.5, respectively. When plotted on a δD vs $\delta^{18}O$ graph, the mean isotopic composition of all Everglades surface waters fell on a line with a slope of 4.6 and intersected the meteoric water line near the weighted-mean rainfall value. These results suggest that the Everglades surface waters originated from local precipitation, and subsequently exposed to evaporation. Most of the groundwaters sampled plotted along the same line, indicating that these groundwaters were recharged locally by evaporated surface water. Groundwater from within Shark Slough had the most positive $\delta^{18}O$ and δD values, indicating that groundwater in Shark Slough was recharged by Everglades surface water and/or canal water that was exposed to evaporation prior to infiltration. Groundwater from within the Rocky Glades tended to have the most negative $\delta^{18}O$ and δD values within ENP, and groundwater in this region most likely was recharged by local precipitation. The $\delta^{18}O$ and δD values of both groundwaters and surface waters from within the C-111 basin were variable, yet indicate exposure to evaporation. The isotopic composition ($\delta^{18}O$ and δD) of groundwater and surface water in Taylor Slough suggest they were a mixture of waters from the Rocky Glades, C-111 Basin, and precipitation. There was no geochemical evidence of an influence of Shark Slough waters into Taylor Slough. Deep groundwaters had negative $\delta^{18}O$ and δD values that fell on or near the meteoric water line. For the deep groundwaters to have $\delta^{18}O$ and δD values more negative than the overlying shallow groundwater suggests that the deep groundwater was recharged either far upgradient of the study area and/or recharged directly by rainfall during high rain events.

The Hawthorn formation had high concentrations of ^{4}He relative to the overlying Surficial Aquifer. Elevated concentrations of ^{4}He, relative to atmospheric levels, within the Surficial Aquifer suggest that Hawthorn formation groundwater was recharging upward and mixing with the Surficial Aquifer water. Major ion chemistry from one well screened in the Hawthorn formation, and an adjacent well screened in the Surficial Aquifer support the ^{4}He data in suggesting there was an upward flux of Hawthorn formation groundwater into the Surficial Aquifer. Based upon water levels in these two wells, and upward flux of groundwater from the Hawthorn Formation to the Surficial Aquifer was estimated at 0.158 m/yr.

Groundwater ages as determined by ^{3}H/^{3}He varied from zero to greater than 60 years. Wells that were typically deeper than 17 m contained little to no tritium, and their ages could only be defined as greater than 60 years. Groundwater with the lowest apparent ^{3}H/^{3}He age (>10 years) were found in shallow (<17m) wells from the Rocky Glades and northern Taylor Slough. Groundwaters determined to be 25 years old or less contained concentrations of ^{3}H and ^{3}He that were comparable with atmospheric ^{3}H concentrations measured in Miami, FL.

There was little to no correlation between the apparent groundwater ages as determined by CFC-12 and ^{3}H/^{3}He, with the CFC-12 ages typically older. However, groundwater flow rates obtained from both methods were similar. Horizontal groundwater flow rates in Taylor Sough as determined by ^{3}H/^{3}He varied from 370 to 766 m/yr. While groundwater flow rates of 607 to 1149 m/yr, were obtained using CFC-12. The groundwater flow rates estimated by ^{3}H/^{3}He and CFCs were slightly lower to within the range estimated by Darcy's Law (1022 - 1377 m/yr). All ^{3}H/^{3}He and CFC-12 samples were collected during the wet season (June through October) when groundwater hydraulic gradients were at their highest. The groundwater flow rates obtained using these chemical means, therefore, most likely represent high end estimates, with lower flow rates expected during the dry season

Specific conductance measurements along with major ion analysis in wells from the C-111 basin, Taylor Slough and the Rocky Glades areas indicated that seawater intrusion extended five to six miles inland of Florida Bay. In addition, groundwater sampled from wells that were 100 feet deep or deeper within the Rocky Glades and C-111 basin areas were brackish, indicating that saltwater intrusion extended throughout the entire thickness of the Surficial Aquifer. From these results, no fresh groundwater was expected to discharge into Florida Bay from the Surficial Aquifer. Fresh groundwater from within the Surficial Aquifer was expected to flow upward along the saltwater intrusion front, mix with the saltwater to produce a mixing zone, and discharge to the overlying Everglades' surface water. Freshwater flow from these areas into Florida Bay most likely occurred only as surface water flow. Estimated fresh-groundwater discharge to the overlying surface water along the salt water intrusion front was about 1 x 10^{9} m/yr. This result was was two orders of magnitude lower than the estimated surface water flow into Florida Bay based upon flow estimates at Taylor Slough Bridge and the C-111 canal, which may also underestimate the freshwater flow into Florida Bay.

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Synthesis on the Impact of 20th Century Water-Management and Land-Use Practices on the Coastal Hydrology of Southeastern Florida

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The urban and agricultural corridor of southern Florida lies between the Everglades and water-conservation areas to the west and the Atlantic Ocean to the east. This area includes eastern Dade, Broward, and Palm Beach Counties and is subject to widely conflicting stresses on the environment. The Shark River Slough is located immediately west of this corridor. A highly controlled water-management system has evolved during this century largely to provide drained land for a rapidly expanding population. Reclamation of Everglades wetland areas during the last 75 years provided the opportunity for westward expansion of agricultural, mining, and urban activities. Surface water is impounded in water-conservation areas that lie west of the protective levee system partly to sustain an Everglades ecosystem, partly to keep overland sheetflow from moving eastward and flooding urban and agricultural areas, and partly for water supply. In coastal areas of the urban-agricultural corridor, parallel environmental conflicts exist. Coastal residential and urban areas must be drained for flood control; the underlying aquifer system simultaneously serves as the principal source for water supply and heads must be maintained to prevent saltwater intrusion. Changes in predevelopment ground-water flow patterns and the associated reduction in ground-water discharge to coastal bays have altered salinity and affected the local ecology.

Saltwater intrusion in the surficial aquifer system is a direct consequence of water-management practices, concurrent agricultural and urban development, and natural drought conditions. The objectives of this synthesis are to: (1) provide a temporal and spatial overview of coastal saltwater intrusion in southeastern Florida; (2) identify the principal factors that control the extent of saltwater intrusion; (3) evaluate long-term trends in ground-water withdrawal rates, ground-water-level change, rainfall, and increases in chloride concentration; and (4) illustrate causal relations between the position of the saltwater interface, water-management practices, and the expansion of agricultural and urban areas. Hydrologic maps and interpretive analyses, land-use and population density maps, and geologic information are being used in combination to illustrate the effect of anthropogenic change during the 20th century on the coastal ground-water hydrology of southeastern Florida.

Urban and agricultural growth and land-use change has greatly impacted the ecological health and stability of the Everglades and Biscayne Bay area. A review of 100 years of land use and population changes is being conducted, mapping key historical events such as the development of the Florida East Coast Railroad, the 1920's land boom and bust, Cuban immigration, and post-war development and redevelopment. The population growth has been explosive; in 1900, southeastern Florida included a few small towns that has grown to a modern-day megapolis with almost 4 million inhabitants. Canal construction, designed to drain lands west of the Atlantic Coastal Ridge, has helped to provide the impetus for the westward expansion of agricultural and urban development.

Urban areas are encroaching and replacing agricultural areas in Miami-Dade and Palm Beach Counties.

Average ground-water levels have risen in coastal areas, but have declined in western developed areas between the 1940's and 1990's. Some declines in water levels can be directly attributed to municipal ground-water withdrawals; however, water-level declines over wider areas are a direct result of canal drainage. Canal discharge to the ocean has declined, but coastal canal stage has been increasing, largely as a hedge to impede saltwater intrusion into the major canals and the aquifer. Conversely, canals near the western margin of the urban areas do not exhibit increasing or declining flows. A potential factor in this process is that municipal ground-water withdrawals from the surficial aquifer system in the Miami-Dade, Broward, and Palm Beach tri-County area increased from 85 million gallons per day in 1940 to 756 million gallons per day in 1995. Possible factors that contribute to a decrease in canal discharge to the ocean include: Flow in major canals recharge the surficial aquifer system along the urban reach, and surface-water flow is being rerouted to secondary canals to elevate coastal ground-water levels.

The landward movement of the saltwater interface has been an issue of local to regional concern since the 1940's. Miami-Dade, Broward and southeastern Palm Beach Counties are the areas most affected by saltwater intrusion. In decreasing importance, canal overdrainage, overpumpage from wells located near the coast, and upconing of relict water are the primary sources of saltwater in the surficial aquifer system.

The marine ecosystem of Biscayne Bay has been profoundly affected over the past 150 years. Significant changes in land and water uses and within the bay, in addition to natural phenomena, have contributed to the deteriorating conditions of its marine ecosystem. Water quality has greatly deteriorated with increased nutrient loads, heavy metals, and other pollutants. Dredging and channelization within the bay decreased the water quality by removing natural seagrass beds and increasing turbidity. Sediment cores from Biscayne Bay record distinct changes in the marine ecosystem over the past 150 years. Shallow-water marine organisms are very sensitive to environmental changes such as salinity, temperature, nutrient input, and dissolved oxygen, among others.

The Biscayne Bay ecosystem was different in the early to mid-1850's than it is today. The salinity of the bay was much lower than the normal marine salinities found today. The southern extreme of Biscayne Bay was nearly of freshwater salinity. The central bay also was lower in salinity, possibly with lowered oxygen or higher organic concentrations in the surficial sediments, which may have had a profound effect on the limited seagrass abundance or density present during that time. The early 1900's recorded the first profound salinity change, reaching close to normal marine salinity, reflected by a significant increase in the abundance of typical Atlantic Continental shelf fauna components. Seagrass indicators became increasingly more abundant from the early 1900's to present time in the central bay. A similar record of ecosystem change is recorded in the coastal region, Manatee Bay, with a significant change in salinity to mesohaline conditions occurring in the early 1900's. Coastal vegetation changes at that time are consistent with marine records, indicating increased salinity conditions by the initial presence of red mangrove in this region. Bay salinity remained relatively stable until the early 1940's when it increased to euhaline and polyhaline conditions, but was subject to broad salinity fluctuations. The occurrence and increasing abundance of epiphytal and macro-algal habitat dwelling organisms indicate a change in substrate conditions and increased seagrass abundance during this time. From the late 1980's to present, a slight salinity decrease in Manatee Bay has been found, and field observations in this region suggest deteriorating conditions in the health of the seagrasses.

Observations of salinity and seagrass changes in Biscayne Bay over the past 150 years have been consistent with records obtained for Florida Bay. The timing and magnitude of the change are correlative, indicating that the southern Florida marine ecosystem has been affected on a broad geographic scale and that the impact of Everglades restoration measures will be as great on Biscayne Bay as it will be on Florida Bay.

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Development and Testing of a Surface-Water Flow Model for Shark River Slough

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The Shark River Slough supports a variety of plant and animal communities and serves as an important pathway for freshwater delivery to the coastal mangrove zone of Everglades National Park. Management of the Shark River Slough relies on the ability to predict how surface-water flow characteristics respond to changes in meteorological conditions, operational plans, and system structure. These predictions, in turn, depend on the application of hydrologic simulation models.

We develop a two-dimensional mathematical model for surface-water movement, and we test this model against hydrologic data collected from the central portion of Shark River Slough. The model is based on the nonlinear diffusion equation, which is derived by combining the appropriate forms of the continuity and momentum equations. We assume that surface-water flow is laminar and that a power-law relationship quantifies the dependence of flow velocity on water depth. We solve the governing equations of the model using a finite-difference method, with a predictor-corrector time-stepping scheme.

We applied the two-dimensional flow model to a region of Shark River Slough measuring 30 km in length and 10 km in width. Owing to the lack of information on the spatial distributions in wetland properties and in atmospheric exchanges of water, we made several assumptions that simplified the input requirements of the model. These assumptions are that (1) variability in rainfall rates can be described by a three-zone discretization, (2) evapotranspiration rates are uniform, (3) the ground-surface slope is uniform, (4) vertical exchange of water between surface and subsurface horizons is negligible, and (5) the vegetative cover is homogeneous.

We tested the model in a sequence of inverse and predictive simulations. In the inverse simulation (calibration), values of the two parameters that govern vegetative resistance to flow were adjusted to minimize the sum of the squared residuals between calculated hydraulic heads and those measured at monitoring sites within the slough. The hydrologic record used for the calibration covered an eight-month period, beginning in June 1996 and ending in February 1997. Using the parameter values estimated from the calibration simulation, we predicted the spatial and temporal variability in hydraulic heads measured within the slough during two additional time periods.

We find excellent agreement between field-measured hydraulic heads and model-calculated hydraulic heads for both the inverse and the predictive simulations. In addition to quantifying the magnitude of the head decline over the 30-km long study area, the model closely reproduces the timing of rainfall-induced head oscillations recorded at each monitoring site (Figure 1). These results suggest that accurate predictions of surface-water flow for extended times and over long distances can be accomplished without extensive characterization of the spatial variability in atmospheric exchanges of water and by treating the physical properties of the wetland as homogeneous.

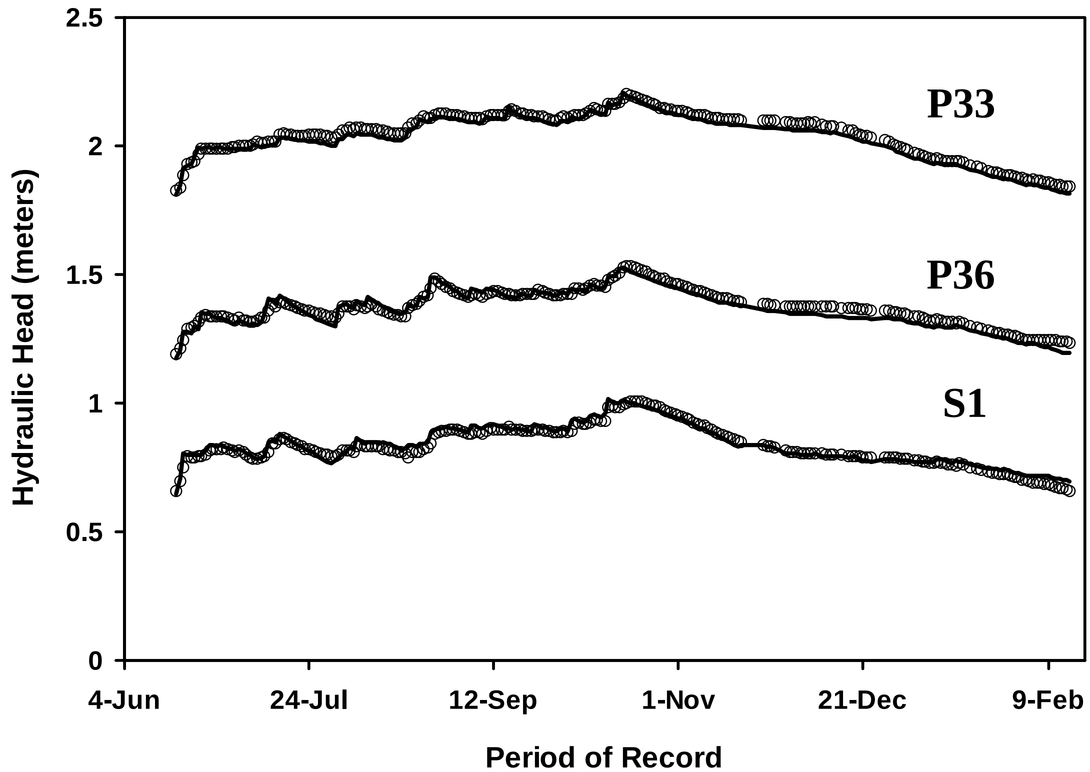

Figure 1. Field measured hydraulic heads (symbols) and those calculated by the surface-water flow model (lines) for the P33, P36, and S1 monitoring sites.

In order to explore further the hydrologic functioning of the slough, we conducted a suite of conditional simulations with the model. These simulations involved calculating the response of surface-water levels to changes in precipitation, evapotranspiration, and controlled deliveries of water into the slough. Our results demonstrate that water depths within central Shark River Slough are more sensitive to variation in water management practices than to variation in climatic forcing functions.

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Calculating Pollutant Travel Times to Public Water Supplies Using the Enhanced Reach File and Real-Time Stream Flow

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A GIS-based tool has been developed to calculate the time of travel (based on real-time stream flow measurements), decay, and dispersion of a constituent introduced into surface water. The tool allows the user to:

- select a location on a river to introduce a chemical or biological constituent
- track the constituent downstream, under real-time flow conditions, to a water supply intake
- further track the constituent to a water filtration plant, and
- Identify the overall population served by the plant.

The databases required for this tool include the Enhanced River Reach File (ERF1), the USGS real-time stream flow measurements, and the EPA Safe Drinking Water Information System (SDWIS). The Arcview Network Analyst extension is used to integrate the databases and to provide the user with a tool to quickly assess the consequences of the introduction of a chemical or biological contaminant to the source waters (surface water) of a public water supply.

The original EPA Reach File Version 1.0 (RF1) is a vector database of approximately 700,000 miles of streams and open waters in the conterminous United States. The RF1 stream flow data consist of mean annual flow and 7Q10 low flow estimates made at the downstream ends of more than 60,000 transport reaches.

The digital data set ERF1 includes enhancements to the EPA’s River Reach File 1 (RF1) to ensure the hydrologic integrity of the digital reach traces and to quantify the time of travel of river reaches and reservoirs. ERF1 was designed to be a digital data base of river reaches capable of supporting regional and national water-quality and river-flow modeling and transport investigations in the water-resources community.

The stream-gauging program of the USGS is an aggregation of networks and individual stream flow stations that originally were established for various purposes. Approximately 5,000 of the 6,900 U.S. Geological Survey sampling stations are equipped with telemetry to transmit data on stream flow, temperature, and other parameters back to a database for real-time viewing via the World Wide Web.

The locations of public water supply plants and intakes was obtained from the EPA Safe Drinking Water Information System (SDWIS). The Safe Drinking Water Information System (SDWIS) contains information about public water systems and their violations of EPA's drinking water regulations. SDWIS (Safe Drinking Water Information System) is an EPA national database storing routine information about the nation's drinking water. The SDWIS stores the information EPA needs to monitor approximately 175,000 public water systems.

The GIS-based tool developed for this project consists of three major components:

- **Time of Travel calculation using real-time stream flow data**
- Given: Enhanced Reach File, for each reach we know: Q_{mean} (mean flow), V_{mean} (mean velocity), T_{mean} (mean travel time), and Length
- The steps to calculate the time of travel, based on real time flow data are as follows:
  1. Find nearest gage – retrieve real-time flow (Q_{rt})
  2. Calculate real-time velocity (V_{rt})
     $V_{rt} = aQ_{rt}^{b}$
     coefficients "a" and "b" calculated based on an analysis of USGS and EPA flow data associated with Reach File (version 1)
  3. Calculate Velocity Factor (VF)
     $VF = V_{rt}/V_{mean}$
  4. Scale T_{mean} for each reach by VF to yield T_{rt}
     $T_{rt} = T_{mean}/VF$
  5. Calculate TOT to intake - sum T_{rt} for all reaches between input location and intake
- **Time decay of the constituent based on time-of-travel to the public water supply intake**
- The initial mass (Mo) of substance will be reduced to a secondary mass (M) using the temporal decay parameters assigned to that substance.

$$M = M_o \exp^{-kt}$$

where k = decay coefficient (= $0.693/_{t1/2}$), and $t_{1/2}$ = half-life of the agent

- **Dispersion of the constituent based on convective-diffusion equations for turbulent flow**
- The distribution of a substance introduced to a river is governed by the convection-diffusion equations for turbulent flow.
- Consider the concentration of substance to be a function only of time and along the stream dimension.
- An instantaneous release is modeled by introducing a finite amount of substance at a selected location.
- If the initial mass (M) of the substance is released over the cross section (A) and allowed to spread diffusely, the central concentration (C) of substance will be given by:

$$C = 0.003 * M/(A(UR^{5/6}t)^{1/2})$$

where U = velocity (V_{rt}), R = hydraulic radius, t = travel time

Prototype systems have been set up and tested for Ohio and Utah. The databases and software are directly extensible to the rest of the US.

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Recent enhancements to the South Florida Water Management Model

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The South Florida Water Management Model (SFWMM) has been used extensively to evaluate the effects of different water management alternatives in regional and operational planning efforts in southern Florida. Most notable was the use of SFWMM version 3.5 (SFWMD, 1999) in simulating alternatives that led to the development of the Comprehensive Everglades Restoration Plan. The SFWMM continues to be refined and improved to enhance its ability to meet the regional-scale hydrologic modeling needs in southern Florida.

Major enhancements to the model, driven by application needs since the documentation of SFWMM version 3.5, are presented. Simulation of the current Water Supply and Environmental (WSE) operational schedule for Lake Okeechobee was incorporated in version 3.6, enabling the use of climate forecasting in simulations for the Everglades Construction Project. Operation of the S-12 structures was improved in version 3.7 to permit the structures to be simulated individually for the Modified Water Deliveries project and the Lower East Coast Regional Water Supply Plan. Further operational flexibility in the timing of operations at the S-12 structures was later introduced in version 3.8 used for operational planning. An improved interpretation of topographic data in the vicinity of the western Subpopulation of the Cape Sable Seaside Sparrow was also used in v3.7. The ability to run the model in position analysis mode was incorporated in v3.8 allowing extensive use of the model in operational planning. Other enhancements to version 3.8 of the model include the ability to simulate structures in the Water Conservation Areas using input-driven tailwater constraints, the ability to simulate operational flow-through releases from Lake Okeechobee to the Lower East Coast when the Water Conservation Areas are below schedule. The ability to simulate flow from small reservoirs (smaller than the 2 x 2 mile grid scale of the model) has been incorporated to simulate small reservoirs in the Water Preserve Area project and operational planning.

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Flow Velocities in Wetlands Adjacent to Canal C-111 in South Florida

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Wetlands between canal C-111 and the eastern panhandle area of Everglades National Park (ENP) are of particular concern to south Florida ecosystem restoration efforts in that they constitute a major pathway for fresh water to reach nearshore embayments of Florida Bay. Past construction features of the Central and Southern Florida Project are suspected of contributing to the reduction of marsh hydroperiods in the C-111 basin and to the development of hypersaline conditions in the subtidal embayments of central and northeast Florida Bay as a consequence of channeled and diminished freshwater flows. Changes in the hydraulic infrastructure and water management operations are being implemented to restore more natural temporal and spatial flow patterns through the wetlands. In 1996 and 1997, spoil mounds along the southwest bank of the C-111 canal between hydraulic-control structures S-18C and S-197 were removed to enable overbank flow from the canal to enhance sheet flow in the wetlands. In September 1997 and 1999, extensive sets of flow-velocity data, basic water-quality parameters, and information on vegetation characteristics were collected in the wetlands adjacent to the canal to determine flow patterns in the wetlands, to analyze canal/wetland flow exchanges, and to support the development of a model for this canal and wetlands ecosystem (Schaffranek, 1996).

In September 1997, near the conclusion of the spoil removal efforts, flow measurements were made at nine transects spaced at variable intervals along the 8-km overbank segment of the canal. Transects were spaced at variable intervals perpendicular to the canal and extended approximately 2 km into the adjacent wetlands. Measurements were repeated along similar transects in September 1999 and the spatial extent of wetland coverage was expanded to include two new transects—one oriented north-south and the other east-west—along the ENP Boundary. These new transects were added to evaluate inter-basin exchanges between Taylor Slough and the C-111 wetlands and to quantify other potential inflow sources. The north-south transect extended southward from canal L-31W along and parallel to the ENP Boundary to the point where the Boundary makes a 90˚ turn eastward. The east-west transect extended eastward from the southern end of the north-south transect along and parallel to the ENP Boundary and terminated at the C-111 canal.

Flow velocities were measured using portable SonTek[1] 10-MHz acoustic Doppler velocity (ADV) meters suspended from tripods. The meters were retrofitted with electronic compasses to geodetically reference flow directions to East, North, and Up (ENU) coordinates. The SonTek ADV meter measures flow in a 0.25 cm^3 remote sampling volume to a resolution of 0.1 mm/s (SonTek, 1997). Velocity data were typically collected at 0.2, 0.5, and 0.8 depths, measured from the water surface to the top of the litter layer. At each depth, two-minute burst samples were taken at a frequency of 10 Hz. Measured ENU velocity components were processed through a series of automated filters and plotted for visual inspection to identify anomalous data (Ball and Schaffranek, 2000). Examination of the component-velocity standard deviation and visual inspection of the plots generally identified suspect data not detected by the automated filters. Anomalous data were eliminated and depth-averaged velocity magnitudes and flow directions were computed and plotted for subsequent analyses (see fig. 1).

[1] Use of firm, trade, and brand names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Flows in the wetlands adjacent to the C-111 overbank area were fairly consistently in south-southwest and south by west directions within and between measurement years averaging 205 and 191 degrees clockwise from magnetic north in 1997 and 1999, respectively. Flow velocities were slightly more variable within years but consistent between years averaging 0.8 and 0.5 cm/s in 1997 and 1999, respectively. In the wetlands adjacent to the canal, velocities were greatest in the immediate vicinity of the re-graded spoil mounds, but decreased rapidly and variably away from the canal. The spatial variability of the wetland flow velocities is likely due to the variable influence of overbank flows combined with local effects of the irregular topographic relief, wind effects on the flow, and frictional resistance of the heterogeneous vegetation. Several mangrove-lined channels extend southward from the canal and likely act to convey sheet flow away from the wetlands—additional monitoring is needed to identify sheet versus channel flow differences.

Flow directions measured along the north-south and east-west ENP Boundary transects in 1999 averaged 170 and 186 degrees clockwise from magnetic north, respectively, with average magnitudes of 1.9 and 0.7 cm/s. Along the north-south transect, velocities were greatest at the northern end near the L-31W canal outlet, where discharges were high due to the S-332D Pump Test (http://www.sfwmd.gov/org/erd/webboard/s332dtest.html) and to releases from the S-175 control structure related to tropical storm Harvey. Higher flow velocities along the north-south boundary indicate a significant inflow into the C-111 basin from a north by west direction likely originating from the L-31W canal or eastern Taylor Slough. Along the east-west transect, velocities were greatest near the U.S. Highway 1 end with significant flow toward the eastern part of Long Sound. Flows along the east-west transect from its western end to approximately the midpoint of the C-111 overbank area were consistently in the direction of Joe Bay, indicating that Joe Bay is the primary recipient of flows from the upstream part of the overbank segment of the C-111 canal. This indicates that a significant amount of fresh water from C-111 and potentially eastern Taylor Slough flows into Joe Bay which supports findings that discharges from Joe Bay are a major source of fresh water for northeastern Florida Bay (Patino, 1999).

Graphical representation of measured flow vectors from September 1999, overlaid on a satellite image for visual inspection, can be found in the What's New page of the Tides and Inflows in the Mangroves of the Everglades (TIME) website (http://time.er.usgs.gov). Un-edited velocity data collected during 1997 and 1999 along with associated correlation statistics, signal strength values, water-quality parameters, and vegetation characteristics are available at the South Florida Information Access (SOFIA) website (http://sofia.usgs.gov/). Site averaged data summaries, data-quality indicators, and velocity filtering results are available at the SOFIA website and presented in Ball and Schaffranek (2000).

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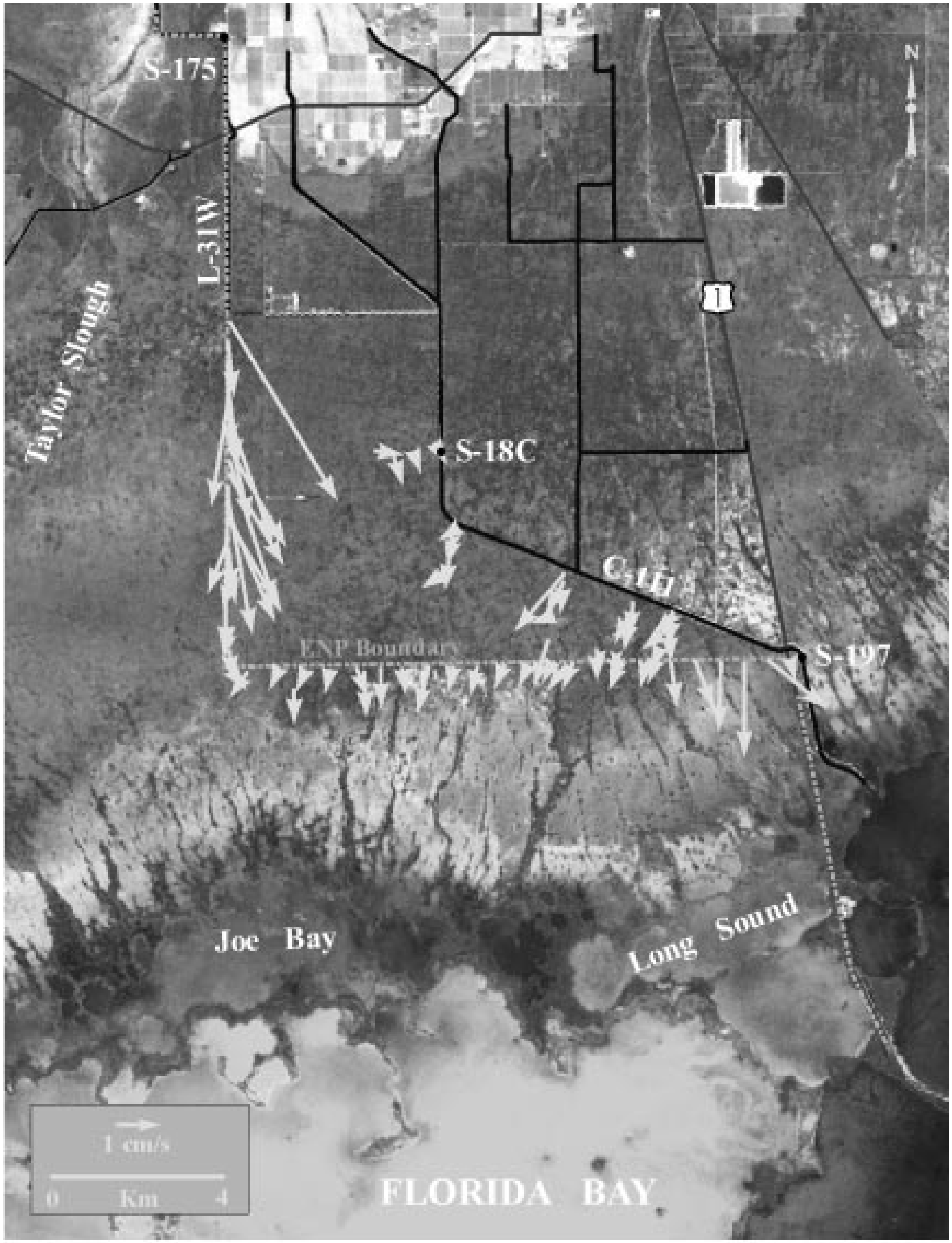

Satellite image courtesy Land Characteristics from Remote Sensing Project, J.W. Jones.

Figure 1. Flow velocities measured in C-111 wetlands on September 22-23, 1999.

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Modeling the Flow Dynamics of the Southern Everglades Using a Continuous, Distributed Model

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The Hydrologic Simulation Engine (HSE) of the South Florida Regional Simulation Model (SFRSM) is used to simulate the flow-dynamics in the southern Everglades. The implicit, finite-volume, rainfall-runoff model, HSE is capable of simulating two-dimensional flow in arbitrarily shaped areas by using a variable triangular mesh structure. The model domain encompasses the Everglades National Park (ENP) and the southern portion of the Big Cypress National Preserve covering an area of 5770 km^2. The variable mesh covering this domain is conformed to account for the major hydraulic structures and highways within the ENP. A distributed, saturation-excess hydrologic model such as HSE is ideally suited for simulating the high water table and the relatively flat terrain of this model domain.

The model is calibrated by using stage measurements from 1988 to 1995. Automated model calibrations are conducted using a stochastic optimization technique developed by Duan et al. (1992). The values of three sensitive model parameters are changed as a function of land-use by this optimization technique during model calibration until a near optimal solution is obtained. Root mean square error values from over 40 stage-measuring stations are used to identify and isolate this near optimal solution. A validation test is performed to evaluate the robustness of the calibrated data set, and to assess the suitability of HSE for model forecasting work. The results of this test reveal that the HSE has significant potential for the simulation of flow dynamics in the southern Everglades region.

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Seepage beneath Levee 30, Miami-Dade County, Florida

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In 1948, the United States Congress authorized the Central and Southern Florida Flood Control Project (currently managed by the South Florida Water Management District) in response to catastrophic floods that had occurred in south Florida. This enormous undertaking resulted in the construction of levees, canal networks, pumping stations, and water-conservation areas (fig. 1) to provide adequate control of water levels and surface-water routing. The initial effort established an interconnected network of levees and adjacent canals from central Palm Beach County to southern Miami-Dade County. This 80-mile long network of levees and borrow canals constitutes the eastern limit of the water-conservation areas and prevents Everglades overland sheetflow from reaching the developed areas to the east. This network includes the 14-mile long Levee 30 and adjacent canal in central Miami-Dade County. Completed in 1954, Levee 30 is part of the eastern boundary of Water Conservation Area 3B.

Determining the volume of water seeping from the water-conservation areas to the underlying aquifers is important in managing water levels in the conservation areas and freshwater deliveries to Everglades National Park. From Water Conservation Area 3B, water seeps into the Biscayne aquifer and flows relatively fast (due to high permeability of the aquifer) toward the urban and agricultural areas to the east. Ground water is also discharged to the canal along the eastern part of Levee 30. The stage in the canal, which affects the rate of discharge, is controlled by structures at the northern and southern ends of the canal. This seepage to the aquifer and canal discharge of water are critical for water-supply wells to the east and for preventing saltwater intrusion. However, lowered ground-water levels to the east have resulted in higher ground-water seepage and canal discharge, reducing surface-water flows to the south in the water-conservation area. The altering of historical flow directions and water-level durations has adversely affected parts of the Everglades ecosystem. Water managers want to restore predevelopment flow conditions and keep this ecosystem viable, while also providing for urban and agricultural needs.

A two-dimensional, cross-sectional, finite-difference, ground-water flow model and a simple application of Darcy's law were used to quantify ground-water flow from the wetland beneath Levee 30. Geologic and geophysical data, vertical seepage data from the wetland, canal discharge data, ground-water-level data, and surface-water stage data collected during 1995 and 1996 were used to develop boundary conditions and to calibrate the ground-water flow model. These data were also used as input for the application of Darcy's law.

Vertical seepage data (fig. 2) indicated that water from the wetland infiltrated the subsurface near Levee 30 at rates ranging from approximately 0.03 to 0.25 foot per day, with the gates at the structures in Levee 30 canal closed. During the same period, stage differences between the wetland (Water Conservation Area 3B) and Levee 30 canal ranged from approximately 0.10 to 1.25 feet (fig. 3). A layer of low-permeability limestone, located 7 to 10 feet below land surface, restricts vertical flow between the surface water in the wetland and the ground water. Based on measured water-level data, ground-water flow appears to be generally horizontal, except in the immediate vicinity of the canal. The increase in canal flow rate along a 2-mile reach of the Levee 30 canal ranged from approximately 9 to 23 cubic feet per second per mile (fig. 2) and can be primarily attributed to ground-water inflow. Flow rates in Levee 30 canal were greatest when the gates at the control structures were open.

The ground-water flow model data were compared with the measured ground-water heads and vertical seepage from the wetland. Estimating the horizontal ground-water flow rate beneath Levee 30 was difficult, owing to the uncertainty in the horizontal hydraulic conductivity of the main flow zone of the Biscayne aquifer. Measurements of ground-water flows into Levee 30 canal, a significant component of the water budget, were also uncertain, which lessened the ability to validate the model results. Because of vertical ground-water flows near Levee 30 canal and a very low hydraulic gradient east of the canal, a simplified Darcian approach does not accurately estimate the horizontal ground-water flow rate. Horizontal ground-water flow rates simulated with the ground-water flow model (for a 60-foot deep by 1-foot wide section of the Biscayne aquifer) ranged from approximately 150 to 450 cubic feet per day west of Levee 30 and from approximately 15 to 170 cubic feet per day east of Levee 30 canal. Vertical seepage from the wetlands within 500 feet of Levee 30 generally accounted for 10 to 15 percent of the total horizontal flow beneath the levee. Horizontal ground-water flow was highest during the wet-season simulations and when the gates at the control structures were open.

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Prehistoric Hydrologic Shifts in the Everglades and Implications to Restoration

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The Everglades evidence past eras of substantial hydrologic shifts that mimic or are analogous to some principal modern disturbances. That the ultimate peatland developed or recovered from such notable natural alterations gives encouragement to restoration efforts. The Everglades peatland originally succeeded largely upon marl marshes of shorter annual hydroperiod under the apparent control of a climatic shift ca. 5500-4500 BP (^{14}C years *before present*). This marks the onset of the present prevailing regime of overall climate and hydrology. Thereafter, one-way evolution of the Everglades was influenced largely by hydrologic and successional feedbacks associated with a sediment-accreting peatland that modified surface conditions (e.g., topography, permeability). In essence, the existence and characteristics of the classical Everglades of European contact times had developed by 4000 BP through this one-way evolution or succession. Later, however, several profound and often prolonged environmental excursions, stages, or disturbances occurred that had eventual reversals to previous conditions of marsh-peat deposition. Both reduced hydroperiods and deeper flooding are evidenced among these stages in separate areas. For a few other sites, evidence of severe peat burning has been reported. All occurred prior to historic times. Thus the impacts associated with 20th century drainage and impoundment do not represent the only time the Everglades peatland has been sharply and widely altered in hydrology, vegetation, sedimentation, and more locally by severe loss of peat to fire. These natural shifts and recoveries offer encouragement for restoration efforts. The classic Everglades of the late 19th century, an idealized theoretical target for restoration, had succeeded or recovered from substantially altered conditions of earlier times, both regionally and locally.

The peatland sedimentary record is used here to interpret some major natural pre-engineering hydrologic shifts in Everglades sedimentation, and by ecological inference shifts in vegetation and surface-water hydrologic conditions. Analogies are suggested between these former natural shifts or stages and modern engineering-induced alterations or disturbances. Finally the dynamic nature and resilience of the Everglades peatland ecosystem in the past strongly suggests that a high degree of recovery to its former (ca. AD 1880 or 1900) natural condition is at least possible if managed astutely and correctly and given enough time.

The Everglades now contains a vast freshwater peatland whose stratigraphy gives an essentially continuous record of prevailing hydrological conditions in the past. In general the marsh peats (mainly sawgrass or waterlily) evidence an origin in an environment of prolonged seasonal to semi-continuous shallow flooding. In two wide areas there occur midlevel layers of distinctly different sediments that imply substantially different flooding regimes. Their thicknesses or radiocarbon dating of their vertical boundaries indicate that these atypical layers represent prolonged stages (>>100 yr duration in main layers; perhaps <100 years in the most minor occurrences). In each case the peatland had shifted to a different kind of sedimentation, which implies a significantly different flooding regime, controlling hydrology, and presumably different vegetation. Each stage lasted for many years but was later reversed to the typical peat-forming marshland. Multiple episodes with shifts back and forth sometimes occurred within these divergent stages, but the last reversion to peat marsh continued up to the historic-era environment.

Marl, a whitish freshwater calcitic mud, forms a midlevel layer(s) in peats of the central Everglades. This layer extends for tens of kilometers but has not been mapped in N-S extent. Marl in South Florida forms in marshes, not lakes, and specifically in wet-prairies (sparser marshes) that are flooded seasonally but typically for less than half of each year (it forms now in parts of the southern Everglades). A marl layer within marsh peat derived from waterlily and sawgrass implies a stage of reduced annual hydroperiod, i.e., a significantly drier but still seasonally flooded wetland. A single layer at one site dated from roughly 3000 to 2000 BP. A ca. 1000-year era of less-wet conditions is indicated. Dating at several other sites confirms this approximate age and shows some older and younger episodes. Sometimes the marl layer is split by a minor peat layer or elsewhere thin marl layers lie slightly above or below the main layer. Shorter term shifting between sediment types and hydrologic conditions is evidenced, showing that a depositional peatland can reestablish readily and fairly rapidly given suitable hydrologic conditions.

The second main stratum of divergent sediment in the peatland is muck that lies near the Lake Okeechobee/Everglades boundary. Muck is a fine-grained, mineral-codominated (but without marl carbonates) dark to black mud that contrasts strongly with the fibrous brown marsh peats of little fine mineral content (except occasionally marly carbonate). Muck formed the ground surface as a thick layer above peat in the ca. 5 km zone nearest the lake and extended buried within peat for kilometers beyond that away from the lake. Sawgrass marsh peat of the northern Everglades had buried the muck over a wide area. The high content of fine-mineral grains and the proximity to the lake indicates that an expanded lake influence into the Everglades had occurred in the past (noted by Dachnowski-Stokes). *Relatively* open water is indicated. Water depths were apparently significantly greater, at least seasonally, to accomplish this deposition. The fineness of the organic matter suggests that a dense marsh environment was not present, although a typical Everglades environment preceded and succeeded the muck stage. Reportedly common were thinner multiple interlayers of fibrous plant remains within the muck stratum and if of peat they evidence occasional re-establishment of typical marsh. This muck is now widely homogenized by subsidence and plowing and the stage is not well dated. Clearly though, when the muck stage ended at its farther reaches, sawgrass marsh re-established itself.

Lesser strata are reported to have occured interlayered within the peat deposit elsewhere: several layers of “ash” and at least one of sand. Even without confirmation of the origins of these layers, each also reveals a substantial perturbation with subsequent recovery to the ultimate peatland.

The two main layers of nonpeat sediment—marl and muck—indicate conditions that were drier and wetter, respectively, than the preceding and subsequent peat marshes. These can be taken to closely represent the hydrological end-conditions of modern disturbance and alteration of the marshes. Wide areas have been partially drained, including northern portions of several conservation areas and several large parcels outside the levees. Both marl and ash layers can mimic the conditions in presently drained and disturbed areas, as well as those where peat has been lost altogether by modern subsidence or fire. The mineral surface upon which the Everglades peatland first established also can represent such highly disturbed areas of complete peat loss. Conversely, the muck can represent areas that are now much more continuously or deeply flooded and highly modified vegetationally and in sedimentation, notably the southern ends of impoundments. Presently, an organic mud (“detritus” or “gyttja”) is found depositing in such deeper areas of sparser vegetation. In each case of recorded prehistoric disturbance, no matter how great or prolonged, the disturbed zone is directly overlain by seemingly typical marsh peat, suggesting a fairly direct return to overall typical Everglades conditions.

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Poster, Hydrology and Hydrological Modeling

Modeling Water Budget for Wetlands with Complex Plateaus

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In studying sensitive ecosystem such as the Everglades, one major concern is to provide habitat for a wide variety of wetland-dependent and terrestrial wildlife species, flood water retention, production export, and nutrient retention. Meeting all these requirements calls for a wetland with complex plateaus with different grade elevations. Proper water budgeting is of paramount importance in such a setting and there is a need to integrate surface water – groundwater interaction and the different plateau elevations. A method is devised to incorporate surface water – groundwater interaction and the features of the complex terrain into the water budget computation for an accurate assessment of water level elevation. The method was applied to the New Jersey Turnpike Interchange 1 Toll Plaza relocation project and shows promise for accurate water budget computation on wetlands with different plateau levels and hydrologic regimes.

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Poster, Hydrology and Hydrological Modeling

Seasonal to Multi-decadal Climate Variability and its Contribution to South Florida Hydrology

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The increased understanding of climate variability on extended temporal scales is a valuable asset for regional water management authorities in their efforts to enhance and restore natural ecosystems. To most effectively benefit operationally from the advancement made in the understanding of climate variability, it is necessary to have a global perspective of the state of various atmospheric and ocean systems that cause this regional climate variability.

Global climate indices give a measure of the state of large scale global atmospheric and oceanic systems. These systems oscillate with seasonal to inter-annual periodicity that cause extended persistent shifts to occur in the mean and extremes of regional meteorological and hydrologic variables. The statistical relationships that exist between global climate systems and the regional hydrologic variables allow that operational adjustments to be made to improve on the long term regional hydrologic performance.

The statistical ties of the central and south Florida (south Florida) climate variability to the 3 to 7 year El Nino-Southern Oscillation (ENSO) ocean-atmospheric oscillation centered in the tropical Pacific Ocean has been well documented. In this analysis, apparent strong links of the south Florida climate to two additional global oscillation: 1) the Atlantic Multi-decadal Oscillation (AMO), and 2) the Pacific Decadal Oscillation (PDO) are identified. Shifts in wet season (May through October) rainfall distributions in south Florida appear be linked to the AMO while shifts in dry season distributions (November through April) are more closely linked to the PDO on multi-decadal and decadal scales respectively.

The extended dry period from mid 1970 through 1976 represented a period in which both the AMO and PDO favored drier than normal conditions while the very wet period beginning in 1995 through early spring of 1998 represented a period in which both long term climate indicators favored a shift towards wetter than normal conditions. Finally, a new perspective is taken at how solar variability may contribute in significantly to climate and hydrologic variability within southern Florida.

The possibility of discovering new contributors to the Florida climate variability appears promising. As these newly discovered contributors are identified with their associated confidence limits defined, they should be considered for their potential value in the Everglades operational guidelines. Accounting for seasonal to multi-decadal climate variability has potential to lead to more robust guidelines for Everglades operations.

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Oral Abstracts

Information Systems

The Data Web Pages of the Tides and Inflows in the Mangroves of the Everglades (TIME) Project

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The Tides and Inflows in the Mangroves of the Everglades (TIME) project of the U. S. Geological Survey (USGS) South Florida Place-based Studies Program is a joint research effort to investigate the interacting effects of freshwater inflows and tides in and along the mangrove ecotone of south Florida. This investigation is being accomplished through the use of coupled, numerical, surface-water and groundwater flow models of the region.

The primary purposes of the TIME web site (http://time.er.usgs.gov) are: 1) to provide project scientists ready access to all data required as input to the models; 2) to provide project scientists with an efficient mechanism for sharing data, model output and other information among themselves; and 3) to disseminate project findings to other interested researchers. The TIME web site is organized into several sections, including "TIME Data" for sharing data, "What's New?" for displaying timely results, and "Scientific Links" for directing users to additional sites of scientific interest in south Florida. Each of these sections can be viewed by selecting an appropriate link on the main TIME web page.

Data from over 100 gaging stations in the TIME modeling domain can be viewed and downloaded from the "TIME Data" web pages. The user may choose 1) to view and/or download data from an individual station for a user-specified time period; 2) to download data from multiple stations for a user-specified time period; 3) to view a map of the previous day's rainfall throughout the TIME domain; 4) to view a map of the relative water-level change over the last week at stations throughout the TIME domain; or 5) to view a map of measured winds throughout the TIME domain for a user-specified date. Each of these views or downloads can be obtained by selecting a link on the main TIME data page or by selecting a station on a map of the TIME domain in the case of viewing and/or downloading data from an individual station for a user-specified time period.

The TIME Data database is designed to store all data that is available for a gaging station during the time period January 1, 1995 to present. Data frequencies are typically hourly, but the database can, and does, store data at other frequencies as well. A majority of the stations' data are updated daily.

The TIME data system is designed to store timeseries of scalar variables. At present, these include stage, rainfall, discharge, salinity, conductivity, wind speed and wind direction. However, there is no practical limit to the number of different types of timeseries data that the data system can accommodate, and more types are planned.

Data in the TIME data system are collected by the USGS, the National Park Service, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration and the South Florida Water Management District. Information regarding a data point's source, and any disclaimer provided by the source, is stored with each data point in the system.

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Some Lessons from the ATLSS Project: Modeling and Everglades Restoration

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For much of the last decade, the ATLSS (Across Trophic Level System Simulation - see http://atlss.org/) project has been developing and applying a set of models designed to aid in restoration planning for South Florida. These make up a multimodel, consisting of a collection of submodels which utilize different mathematical and computational approaches in order to account for trophic components which operate at differing levels of spatial, temporal and biotic complexity. Developed in close collaboration with many field researchers with long experience in the Everglades, ATLSS has been extensively applied throughout the planning process and used in the evaluation of the biotic impacts of alternative hydrologic scenarios. We expect the process used for the development of ATLSS to be useful in similar efforts for regional environmental assessment.

Developing succinct summaries of complex spatial model outputs in order to allow rapid analysis by field researchers of alternatives was essential. This led to the development of a relative assessment protocol in which all ATLSS outputs were compared to a base plan. Project managers could use this to develop a ranking of various alternative plans utilizing their own preferences for spatial regions to be considered. A uniform methodology across species and functional groups also allowed managers to apply their own criteria when accounting for differences in species responses between scenarios. The relative assessment approach has additional advantages in that the dependence of the rankings obtained on model assumptions can be explicitly tested. Though considerably more complex than aggregated spatial averages, spatially-explicit models evaluated through a relative assessment protocol provide details of trophic component responses that are essential for systems with explicit spatial controls.

We will describe a number of general lessons for modelers and managers that have arisen as we pursued the development of ATLSS. These are focused on three areas: (i) doing the modeling; (ii) personnel matters; and (iii) interacting with stakeholders.

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South Florida Ecosystem Database Access

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The South Florida Ecosystem Restoration Program is an intergovernmental effort to restore, preserve, and protect the fragile ecosystems of southern Florida. One goal of the restoration effort is to develop a firm scientific basis for resource decision-making. Information required for the decision-making process includes biologic, cartographic, geologic, and hydrologic data that relate to the ecosystems of the mainland of southern Florida, Florida Bay, the Florida Keys, and the Florida Reef tract. Numerous Federal, State, and local agencies and other scientific organizations individually collect, analyze, and store data in separate databases, making access to the information difficult.

The U.S. Geological Survey has developed the South Florida Information Access (SOFIA) website and database (http://sofia.usgs.gov) as a central location for storing, maintaining and retrieving data, metadata, and geospatial by referenced data sets produced by participating Federal, State, regional, and local agencies. All data being collected by the U.S. Geological Survey as part of the South Florida Ecosystem Program (SFEP) database will be included in the database, either in data tables or as related files. The database currently holds information for 64 projects, 53 stations, and more than 3 million data values for 48 environmental parameters. This is a dynamic database with new projects and data added daily.

The SFEP database is online and available through the SFEP public web site or directly at URL http://www.envirobase.usgs.gov. The web-based interface allows direct query and retrieval of project information, data collected, findings, and summaries. Although most of the data is stored in the database, the interface also provides access to the project information found on the main SOFIA website and to U.S. Geological Survey data stored in other databases. Project information can be retrieved by title, geographic area, principal investigator, investigating agency, or ecosystem topic. Data are retrieved through a multistep process such as by data type, station name, county, parameter, or collecting agency. The data are output as text files, along with a base map with the designated station locations. Users can register on the site to receive updates when new information becomes available.

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Everglades National Park Scientific Database: Lessons Learned in Developing an Integrated Relational Database Using Historical Data

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The South Florida Natural Resources Center (SFNRC) has been collecting biological and physical information on Everglades National Park for almost twenty-five years. Additional data sets beginning in the 1950's have also been acquired. This information has been stored using a variety of formats and computers over the life of the data sets. All the Everglades data sets were stored in each investigator's format, using their software of choice and accessed using individually written programs. Access was difficult and many scientists found it impossible to work with their historical data because of the size of these data files. Also, integrating and analyzing different data sets was difficult and could not be performed by the average user. When investigators left the park, understanding, using and maintaining their databases and applications was difficult and time consuming.

The SFNRC has developed an integrated database where most of the biological and physical data are stored. Scientists can merge data from different studies and analyze the effects physical factors have on biological organisms. In addition, this database will enable easy and secure long-term maintenance of data as investigators come and go. We began to develop individual parts of the database by data type because of the database size and the variety of data types. We tried to use common data elements wherever possible, however, we quickly learned that most of the data element codes used over the years were different from data set to data set. Basic data elements, such as species codes, were different from study to study and in some cases where the codes were originally the same, they have been modified over the years.

Frequently over the life of a data set, methodologies have been changed and the database was modified to reflect these changes. Quite often, certain methodologies were used ten or twenty years ago and were no longer in use. The researcher in charge of the data set would frequently not be aware of these changes since the responsibility for the data set had changed several times over the life of the data collection activity. To resolve these inconsistencies, the researchers would have to work with the data as well as look back through the literature and determine the methodology or codes used in the data sets.

Currently the Everglades Database has several data sets, which are loaded, and being accessed by users. These data sets are the physical, systematic reconnaissance flights (SRF), creel census, marine benthic ecology, fresh water fish and invertebrates, and vegetation databases. These databases have many different parameters and can be interfaced using a variety of fields. Although the databases currently are only used locally, the SFNRC has begun an effort to provide a web interface.

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Poster Abstracts

Information Systems

Communication of Hydrologic Modeling Results via the Internet

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With increased use of ground water and surface water models for water resources planning and operational decision making there is also increased need to effectively communicate hydrologic modeling results to water managers and to the public. Performance measure graphics, water budget maps and flow animations enhance graphical communication of model results in a simplified way. Projects such as the Comprehensive Everglades Restoration Plan (CERP) required the dissemination of results to many participating agencies and a wide audience; the Internet provided the best platform to accomplish this.

Web pages used to communicate the hydrologic performance measure graphics evaluated in the development of the CERP are presented. Performance measures include various maps, graphs and animations of Natural System Model (NSM) and South Florida Water Management Model (SFWMM) simulation results.

An accompanying computer presentation will highlight the animations used to communicate these and other pertinent hydrologic modeling results.

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The Everglades National Park Relational Scientific Database

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The South Florida Natural Resources Center (SFNRC) has been collecting biological and physical information on Everglades National Park for almost twenty-five years. Additional data sets beginning in the 1950's have also been acquired. This information has been stored using a variety of formats and computers over the life of the data sets. All the Everglades data sets were stored in each investigator's format, using their software of choice and accessed using individually written programs. Access was difficult and many scientists found it impossible to work with their historical data because of the size of these data files. Also, integrating and analyzing different data sets was difficult and could not be performed by the average user. When investigators left the park, understanding, using and maintaining their databases and applications was difficult and time consuming.

Over the past few years the SFNRC has been developing an Oracle database to store the major data sets collected by the SFNRC. This database contains information on physical and biological data collected by the park and its cooperators. The aim of this database is to store and document information in a secure environment for scientific use. A great deal of effort has been expended in the development of the database, loading the data and providing access to the users. Instead of having many disparate databases, the SFNRC is building a consolidated integrated database, providing users with the ability to look at changes in certain environmental factors and investigate the possible effects these factors may have on the animals and plants of the Everglades.

The SFNRC has several data sets loaded into the database. Where possible, common tables have been developed to integrate the data sets. The Everglades database currently has the physical, systematic reconnaissance flights (SRF), creel census, marine benthic ecology, fresh water fish and vegetation data sets loaded into the database. Each of these data sets contain many parameters which are stored in individual tables and in cases where the parameter tables were large, summary tables were developed for quicker access.

The physical data set contains information on water levels (stage, depth), rainfall, temperature and salinity (conductivity) which were collected at stations located within Everglades National Park (ENP). This data set has the first web-enabled data retrieval system developed at the SFNRC. Currently this retrieval system is being used within Everglades National Park; however, it will soon be available on the web.

The SRF data set contains data on deer, bird and alligator populations in the ENP. The Creel Census data set has fisherman, guide and commercial fish landings from the ENP. The Marine Benthic Ecology data set is a study of organisms which inhabit Florida Bay, while the Fresh Water Fish data set is a study of organisms which inhabit the fresh water areas of the ENP. The vegetation data set is a compilation of plants located within the ENP.

Wherever possible these data sets have been related using common tables. Such fields as location, species and project are common to most data sets and can act as an easy reference to the contents of the database. Other fields such as date can be used to relate data and often these fields are used as keys within the individual tables. As additional data sets are added to the database, more common fields will be determined.

Currently the SFNRC is developing a web server so that portions of the database can be available for general use. The user will be able to generate queries and receive reports from information in the database. This system is being developed using Oracle forms and reports server and will directly access the database for information.

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Unpublished Data and Document Search and Rescue for South Florida

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The Coastal and Estuarine Data/Document Archeology and Rescue (CEDAR) locates unpublished documents and data related to the South Florida by contacting academia, Federal, state and municipal governments, industry, and non-profit organizations and individuals. A database of found materials has been created containing the following data: full bibliographic information (author, title, year, funding agency, pagination, key words, etc.); physical location of original material; physical state of original materials (mimeograph, photocopy, etc.); and summary. Priorities for data or document restoration of the found material will be establish based on topic (chemical measurements, physical measurements, assessment studies, contamination evaluation, anthropogenic damage, monitoring, restoration efforts and results, and dredging) and geographical coverage (Biscayne Bay, Florida Bay, Florida Keys and coral reefs offshore, St. Lucie Estuary, Ten Thousand Islands, Dry Tortugas, Tampa Bay, and Apalachicola Bay). Primary coastal environments of interest include estuaries, bays, mangrove forests, seagrasses, and coral reefs. Conversion of priority data and documents into electronic form and publication in printed form and on the Internet will co-occur with data and document search.

Documents rescued are available online as full text pdf files at the CEDAR site resident at the NOAA Miami Regional Library Internet site <http://www.aoml.noaa.gov/general/lib/CEDAR.html>.

The search for unpublished material continues. Please contact one of the authors if you know of unpublished data or documents related to the coastal environment of South Florida, specially material dated before the 1970s.

NOS/National Centers for Coastal Ocean Science (NCCOS) and NESDIS were awarded 2-year funding by the South Florida Ecosystem Restoration Prediction and Modeling Program (SFERPM) -- a competitive program conducted by CSCOR, in association with the South Florida Living Marine Resources Program (SFLMR) -- for South Florida.

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Development of a Digital Bio/Geo-library for the Greater Everglades Ecosystem

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To enable all stakeholders of the south Florida community to use "sound science as a basis for informed planning decisions and resolution/prevention of resource-management problems" (USGS Place-Based Studies Program, Program Priorities, 1999), efforts to synthesize, manage and disseminate high-quality scientific information about the greater Everglades ecosystem have gained increasing support and urgency. The information systems project presented here addresses the need for timely, high-quality and relevant information through the development of a digital library for the greater Everglades. This digital library focuses on textual and multimedia scientific information concerned with water, minerals, biota, and land in the south Florida ecosystem. The digital services of the system include the tools to search for, evaluate, visualize and acquire needed information resources from any Internet-connected computer. In combination, the collections and services of the greater Everglades digital library provide a comprehensive and coherent information system that facilitates the exchange, analysis and use of high-quality information resources across the diverse agencies, disciplines, and communities concerned with Everglades research, restoration and resource management.

The "digital library" approach encompassed in this project recognizes the importance of users' needs, skills and concerns in designing and developing a large-scale information system. Modeled on the concept of a library -- the institution most experienced in putting useful, high-quality information into the hands of users-- the digital library approach seeks to enhance users' abilities to identify, find, browse, and retrieve information by combining powerful information and publishing technologies with the convenience and ease of the Internet. Through the processes of selection, classification, indexing, and archiving, the digital library developed in this project will provide coherent access to, and long-term preservation of, a comprehensive knowledgebase about the south Florida ecosystem - from field studies and records from the early 20th century to the latest results reported by scientists and managers today.

The design and architecture of this digital bio-geolibrary reflects the specific needs and issues relating to the greater Everglades research and restoration. Digital collections are primarily place-based, referencing specific locations or regions within the greater Everglades either by absolute location or by place name. A large part of the collections are also biotic, referencing specific plant or animal species, habitats, or the biotic and abiotic factors impacting their survival or eradication. Ensuring access to these collections based on their biotic and geographic attributes (in addition to the more 'traditional' attributes of topic or author) is a key design feature of digital library development in this project.

The design and architecture of the system is based on sound information standards and practices, including the application of extended Markup Language (XML) for structured text files; the Federal Geographic Data Committee (FGDC) /National Biological Information Infrastructure Content Standard for descriptive metadata; and the Integrated Taxonomic Information System (IT IS) for taxonomic classification. Where national standards are unavailable, application of best practices from existing digital libraries such as the Alexandria Digital Library Project at the University of Santa Barbara; the Florida State University Systemote s Digital Library; and the Florida Data Directory's Automated Library System maintained by the Florida Geographic Board. Adherence to standards will ensure that the digital library for the greater Everglades is extensible, enduring, secure, and interoperable with related information systems maintained by other agencies. The digital library comprises four principal elements, tiered as follows:

1. Repository

The foundation of the digital library is the repository, providing storage of the the digital objects and associated metadata files. Services for loading and storing files, generating derivative versions for browsing and access, and digital archiving and back-up are also provided in the Repository. Delivery of files into the Repository is designed to occur through two possible events: either by direct loading by project personnel, using secure file transfer procedures, or by disposition of digital files as a final step in an electronic publishing process. The latter process is being developed as an enhancement to agency document management and media asset systems, in cooperation with the USGS Domino Development Team.

2. Applications and Services

The applications operating in the 'middle tier of the digital library system include services in support of information retrieval, including indexing of text files, parsing and indexing of metadata records; on-the-fly conversion of digital objects for on-demand Web viewing or publishing; and tools for displaying and visualizing items retrieved from the repository.

In support of effective indexing and metadata services of the digital library, two specialized tools are being developed in this project to facilitate retrieval in a biotic/place-based context. The *South Florida Ecosystem Thesaurus* provides a set of keywords and phrases used to sescribe digital items on the supply side, and to search for information resources on the user side. The *South Florida Ecosystem Gazetteer, a* geospatial dictionaries of geographic names which includes entries for place ; location (coordinates representing a point, line, or areal location); and feature type (selected from a controlled list of categories for places/features). Each of these tools will be incorporated into the digital library system for use both by humans (information providers and online searchers), and by machines (in automated query processing, indexing and searching).

3. Access Services/Interface

Given the broadly-defined user base with diverse needs, interests and skills, it is recognized that the digital library must provide multiple views of the same information from various perspectives. A user friendly interface is being designed to allow searches by geographical location (coordinates or place name); by subject theme or time period; and by taxonomic classification. Due to the fuzziness and varying scale of some geospatial footprints, geographic querying needs to support spatial relationships such as intersection, containment, boundary, adjacency, and proximity. Biotic searches need to support queries by scientific or common names. Several "browse" views of the digital library contents, including a hierarchical subject tree and a clickable map showing the geographic extent of the collections, will also be provided in the user interface.

4. User Support

The library model of information services provides significant support for users, including online help; electronic reference service; training; and assessment and feedback by users. There is certain to be a need for such user support in a digital library, particularly using the biologically- and geographically-referenced services under development in this project. Project planning includes a future phase focusing on the design of a user support program for the digital library.

Early prototypes from this project demonstrate the power and ease of using a digital library to identify, evaluate, and retrieve information resources on demand, from the convenience of one's own desktop. A test set of over 4000 records is already available through the *Everglades Online* database. Initial collections include materials from Florida International University, the University of Miami, the Historical Museum of South Florida, Everglades National Park, the USGS Florida Caribbean Science Center and the USGS South Florida Ecosystem Program.

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Spatially-Explicit Species Index Models in Application to Everglades Restoration

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The ATLSS (Across Trophic Level System Simulation) hierarchy of models is designed to utilize varying levels of detail and data availability to assess the relative impact of alternative hydrological plans on the biotic components of South Florida. ATLSS is being used regularly in the ongoing planning for Everglades restoration (see http://atlss.org/). A key segment of the ATLSS hierarchy includes models that make use of information on breeding and foraging requirements for species and how these relate to localized habitat conditions and within-year dynamics of hydrology. These Spatially-Explicit Species Index (SESI) models compare the relative potential for breeding and/or foraging across the landscape without tracking in detail the population dynamics or behavior of individuals for these species. SESI models are viewed as approximations, which are useful in coarse evaluations of scenarios and are an aid in interpreting more detailed ATLSS models.

We describe the general construction and application of SESI models for the Cape Sable Seaside Sparrow, the Snail Kite, Short- and Long-Legged Wading Birds, White-tailed Deer, and Alligators. These models have been applied on a regular basis during the Central and South Florida Comprehensive Restudy to assess the relative effects of alternative scenarios compared to various the base scenarios. The SESI approach offers advantages over Habitat Suitability Index (HSI) methods as it can incorporate both static and dynamic landscape features.

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South Florida Information Access (SOFIA) Website

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South Florida is one of several study areas within the United States Geological Survey's Place-Based Science (PBS) Program. This program was established to provide scientific assistance to resource managers and scientists, who require an improved scientific information base to resolve or avert complex resource conflicts or environmental problems at specific ecosystem sites. The information is designed to have a direct, significant, and immediate impact on management and policy decisions.

The South Florida Information Access (SOFIA) website, which is part of the PBS program, was created as a 'one-stop-shopping' access point for research in south Florida. The site was designed around the research projects within the program. Each project on the SOFIA site addresses a specific problem or issue in south Florida. Every project in the program is online at this site, complete with project publications, abstracts of conference presentations, contact information, and links to online project data, stored on the associated data exchange pages and on the database website. But the site is not merely a centralized warehouse of material for the research community.

The SOFIA website was designed to be accessible to all visitors and usable by anyone. We provide contextual navigation at the top of every page, which shows the user exactly where they are within the site. This not only clues the visitor in to where they are, but it also allows them to move up through as many levels within that section as they would like. Each individual project page contains the same set of links - proposals, abstracts, data, metadata, publications, biographies, and related links - which gives the visitor access to each section of that project. The visitor can immediately see what information is available for that specific project. The website also has a fully functional search engine that allows visitors to search the entire site for specific information. In addition, this site also has a text-based site map, which allows the visitor to view the entire site at a glance. We also provide contacts for various parts of the SOFIA program. Should a visitor have a question or comment about any aspect of the site, this page provides direct access to the right person.

In addition to the SOFIA site, we also began hosting the website for the South Florida Restoration Science Forum in May 1999. The South Florida Restoration Science Forum website highlights the powerful connection between science and management decisions in restoration efforts. This site affords a unique opportunity for everyone to see highlights of the most significant restoration science and management efforts underway. Hundreds of scientists from numerous organizations have prepared over five hundred posters and exhibits to show you the strength of the science that is being done to help science-based decisions in managing the restoration effort. This website houses over 400 pages (including on-line versions of the posters that were presented at the forum) and audio and video clips of presentations. This site is organized into ten topics, including coastal ecosystems, nutrients, wildlife and wetland ecology, and hydrology.

There are several future directions for the SOFIA website. In addition to adding new information daily, we will also be working on adding educational materials to the site. Part of this initiative will include working with the students at Forest Hill High School in West Palm Beach, Florida. The USGS has helped install a state-of-the-art weather station on the Forest Hill campus that will help the students collect meteorological and groundwater data. The students of Forest Hill will be using these data to help forecast weather and will publish their findings in their school newspaper. The SOFIA web site will also be working with the school to help develop a similar web site for their project. We also plan an interactive tour of the SOFIA site, which will allow visitors to experience the sights and sounds of the south Florida ecosystem. This tour will also highlight USGS research projects in the south Florida region, including the Everglades and the Florida Keys.

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The ELM Web Application

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The Center for Environmental Studies was consulted to assist the South Florida Water Management District's Everglades Landscape Modeling effort by designing a site that effectively presents data output model runs while requiring minimal maintenance for future expansion. To accomplish this task the web site needed to present a large amount of data in several different formats, to a diverse group of individuals in a highly usable fashion. A structured design and use of new programming tools were used to provide an automated system for the future development of the site.

The ELM Web Application involves many different project evaluations and model runs. Several data formats are produced including graphs, tables, animations, and maps. In presenting these different types of data Adobe Acrobat PDF files are used to format graph information, GIF and Quick Time movie files are used for animations and image maps are used to assist with geographic region selection.

ELM results are presented on the internet to a diverse audience which includes scientists, managers, lay people and students. Taking this into consideration the data is presented in ways that are easy to understand yet valuable for analysis to different levels of users. Project evaluations can be selected from a directory tree menu and comparative evaluations can be created easily with a wizard that steps the user through the process. The procedure that finds new and existing data to present is what truly makes this site unique.

To accommodate the continuous and substantial growth of data from new model runs, an automated process was created using open source tools, PHP and JavaScript. Through the use of a standardized directory structure newly added data is recognized and presented automatically on the web pages. In addition to identifying the data the process finds and replicates new file structures and presents them on the web site similar to the actual structure on the server.

The Everglades Landscape Model poster will present the ELM web site's of presentation different data types, navigation of a complex system, and automation of the site's maintenance and expansion.

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Region Science Plan for Southwest Florida's Big Cypress Basin

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The Region Science Plan for the Big Cypress Basin region of southwest Florida identifies priority science and information management needs for the region's research and land management community. Developed over a three-year period through the cooperative efforts of public and private interests, the Plan is intended to provide guidance for the South Florida Ecosystem Restoration Task Force (SFTF), the Southwest Florida Project Coordination Team (SWFPCT), and federal, state, and local agencies and private organizations. The Plan provides specific priority recommendations for science information relevant to restoration and management issues, as identified by over 70 local professionals and a review of over 200 research and monitoring projects within the Basin.

In 1996, a Steering Committee was established at the request of Interior Secretary Bruce Babbitt and the SFTF, to develop a region Science Plan. The Committee was comprised of public land managers, region planners, researchers, and agriculture interests. The Committee accomplished the following tasks:

1. Identified a boundary for the Big Cypress Basin Region that encompasses priority coastal estuaries and watersheds representing key land and water resources within the Basin. This boundary was adopted by the SWFPCT.

2. Conducted an inventory of over 200 region research and monitoring projects, and provided summaries on the internet through a web site sponsored by the Florida Gulf Coast University and the South Florida Water Management District.

3. Planned and conducted a series of workshops, targeting professionals involved in environmental research, management, and land use planning. Participants identified priority resource issues of regional significance, reviewed the science inventory database, and developed draft recommendations to address priority science information needs linked to restoration and resource issues.

Three initial recommendations of the draft Plan, with the approval of the SWFPCT, have already been implemented: A multi-agency coalition has been established to review water quality monitoring efforts within the region; the region science database has been updated and is available on the internet; and a science coordination workshop was conducted in June 2000 to review restoration plans and relevant research for the Southern Golden Gate Estates.

The presentation will consist of an overview of the planning process, and a discussion of priority region issues including water quality, hydrology, biodiversity, and region coordination. Examples of specific project recommendations will be reviewed.

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Design and Development of the Florida Bay Salinity Database

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The purpose of this project is to develop a temporally- and spatially-referenced database of salinity data from the diverse literature on Florida Bay, and to provide access to this database through an effective, user-friendly interface via the Internet. This project is part of a larger effort to synthesize salinity conditions in Florida Bay over the last century.

Understanding the salinity dynamics of Florida Bay is central to its restoration. Salinity is an intermediate link in the cause and effect that connects upstream water-management activities to the structure and function of the Florida Bay ecosystem. Long-term regional water-management practices are widely thought to have reduced the quantity of freshwater inflow into the bay and shifted its distribution and timing, leading to a marinification of Florida Bay. The perception of ecological decline in Florida Bay, as evidenced by seagrass die-off, the onset of extensive turbidity/algal blooms and corresponding declines in dependent fisheries, is often linked, at least in part, to salinity stress and long-term changes in salinity within the bay. Prominent elements within the Florida Bay Restoration Program include: restoring freshwater inflows; enabling predictions of Florida Bay salinity based on upstream hydrology and water-management; and developing, as a possible restoration target, a model of the salinity regime in Florida Bay prior to water management. The success of these restoration efforts requires a complete understanding of the historical salinity pattern in Florida Bay.

To compile a comprehensive salinity database for Florida Bay, extensive searches for salinity data were conducted across a diverse body of literature and collections spanning more than 150 years. The primary aim of the search was to identify and locate salinity observations that met the following criteria:

- the observation was made within Florida Bay waters or in waters adjacent to the bay;
- the measurement was a discrete observation (not an average value);
- the date and time that the observation was made is known;
- the location at which the salinity observation had been made was available or could be estimated;
- and the depth at which the observation was made could be determined.

A second aim of the search was to identify and retrieve reference and anecdotal materials containing information interpretable in terms of salinity conditions within the bay. Sources include both quantitative salinity values as well as anecdotal observations about salinity and related conditions (e.g., direct observations of freshwater occurrences, fish kills, and other phenomena reflecting changes in water quality).

For the purposes of this project, ‘Florida Bay’ has been defined as the region south of mainland Florida and includes the semi-enclosed bays and sounds of the mangrove estuary, north and west of U. S Route 1 from its junction with the mainland southwest through the Florida Keys to the southern tip of Long Key and east of a line between Long Key (80^{o} 56.0', 24^{o} 48.1') and East Cape Sable (81^{o} 05.3', 25^{o} 07.0'). Generally this region encloses Florida Bay as contained within Everglades National Park. However, salinity patterns in Florida Bay are dependent on processes occurring along its periphery. As such, data and reference material were included for Manatee Bay and Barnes Sound to the east, Largo Sound and the major passes through the Florida Keys south to Long Key, near vicinity Gulf of Mexico waters, and Whitewater Bay and the rivers and bays from Lostman River south. Future efforts will extend this west coast search area north as far as Cape Romano.

The search for relevant data and references was conducted across a diverse body of literature and collections including both the scientific literature and the body of historical records contained in archives, libraries, and other repositories. Sources of relevant information included published bibliographies, journal articles, technical reports, dissertations, theses, and unpublished datasets; records, diaries and personal accounts.

To date this effort has produced a database containing 232 references, including 70 sources of salinity data extending from 1936 to the present. Spatially extensive data are available from the mid-1950's. Comprehensive salinity monitoring begins in the late 1980’s. Less quantitative or anecdotal references to salinity conditions date back to the turn-of-the-century in the scientific literature, and to the mid-19^{th} Century in the historical record.

A principal goal of this project is to integrate these diverse studies and observations into a relational database within which the data can be explored, data sets developed, and data files exported for further analysis. The primary data for each study is available in the database; however, an integrated data set of daily average salinity calculated for each station within each study will form the basis for integrated data searches. To expedite data searches data summaries will be available of monthly, seasonal (wet/dry), and annual time steps.

Metadata records providing summaries of the study; geospatial and temporal coverage of the study; descriptive keywords and place names; and related references where applicable will accompany data from each study. The database interface supports multiple types of queries, including geospatial, temporal, topical, and study author(s) or title. From the results of any query, searchers may retrieve both salinity data and annotated reference materials.

Initial analysis of the data in the Florida Salinity Database indicates that, over the period-of-record, Florida Bay has varied between being a positive (salinity decreasing west to east) or a negative estuary (salinity increasing west to east). These patterns of salinity appear to be linked to the wet/dry cycle characteristic of South Florida. During periods of drought the bay often behaves as a hypersaline lagoon (a negative estuary with evaporation exceeding rainfall and runoff). Hypersaline conditions appear first and have been most severe and persistent in central Florida Bay where salinities have reached or exceeded 40 psu for almost 60% of the period-of-record. In contrast, Florida Bay behaves as a positive estuary less often. Episodic events associated with high rainfall such as tropical waves or depressions, hurricanes or periods of above average rainfall like the 1993-1995 period are needed for Florida Bay to be a positive estuary. Water management in South

Florida has achieved this effect as well. Increased flows through the cutouts in the C-111 Canal into Florida Bay due to operational changes upstream had the effect of maintaining Florida Bay as a positive estuary during the period 1983-1985, a period of significant below average rainfall in South Florida.

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Development of the Cook Inlet Information Management/Monitoring System (CIIMMS)

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The Cook Inlet Information Management/Monitoring System (CIIMMS) provides an interactive website that links to a geographically distributed system of information providers. Through the CIIMMS website, users are able to identify and access (e.g., download and print) information ranging from primary data (geospatial and tabular) to reports, project descriptions, and other documents across a variety of themes, such as habitat, land use, resource management, pollution, and water-quality information. CIIMMS will also provide (on-line) tools to make it easy to contribute information to the CIIMMS network. In the long term, CIIMMS will use integrated information resources and tools to create a virtual community center for Cook Inlet learning, resource management, and related activities.

CIIMMS not only comprises the hardware, software, and information contact components of the Cook Inlet information management system; it also establishes a framework for managing information resources more efficiently. Two important components of CIIMMS development are (1) establish an advisory group made up of data providers and users to oversee implementation and (2) publish guidelines on how to implement various aspects of the framework (e.g., compile metadata). By providing the tools and the framework that enable a unified approach to information management throughout the watershed, CIIMMS will help agencies and organizations use existing resources more effectively.

The CIIMMS is a three-year project, funded by the *Exxon Valdez* Oil Spill Trustee Council. This site and its associated graphical user interface will support monitoring, management and restoration of resources and services injured by the *Exxon Valdez* Oil Spill, as well as provide access to data sets and tools valuable to addressing the ecological health of a watershed. This system is unique in that it will provide access to a broad spectrum of timely data and visualization tools via the Internet. CIIMMS will allow regulators, resource managers, planners, and others to approach decision-making from a watershed perspective.

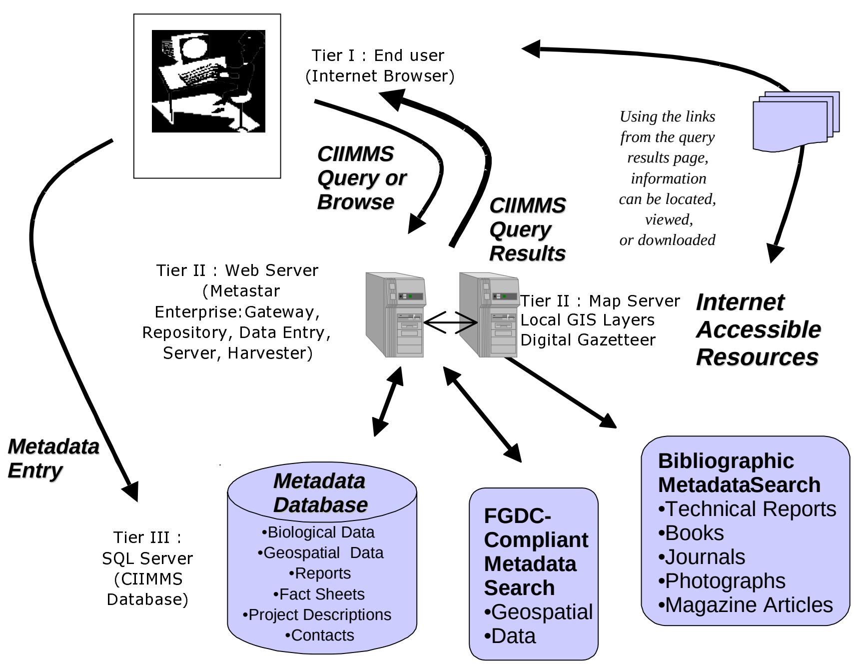
The Cook Inlet watershed is a large and complex ecosystem containing a diverse and abundant biota that is subject to intense physical forces as well as to increasing human influences. Each year, industry, government, the scientific community, and citizen watchdog groups generate and use large quantities of information about this area and its resources. Typically this information is used to focus on a single resource, issue, or problem, and data management techniques are used that are specific to that need. These actions may lack a coordinated, comprehensive ecosystem approach. Ecosystem or watershed level management requires integration and access to data from many different projects and initiatives.

In October 1998, the Alaska Department of Natural Resources (ADNR) and the Alaska Department of Environmental Conservation (ADEC) launched the CIIMMS project. A multi-agency project team was formed and presently includes members from U.S. Environmental Protection Agency, the U.S. Forest Service, the U.S. Geologic Survey, and the ARLIS Library (Alaska Resources Library and Information Services). Science Applications International Corporation (SAIC) provides technical guidance and support to the CIIMMS team.

The figure below shows a high-level schematic of the prototype system architecture. The system is structured into three tiers, as follows:

- Tier I: End user machine with an Internet browser, such as Netscape or Internet Explorer
- Tier II: Web Server, which houses the MetaStar Enterprise software for discovering and accessing metadata and information from all levels of the CIIMMS Information Pyramid, and the Map server, which provides the map-based metadata search function. This function displays local GIS layers and a digital gazetteer. The map presentation and GUI allow for bounding coordinates, place names and subject keywords to be passed to the MetaStar Enterprise software.
- Tier III: SQL Server, which houses the CIIMMS metadata, projects, and contacts database.

CIIMMS high-level system architecture.



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South Florida Information Access (SOFIA) Metadata

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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. Resource managers within Federal, State, and local agencies and other groups are seeking to reverse environmentally damaging actions of the past. 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 scientists have been conducting research projects designed to provide sound scientific information on 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 the 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 Ecosystem Program research projects, ranging from monitoring mercury contamination in the Everglades to investigating coral reef decline, are online at this site. The Web site provides project descriptions, publication references, data, presentations, and contact information, as well as general interest items, such as photographs and posters.

A primary goal of the USGS Place-Based Studies Program is providing sound scientific data and synthesis of the research results to aid managers in making responsible decisions regarding restoration of the Everglades and the ecosystem of southern Florida. The next major effort is to make the research data and synthesis easily accessible to managers, scientists, and the public.

A tool for doing this is metadata. The Federal Geographic Data Committee (FGDC) developed a common set of definitions and terminology for geospatial data to be used for documenting the data and for searching to identify potentially useful data sets. Metadata provide information about the data, such as the name of the data set, the reason it was created, who created it, how accurate the data are, the physical location of the data on the ground, restrictions on using the data, and how to obtain the data.

The format for FGDC-compliant metadata is often confusing to generate and read unless the user is familiar with the document that gives the metadata element names and definitions. The most common format for FGDC metadata records is referred to as the outline form. It was designed for ease in searching on specific elements, such as geographic coordinates, places, topics, or even an individual project chief’s name. Peter Schweitzer of the USGS has developed an alternate format to make the metadata more user friendly. This format is called Question and Answer and presents the metadata as a series of questions and responses to the questions.

The metadata part of the SOFIA Web site documents current and previous research conducted by the USGS. Most of the projects have FGDC-compliant metadata, with the exception of some projects started in fiscal year 2000. Work is continuing on using FGDC-compliant metadata to document data sets available on the SOFIA Data Exchange pages. Eventually historical data sets will be included to allow time-series studies to be conducted. The collection of metadata for relevant data from other Federal, State, and local agencies is in progress. The metadata for projects and data sets will be updated as new information is obtained from project chiefs.

FGDC-compliant metadata records on the SOFIA site are in three formats - HTML, plain text, and the Question and Answer format. It is hoped that making metadata available in the latter, more readable format will encourage users to browse and discover what types of data are available through the SOFIA site.

Visit the SOFIA Web site at http://sofia.usgs.gov/. The outline form of the metadata is also available through the FGDC Clearinghouse (http://clearinghouse1.fgdc.gov/FGDCgateway.html) by searching on the South Florida Ecosystem Project database.

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Oral Abstracts

Social and Human Sciences

Environmental Decisionmaking by Stakeholder Consensus

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Environmental problems occur where ecosystems and human social systems converge. Since the various parties involved in an environmental issue bring different interests, values, information, positions, concerns, and power with them, contentious situations often develop. In the realm of public policy and planning, when advocates of different positions have disparate positions or concerns, utilizing authoritative means may not be an effective way of reaching goals and objectives. Environmental controversies, with complex and competing issues, are not well managed by strict decisionmaking processes. As a result, some decisionmakers are beginning to resolve environmental issues by means of collaborative techniques.

Collaboration is a method of joint problem solving based upon an application of social learning theory. Social learning acknowledges that people naturally resist change and believe their opinions are the only possible correct ones. Social learning attempts to overcome these barriers by linking formal, theoretical knowledge to informal, practical wisdom through face-to-face dialogue among contending parties. The usual categorizing of parties as adversaries is altered in an attempt to reach well-conceived decisions that are respected by all participants in a decisionmaking process. This approach fosters civic dialogue, features good science, and incorporates local knowledge into discussions, discourse, and open meetings.

Collaborative processes are being utilized to build consensus and foster creative alternatives and solutions through a convergence of the positions or concerns of the people participating in the process. Collaboration recognizes that decisionmaking should involve all interested stakeholders in a procedure that can produce several alternative solutions to existing problems.

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Land-use Changes and Flood Protection Policies in South Florida

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Urban areas that are intertwined with natural ecosystems represent a complex pattern of human-environment systems. Human needs for lands suitable for urban development and agriculture result in widespread modification of the spatial structure of landscapes, hydrology and vegetative cover. This human intervention is not a one-time event that occurs at the point of original modification of the landscape, but a dynamic process through which evolving population will continue to put pressure on the natural environment. Understanding the socio-economic processes underlying land- and water-use changes is the logical first step in efforts to ease the human impacts on the environment.

Rapid urban land development in the Lower East Coast of South Florida has been made possible by extensive draining of swamps and constructing canals and water basins. The main design functions of large-scale water delivery system are to protect the adjacent urban areas against floods, to control water elevations in adjacent areas, to prevent salt-water intrusion and over drainage, to provide freshwater to Biscayne Bay, and to provide water for public consumption (USACE, 1999). Thus, the single most urban impact on the ecosystem in the region occurs through a profound alteration of the hydrological regime that was a major driver of South Florida's natural environment.

With changes in urban land-cover pattern (westward urban sprawl, inter-county migration of households, and Eastward Ho initiative and agricultural uses) relative to permanent flood control structures built 50 years ago, the flood control operation has become complicated. This paper tracks the history of flood control criteria and operations of the South Florida Water Management District (SFWMD) and the US Army Corps of Engineers (USACE) in response to changing land-cover patterns and various weather events in the last 40-50 years. We begin our analysis by conducting a series of interviews with the District's water managers, emergency managers and resource regulation personnel, and the USACE water operations staff. We also review the District's flood control criteria developed over the years and operating data for selected flood control structures in the three-county urban area. The information on flood control criteria are obtained from the Structure Books located on the District's internal web site (Schweigart, 1999). Our purpose here is to look for signs of key flood control policy changes made in response to socio-economic pressures, particularly land-use changes.

The preliminary analysis of flood control criteria indicates that more often than not how the water gets managed in the basin, and whether the original environmental intentions of the water management system in South Florida (e.g., freshwater flow into the Biscayne Bay and freshwater-saltwater balance) of this water delivery system are fulfilled have been very much influenced by the nature of urban land-use changes and the associated water and flood protection demands. The study further attempts to predict the direction of future flood control criteria, under the alternative future scenarios of population and urban planning and growth. Understanding of such future policy directions is essential to developing flood control and water delivery data inputs for hydrological models (e.g., SFWMD's the South Florida Water Management Model) and, in turn, ecosystem models (e.g., ATLSS) which are often used by resource managers in the region in planning ecosystem restoration.

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A Model for Ecosystem Management Through Land-Use Planning: Understanding the Mosaic of Protection Across Ecological Systems in Southern Florida

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Problem Statement

In response to increasing decline of critical natural resources, managers and planners are abandoning the traditional species by species approach to regulation where policies are fragmented by administrative lines, and are instead embracing the emerging paradigm of ecosystem management. The state of Florida has been a leader in designing and implementing ecosystem management projects at both the local and regional levels. While much research has been geared towards instituting the broad principles of managing natural systems, comparatively little work has been done to evaluate the specific tools and strategies involved in implementing the State's Everglades ecosystem management/restoration strategy at the local level. Managing ecological systems requires planners to look beyond site-specific locations and focus on broader spatial scales. However, the factors causing ecosystem decline, such as urban land use and habitat fragmentation occur at the local level and are generated by local land use decisions. To date, little or no research has been conducted to determine how local jurisdictions can incorporate the principles of ecosystem management into their planning and regulatory frameworks.

Research Objectives

This research project examines the ability of local comprehensive plans in the Everglades region to embody and implement the principles of ecosystem management. The results of this study will increase understanding of how and exactly where to incorporate ecosystem management most effectively into local level resource planning decisions. They will not only advance the theory on what constitutes a quality environmental plan, but by using Geographic Information Systems (GIS), the findings will also provide guidance for both local and regional planners on where to set future land use policies to reduce the decline of biological diversity associated with the Everglades ecosystem. By understanding the degree to which plans protect ecosystems, decision makers can be more precise and effective in their efforts to promote sustainable growth.

The study will develop a model for ecosystem planning based on an analysis of the best elements of existing plans and planning processes. It will seek to better understand how comprehensive plans can effectively manage ecological systems by addressing the following research questions: 1) what are the main components of a sound ecosystem management plan; 2) which state mandated comprehensive plans are most geared to ecosystem management and why; 3) what are the factors and processes influencing the quality of comprehensive plans with regard to ecological management; 4) how well are local jurisdictions protecting and managing ecosystems across Florida; and 5) how can plans, planning processes, and the State growth management program that mandates them be improved to enhance ecosystem management?

Analysis

A detailed protocol has been developed based on established planning theory, which will be used to quantitatively evaluate the ability of a plan to implement the principles of ecosystem management. Plan quality for county jurisdictions will be evaluated using the protocol across several ecosystem management areas (EMAs) in the southern half of the State to encompass the Everglades. The plan quality of each jurisdiction will be statistically measured and then mapped (through the use of GIS) as an overlay on top of the EMAs, areas of high biodiversity, and areas that are threatened/disturbed. With this technique, the mosaic of protection can be spatially and statistically analyzed for specific ecosystems. Mapping plan quality will reveal the degree to which communities are protecting natural systems that extend beyond their boundaries, providing a better understanding of how local jurisdictions can amend their plans in the future to more effectively accomplish the State-wide goals of ecosystem management. Statistical and visual results will indicate to planners where to focus future policies and amend comprehensive plans to protect important ecosystem functions. In this sense, mapping specific policies, as well as overall plan quality will serve as a rapid assessment of ecosystem protection and a strategic tool with which to plan more effectively at the level of natural systems.

Mapping and analysis will involve the following phases: 1) Visual interpretation by mapping plan scores, and thus the mosaic of protection across selected EMAs; 2) Measurement and comparison of total ecosystem protection by aggregating weighted plan scores within EMAs; 3) Exploration of biodiversity and disturbance levels as predictors of plan quality and ecosystem protection by using remote sensing data and GIS analysis techniques; and 4) Investigation of spatial association among plan quality score by using several measures of spatial autocorrelation to determine if the location of a jurisdiction is a significant factor in explaining plan quality.

Pilot Study To Obtain Initial Results

A pilot study based on a random sample of 24 local jurisdictions has been conducted to test the plan evaluation protocol, GIS measurement techniques, and make initial statistical conclusions about the ability of local jurisdictions to manage ecological systems. Initial results statistically identify the strengths and weakness of comprehensive plans across the State and reveal the factors influencing ecosystem plan quality in general. A major finding indicates that while high levels of biodiversity do not positively influence plan quality, when biodiversity is under threat or disturbance, environmental components of plans are significantly stronger.

Conclusion

While the general principles and guidelines for ecosystem management are well developed, little research has been done to understand how to actually implement this management approach. Examining comprehensive plans will reveal insights into how to accomplish effective ecosystem management in the Everglades as well as the entire state of Florida. Focusing on a specific EMAs will statistically and spatially demonstrate the extent to which communities are coordinating their environmental policies and protecting the broader natural system. Recommendations can then be made to improve plans and policies to protect Florida's critical natural resources over the long-term.

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Forecasting the Human Population of South Florida: The State of the Art and Directions for the Future

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Past growth of the human population in south Florida is often cited as one of the underlying core causes of the deterioration of the greater Everglades ecosystem. Though individual and societal patterns of resource consumption and landscape alteration are important components of the impact of any human population on the environment, the absolute number of people in an area remains a significant predictor of change. Therefore, the ability to forecast the size of the human population in south Florida is critical to any plan for a sustainable south Florida ecosystem. Leading demographers have recently begun to question traditional population projection methods which tend to present at best a range of population outcomes, from "high" to "low" variants without associated indications of certainty, while sophisticated end users require well-developed demographic scenarios under different socio-economic or environmental circumstances. In this paper I review the methods currently used by local, regional and state agencies to prepare population projections for south Florida counties, summarize the outcomes of these models, and suggest improvements based on recent advances in demographic forecasting methods.

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The Human Side of Everglades Restoration

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Predominant attention regarding the Greater Everglades Ecosystem Restoration has been on restoring the natural system including the natural hydrology. However, the Greater Everglades Ecosystem is also home to millions of people and their environment. The natural system and the built environment components are inextricably linked in the larger ecosystem. The built environment has also been shaped through key forces such as the demographic and economic dynamics. In order to leverage the tremendous national, state, regional and local investment expected in ecosystem restoration for the next several decades, compatibility between the built and natural systems must be fostered.

This presentation, "The Human Side of Everglades Restoration", will explore the demographic and economic trends and dynamics in Southeast Florida including Broward, Miami-Dade, Monroe and Palm Beach Counties. Regional policy framework aimed at restoring the urban environment will be discussed. The presentation will also highlight key urban initiatives supportive of ecosystem restoration goals. The presentation will consist of the following five parts:

1. Population growth and dynamics
2. Changing economic base
3. Persistent economic disparities
4. Overall trends for urban development
5. Highlights of selected urban initiatives supportive of ecosystem restoration goals

Population Growth and Dynamics: Sources of population growth in Southeast Florida will be analyzed. Contrasts of domestic and international migration among counties will be made. Age distributions between the Southeast Florida and the state will be compared. In addition, trends toward increasing cultural diversity will be discussed.

Changing Economic Base: Impacts of globalization on the regional economy will be discussed. Sources of personal income will be analyzed. The overall economic performance of Southeast Florida will be assessed and its implications explored. Recent development of the Internet Coast Initiative and the potential deployment of a Network Access Point (NAP) in Southeast Florida will also be briefed.

Persistent Economic Disparity: Economic disparity continues to mark the Southeast Florida landscape. This disparity will be analyzed from various perspectives regarding different economic classes and different places within the region. For example, changes in average income between the top 20% and bottom 20% of families for the past twenty years will be compared and assessed.

Urban Development: Historical trends will be discussed. Fiscal impacts of alternative development patterns from the study conducted by Dr. Robert Burchell will be highlighted. The presentation will then discuss the overall regional policy framework for restoring the built environment within which many initiatives have been undertaken.

Urban Initiatives: The presentation will highlight two important urban initiatives supportive of the ecosystem restoration goals. They include the Eastward Ho! Brownfields Partnership and the South

Florida Regional Transportation Organization. The tri-county area, including Palm Beach, Broward and Miami-Dade Counties, was designated as a Brownfields Showcase Community by the U.S. Environmental Protection Agency in 1998. An important goal of the designation is to encourage urban core brownfields redevelopment and lessen the pressure for sprawl developments that encroach into the Everglades. The Council has been serving as the administrative entity for the Showcase Community. In addition, in 1998, the three counties also formed a Regional Transportation Organization (RTO) to address regional transportation improvements supportive of redevelopment and economic development. Council staff serves on the RTO's Technical Advisory Committee.

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Space, Place, and Environmental Attitudes in South Florida

Hugh Gladwin and Elena Sabogal
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This presentation presents social research results indicating that perceptions of space and place by South Florida residents affect their attitudes toward the environment and environmental policy. People see themselves as being situated in different types and sizes of space. These spaces range from a person's home, to immediate neighborhood, to different types of community, and out to the whole South Florida region. Each of these spaces work significantly but differently as contexts in which people develop beliefs and feelings about things related to the environment.

An important concept for this research is the distinction between *space* and *place*. Space can be defined as a property or location in the real world that can be experienced and measured. Place requires human agency; places are socially constructed in space. Spaces may be measured and placed on a map (as is done in the GIS analysis of survey data that is part of this presentation). To see how people transform space into place, in-depth interviews were conducted to find out how urban places are created and understood by the people who live in them. The interviews reveal a variety of cultural mental schemas or models people have of places and the environment. These schemas develop through continual interaction between the person and the spaces he or she lives in. There is thus a linkage between community/place and learned behavior, so that learned behavior can be located in the landscape.

The research involves two approaches converging from opposite dimensions. One is the in-depth interviewing described above. The other is the analysis of survey research data on environmental attitudes. An example of the convergence of both approaches is the answer to the question: how are feelings about the place called the Everglades affected by where people live. The in-depth interviews reveal mental schemas--beliefs and feelings that construct the known place people call the Everglades. The interviews also generate questions that for use in surveys. GIS analysis of survey results allow a comparison of space on maps (where people live vs. where the Everglades is located spatially) with beliefs and feelings people report in the survey data.

The data show that space and place differentially affect the images and valuations of urban and ecosystem space people have. When the focus is on one's immediate surroundings (homes and neighborhoods) people support or oppose policies based on a very local frame of reference. Decisions about using resources (e.g. water), public financing, moving to another neighborhood, are all usually made in the context of this focus on immediate surroundings. But when the focus is on a different kind of place, such "the environment" or "the Everglades" different mental schemas come in to play producing other often equally strong beliefs and feeling. Understanding the how the transition between different kinds of place work in people's minds is key to devising environmental policy that makes sense to people and thus can work.

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Integrating Environmental Justice Into The Comprehensive Everglades Restoration Master Program Management Plan

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The National Environmental Policy Act (NEPA) is the basic national charter for protection of the environment. NEPA requires that a detailed statement accompany every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The Act imposes general and specific requirements on all Federal agencies (including considerations on environmental justice). Agencies are required to "utilize a systematic, interdisciplinary approach to ensure the integrated use of the natural and social sciences and the environmental design arts in planning and decision making." They are also to insure that "unquantified environmental amenities and values are given appropriate consideration in decision making along with economic and technical considerations".

Environmental justice issues covered by NEPA, include impacts on the natural or physical environment and interrelated social and economic effects. Implementing regulations define "effects" or "impacts" to include those that are "ecological... aesthetic, historic, cultural, economic, social or health, whether direct, indirect or cumulative." In preparing environmental impact statements, NEPA requires consideration of both impacts on the natural or physical environment and interrelated social and economic impacts.

Environmental justice concerns may arise from impacts on the natural or physical environment, such as human health or ecological impacts on minority populations and low-income populations, or from inter-related social or economic impacts. The U.S. Environmental Protection Agency (EPA) NEPA guidance suggests that when it is unclear whether impacts are small, or something more than small, but less than significant, the environmental assessment (EA) should include an analysis of interrelated social and economic effects. This might justify an EIS-like scoping process particularly if the screening analysis indicates that there may be disproportionately high and adverse effects on minority and/or low-income communities. The EA should include socioeconomic analyses scaled according to the severity of the impacts.

NEPA guidelines and recommendations (promulgated particularly by EPA) ensure those disproportionately high and adverse effects on minority and/or low-income communities are identified and analyzed, by "institutionalizing" the process of identification and analysis. The presentation will highlight on-going collaborative efforts between the South Florida Water Management District, the U.S. Army Corps of Engineers, and Florida's Center for Environmental Equity and Justice and discuss the steps they are taking to integrate Environmental Justice considerations into the Comprehensive Everglades Restoration Master Program Management Program.

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Adaptive Learning in Ecological Policy and Management

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Stated objectives of the Greater Everglades Restoration Science Conference are "to define specific restoration goals, determine the best approaches to meeting these goals, and providing benchmarks that can be used to measure the success of restoration efforts over time." Additionally, "the conference will recognize the need to synthesize information gathered since the first Everglades Conference, the interdisciplinary nature of Everglades restoration, and the need to adapt scientific understanding to management action." This paper focuses on means to relate such unfolding scientific knowledge and understanding to the realm of unfolding Everglade restoration policy.
It is clear to all that are interested and involved in the Everglades restoration that restoration is an endeavor that will occur over many years and that much learning will result as specific actions are undertaken. While this conference is dedicated to advancing knowledge and understanding, it is recognized that learning will take place during the years of restoration and that the advancing knowledge and understanding must be linked to the public policy that legitimizes the restoration actions. The goal of this paper is to present an approach which will facilitate systematic learning during restoration activities and clarify science-based policy. In many ways it is a continuation of what is occurring at this conference, but in an on-going systematic way.

The framework being offered, while concerned about broad public policy concerning the Everglades, will focus more on the role of scientific and technical information in policy deliberations. The foundations of the approach are in adaptive ecosystem management (AEM), but go deeper into ecological learning than previous AEM proposals. An *adaptive ecological learning system* (AELS) is embedded in AEM and brings scientists, engineers, and policy analysts together in a way useful to policy makers. While the approach draws on scientific methods, the objectives for AELS are less the objectives of science, and more the pragmatic objectives of policy and management. The objectives are not so much to establish *ecological truths*, although this is desired, as much as they are to acquire knowledge sufficient to facilitate ecological policy and management that meets societal goals.

AELS in essence is an institutional relationship among scientists, engineers and policy makers. Organizationally there are many ways to set it up. The purpose of AELS is to establish increasingly meaningful categories of ecological knowledge over time. The intellectual roots of AELS are in the part of epistemology dealing with induction, and the specific ideas behind AELS stem from recent advances in the understanding of human learning. The specific framework of AELS follows Carpenter and Grossberg's adaptation of adaptive resonance theory to create a system that "actively searches for recognition categories, or hypotheses, whose top-down expectations provide an acceptable match to bottom-up data" (Carpenter and Grossberg 1994). The result is a system that carries out match-learning. The structure of AELS, instead of being a neural network in a computer, is a framework relating people responsible for ecosystem management and policy in a way that facilitates purposeful learning. The thought is that an institutional structure that capitalizes on the knowledge and diversity of policy analysts, engineers, ecologists, and disciplinary scientists offers a way of identifying important facets of ecosystems and their management. By structuring institutional relationships among these groups in a way that parallels adaptive resonance approaches, a means is created for considering data from perspective broader than the perspective of any of the individuals doing research, managing the ecosystem, or setting policy. Patterns can be recognized and categories of phenomena created that incorporate more ecological meaningful scales

AELS consists of two major components, a structured relationship among scientists and technologists and a structured relationship among policy analysts. These two components are interrelated by a third component. In each of the two major components there are two levels within which scientists and analysts consider data and hypotheses and establish categories of understanding (i.e., reach some form of resonance). AELS is institutionally structured in a way to allow creative tension between the levels and yet reach some form of agreement useful in establishing scientific understanding in policy considerations, leading to what all agree are science-based policies. The overall goal of AELS is what Pickett et al. (1994) are dealing with as they seek ecological integration and understanding: a way of bringing together existing data, perspectives, approaches, models, or theories, that are otherwise disparate, in a way that advances ecological understanding and provides a scientific bases for policy.

The paper presents details of AELS as related to AEM, and uses Everglades cases to illustrate the operations.

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A Strategic Plan for Everglades Restoration: Defining Success — The Marshall Plan

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A Strategic Plan is provided for Everglades restoration, preservation and protection, using a top-down doctrinal approach to systems development. The broadly stated goals and objectives of the Programmatic Environmental Impact Statement are translated to a system requirements list, relative to existing baselines, with specified targets. This provides the means to depict, track periodically, graph, and analyze results of the Plan by Congress and the public, in a one-page executive summary rendered by a top down spread-sheet model. An approach to total quality management using a cost effectiveness model provides the methodology for adaptive management. Adherence to a govt. performance & results approach thus defined presents the opportunity for restoring, preserving and protecting Everglades ecosystem performance at least cost, long term. The defined approach & methodology, used in conjunction with National Environmental Policy Act and Water Resources Development Act, provides the basis for Congressional approval, authorization and appropriation, of the Plan, as beneficially suggested here. As noted by Art Marshall, and Buzz Holling, Arthur R. Marshall Eminent Scholar Chair (University of Florida, Retired), this is better done in an independent "institution". Most importantly, the approach herein provides a mechanism whereby Everglades restoration can proceed on a basis independent of political institutions, where policy inevitably fails to adequately incorporate science to the detriment of comprehensive planning and implementation.

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Ways to Make Science More Usable for Policy Makers and Managers in Greater Everglades Ecosystem Restoration and Management

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Three bioregional assessments of the Greater Everglades/South Florida Ecosystem have been completed and are a culmination of a series of efforts involving many agencies and institutions in the region. The first began as a symposium on the Everglades organized by the U.S. National Park Service and South Florida Water Management District in 1989. This "Everglades Symposium" had the immediate purpose of compiling, synthesizing, and interpreting existing knowledge on the Everglades system. Five years later the book, *Everglades: The Ecosystem and its Restoration* (Davis and Ogden 1994) was published, completing the long term objective of making this information available to provide momentum and a technical basis for ecosystem restoration efforts. Criticized more for what was not included in the "Everglades" book than its contents, Davis and Ogden succeeded admirably at their daunting task. Inspired by the "Everglades" book and increasing evidence of ecosystem collapse, the U.S. Army Corps of Engineers initiated its "Comprehensive Review Study" of the Central and Southern Florida Project in 1993 and as part of this planning effort completed its assessment "Reconnaissance Report" in 1994 (U.S. ACE 1994). The Science Sub-Group of the Federal Interagency Task Force on the South Florida Ecosystem also completed assessments (1993, 1994), and together with the Engineers' report defined a Greater Everglades/South Florida System.

These assessments, conducted to provide direction and impetus to restoration have not yet had the desired effect on policies being made in the region. To focus on ways to make information from scientific analysis more usable for policy makers and managers, this paper will discuss obstacles affecting our ability to apply the scientific knowledge that we have gained.

Themes that linked these assessments included describing the pre-drainage ecosystem, enumerating changes that have occurred to the Everglades, characterizing current conditions, and providing guidance and initiative for ecosystem restoration activities. These assessments did not address social or economic issues.

The effects of the changes to Greater Everglades Ecosystems now threaten not only the rich biological heritage of a naturally functioning ecosystem but a human population whose water supply, economy, and quality of life are dependent on it. It is important to recognize the consensus among these assessments that these changes continue to threaten and degrade the ecological integrity of South Florida.

Even with the increased understanding these comprehensive assessments have provided, it must be understood that management and policy decisions will inevitably be made based on incomplete data and uncertain outcomes. Yet clearly we cannot wait until all the data have been collected, for instead of gaining the knowledge needed to save the Everglades, we will have documented its death. Although specific objectives and plans for ecosystem restoration are still being articulated, it has been possible to synthesize the above observations, to provide guidance for policy makers to keep the South Florida ecosystem from further degradation, and to prevent the loss of restoration options.

Immediate recommendations to environmental decision makers for reducing or preventing further degradation of natural resources can be lumped into the following categories: scientific integration - scientific knowledge and peer review should be incorporated at all stages of research, planning and environmental decision making, management integration - the hierarchy of agencies with policy and decision making powers should work together in an integrated setting with a shared vision and goals for a regional plan for South Florida ecosystem restoration, policy integration: land and water use planning should be better integrated and should not compromise restoration alternatives, and immediate action - improve hydrological patterns, reduce loss of spatial extent of habitats, and develop management plans for non-native species

These assessments have proven useful to those planning ecosystem restoration, but unfortunately, these recommendations circulate in rather narrow confines, and are not directly delivered to those making land and water use decisions. Instead, each stakeholder is seeking to control information to benefit their own agenda, not restoration as a whole. The inability of institutions participating in Everglades restoration to escape the limitations of their own agendas and philosophies may be a formidable barrier to ecological improvement.

For science to have an effective voice in environmental policy and decision making, the following obstacles must be removed: lack of a comprehensive, regional, land and water use plan, lack of a systematic effort to educate policy and decision makers about scientific knowledge gained from bioregional assessments, and institutional limitations.

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Measuring the Economic Benefits of Everglades Ecosystem Restoration

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One of the most important issues identified by the South Florida Ecosystem Restoration Working Group in their 1999 report, *South Florida Action Plan for Applied Behavioral Sciences*, is the question "What are the economic costs and benefits of restoration?" While the final feasibility report for the Restudy presented a variety of cost estimates related to alternative projects, most of the environmental benefits were not quantified. This paper presents the results of recent research to identify and measure Florida residents' economic values for Everglades restoration.

Restoration of ecosystems presents one of the most difficult challenges in contemporary science and environmental decision-making. Numerous technical questions arise over methods and procedures to restore perturbed ecosystems and what the recovery path of these systems will be in response to existing, and potentially new, stressors. Equally, if not more, vexing is the problem of deciding what the objectives of restoration will be. Several alternative points of view may exist about the services of the ecosystem that are most important and what constitutes a restored ecosystem. The decision process to deal with these problems requires natural science models of ecosystem processes and responses as well as social science research to identify the importance of different ecosystem services to society and the public's preferences for different levels of restoration.

Multiattribute utility choice analysis was used in this study to identify public preferences in Florida for restoration of the Everglades/South Florida ecosystem.
In their simplest form, multiattribute choice surveys consist of one or more alternatives that are evaluated by a decision-maker. Decision-makers may be a small group of specialists or a large group comprising members of the public. Alternatives are described by sets of attributes that are deemed essential to the decision and are understood by the decision-maker. A variety of different approaches have been followed in multiattribute choice analysis to evaluate individual's perceptions of attributes and preferred choices.

In the design of a multiattribute choice survey to identify preferences for ecosystem restoration, a critical issue is the choice of attributes to represent different states of the ecosystem. This analysis utilized both structural (species populations) and functional (water levels and timing) attributes to represent states of the ecosystem in conjunction with other attributes to represent social tradeoffs in restoration planning. These tradeoffs included different levels of domestic water restrictions, taxes to finance the projects, and changes in agricultural land acreage (complete details are provided in Milon et al., 1999). A total of 480 interviews were conducted in 1998 in Miami, West Palm Beach, Ft. Myers, Orlando and Tampa using randomly selected households from a stratified design based on census tract median income and ethnic composition. The first three cities were selected to represent the opinions of citizens most directly impacted by restoration plans since they reside in South Florida. The latter two cities represented the opinions of urban Floridians in other parts of the state.

One feature of the multiattribute choice approach is that the statistical coefficients (weights) for the attributes can be used to evaluate a range of alternative restoration plans with various combinations of the attributes. A set of possible restoration plans was constructed with the attribute levels used in the survey. These plans were intended to reflect some alternatives that have been discussed for an Everglades/South Florida restoration plan but were not intended to represent any specific plan. These alternatives included full and partial levels of restoration along with different levels of costs to Floridians

Results from the analysis showed that both structural and functional attribute choice sets yielded similar information about public preferences for tradeoffs between Everglades ecosystem restoration and other social objectives. The maximum willingness to pay ranged from $58.79 to $69.86 per household. If extrapolated to the Florida population, the annual benefits would range from $342.2 to $406.5 million. Respondents' preferences for restoration, however, were tempered by the potential consequences of restoration decisions on municipal water users and agricultural interests in South Florida. Plans that imposed high costs and/or major water restrictions would yield low or negative benefits. In addition, there were significant differences in the preferences of South Floridians versus Floridians in other parts of the state and between different socioeconomic groups.

In the context of research and planning for Everglades restoration, the multiattribute choice methods used in this study can provide a unifying framework to integrate the work of natural and social scientists. Repeated studies over many years, especially for projects that may span several decades such as the Everglades/South Florida restoration, offer a mechanism to update scientific information about changes in attribute levels and to objectively evaluate how public perceptions change over time. Applications of this type of decision-making tool in ecosystem restoration planning offer the promise of better information for resource managers about public preferences for different types and levels of restoration.

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From Boon to Affliction: How the *Melaleuca quinquenervia* Became a Weed

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Few trees share the *M. quinquenervia's* distinction in south Florida. Nearly a century ago it embodied the hopes of homesteaders and pioneers; today it serves as a potent symbol of human agency in the destruction of the Everglades. The first section of this paper is a history of *M. quinquervia's* reputation. The second uses the *M. quinquenervia* as a case study of the debate regarding native/non-native species.

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The 8 1/2 Square Mile Area: A Case Study of the Social Impacts of Everglades Restoration

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The 8 1/2 Square Mile Area, located in western Miami-Dade County, exemplifies the social challenges than can emerge as obstacles to the proposed technical solutions offered as part of the Everglades restoration effort. The neighborhood contains over 1,900 properties that include more than 500 residences owned largely by Cuban-Americans. The area of isolated development in the Everglades Ecosystem has been targeted for full buyout in recent years by the South Florida Water Management District (SFWMD) in order to implement hydrological restoration in the eastern Everglades and infuse more water into Everglades National Park and Florida Bay. However, lobbying efforts of many of the residents, the lack of enthusiasm for a buyout by the Miami-Dade County Commission, and a major policy shift by the governing board of the SFWMD have joined to shift the apparent outcome to this conflict.

The case of the 8 1/2 Square Mile Area provides an excellent example of interagency conflict and cooperation, as well as superposition of authorities in the Everglades environmental restoration effort. It also highlights the difficulties in obtaining equitable funding for the multi-agency restoration project. Pitting property rights against ecological restoration, the 8 1/2 Square Mile Area offers environmental policy analysts a case study of environmental conflict resolution, shifting alliances, the ethnicity factor in environmental management, and the social elements which technical planners often tend to ignore. This case study analyzes the development of this issue and the responses of various agencies and stakeholders, identifies factors that promote intractability and difficulty in conflict resolution, and suggests lessons for considering social impacts of future ecological restoration efforts.

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Poster Abstracts

Social and Human Sciences

Smart Growth for Wildlife

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The Western Everglades includes many of the most pristine and wild lands in all of Florida. While some is public land and enjoys a protected status, much is privately-owned. An escalating human population threatens to destroy the ecological integrity of the western Everglades. For five years the U.S. Housing Market's Hotness Index has listed Collier County, the most significant land area in the western Everglades, as the hottest building market in the nation. According to the U.S. Census Bureau, the county's growth rate continues to outstrip state and national averages. From 1990 to 1997 population grew by almost 29% adding 36 new residents each day. Collier County's Growth Management Plan projects a permanent population of over 500,000 people by 2020. As southwest Florida approaches build out, rural and agricultural lands outside of the recognized urban area are targeted for development. This land is also identified as critical habitat for the Florida panther and other wildlife, and important for water supply flow ways.

The conflicts that arise over whether to preserve or develop this land are at the heart of land use controversies in the western Everglades. These disputes are likely to continue unless there is a fundamental change in land use strategies. People across the country have begun to reject the economics of unchecked growth as the best measure of progress. The goal of the National Wildlife Federation's Everglades Project Office is to demonstrate that *smart growth* is achievable through conservation-based land use planning that recognizes a healthy environment is essential to long-term economic growth, jobs, and a higher quality of life. When and where growth occurs should depend on making proper land use decisions that protect the water supply and natural resources of the western Everglades. Conservation-based land use planning offers a solution to most land use conflicts. Smart growth will demonstrate how we can protect natural resources, maintain the quality of life residents expect, and accommodate growth. It is the first step in increasing understanding of how the region can prosper economically by enhancing the health of the western Everglades ecosystem.

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The Florida Earth Project

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The University of Florida's Institute of Food and Agricultural Sciences initiated the Florida Earth Project (FEP) to help restoration outreach efforts in a variety of environmental disciplines after reviewing studies that identified a lack of public understanding in the area of natural resource science and policy issues. FEP is a partnership of over 30 governmental agencies, universities, companies and "grass roots" groups who have coalesced to combine their resources for environmental and natural resource education activities. The first activity of FEP was the development of a 4 credit-hour course for masters degree level students, which is a field-based survey of natural resource science and issues of the South Florida ecosystem. The first delivery of this course began on July 17, 2000 and was completed August 5, 2000. A description of the course, AGG 5905 – Survey of a Land System, can be found on the World Wide Web at http://earthproject.ifas.ufl.edu. This course involved 100+ instructors from the FEP partners and was held in over 20 South Florida locations of the instructors' area of expertise. The 18 day course is divided into six modules that are broad categories of environmental interest: 1) Survey of South Florida, 2) South Florida Water Management District, 3) Natural Systems, 4) Role of Agriculture in South Florida, 5) Water Quality and Quantity, and 6) Restoration. Each module contained 10 to 20 instructors and lasted for 3 days.

Prior to and during the delivery of the course instructors submitted summaries of their presentations that are posted on FEP's website and will be compiled and published as a text called the **South Florida Earth Journal**. During the course, over 15 hours of video were taken to become a half-hour television special for a series called **Florida Life Styles**. The Journal will become the basis for the development of University of Florida Extension courses centered around the module themes, which will be developed in the Fall of 2000. The Project is also collaborating with the South Florida Ecosystem Restoration Task Force and Fort Lauderdale's Museum of Discovery and Science on ways to physically demonstrate and exhibit module subjects and concepts in various locations.

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Environmental Restoration of Lake Trafford

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Lake Trafford is a shallow eutrophic lake in Southwest Florida. It is the only large lake in this region of Florida. It is regionally significant as the headwaters of the Corkscrew Swamp and the Camp Keais Strand that drains south into the Gulf of Mexico and the northwest edge of Florida bay. At one time, the lake was sand bottomed; now, it has a layer of nutrient-rich, organic sediment two to six feet thick, which occupies 50 percent of the lake volume. This layer interferes with fish habitat and has resulted in periodic fish kills. It is necessary to remove the sediment from the lake to improve the fishery and reduce downstream discharge of nutrient-rich water.

The Lake Trafford Environmental Restoration is one of the Water Resources Development Act of 1996 restoration projects. The restoration began as a project with Florida Freshwater Fish and Game Commission to control aquatic weeds in the lake to improve the fishery. Additional research indicated the need to remove the sediments to improve littoral- zone and lake- bottom habitat and the water quality of the lake. This resulted in a proposed project for sediment removal. With the availability of WRDA funds, the project was proposed as a comprehensive sediment removal and lake restoration project.

The restoration will begin with the removal of the organic sediment during the next two years. The sediment will be removed and deposited in a spoil area a mile from the lake. The water from the sediment removal will be returned to the lake through a series of wetland treatment areas to remove excess nutrients and residual dissolved and suspended organic matter. Coincident with sediment removal, a watershed protection plan will be developed that reduces the future inflow of nutrients into the lake. This includes nutrients from the Immokalee sewage treatment plant and urban and agricultural stormwater runoff. Following sediment removal, the littoral zone will be restored by removal of willow tussocks and revegetation with emergent grasses and sedges.

Restoration of Lake Trafford was initiated by the Immokalee Chamber of Commerce and is jointly sponsored by Collier County and Big Cypress Basin of the South Florida Water Management District (SFWMD), with the support of the Department of Environmental Protection, the Freshwater Fish and Game Commission (FFGC) and the US Army Corps of Engineers. Environmental groups such as the Audubon Society and the Conservancy of Southwest Florida, have supported the project. A key component of the project support has come from the Lake Trafford Task Force that was recommended by the Chamber of Commerce and established by the Collier County Commission. The Task Force mobilized the users of the lake into a broad-based, politically active, community force. The users of the lake come from all 48 states that have sent support letters encouraging support among the various levels of government on selected funding issues. All agencies were involved in the lake from the beginning. The Friends of Lake Trafford have ensured the continual communication with the fishers and ecotourists about the project and focus their support on agency activity in the restoration.

There are several key components of the project. The early commitment was made by FFGC to spend $1 million for sediment removal. The FFGC remains committed to restoration of the lake habitat for the long term. Collier County has provided the necessary water quality sampling and analysis necessary to understand the problems in the lake and provide substantial funding from the

Tourism Development Agency for enhancing the lake for fishing and ecotourism. The Department of Environmental Protection has provided funds for purchase of the land for disposal of the sediment. The Big Cypress Basin has adopted the lake as a Works of the District that commits the SFWMD to long-term management and maintenance of the lake. These commitments have been made by individual agencies based on information supplied by the Restoration Task Force.

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*Lake Trafford Restoration Task Force is an advisory committee of the Collier County Commission charged with advising the Commission and the Big Cypress Basin, South Florida Water Management District, on the restoration of the lake. The members are Barbara Berry; Pam Brown; Friends of Lake Trafford, Immokalee; Ed Carlson; National Audubon Society, Naples; Eric Flaig, South Florida Water Management District, Immokalee; Gene Hearn; Rex Properties, Immokalee; Jon Iglehart, Department of Environmental Protection; Frank Morello, Florida Freshwater Fish and Game Commission; Edward Olesky, Lake Trafford Marina, Immokalee; Miles Scofield, Scofield Marine Consulting, Naples; Micheal Simonik, The Conservancy, Naples; Jackie Smith, DEP; Clarence Tears, Big Cypress basin, Naples; Fred N. Thomas, Jr. and George Yilmaz, Collier County, Naples.

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Oral Abstracts

Water Quality and Water Treatment Technologies

Nutrient Ratios and The Eutrophication of South Florida Coastal Waters

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N:P ratios

Although much of the ocean is nitrogen (N) limited, shallow tropical waters tend to be phosphate (P) limited because calcium carbonate chemically scavenges P from the water. Indeed, ratios of total N : total P and inorganic N : inorganic P are well above the Redfield ratio of 16 throughout most South Florida coastal waters. This has led many researchers to assume that P is the primary limiting nutrient and that inputs of N are not a significant cause of eutrophication in South Florida coastal waters. It is well known however that many organic N molecules are not readily available to phytoplankton while many organic P molecules are available, due to the activity of phosphatase enzymes. This reflects the fact that organic N is bound by direct carbon bonds while organic P is bound by ester bonds. Therefore, inorganic N : total P ratios may more closely reflect the nutrient ratio available to phytoplankton.

An examination of the ratio of inorganic N : total P in South Florida indicates a more complex situation, with some areas higher than the Redfield ratio and some areas lower. For example, inorganic N : total P are greater than the Redfield ratio in eastern Florida Bay and less than the Redfield ratio in western Florida Bay. This suggests the potential for P limitation in the east and N limitation in the west. Nutrient bioassays show mostly N limitation in the west and P limitation in the east with a spatial distribution similar to the inorganic N : total P ratios. The observation of N limitation in western Florida Bay suggests that indeed much of the organic N from the west is not available to the phytoplankton. The largest algal blooms are in central Florida Bay where high P from the west meets high N from the east, and the inorganic N : total P ratio is close to the Redfield ratio. The entire southwest coast of Florida has low inorganic N : total P ratios and nutrient bioassay data show that it is strongly N limited. In contrast, much of south Biscayne Bay has high inorganic N : total P ratios (or ratios close to the Redfield ratio) and nutrient bioassay data show that it is primarily P limited.

Sources of P

Because calcium carbonate chemically scavenges P, much of the P derived from inland agriculture and sewage never makes it to South Florida coastal waters. Most P is associated with soil and detritus that is not transported to coastal waters except during episodic high runoff periods. It is hypothesized that natural phosphorite deposits along the western side of Florida is the major source of the persistent P found in many South Florida coastal waters in the west. P from erosion of surface phosphorite deposits in central Florida, enhanced by phosphate mining, is transported down the Peace River and may account for a significant fraction of the P along the southwest coast of Florida. Underground Miocene-Pliocene phosphorite deposits mixed with quartz sand eroded from the Appalachian Mountains along the west side of the Florida platform may have groundwater moving up through them, transporting P up into the southwest coastal waters, particularly in western Florida Bay and the Ten Thousand Islands area where the phosphorite deposits are thickest. The distribution of water column P correlates well with phosphorite deposit thickness; and ^{4}He tracer data indicate significant amounts of groundwater entering Florida Bay. It is possible that these phosphorite deposits are spread throughout large areas of the west Florida shelf and may account for the relatively high P concentrations (compared to N) on much of the southwest Florida shelf. It is hypothesized that these natural phosphorite deposits have shifted western South Florida coastal waters from P limited carbonate systems to N limited ecosystems.

While the persistent high P concentrations in the west appear to be derived from the natural phosphorite deposits on the western side of the Florida peninsula, sporadic runoff events appear to carry additional P from inland anthropogenic sources and may be important in promoting algal blooms along the P-limited eastern side of the Florida peninsula on occasion. Although P from inland anthropogenic sources normally does not make it to the coastline, it appears to do so during episodic high runoff periods when soil and detritus are carried into coastal waters. For example, the largest algal blooms in P limited Biscayne Bay appear right after the first large rains of the wet season.

Sources of N

N is not chemically scavenged by calcium carbonate like P and can easily flow from inland agricultural and sewage sources to coastal waters. This can be readily seen in the canals that lead from Lake Okeechobee to Florida Bay. While most of the P is scavenged out quickly by the limestone and vegetation in the Everglades, approximately 60 µM N remains in the water at the southern end of the Everglades. This explains the high concentrations of N and low concentrations of P in the northeast corner of Florida Bay and in south Biscayne Bay. The flow of this N-rich water into Florida Bay increased around 1980 for two reasons. As a result of the eutrophication of Lake Okeechobee, backpumping of water from the Everglades Agricultural Area into the lake was greatly reduced and the flow of water to the south was greatly increased. At the same time, more agricultural land in South Dade county was drained, and more land was drained for development of suburban areas west of the Miami-Ft. Lauderdale metropolis. As a result, more N-rich water was pumped through an expanded South Dade Conveyance System into Florida. This increased flow coincides with the observations by frequent boaters in Florida Bay of increased algal blooms in Florida Bay starting around 1981. More increases around 1991 in water flow through Taylor Slough further to the west and closer to the high P area in the west led to huge algal blooms in north central Florida Bay in the 1990s. The algal blooms in central Florida Bay where natural P from the west meets anthropogenic N from the east respond seasonally to freshwater runoff of N-rich water from the Everglades-agricultural watershed, with large blooms during high runoff periods and small blooms during low runoff periods.

Algal blooms and land runoff

Because western South Florida coastal waters are N limited, large algal blooms develop in response to land runoff enriched by anthropogenic N. Eastern South Florida coastal waters have much lower algal biomass because of calcium carbonate induced P limitation and the chemical scavenging of P from most land runoff. Algal blooms occur in the east only after high runoff events that inject soil- and detritus-bound P into coastal waters.

It is hypothesized that the increase in freshwater flow into Florida Bay proposed by the Central and Southern Florida Project Comprehensive Review Study will increase the flux of N into eastern Florida Bay, which will then mix with the P from the west and increase the algal blooms observed in central Florida Bay. Increased runoff into Biscayne Bay could increase the flux of P normally associated with detritus and soil and promote algal blooms along the western side of the bay.

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Salinity, Turbidity, Algal Blooms and Seagrass Dieoff in Florida Bay – Spatial, Temporal and Causal Relationships

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Within the past 20 years, a number of ecological changes have occurred in Florida Bay. Large algal blooms have developed and persisted, the water has become more turbid, large areas of seagrasses and sponges have died off, and major changes have occurred in fish populations. A dominant hypothesis for explaining many of these changes is that reduced freshwater flow into Florida Bay from the Everglades led to hypersaline conditions, which then led to massive seagrass dieoff. This hypothesis further proposes that the seagrass dieoff and subsequent organic decomposition and sediment resuspension released nutrients, which then generated the algal blooms. This hypothesis has been used as a rationale for pumping more freshwater into Florida Bay as part of a large scale alteration of water management in South Florida. The hypothesis is a reasonable one to begin with, but an examination of the data available leads to serious doubts about the validity of the hypothesis and the predicted ecological consequences of pumping more freshwater into Florida Bay.

<u>Salinity and Seagrass Dieoff</u>

While hypersaline water may generate physiological stress on seagrasses, there is very little temporal or spatial correlation between high salinity and the seagrass dieoff in 1987 in Florida Bay. Salinities up to 70 psu have occurred in Florida Bay in the past 50 years. The highest salinity observed during the time of the seagrass dieoff in 1987 was 46.6 psu, while no massive seagrass dieoffs were observed at previous times when salinities up to 70.0 psu were measured. There is no evidence that the seagrass died off in 1987 as a result of increasing salinity.

While some seagrass dieoff in 1987 did occur in areas of high salinity, much of the seagrass dieoff occurred in areas that had near normal marine salinity even in the drought years of 1989 and 1990. Satellite imagery shows that even larger areas of seagrass to the west of Florida Bay died off as well, as local fishers and other boaters had reported at the time. The fact that this area of seagrass dieoff has normal marine salinity and occasionally lower salinity because it is downstream of the Shark River outfall suggests that high salinity was not the dominant cause of the seagrass dieoff. The lack of significant spatial or temporal correlations between high salinity and seagrass dieoff suggests that simply pumping more freshwater into Florida Bay will not solve the ecological problem. Indeed, the data show that South Florida Water Management District began pumping more freshwater into Florida Bay from the Everglades well before the seagrass dieoff.

<u>Seagrass Dieoff and Algal Blooms</u>

A second part of the dominant hypothesis is that the seagrass dieoff and subsequent organic decomposition and sediment resuspension then released nutrients that generated the algal blooms that now persist in Florida Bay. Again, this is a reasonable hypothesis, but the facts do not support the hypothesis that it is the major source of nutrients generating the algal bloom.

Unfortunately, there appear to be no quantitative data on the early development of the algal bloom, so we have to rely on the visual observations of persons who were on the bay for long periods of time. Many fishers and other boaters who are frequently in Florida Bay have been quoted as observing algal blooms and water "discoloration" beginning in 1981 and increasing thereafter, well before the 1987 seagrass dieoff. These observations suggest that there was another source of nutrients, well before the seagrass dieoff.

It has now been 13 years since the seagrass dieoff, yet the algal blooms in Florida Bay persist, and have even increased in the 1990s. Residence time of water in the bay has been estimated on the order of a month. It is hard to believe that the nutrients from decomposed seagrasses 13 years ago have not been flushed out and are instead continuing to fuel the bloom. Furthermore, seagrass dieoff cannot explain the highly seasonal occurrence of the algal blooms, which correlate with the seasonal freshwater runoff from land.

Seagrass dieoff and the resulting biomass decomposition and sediment resuspension also cannot explain the spatial distribution of the algal blooms or nutrients in Florida Bay. A comparison of the distribution of average chlorophyll concentrations in the 1990s with the distribution of seagrass dieoff in 1987 indicates that much of the algal bloom area is upstream, not downstream of the seagrass dieoff areas. Furthermore, a comparison of the inorganic nitrogen (N) and total phosphorus (P) spatial distributions with seagrass dieoff areas reveals that most P is upstream to the northwest and most N is to the northeast of the seagrass dieoff area**.** While seagrass dieoff most likely did result in the release of nutrients, it cannot explain the spatial pattern of nutrients or algal blooms in Florida Bay today.

Seagrass dieoff and turbidity

A comparison of turbidity data collected between 1973 and 1976 and between 1996 and 1999 indicates a dramatic increase in turbidity in Florida Bay. During the rainy season, when wind speeds are usually low, turbidity levels are only around twice as high in the 1990's as in the 1970's. During the dry season, when wind speeds are usually higher, turbidity levels are much higher than in the rainy season in most parts of the bay in both the 1970's and 1990's. Dry season turbidities are also dramatically higher in the 1990's than in the 1970's. This is particularly true in eastern Florida Bay.

In the central and western parts of the bay, the increase in turbidity is most likely the result of the massive seagrass dieoff in the 1980's. Lack of thick meadows of seagrass blades to reduce currents, and roots to hold down sediments could easily lead to the high turbidity observed today. More problematic is the large increase in turbidity in the eastern part of the bay where there were few seagrasses to begin with and little seagrass dieoff. This is also an area that is relatively sediment starved. One possible explanation is that after the seagrass dieoff, resuspended sediments from the central bay were eventually transported to the east where they are easily resuspended because of sparse seagrass cover. The problem with this hypothesis is that satellite imagery shows high turbidity in northeast Florida Bay in the winter of 1986 before the seagrass dieoff. This suggests that the turbidity increase occurred between 1976 and 1986. It appears that an increase in turbidity preceded seagrass dieoff in both eastern Florida Bay and in the west where "The commercial fishermen saw the water [in western Florida Bay] changing - first by becoming dirty, then algae blooms started, and then seagrass died off." Other sources of turbidity besides seagrass loss need to be considered.

To summarize, the spatial and temporal relationships between salinity, turbidity, algal blooms, and seagrass dieoff do not support the hypothesis that high salinity caused the massive seagrass dieoff or that the seagrass dieoff caused either the algal blooms or all of the increase in turbidity. Increasing freshwater flow from the Everglades into Florida Bay will not necessarily improve the ecosystem and indeed may lead to more ecological deterioration.

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Characterization of Phosphorus Cycling and Speciation in the Northern Florida Everglades by High Resolution Mass Spectrometry

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In this presentation we summarize the results of experiments on phosphorus cycling in the Everglades Nutrient Removal (ENR) area. This work was part of a larger effort to estimate the potential for further phosphorus enrichment in the pristine areas of the Everglades and to better understand the bioavailability of organic phosphorus that is formed in treatment wetlands. Little is known about the cycling of the various forms of phosphorus due to limitations of the currently available analytical methods. These methods are characterized by limits of detection and quantitation that are close to the natural background levels of phosphorus in the pristine Everglades. Furthermore, they provide little information about phosphorus speciation.

Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) was investigated as a new analytical method for analyzing very low levels of phosphorus in natural surface water samples. Our Finnigan MAT Element ICP-MS operating in medium resolution mode ($m/\Delta M = 3000$) demonstrated superior sensitivity and detection limits for phosphorus when compared to the current EPA colorimetric method. A conservative estimated detection limit of ~0.4 parts-per-billion-P (ppb-P) and quantitation limit of ~ 1.7 ppb-P was achieved by ICP-MS, well below values of 3.6 and 11.9 ppb-P estimated for the colorimetric method. Results of ICP-MS measurements of orthophosphate and dissolved organic phosphate (DOP) in surface water samples from various sites within the ENR suggest that this treatment wetland it is more efficient at removing bioavalable o-phosphate than indicated by colorimetric data.

ICP-MS is also sufficiently sensitive and robust to serve as an on-line, phosphorus-specific detector for separation techniques such as High Performance Liquid Chromatography (HPLC) and Capillary Electrophoresis (CE). Methods were developed for the separation and detection of organic phosphorus compounds with on-line CE-ICP-MS and with HPLC coupled both on-line and off-line *via* fraction collection to the ICP-MS. These separation methods, when coupled to phosphorus-specific ICP-MS detection, provided information on phosphorus speciation in different treatment areas within the ENR.

Molecular characterization of individual dissolved organic phosphorus compounds formed in the ENR was also a major part of this project. Ultrahigh resolution Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) experiments were carried out on DOP isolated from the same sites for which quantitative low-level phosphorus data was available. Before this molecular speciation work could begin it was first necessary to concentrate the DOP and remove it from the overwhelming background of dissolved organic matter (DOM). The entire DOM pool was first separated according to molecular weight by tangential cross-flow ultrafiltration (CFF). DOP was then selectively isolated and concentrated from DOM fractions by a barium precipitation procedure. The DOP isolation/concentration step can provide concentration factors of up to 15-fold, and when combined with the inherent concentration provided by CFF, 300-fold concentration of high molecular weight DOP was accomplished. Prominent phosphate-containing peaks in the DOP concentrate were then identified by high resolution ($m/\Delta m \geq 500,000$) FT-ICR MS at 9.4 Tesla. The spatial relationships identified indicate that there are many stable organic-P compounds formed within the ENR that are resistant to chemical and/or microbial degradation. In this presentation we will provide some chemical rationalizations for the stability of the DOP compounds we observed.

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Sequenced Vegetation Communities for Optimizing Phosphorus Removal within Stormwater Treatment Areas

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Over 16,000 ha of constructed wetlands, termed Stormwater Treatment Areas (STAs), are being constructed to remove phosphorus (P) from agricultural drainage waters (ADWs) prior to introduction into the Everglades. The STAs were initially designed to provide a 50 μg/L total P outflow concentration. But recent investigations on the impact of P-loading to native wetland communities have suggested that the ultimate target P levels for discharge to Everglades waters will need to be substantially lower. To achieve this performance goal, several government agencies and private firms are evaluating a broad range of techniques that include "green" technologies, such as optimized wetlands and sequential systems, as well as conventional technologies, such as chemical treatment and membrane filtration.

In this presentation, we discuss a promising sequence of "green" technologies that to date has not received much attention. The findings were generated from a research project on ADW P removal sponsored by the National Science Foundation. This work was performed in Palm Beach County, adjacent to a drainage canal in the Everglades Agricultural Area (EAA). In this study, we tested the effectiveness of floating macrophytes, high velocity periphyton systems, submerged macrophytes, and low velocity periphyton communities for removing P from ADWs. Our prior studies in Florida have suggested that the first two systems can remove P at a high mass removal rates when properly managed, and that the latter two communities can provide extremely low outflow P concentrations. The results from our present study suggest that these communities can be effectively sequenced to treat ADW to very low effluent P concentrations (10-20 μg/L).

ADWs from the EAA contain P in several forms including soluble reactive P (SRP), dissolved organic P (DOP) and particulate P (PP). Most of the vegetation communities were effective at removing SRP, but were less efficient at removing DOP and PP. The floating macrophytes, such as *Eichhornia crassipes*, and high velocity periphyton systems removed SRP principally through direct plant uptake, so long-term sustainable P removal in these systems will require periodic plant harvest. In beds of submerged macrophytes, such as *Najas guadalupensis*, SRP is removed by plant uptake and also by chemical precipitation. In hard water conditions such as in the EAA, P coprecipitates with $CaCO_3$ under elevated pH conditions caused by plant photosynthesis in the water column.

In terms of both performance and ecological suitability, our study demonstrated that a managed floating plant system could be an effective "front-end" unit process in an STA because of its ability to remove large quantities of P in a relatively small area. Similarly, SAV and low velocity periphyton are more appropriate for "back-end" treatment because of their ability to achieve outflow total P concentrations in the range of 10 – 20 μg/L.

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Water Quality Monitoring of Tidal River and Canal Systems in the Ten Thousand Islands Estuaries: Implications for Essential Fish Habitat and Watershed Dynamics

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Water physical-chemical properties were monitored along a 4 kilometer transect in six river and three major canal systems in the Ten Thousand Islands estuaries of southwest Florida from June-December, 2000. Water temperature, depth, dissolved oxygen and salinity were continuously recorded in conjunction with a juvenile jewfish, *Epinephelus itajara*, mark/recapture study. Secchi disc depth readings were made at all sites.

From observations made during previous tagging efforts it was hoped to be able to quantify the distribution, abundance and movements of jewfish with regards to basic water physical-chemical properties, and abrupt changes accompanying storm events. Degraded water quality associated with large storm events such as hurricanes have been known to cause fish kills and greatly effects all biota in the affected areas. Smaller storm events may also impact river/canal biota, with the more mobile animals exiting upper reaches to a point where water quality is not harmful.

The data collected permits comparisons to be made within an individual river/canal and between different rivers/canals. In most cases, oscillations in salinity and dissolved oxygen correlate directly with the tidal regime. Rainfall events may either slowly lower salinity or create fast drops and large fluctuations in salinity levels, 25 ppt within six hours. Dissolved oxygen levels were found to be low enough in some areas to effectively create “dead” zones.

Inferences can be made as to the dynamics of watersheds supporting each of the rivers or canals. Additionally, the data will serve as a useful baseline resource to quantify changes brought about by planned hydrologic restoration activities. Hydrologic restoration will alter the flow of fresh water into a particular river/canal system by either increasing or decreasing the effective size of the watershed supplying the river/canal.

The water quality monitoring devices (YSI 600 XLM sonde) were deployed 0.5 meter above the river/canal floor by being attached to the topside of a fish trap. Sondes were deployed at sites designated as upstream, midstream and downstream in each river/canal for a period of one week. After one week, data was downloaded and the sonde recalibrated and redeployed to a different location for another one week monitoring period. After the three weeks of monitoring in a particular river/canal sondes were removed for six weeks. Monitoring was repeated three times for a total of nine one week monitoring periods in each of the nine rivers/canals. Three sondes were available for use so there are temporal gaps in data for some of the between river/canal comparisons.

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Nutrients Sequestered in Microbial Mats Reflect Remote Source Water Quality in Everglades National Park

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Elevated phosphorus (P) in water entering Everglades National Park has been implicated in causing changes in ecosystem function that are detectable at significant distances from inputs. The goal of this study is to establish definitive Class III water quality standards in the Everglades Protection Area, based on P levels that elicit an imbalance in ecosystem properties. This is the first dosing experiment designed to determine long-term, long-distance effects of continuous delivery of slightly elevated concentrations of P. We constructed 3, 100-m long flowthrough flumes in Shark River Slough. Flumes are open at both ends and plastic walls separate areas of natural marsh into 4 channels. At the head of each 3-m wide channel, a 10-m long mixing zone receives continuous additions of 0, 5, 15 or 30 $\mu g\ l^{-1}$ of P above ambient concentrations. A suite of abiotic and biotic parameters are measured at several downstream locations on a regular basis for a period of 4 years to test hypotheses that: (1) any constant increase in P above ambient will alter ecosystem state, and (2) changes will occur at rates relative to P dose level and distance from source. After 6 months of dosing, we found no significant treatment effect for water column, soil, floc or macrophyte TP. However, significant elevations in periphyton mat TP were detected 20 m from the low dose (5 $\mu g\ l^{-1}$) source and as far as 70 m from the high P (30 $\mu g\ l^{-1}$) source. Structural and functional consequences of elevated periphyton TP, including significant loss in mat biomass and altered species composition, can cause a cascade of effects through the ecosystem that we expect to observe as dosing continues. Early indications from this study are that impacts occur at concentrations lower than previously reported for this and other oligotrophic systems, at levels 10 % of current regulatory standards for the Everglades. We urge that assessment programs include measurements of periphyton TP to detect elevated inputs of P, since water quality evaluations based on local soil or water column TP can underestimate source concentrations by as much as 500 %.

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Spatial Changes in Redox Conditions and Food Web Relations at Low and High Nutrient Sites in the Everglades

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A clear understanding of the aquatic food web is essential for determining the entry points and subsequent biomagnification pathways of contaminants such as methylmercury (MeHg) up the food chain. The isotopic compositions of sediment, plant, insect, and fish samples collected at several hundred sites in the Everglades show strong spatial patterns on a landscape scale. We speculate that biogeochemical processes (such as denitrification, sulfate reduction, photosynthesis, respiration, and methane production/oxidation) control the isotopic compositions of dissolved nutrients, and that the local isotopic compositions of biota then reflect those of the nutrients utilized, as modified by trophic fractionations and other factors. In particular, areas dominated by sulfate reduction, which often correlate with high methyl mercury contents, appear to be "labeled" by the C, N, and especially the S isotopic compositions of organisms. The temporal and spatial isotopic patterns caused by environmental conditions must be "subtracted" from the biota isotopic compositions before spatial and temporal changes in trophic relations can be determined.

The traditional method of food web investigation focused on the determination of gut contents (literally, "who ate what"), and is still used today. More recently, stable carbon, nitrogen, and sulfur isotope analyses of plants and animals have been used to establish relative trophic levels among various organisms because at each ascending trophic level (from prey to predator), there is an increase in the ^{13}C content ($\delta^{13}C$ value) and ^{15}N content ($\delta^{15}N$ value) of the organism due to selective metabolic loss of ^{12}C and ^{14}N during food assimilation and growth. Thus, an organism is typically enriched in ^{13}C and ^{15}N relative to its diet by 1 to 3 parts-per-thousand. There appears to be little or no enrichment in ^{34}S with increasing trophic level.

The average $\delta^{15}N$ and $\delta^{13}C$ values of selected fish have been normalized to the compositions of mosquitofish, an important indicator species, to allow direct comparisons of samples collected at different sites and times. Normalization is accomplished by subtracting the average isotopic composition of mosquitofish from the average isotopic composition of the organism of interest. The

$\delta^{15}N$ values are in good agreement with suspected trophic positions; primary producers have lower values than herbivores, while omnivores and carnivores have successively higher values. In contrast, the $\delta^{13}C$ values of algae, invertebrates, and fish show considerable variability with little or no consistent increase in $\delta^{13}C$ with increasing trophic level. Hence, bulk carbon isotopes are not very useful for determining trophic position. The generally high $\delta^{13}C$ values of the macrophytes (e.g., lily pads, sawgrass) are inconsistent with their being a major food source in most locations.

Isotopes can be used to distinguish between what a fish eats and what it assimilates. For example, the $\delta^{15}N$ values of organisms can be used to test the diet estimates determined by gut contents analysis. Using this approach, we find that although algae (periphyton) often is a major component of the stomach contents of mosquitofish, it appears to be only a minor component of what is actually digested. This is an important observation since the MeHg content of algae can be high in some environments; however, it is not known whether MeHg within the algal mats can be absorbed by the fish even if the algae is not assimilated.

In general, organisms collected in high-nutrient sites near the Everglades Agricultural Area have higher $\delta^{15}N$ values than ones collected in more pristine areas to the south. Near the agricultural areas, organisms in the canals generally have higher $\delta^{15}N$ values than samples from adjacent marshes, and the $\delta^{15}N$ values decrease with distance from the canals. This difference probably reflects denitrification and ammonium uptake in anoxic waters and sediments in stagnant parts of the canals.

The isotopic compositions of organisms from areas of high and low nutrient concentrations are very different. We observe the expected increases in $\delta^{13}C$ and $\delta^{15}N$ with increasing trophic level at low-nutrient marsh sites (e.g., the USGS sites referred to as U3, 2BS, 3A-15, and 3A-TH). However, at high-nutrient marsh and canal sites (e.g., the USGS sites referred to as ENR Cell 3, E0, F1, and L67), the $\delta^{13}C$ values consistently decrease with increasing trophic level, producing food web structures that are not consistent with theory. For example, we observe an **increase** in $\delta^{13}C$ and $\delta^{15}N$ with increasing trophic level at U3, a low-nutrient marsh site near the middle of WCA-2A. The food web at this site behaves in accordance with an isotopic theory. However, at F1, a high-nutrient site in WCA-2A near the Hillsboro Canal, the $\delta^{13}C$ values **decrease** with increasing trophic level, producing a isotopic food web structure that is not consistent with theory (i.e., it has a trend-line backwards from the expected pattern). While is not yet clear what causes the striking isotopic difference between nutrient-impacted sites and more pristine sites, isotopes appear to provide a quick and easy method for determining if high-nutrient areas might be causing significant changes in food web relations.

Spatial variability of $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ values in the Everglades 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 these same patterns are incorporated throughout the food web. Therefore, organisms that live sites where geochemical conditions are dominated by particular redox reactions have distinctive isotopic compositions. The **"isotopic labeling"** of different environments suggests that isotopic techniques could be useful for determining whether fish migrate in and out of the marshes in response to hydrologic or nutrient-level conditions. Furthermore, because MeHg concentrations are a function of local environmental conditions, these isotopic data should prove useful for determining where some populations of game fish are acquiring elevated levels of MeHg. Stable isotope analyses distinguish fish populations and offer a more **cost-effective** alternative to tag-and-release programs for the determination of migration habits. Furthermore, stable isotope analyses complement gut-content based food web studies, provide an independent check on diet estimates, and provide insight into the difference between what an organism eats and what it actually assimilates. Such an assessment should prove useful for the better regulation of hydrologic, geochemical, and biological conditions most favorable to the restoration of the Everglades.

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First Year Total Phosphorus Mass Balance for STA Optimization Research in the Everglades Nutrient Removal Project North Site Test Cells

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The Everglades ecosystem is known to be extremely sensitive to phosphorus (P) loading. 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 Everglades Nutrient Removal Project (ENRP) test cells. This research will examine how hydrologic conditions may influence STA performance; i.e., what water management scenarios will promote maximum TP removal efficiency in these systems and conversely, under what hydrologic conditions will 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 the ENRP 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. While holding depth constant, HLR in two experimental test cells was incrementally decreased by 50% (therefore increasing hydraulic residence time) every 15 weeks to a final HLR of 0.3-cm/d (low HLR experiments). Concurrently, the HLR in the remaining experimental test cells was incrementally increased by 50% (conversely, decreasing hydraulic residence time) every 15 weeks to a final HLR of 20-cm/d (high HLR experiments).

Weekly grab and/or composite water quality samples were collected, depending on the parameter, at the storage cell outlet (inflow source water) and the outflow of all STA Optimization test cells and analyzed for 30 parameters. All sample collection and analyses have been conducted in accordance with the District's Comprehensive Quality Assurance Plan, which requires the use of either EPA or APHA approved analytical methods.

Water Year 1 for the test cells extended from 1 May 1999 through 30 April 2000 and separate water budgets were calculated for each test cell based on daily inflows, outflows, and change in storage capacity using the general water mass balance equation:

$$I - O + P - ET = \Delta S + r$$

where:

I = inflow water volume to the test cell (m^3)
O = outflow water volume from the test cell (m^3)
P = direct precipitation and runoff water volume to the test cell (m^3)
ET = evapotranspiration (m^3)

ΔS = change in storage capacity within the test cell (m^3), and
r = residuals to the water budget (m^3).

A calibrated tipper bucket was used to verify the inflows for each HLR. Water budget residuals (i.e., unmeasured components and measurement error) ranged from 16.27 to -1.29%. Surveys of various lake and wetland water balance studies showed that it is not uncommon for residuals to range between 10-20%.

Total phosphorus (TP) mass into and out of the test cells and TP mass retention was determined for each HLR in Year 1 (Table 1). In the high HLR experiment and control test cells inflow water accounted for 98-99% of TP loading. For the low HLR test cells, precipitation and runoff accounted for 6% of the TP mass input as a result of the low loading rates.

Table 1. Total Phosphorus Mass for Water Year 1 (05/01/99 through 04/30/00)

Treatment	Mean HLR (cm/dy)	Mass Inflow ($g/m^2/yr$)	Mass Outflow ($g/m^2/yr$)	% Mass Retention	TP Outflow Conc. (μg/L)
Low HLR	0.78	0.26	0.10	61.8	41.2
Control HLR	2.65	0.88	0.44	49.7	42.9
High HLR	9.30	3.35	2.28	31.9	62.1

Although the high HLR test cells did retain more P mass than either the control or low HLR test cells, the percent retention was considerably lower. The higher inflow loading rates (i.e., high HLR) resulted in more P mass export from the test cells than from test cells with lower loading rates (Table 1).

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An Analysis of Changes in Basin-Wide and Farm-Scale Phosphorus Loading from the Everglades Agricultural Area Due To Implementation of Best Management Practices

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The Everglades Agricultural Area (EAA) is an agricultural community of approximately 630,000 acres of rich, organic muck soils at the southern end of Lake Okeechobee in south-central Florida with sugar cane as the primary crop. In the early 1980's scientists and researchers concluded that the primary cause of the extensive cattail growth that was forcing out indigenous sawgrass marshes in the Everglades National Park (ENP) was phosphorus nutrient loading. Further studies concluded that the primary source of the phosphorus loading was agricultural runoff from the EAA.

A series of lawsuits was filed against the South Florida Water Management District (SFWMD or District) on behalf of the Federal government, Native American Nations and the State of Florida for not enforcing water quality standards for water discharged to the ENP. These lawsuits resulted in the Marjorie Stoneman Douglas Act in 1991 which was later reinforced by the Everglades Forever Act (EFA) in 1994. The EFA authorized a series of comprehensive measures intended to ensure the restoration and protection of the EPA. These measures include the utilization of Best Management Practices (BMPs) to reduce phosphorus levels in agricultural discharges.

As a result the EAA BMP regulatory program was developed by the SFWMD and adopted by the Florida Legislature (Rule 40E-63 F.A.C.). The program requires implementation of farm level BMPs to achieve a minimum twenty-five (25) percent reduction in total phosphorus discharged from the EAA basin as a whole. Farm level BMPs are generally grouped into three major categories: fertilizer management practices, water management practices, and sediment and particulate matter control practices. During the rulemaking process for Rule 40E-63, through a series of public workshops with representatives from the agricultural community, researchers, scientists, consultants and District staff, a list of BMPs applicable to the EAA was developed. Rule 40E-63 required all landowners to fully implement BMPs by 1996 which was the first year of measurement of compliance with the 25% reduction in phosphorus loads discharged from the EAA basin.

In addition, each landowner was required to implement an on-farm water quality monitoring program to measure phosphorus loads discharged from each individual farm basin. The District maintains an Oracle® database of daily flows, loads and rainfall for each farm structure dating back as far as 1993 for some structures. With this information, the District is able to calculate annual phosphorus loads and concentrations from each of the individual farm basins within the EAA as well as the basin wide calculations used to determine compliance with the 25% reduction. These calculations are done for each "water year" defined as running from May 1st to April 30th and the results reported back to the landowners on an annual basis.

The Everglades Forever Act specifically mandates a method to measure and calculate the annual EAA export of phosphorus in surface water runoff from the EAA lands (farms, cities, and industry) to the EPA. The method consists of mathematical equations that predict what the average annual phosphorus load for the EAA during the Base Period would have been if the annual rainfall and distribution measured for a current year had occurred during that base period. The calculation of "percent reduction of phosphorus" is determined from the relative difference between each annual measured phosphorus load and the corresponding predicted phosphorus load for the Base Period. The mathematical equations were calibrated to effectively predict more than 90 percent of the data variability during the base period.

For EAA Basin discharges, the relative difference between the WY2000 measured phosphorus tonnage and the predicted Base Period phosphorus tonnage (adjusted for hydrologic variation) indicates a 55% reduction in phosphorus load. The 3-year trend of phosphorus load from the EAA is a 48% reduction. The overall trend over the past several years appears to indicate a reduction in phosphorus load occurring with the implementation of BMPs. The annual flow-weighted phosphorus concentrations attributable to the EAA show a similar trend. The recent 3-year cumulative concentration of 114 ppb with BMPs implemented as compared to the 173 ppb prior to BMPs being implemented indicates a reduction in phosphorus concentrations occurring. These measurements represent the fifth full water year of required Best Management Practices (BMP) implementation throughout the EAA. As the number of annual calculations increases, the District has increased confidence in the long-term phosphorus reduction attributable to BMPs. Given the encouraging preliminary BMP program measurements and the performance of the initial SFWMD stormwater treatment areas (ENR Project and STA-6), there is increased confidence that the Everglades Forever Act's interim goal of achieving 50 ppb phosphorus concentration through the combination of existing landowner BMPs and downstream stormwater treatment areas is achievable.

Farm-scale calculations for Water Year 2000 have not been completed at the time of this writing but will be included in the paper. Review of the data for the farm discharge structures from Water Year 1994 (prior to implementation of BMPs) through Water Year 1999 indicate trends in phosphorus load reduction and concentration although there is significant variability from one site to another. This variability is likely attributable to different crop types, soil types, BMP plans and farm management styles.

This paper will give a detailed history of the EAA BMP program, a discussion of the load reductions attributable to the BMPs at the basin and farm level, and a comparison of these data sets.

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Nutrient and Sulfur Contamination in the South Florida Ecosystem: Synopsis of Phase I Studies and Plans for Phase II Studies

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Background

The south Florida ecosystem, including the Everglades, has been greatly impacted by anthropogenic activities. The studies described here focus on several of the major water quality issues facing this ecosystem, and the biological impacts of water quality issues. Specifically, this study is examining: (1) the major sources of excess nutrients (nitrogen and phosphorus), and sulfur to the ecosystem, (2) the important role of chemical and biological processes in sediments (biogeochemical processes) in sequestering and recycling these substances, and (3) the ultimate fate (i.e. sinks) of these elements in the ecosystem.

The focus on nutrients reflects the problem of eutrophication in the ecosystem, whereby excess phosphorus (P) and to a lesser degree nitrogen (N) from canal discharge has dramatically altered the biology of the ecosystem. Studies of sulfur (S) contamination are important for understanding the processes involved in methylmercury production in the Everglades. Methylmercury (a neurotoxin) poses a health risk to biota in the ecosystem and potentially to humans, and S is a key control on the methylation of mercury by sulfate-reducing bacteria in wetland soils. In addition, excess sulfide produced by bacterial sulfate reduction in wetland sediments may have toxic effects on macrophytes and tree islands in the ecosystem by limiting oxygen transport to root systems.

In addition to a focus on water quality issues, our sediment studies are being used to construct a geochemical history of the ecosystem. An understanding of past changes in the geochemical environment of south Florida will provide baseline information defining water quality parameters of the pre-drainage Everglades. Historical geochemistry in combination with paleoecological studies will deliniate ecosystem response to natural environmental change, and allow prediction of likely ecosystem response to changes that will accompany restoration efforts.

Synopsis – Phase I Studies (1994-1999)

Our previous work showed that excess P, N, and S enter the Everglades from canal discharge originating in Lake Okeechobee and the Everglades Agricultural Area (EAA). Uranium concentrations and isotopic activity ratios ($^{234}U/^{238}U$) were used as tracers to show that P contamination in the northern Everglades is derived from phosphate fertilizer used in the EAA; the first definitive evidence that the phosphate contamination in the Everglades originates from phosphate fertilizer. Concentrations of P at pristine sites in the freshwater Everglades range from 1-20 ppb in surface water, 10-100 ppb in sediment porewater, and 300-500 μg/g dry wt. in sediments. At contaminated sites P concentrations often exceed 100 ppb in surface water, 3,000 ppb in porewater, and 2,000 μg/g dry wt. in sediment. Accumulation rates of P in peat at contaminated sites are typically 10x to 100x higher compared to pristine areas. The increased P load has altered biotic assemblages within parts of the ecosystem, especially in marsh areas near canal discharge where eutrophic-adapted cattail (*Typha domingensis*.) has replaced native, oligotrophic-adapted sawgrass (*Cladium jamaicense*). Sites of excess P accumulation also recycle P rapidly, due to the high biodegradability of cattails compared to sawgrass. Because of the high rate of P recycling in cattail peat, constructed wetlands (STAs) that consist primarily of cattail vegetation may not serve as effective long-term sinks for P.

The extent of S contamination in the Everglades was first documented by results from Phase I studies. Unnaturally high levels of sulfate enter the Everglades from canal discharge, and S isotope ($\delta^{34}S$) studies suggest that a significant fraction of the S contamination may originate largely from the use of agricultural S in the EAA. Accumulation rates of S in surface sediments of the Everglades are about 5x higher near canals compared to areas remote from canal discharge. The principal form of S in sediments at all marsh sites is organic sulfur, reflecting the reaction of sulfide with organic matter in the sediments. S contamination has altered the nature of microbial processes in the freshwater marshes of the Everglades by stimulating sulfate reduction. Collaborative work with the ACME group showed that S contamination in the marsh sediments is a major control on mercury methylation in the Everglades. The relationship between the microbial methylation of mercury and the biogeochemistry of S is complex, but the distribution of S in the ecosystem is a major control on the location of methylmercury "hot spots" in the Everglades.

Geochemical studies of dated cores in conjunction with pollen data deliniate past environmental changes in the ecosystem lasting hundreds of years, and driven by climate variability. For example, cores from WCA 3A show variations in organic carbon and nitrogen contents indicative of wetting and drying-out of the Everglades during climate change associated with transitions from the Medieval Warm Period, to the Little Ice Age (1300-1850), to recent times. In Florida Bay, we observed recent enrichment (beginning in the early to mid 1980's) of nutrients in sediments from dated cores. This enrichment occurred concurrent with the first observations of seagrass dieoff in Florida Bay, indicating a possible link. Earlier periods of nutrient enrichment in the bay were also observed in some cores, especially a large multi-decadal event during the mid 1700's in cores from Whipray Basin . These earlier events may be linked to changes in freshwater discharge to the bay from the Everglades, controlled by changes in climate. These results provide a model of ecosystem response to changes in water flow, such as those that will accompany restoration.

Plans – Phase II Studies (1999-2003)

Phase II will extend Phase I studies using similar field approaches, but with the addition of field and laboratory experimental work to further refine and quantify previous observations and conclusions. This will include the use of environmental chambers (field mesocosms and laboratory microcosms), and isotopic tracers to provide a more definitive means addressing specific management questions, such as: "Over what time scales could we expect to see improvements to the ecosystem if nutrient and sulfur loading were reduced by implementation of agricultural best management practices (BMP's) and the storm water treatment (STA) program?" The effectiveness of cattail-dominated STA's in removing contaminants (nutrients and S) in long-term storage will be investigated in Phase II studies. Detailed studies of sulfur speciation in sediment porewaters and sulfur cycling will provide additional insights on sulfur controls on mercury methylation in the ecosystem. Results will provide critical elements for building ecosystem models and screening-level risk assessment for contaminants in the ecosystem.

Phase II work will expand our existing database on sources of nutrients and S contamination to the ecosystem, including the initiation of work on sources of contamination from cattle ranching north of Lake Okeechobee. The use of Lake Okeechobee water in proposed aquifer storage and recovery

(ASR) approaches to water management in south Florida will require information on the quality of water entering the lake. Sources of organic contaminants (e.g. polycyclic aromatic hydrocarbons) to the ecosystem will also be initiated during Phase II.

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Water Quality Impact Analysis of Southwest Florida Wetland Permitting Alternatives on Surface Water Quality

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The U.S. Army Corps of Engineers (ACOE) has released an Environmental Impact Statement (EIS) to assess alternatives for improving the regulatory process for a study area within Lee and Collier counties of southwest Florida. The EIS is designed to provide a sound decision-making tool for the ACOE that is seeking a balance between the natural ecosystems and economic stability.

Water quality was identified as one of the twelve key issue categories to be included in the EIS environmental impact analysis process. The objective was to develop a methodology for analyzing potential impacts to surface water quality for several conservation and development land use alternatives. For each alternative, a set of Geographic Information System (GIS) attribute files were generated. To accommodate analyses, the study area was partitioned into twelve hydrologic units (watersheds). GIS spatial analyses were performed to estimate potential changes in land use types associated with the various future land uses resulting from the different regulatory alternatives for each watershed. The result was a database of land cover/use types (acres) within each watershed for each of the alternatives.

Water quality change projections were determined for each of the watersheds using a model, which incorporates acres of each land use type and associated surface water pollutant loading rates and state mandated water quality mitigation structures. The resulting model output provided concentrations for key surface water runoff pollutants, which were further summarized into a established water quality index (WQI) for each watershed. Indices for all watersheds were summarized to highlight the percentage change in overall WQI for each regulatory alternative.

This water quality analysis process not only provided a means for the comparison of the South Florida EIS alternatives based on projected changes in water quality, but aids the decision maker with a geographically based analysis tool for estimating water quality impacts associated with future permitting decisions.

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Chemical Treatment: An Advanced Treatment Technology for Everglades Agricultural Area (EAA) Stormwater

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The Everglades Forever Act (EFA) (Section 373.4592, Florida Statutes) mandated the South Florida Water Management District (District) to construct wetlands known as Stormwater Treatment Areas (STAs) as part of the Everglades program to restore the Everglades. These STAs are to be used in combination with on-farm Best management Practices (BMPs) to reduce Phosphorus levels in Everglades Agricultural Area (EAA) stormwater runoff to an interim target of 50 ppb before it is released into the Everglades Protection Area (EPA). The EFA had set a default threshold total phosphorus (TP) concentration of 10 ppb in case a specific limit is not established by December 31, 2003.

As mandated by the EFA, the District implemented research on Advanced Treatment Technologies (ATTs), to reduce TP concentrations. The ATT program focuses research on innovative as well as proven water treatment technologies capable of reducing TP concentrations to 10 ppb. Eight of these ATTs were identified and short-listed by the District to be evaluated and to establish their technical, economic and environmental feasibility for basin-scale application. To date, only the Chemical Treatment Solids Separation (CT-SS) process and microfiltration have demonstrated an ability to produce a treated water total phosphorus of less than 10 ppb.

HSA under contract with the District and with partial cost sharing though US EPA's Section 319h grant program administrated by the Florida Department Environmental Protection (FDEP) recently completed a nine month pilot scale test of the CT-SS technology. The primary objective of the project was to evaluate, for potential full-scale implementation, the technical, economic and environmental feasibility of the technology.

The CT-SS test facility consisting of two process trains (rapid mix, flocculation, inclined plate clarifiers, and a series of 8" diameter filtration columns) was operated at both the inflow (Post BMP) and outflow (Post STA) locations at the District's Everglades Nutrient Removal (ENR) site. Operational variables that were tested and optimized included feed flow rates, flocculation retention times, coagulant (iron and aluminum based) feed concentrations, clarifier overflow rates, sludge recirculation rate, filter media composition and filtration rates. The experimental program including screening, optimization and demonstration phases was carried out from May to December 1999.

Several vendor technologies including dissolved air filtration, ballasted sand (ACTIFLO), high rate clarification, ultra and microfiltration, and CoMag process were evaluated at a pilot scale as an integral and parallel aspect of the CT-SS project.

Preliminary field crop trials were carried out at an EAA site using solids generated by the CT-SS pilot unit to investigate the feasibility of land application as a management option for CT-SS residual solids (sludge).

Based on the process design criteria developed during the pilot testing, conceptual designs and capital, operating and maintenance, and present worth cost estimates were developed for full scale application of the CT-SS technology for both Post-BMP and Post-STA scenarios. Ten year period of record flow and total phosphorus concentrations data for STA 2 comprised the basis of design for the full-scale systems. These conceptual designs incorporated a flow equalization basin, concrete basin coagulators where ferric chloride was added at a dosage of 40 mg/L, concrete basin flocculators where an anionic polymer was fed at an average dose of 0.5 ppm followed by concrete basin inclined plate settlers. The treated water would flow through a buffer cell prior to discharge. The existing STA pumping station would be used to discharge the treated water to the water conservation area. It was assumed that CT-SS residual solids would be managed at a dedicated land application facility.

Significant findings and conclusions from the pilot project were:

- CT-SS treatment of either Post-BMP and Post-STA EAA surface waters using either ferric chloride or alum as coagulants is capable of consistently producing a treated water of less than 10 ppb TP. The principal processes required to achieve these results are chemical coagulation, flocculation and inclined plate clarification.
- Several vendor technologies also demonstrated an ability to produce a treated effluent of less than 10 ppb TP.
- bioassay and algal growth potential (AGP) testing conducted on representative CT-SS feed and effluent samples demonstrated no significant adverse effect on receiving water.
- Residual solids produced by the CT-SS process contain no hazardous constituents as defined by the toxicity characteristics leachate (TCLP) procedure. Results of land application trails are currently being evaluated and will be presented.

It was recommended that prior to any full scale implementation of chemical treatment further larger scale prototype testing of the CT-SS technology be conducted.

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The Effects of Flow Rates on Phosphorus Uptake by Periphyton

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Stream studies conducted since the 1960's have shown that increased water movement correlates positively with phosphorus uptake in periphyton communities. Natural flows in the Everglades, which can be measured in centimeters/day, are historically much slower than in streams. Constructed filter marshes, called Stormwater Treatment Areas (STA's), are artificial wetlands where water movement can be engineered to optimize the positive effects of flow. However, the study of these positive effects in a wetland environment is problematic in that velocity, residence time and hydraulic loading rate must be controlled. In this study we employ a unique mesocosm design that allows for simultaneous control of the above variables. The velocities in the two initial mesocosm designs are approximately 1.0 cm s^{-1} and 0.11 cm s^{-1}. These fall within the range of average flow rates planned for in the STA program.

Preliminary results as measured by both biomass accrual and dissolved oxygen production show a significant increase in both measurements in the faster flow rate mesocosms. Direct measurement of phosphorus uptake is currently being conducted. The results of this first trial will lead to a program of testing that will consider various rates of flow at a larger scale and with a plant community representative of a natural system. The ultimate goal of such testing is to provide the necessary information to allow for optimal flow rates within the STA's to enhance phosphorus uptake.

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Factors Influencing the Calcium Carbonate Precipitation in the Everglade Sloughs

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Factors leading to the calcium carbonate (CaCO3) precipitation by the periphyton in the Everglades sloughs were examined from field measurements. CaCO3 saturation indices estimated from the water column calcium (40-85 mg/L) and carbonate alkalinity (200-280 mg CaCO3/L) concentration showed that the slough water was saturated with CaCO3 (SI: 0-1) at the normal range of pH (7.5 - 8.5) and temperature (15-35 C) observed in the Everglade sloughs. At the elevated pH (9.3) and temperature (36 C) conditions observed on the surface of the periphyton mat calcium carbonate saturation was considerably exceeded (SI > 2.0) resulting in its precipitation from the water column.

Interestingly, the modern rates of calcium carbonate precipitation and deposition in the sloughs were substantially higher compared to the historical rates in WCA 2A. The increases in calcium deposition rates in the last few decades reflect an increased supply of calcium. The increased interaction with the basement limestone rock, facilitated by the construction of the canals may have increased the supply of calcium and carbonates to the surface water thus leading to more alkaline conditions favorable for the enhanced rates of precipitation of calcium carbonate in the Northern Everglades.

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Factors Influencing the Dissolved Oxygen Profiles in the Northern Everglades

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We examined the dissolved oxygen (DO) profiles in the water column of the sawgrass marshes, open water sloughs and cattail marshes in the Water Conservation Area 2A of the Northern Everglades. DO concentration in the water column of the sloughs exhibited a strong diurnal variation (2-8 mg/L) reflecting the activity of photosynthesizing organisms and decomposers. Within the sloughs the DO levels were the highest on the surface of the periphyton mat and lowest near the soil-water interface. DO concentration levels in the water column of the sloughs exhibited wide temporal variations and were relatively low during the low water level periods. The DO levels in the sloughs (median DO: 4-8 mg/L) were substantially higher compared to the sawgrass marshes (median DO: 2-4 mg/L) in the unimpacted interior areas of WCA 2A. The DO levels were considerably diminished in the P-enriched cattail marshes in WCA 2A (<2mg/L). The habitat structure, P-enrichment and the water levels are the primary factors regulating the DO concentration in the northern Everglades.

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Nitrogen Reduction for Periphyton Stormwater Treatment Area (PSTA) Research in the Everglades Nutrient Removal Project Test Cells

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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 nutrient levels to an interim target of 50 ug-P/L. However, the final P standard will most likely be less then 50 ug-P/L, therefore, the EFA directs the District and DEP 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.

Although the EFA specifically addresses P concentration, compliance with water quality standards and compatibility of treated water with the balance in natural populations of aquatic flora or fauna in the Everglades Protection Area (EPA) must also be addressed. The first priority is P reduction in the runoff generated from the Everglades Agriculture Area (EAA) stormwater runoff, but we must also study the effects of the ATTs on other nutrients, such as nitrogen, as well as the resultant ionic constituents of the water discharged into the EPA. Additionally, nitrogen is an important parameter as it may influence the type of periphyton present and may have ecological importance downstream of these treatment technologies.

In 1996, the District completed a comprehensive evaluation of promising water quality treatment technologies, ranging from constructed wetlands that require fairly low maintenance to full chemical treatment for the removal of P (PEER Consultants and P.C./Brown and Caldwell, 1996). The District, and/or its partners, has initiated demonstration studies on eight technologies required by the USACE 404 permit to further determine critical design criteria, such as performance efficacy, hydrologic operating characteristics, capital and operating costs, and identification of potential environmental impacts. 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 and through chemical adsorption algal mediated co-precipitation with calcium carbonate within the water column.

Demonstration and research PSTA projects are ongoing at various locations within STA-1W and adjacent to STA-2. The test cells are shallow, half-acre, lined wetlands located within cells 1 and 3 of STA-1W. Three test cells within the set of test cells located within STA-1W Cell 3 are dedicated for PSTA research. All of the test cells have a sand surcharge directly on top of the liner, however, one of the three PSTA test cells have 30 cm of peat on top of 30 cm of shellrock, while the two remaining test cells have only shellrock. Two of the test cells, one peat and one limerock, were operated with a mean HLR of 6 cm/d and at a mean depth of 0.6 m. 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 storage cell outlet (inflow source water) and the outflow of all PSTA test cells and analyzed for various parameters. Total phosphorus and total nitrogen are reported in this abstract. Total nitrogen is calculated by the addition of total Kjeldahl nitrogen and the nitrate/nitrite parameters. All sample collection and analyses have been conducted in accordance with either the Environmental Protection Agency or APHA approved analytical methods.

Two distinct time periods were considered in the analysis of the test cell data. The first is the entire period of record that began with system startup, on 15 April 15 1999, and continued through the end of Phase 1 research. This period included startup phenomena such as periphyton and emergent colonization and growth, along with a probable nutrient flux from the sediment. The second was the operational period and represents the optimal conditions observed during the first year of operation, the point after which all removal rates remained positive. This period began on 1 July 1 1999 and this is the period reported in this abstract. Phase 1 research ended in January 2000 after which operational changes were made to these experimental units.

Preliminary data indicate that the inlet total phosphorus and nitrogen were very similar between the shellrock and peat-based systems. The mean outflow phosphorus concentrations were 16.6 and 14.0 ug/L in the peat and shellrock systems, respectively. Total mean outflow nitrogen was1.22 mg/L in the peat-based system at the outflow, while the mean outflow from the shellrock system was 1.56 mg/L. The TP percent reduction in the peat-based system was lower (30%) than in the shellrock system (42%). In contrast, the peat-based system has a higher (42%) TN percent reduction rate than the shellrock system (25%) (Table 1). Additionally, the mean nitrogen:phosphorus (N:P) ratio at the outflow of the peat-based system was consistently lower than from the shellrock system, substantiating the pattern seen in the nutrient reduction percentages.

Table 1: Total Phosphorus and Total Nitrogen parameters measured in selected periphyton-based experimental units developed on different soil types. These data should be considered preliminary for this abstract.

	Total Phosphorus (ug/L)			Total Nitrogen (mg/L)		
	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction
Peat	24.4	16.6	30	2.03	1.22	42
Shellrock	23.4	14.0	42	1.95	1.56	25

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The Effect of Drawdown and Presence of macrophytes on P Stability in Soils from the Everglades Nutrient Removal Project

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A series of flow-through tanks were established at the inflow of the Everglades nutrient Removal (ENR) Project site. These systems mimic the stormwater treatment areas (STAs), as they consist of macrophytes and operated as flow-through systems. The objective of this study was to determine the interactive effects of vegetation and draw down on P retention/release characteristics of ENR soils and surface water quality. There were 3 replicates for each of 4 treatments of; continuously flooded with macrophytes, intermittently flooded with macrophytes, continuously flooded with no macrophytes, intermittently flooded without macrophytes.

An inorganic P fractionation scheme was completed on the soils at the project initiation and after 1 year and a mass balance of P was performed on each of the treatments including P loss from the water column, P stores in vegetation as well as stores within the soil. In addition, microbial biomass P and potentially mineralizable P were determined to determine the effects of each treatment on the microbial mediated release of P to the water column. P stored in vegetative biomass was significantly greater than stored within algae. The majority of the P within the mesocosms was stored in the refractory organic pool.

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Geochemical Monitoring Of Restoration Progress

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Carbonate environments such as Florida Bay are characterized by three primary biogeochemical processes including 1) carbonate sediment production by calcifying organisms and dissolution, 2) photosynthesis and 3) respiration (referred to collectively as productivity). These processes are sensitive to changes in water quality including salinity and nutrients, and show distinct rate changes before visual evidence of environmental disturbances such as seagrass die-off, algal blooms, and shifts in ecosystem success indicator species. Water management practices in South Florida are already being altered in an effort to restore the Everglades and Florida Bay. Resulting changes in water chemistry will first affect biogeochemical processes, and may, subsequently, result in changes in species distributions (such as seagrass, algae, etc.). Monitoring changes in biogeochemical processes provides a mechanism for measuring early response of the Florida Bay ecosystem to environmental perturbations. We have performed seasonal measurements of productivity associated with representative benthic substrate types in Florida Bay to begin establishing baseline rates before significant changes occur during restoration. Monitoring changes in productivity during implementation of restoration plans will allow resource managers to evaluate the progress and success of South Florida restoration efforts.

Carbonate sedimentation and organic productivity (calcification, photosynthesis, and respiration) are most effectively determined from precise, in situ measurements of alkalinity, pH, temperature, conductivity, and air:sea CO_2 and O_2 gas fluxes. Net productivity was determined on seagrass beds in basins located in the western bay near Buchanon Keys and in the central bay near Manatee Keys during March of 1999 and 2000 and during September of 1999, and on mud-bottom and hard-bottom (soft corals and small hard corals, sponges, calcareous algae) communities during March 2000. A large incubation chamber called the Submersible Habitat for Analyzing Reef Quality, or SHARQ, was used to isolate water over the substrate and to measure temporal changes in key geochemical parameters over 24 hour time periods. Productivity in the water column was determined in March 2000 by isolating a mass of water inside of the SHARQ from the substrate by placing a floor in the incubation chamber. Geochemical parameters including pH, dissolved oxygen and temperature were measured continuously using a flow-through analytical system throughout the duration of incubation periods. Water samples were removed every 4 hours from sample ports for total alkalinity measurements. Dissolved oxygen, pH and alkalinity data were used to calculate average rates of net calcification, photosynthesis, and respiration for light and dark hours. Productivity on mud-banks located at Russell Bank was measured during March and September of 1999 and March of 2000 using an upstream/downstream sampling strategy. Changes in key geochemical parameters were determined by identifying unidirectional currents across Russell Bank and establishing upstream and downstream sampling sites along 200-400 meter bank transects. Average rates of net calcification, photosynthesis and respiration were calculated from total alkalinity, pH, dissolved oxygen, air:sea CO_2 and O_2 gas fluxes, salinity, temperature, and wind measurements taken every 4 hours during 24 hour time periods at each sampling site.

Rates of calcification for Buchanon Keys Basin and Manatee Key Basin seagrass beds indicate net dissolution of carbonate sediments during March 1999 and 2000 and September 1999. The average rate of net photosynthesis during daylight hours for Buchanon Keys Basin seagrass beds is 0.071 g carbon/m^2/hr with values ranging from 0.04 to 0.08 g carbon/m^2/hour. Net photosynthesis values for Manatee Key Basin seagrass beds ranged from 0.005 to 0.13 g carbon/m^2/hour with an average of

0.069 g carbon/m^2/hour. Average rates of respiration during night hours were 2.5 x 10^{-4} g carbon/m^2/hour for Buchanon Keys Basin and 1.1 x 10^{-4} g carbon/m^2/hour for Manatee Key Basin seagrass beds.

Preliminary results of productivity measurements on representative substrate types during March 2000 were calculated. Highest rates of net photosynthesis occurred on seagrass beds in Manatee Key Basin followed by seagrass and hard-bottom communities in Buchanon Keys Basin. Highest net calcification rates (day calcification – night dissolution) were associated with the hard-bottom community. Rates of calcification and photosynthesis for mud-bottom and water column in Manatee Key Basin were up to an order of magnitude less than rates for seagrass and hard-bottom communities. Generally, for all substrate types, net precipitation of carbonate sediments was observed during daylight hours, while net dissolution occurred at night. Relatively low respiration rates may result from consumption of respired CO_2 by carbonate sediment dissolution reactions.

Results of Russell Bank productivity measurements indicate net carbonate sediment production during March 1999 of 0.071 g carbon/m^2/24 hours and net sediment dissolution during September 1999 of 0.014 g carbon/m^2/24 hours. Average rates of photosynthesis were –0.061 g carbon/m^2/hour for March and –0.042 g carbon/m^2/hour for September indicating net oxygen consumption on the bank top. However, average rates of respiration were -7.0 x 10^{-4} g carbon/m^2/hour for March and –2.3 x 10^{-3} g carbon/m^2/hour for September indicating net carbon fixation. This suggests that oxygen may be consumed through inorganic oxidative processes (e.g. sulfide oxidation, etc.) and that additional nutrient measurements will be required to quantify these processes.

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Poster Abstracts

Water Quality and Water Treatment Technologies

Interactions between Dissolved Organic Matter and Mercury

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Effective management strategies for mitigating mercury (Hg) contamination of game fish in South Florida require understanding of the factors and processes resulting in the transport and controlling the reactivity and bioaccumulation of Hg in the Everglades. Our project focuses on the effect of dissolved organic matter (DOM) on the reactivity of Hg in the Everglades. DOM reactivity with Hg is especially important in South Florida because the high production of organic matter in peat soils and wetlands results in large DOM concentrations in surface water and shallow ground water systems in the region. The findings of our project are important to consider in designing remediation strategies. Factors such as vegetation and hydrology, for instance, may be very important in controlling both DOM and Hg reactivity. In addition, our research efforts to study distribution of Hg between DOM and particulate organic matter, and the determination of Hg-DOM binding constants are critical for adequate modeling of Hg in the Everglades.

Our 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. Specific ultraviolet absorbance (SUVA) measurements, in combination with DOC and DOC fractionation analyses using XAD resins, were used to determine both the amount and nature of DOC along a north-south transect (approximately 40 miles). Samples collected in the northern part of the transect had higher DOC concentrations, were more aromatic, and had a greater amount of hydrophobic acids and hydrophobic neutrals than samples collected further south. In addition, porewaters were found to contain greater DOC concentrations than overlying surface waters. The porewaters in the eutrophic areas to the north were found to contain the highest DOC concentrations. DOC concentrations and SUVA were lower in those areas with higher concentrations of methylmercury. Our field studies have shown that the amount and nature of DOM in the Everglades is dependent on the dominant vegetation types, hydroperiod, and interactions of surface water with peat porewaters. For instance, in areas were water migrates to the surface through the peat, the DOM was found to be more aromatic and contain greater sulfur content compared to samples were surface water was lost to the subsurface.

The speciation of Hg(II) in aquatic systems depends, in large part, on pH, DOM concentration, the concentrations of inorganic ligands, especially sulfide, and the distribution of Hg(II) between dissolved and particulate phases. The hydrophobic acid fraction (HPOA), hydrophilic acid fraction (HPIA), fulvic acid and humic acid were isolated from surface waters along the transect using XAD resins. These isolates and whole water samples were used to study interactions of DOM with Hg in cinnabar (HgS) dissolution and precipitation experiments under a range of pH and concentration conditions. In addition, interactions of Hg with DOM were studied via an ion-exchange technique designed to yield information on Hg-DOM binding constants. In each of these studies, organic matter from the northern, eutrophic field sites interacted more strongly than did samples from the southern part of the transect. These isolates were more aromatic and contained greater amounts of reduced sulfur than other samples studied.

Cinnabar is a relatively insoluble solid (log K_{sp} = -52.4) under most environmental conditions. In the presence of DOM, particularly the humic fractions (HPOA, humic acid, and fulvic acid), a significant amount of Hg (up to 1.7 □M/mg C) was released from cinnabar suggesting strong interactions. 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. In model compound studies, cysteine and thioglycolic acid dissolved small amounts of Hg from the cinnabar surface, while 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 (determined by ^{13}C-NMR) of the DOM.

Conversely, precipitation and aggregation of metacinnabar (black HgS) was inhibited in the presence of low concentrations (≤3 mg C/L) of dissolved organic matter (DOM) isolated from the Florida Everglades. At low Hg concentrations (≤$5x10^{-8}$ M), DOM completely prevented the precipitation of metacinnabar. Organic matter rich in aromatic moieties was more reactive with colloidal and particulate HgS. HPOA, humic and fulvic acids inhibited aggregation better than HPIA. Chloride, acetate, salicylate, EDTA, and cysteine did not inhibit the precipitation or aggregation of metacinnabar. The interactions of DOM with HgS in these experiments appear to be the result of strong DOM-Hg binding and colloidal stabilization.

The strength of DOM – Hg binding interactions was investigated using competitive binding on ion-exchange resins. We compared the distribution ratios for mercury between the resin and water ($[Hg_{resin}]/[Hg_{soln}]$) in the presence of organic matter isolates and several inorganic (chloride, bromide) and organic (citric, EDTA, thioglycolic acid) ligands with known Hg-ligand stability constants. The distribution ratio is inversely related to the binding strength between the ligand and Hg. The distribution ratios determined in the presence of the HPOA isolates were comparable to those obtained for the most strongly binding ligand, thioglycolic acid ($\beta=10^{30}$) suggesting similar reduced sulfur binding sites in both. The HPOA isolates bound mercury more strongly than the HPIA fraction with the samples from the northern sites binding most strongly.

Finally, DOM was also found to influence the binding of Hg(II) to two Everglades peat samples. This is significant because it is hypothesized that dissolved Hg is more bioavailable than particulate bound Hg. Again, the HPOA isolate from the northern, eutrophic site was more effective at competing with the peat for Hg(II). Our studies have demonstrated that the chemical composition of the DOM, especially aromatic carbon and reduced sulfur functional group content, is important in controlling DOM interactions with Hg(II). These interactions are important factors controlling both bioavailability and photochemical reactivity of Hg in the Everglades.

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Trace Metal Contamination in the Everglades Ecosystem

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The goals of this paper are (1) to critically review and evaluate the historical data regarding metal contamination in the Everglades, and (2) to present our preliminary results on the trace element contents in the soil samples collected from the Everglades protection area.

There is concern in the regulatory, scientific and environmental communities that the biotic integrity of the remaining Everglades is endangered (SFWMD, 2000). This position is based, in part, on undesirable changes observed in water quality, flora and fauna in portions of the Everglades during the last several decades. The environmental impacts have been attributed to urban and agricultural development, disruption of the natural hydroperiod resulting from regional flood-control efforts, and the introduction of nutrient-rich agricultural/urban runoff and Lake Okeechobee water releases. Comprehensive studies concerning the sources, fate, transport, and ecological effects of nutrients, especially phosphorous have been conducting by different federal, state, and local government agencies, and academic institutions (EPA, 1998 and SFWMD, 2000). However, as far as chemical contaminants are concerned, only mercury is currently being comprehensively studied. Based on limited information in the scientific literature and results of several toxic substances monitoring studies, it appears that soil/sediment, water, and biota in the Everglades are contaminated by a variety of inorganic and organic compounds, including pesticides and heavy metals (USGS, 1999; Ogden *et al*., 1974; Kushlan and Hunt, 1979; Waller, 1982; and Georgiadis *et al*., 2000). However, the lack of detailed information on the magnitude and extent of these chemical contaminants in this ecosystem hampers the understanding of their ecological effects.

Several national and statewide research programs have attempted to determine the magnitude and extent of trace metals in variety of areas. In south Florida, these programs have focused on estuarine/coastal sites (Cantillo *et al*.1997, and NOAA, 1998). Although trace metals have been evaluated in Florida soils, samples were only collected from upland areas north of Lake Okeechobee (Rice 1999; Ma *et al*., 1997; and Chen *et al*., 1999). Information regarding the magnitude, extent, and ecological effects of trace metals in the unique Everglades ecosystem is extremely limited. In an earlier study, Ogden et al. (1974) investigated the heavy metal and other chemical contaminants in upper food chain levels in the Everglades National Park and vicinity. Among different metals (arsenic, mercury, cadmium, lead, zinc and copper) measured in this study, mercury was found to be present at relatively high concentrations in some freshwater vertebrates, while the concentrations of arsenic approached the levels that may constitute a health hazard. Major ions and trace element concentration at Everglades freshwater marsh stations and in Big Cypress Swamp during wet and drying seasons were reported (Kushlan and Hunt, 1979; Waller, 1982). It must be noted, however, that recent studies have shown that contamination artifacts have seriously compromised the reliability of many past and current analyses (Benoit *et al*., 1997). For example, the mercury concentrations ranged from 0.4 to 6.7 μg/L in the Everglades National Park reported previously were much higher than those found in the current research, indicating serious contamination of the samples. Fortunately, recent developments of the clean method for trace metals analysis have substantially improved the quality and reliability of research and monitoring program (Benoit *et al*., 1997). A recent pilot study gathered preliminary data on the concentrations of trace metals in soil samples from the Everglades (Georgiadis *et al*, 2000).

Nevertheless, information on the magnitude and extent of trace metal in the Everglades ecosystem is very limited. In a recent study carried out in our laboratory, a number of soil samples have been collected in the Everglades protection area. Some environmentally important trace elements have been measured using a sensitive analytical technique (inductively coupled plasma mass spectrometry). The results are used to (1) identify the potential sources and locations that correspond to metal contamination; (2) provide clues for where there is need for intensive investigation of particular toxic pollutants that may be at or near dangerous concentrations; and (3) obtain a useful database for future evaluation on the effects of restoration processes in terms of the fate and transport of trace metals.

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Origin of Elevated Mercury Concentrations in Fish from Florida Bay

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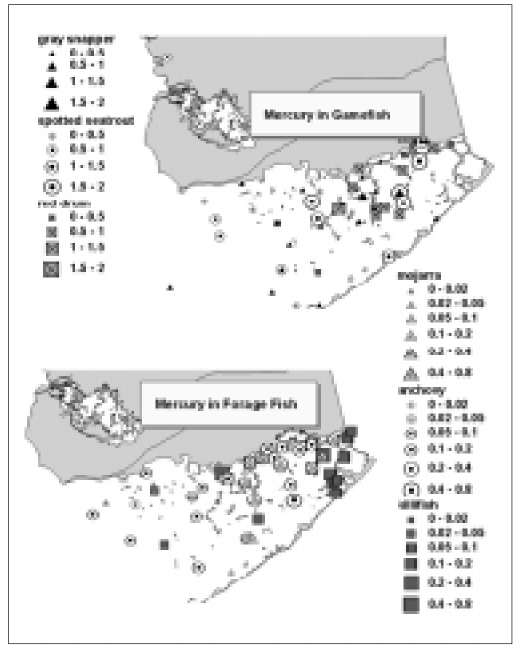
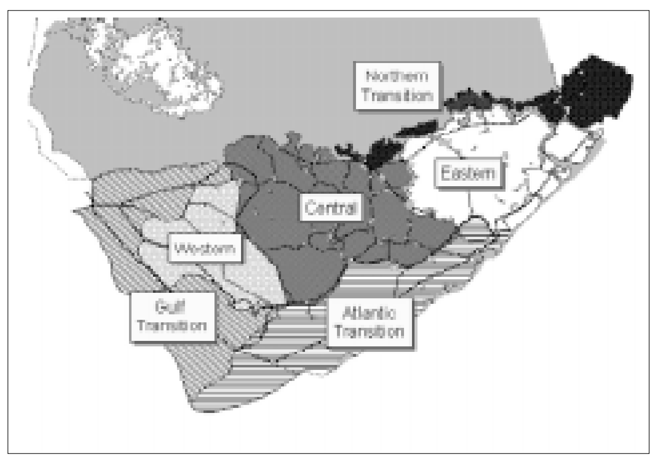


Health advisories are now posted in eastern Florida Bay warning of elevated levels of mercury in some higher trophic level fish. Reduction in body burdens of mercury in top carnivores is one of the success criteria listed by the South Florida Ecosystem Restoration Task Force. An important concern is that freshwater discharged from the Everglades is a major source of methyl mercury accumulating in some game fish in eastern Florida, and that the problem could be exacerbated by planned hydrological restoration activities.

We have analyzed more than one thousand game fish and forage fish for mercury from throughout Florida Bay. In analyzing the spatial distribution of mercury in fish, we have adopted a modification of the PMC's subdivisions of Florida Bay, adjusting boundaries to match the basin boundaries employed in the FATHOM salinity mass balance model, grouping the Northern Transition, Eastern, and Central subdivisions into an "Interior " region closest to freshwater inflows from the Everglades and the Gulf Transition, Atlantic Transition, and Western subdivisions into an "Outer" region remote from freshwater inflows.



Highest mercury concentrations are observed in fish from the interior region in the central and eastern subdivisions of Florida Bay (**Table 1**). Spotted seatrout almost always exceed the 0.5 ppm advisory level in this region, and they frequently exceed 1.5 ppm. Mercury concentrations in red drum frequently exceed 0.5 ppm, while mercury concentrations in gray snapper rarely exceed this level. Because of biomagnification processes, prey species are expected to have about one fifth of the mercury concentration of their predators. Mercury concentrations in bay anchovies are consistent with this expectation, exceeding 0.1 ppm in most of the interior region. Rarely are such concentrations exceeded in the outer region Mercury concentrations in mojarra and rainwater killifish are also highest in the interior.

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

If freshwater flow from the Everglades carries methyl mercury into the interior region of Florida Bay, we would expect fish from the Northern Transition subdivision to be most highly contaminated because they are closest to the presumed Everglades source. This is not the case, however, as fish from the Eastern subdivision have highest mercury concentrations (**Table 1**). We do not observe an inverse relationship between mercury concentrations and salinity for any fish species in Florida Bay. We would expect highest concentrations at low salinities if Everglades runoff is a major source of methyl mercury to these fish.

We are currently completing mercury and stable isotope analyses of previously collected fish and food web organisms to develop a more complete picture of the spatial distribution and food web patterns supporting high mercury concentrations in fish from Florida Bay. We anticipate beginning a new project in collaboration with Darren Rumbold of the South Florida Water Management District titled

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

	Forage Fish			Game Fish		
PMC Subdivision	**Bay Anchovy**	**Rainwater Killifish**	**Mojarra**	**Spotted Seatrout**	**Red Drum**	**Gray Snapper**
Gulf Transition	0.075	------	0.026	0.696	------	0.103
Western	0.071	0.097	------	0.689	0.395	0.152
Atlantic Transition	0.152	------	0.093	0.624	0.178	0.173
Outer Bay	**0.107**	**0.097**	**0.079**	**0.681**	**0.322**	**0.159**
Central	0.172	0.137	0.063	0.744	0.616	0.300
Eastern	0.245	0.161	0.144	1.810	0.720	0.485
Northern Transition	0.175	0.130	0.100	1.553	0.457	0.356
Interior Bay	**0.200**	**0.145**	**0.100**	**1.496**	**0.618**	**0.349**
Lavaca Bay Texas	0.28	------	------	0.37	1.13	------

"Linking Everglades Restoration and Enhanced Freshwater Flows to Elevated Concentrations of Mercury in Florida Bay Fish." In these studies we will be measuring total mercury and methyl mercury concentrations and fluxes through the Everglades margin into Florida Bay on a seasonal basis. Bioaccumulation of mercury by resident fish and invertebrates will be determined along the two water sampling transects. Finally, we will be seeking to identify the relative importance of methyl mercury imported from the Everglades and that formed within the bay itself using compound specific stable isotope techniques. This information should allow us to better predict the consequences to Florida Bay of planned hydrological restoration activities within the adjacent Everglades.

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Water Quality of Lake Trafford, Florida

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Lake Trafford is a shallow hypereutrophic lake in southwest Florida. It is the only large lake in this region of Florida. It is regionally significant as the headwaters of the Corkscrew Swamp and the Camp Keais Strand that drains south into the Gulf of Mexico and the northwest edge of Florida bay. At one time the lake was sand bottomed but now has a layer of nutrient-rich, organic sediment two to six feet thick, which occupies 50 percent of the lake volume. This layer interferes with fish habitat and has resulted in periodic fish kills. It is necessary to remove the sediment from the lake to improve the fishery and reduce downstream discharge of nutrient rich water.

The water quality of the lake has been monitored periodically during the past 30 years. During this period the phosphorus concentration has increased from 200 ug/L to 400 ug/L with occasional values as high as 1600 ug/L. The chlorophyll-a concentrations vary from 20 to 200 mg/L. Total nitrogen varies from 0.2 to 6 mg/L. The nutrients appear to have accumulated in the lake over the past 50 years as a result of nutrient inflows from agriculture and urban sources. Analysis of the lake sediments shows a high nutrient and organic matter content with low levels of metals and pesticides.

The Lake Trafford environmental restoration consists of sediment removal and habitat restoration. During the next three years the organic sediments will be removed from the lake and deposited in a spoil area. The water will be returned to the lake through a series of filter wetlands. A watershed management plan will be developed to prevent future cultural eutrophication. The watershed plan may require urban and agricultural BMPs to reduce nutrient loads as well as hydrologic modifications to improve inflow and outflow form the lake.

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Investigation of Polycyclic Aromatic Hydrocarbons and Quinone Photoproducts Everglades Canals C-11 and C-111

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Urban runoff has been suggested as a major source of PAH contamination in waters of the Everglades. There is a lack of information about the spatial and temporal distribution of aquatic PAHs and their photoproducts. These pollutants of interest are difficult to measure by conventional means of sampling. Furthermore, a means of sampling and measuring ultra-trace levels of PAH photoproducts in the aquatic environment has not been reported. The contaminants of interest in this investigation were selected PAH quinone photoproducts and the priority pollutant PAHs. Semi-permeable membrane devices (SPMDs) are segments of layflat polyethylene tubing containing thin films of triolein (1,2,3-tri[*cis*-9-octadecenoyl]glycerol). When deployed as *in situ* aquatic samplers, the devices sequester hydrophobic organic contaminants from the water. SPMDs were placed in Everglades canals C-11 and C111. After a 28-day sampling period, the SPMDs were retrieved, dialyzed and analyzed for PAHs and photoproducts. The portion for the 16-priority pollutant PAHs was fractionated, separated and analyzed by GC-PID. The quinone photoproducts were analyzed, without further cleanup, by direct HPLC-UV analysis. No chromatographic interferences of co-dialyzed components occurred. The GC and HPLC methods, in conjunction with SPMD sampling, enable PAHs as low as 10ng/SPMD to be measured. The photoproduct detection limits are estimated to be in the microgram/SPMD range by this method. We determined that levels of PAHs and the photoproducts in the waters of these two canals were less than the detection limits of this sampling and analysis method. We also screened the SPMD samples for organochlorine pesticides and found DDT and several other organochlorine pesticides at ng/SPMD levels.

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Linking Aquatic Monitoring with Remote Sensing: Neuse River, NC

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Hyperspectral Remote Sensing (HRS) can provide Chlorophyll, Suspended Minerals, Dissolved Organic Carbon and turbidity data for water bodies. During this project we measured chemical and biological parameters on samples from the Neuse River estuary simultaneously with collection of HRS images. We evaluated results of all data to identify links between field measurements and images, and to determine how the images may be utilized in watershed modeling and regulation.

Pollution from destructive land use/water management practices threatens aquatic ecosystems throughout the world. In the United States massive fish kills have been reported in Maryland, North Carolina, Florida, Texas, California. Domestic sewage, agricultural run-off and agro-industrial effluents are causing enrichment of nitrogen and phosphorous in ecosystems resulting in algae development, eutrophication, fish kills and endangerment of human health.

Analyses on field water samples to characterize water bodies include environmental parameters (Temperature, pH, Dissolved Oxygen, etc…), dissolved inorganic constituents (metals and non-metals), nutrients, pigments (Chlorophyll, Tannin and Lignin, etc…), and stable isotopes (Oxygen, Hydrogen, Nitrogen, Carbon). Traditional water quality modeling, such as, USEPA's QUAL2E-UNCAS model, can use the four hyperspectral parameters, but also may include environmental parameters, nutrients and dissolved constuents.

In order to integrate remote sensing with monitoring and modeling links need to be developed between what is indicated in images, and chemical and biological parameters accurately measured on field samples.

On July 20, 1999, NASA aircraft took HRS images with NASA's AVIRIS system along the Neuse River Estuary in North Carolina. At the same time (over a period of about four hours), the Neuse River was sampled along six transverse transects. Sample locations along each transect included one near each shore and in the middle of the river. Water samples were obtained, where possible, at three depths (surface, middle of the water column and near-bottom) at each sample location. Two additional surface water samples were taken on each side of the mid-river locations (i.e. between the mid-river location and near-shore locations). The total number of samples, excluding replicates, was 53.

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Field sample results were evaluated with geologic, thermodynamic and statistical models. The evaluation indicated the effects of ocean-fresh waters mixing in the estuary, locations of the estuary where chemistry was dominated by groundwater and local tributary input, the source of nitrogen to the estuary, and mathematical relationships for parameters affecting algae development (Chlorophyll*a*, phosphate, nitrogen, pH, dissolved oxygen, and suspended solids).

The parameters in the HRS images correlated closely with field parameters: HRS Chlorophyll with field Chlorophyll*a*, HRS Dissolved Organic Carbon with field Tannin and Lignin, and HRS Suspended Minerals with field Total Suspended Solids.

The mathematical relationships found among the field samples for algae development were applied to the HRS images and the resulting manipulated image indicated the areas where algae blooms were most likely to occur. The evaluation indicated that modeling may be useful in further utilizing the images, but also that the interpretation from the images may affect future modeling.

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Aquatic Cycling of Mercury in the Everglades (ACME) Project: Synopsis of Phase I Studies and Plans for Phase II Studies

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Background

In 1994, a consortium of agencies lead by the U.S. Geological Survey began a multi-investigator study of the factors contributing to the high levels of mercury (Hg) in Everglade's biota, the Aquatic Cycling of Mercury in the Everglades (ACME) project. The overall objective has been to understand Hg cycling well enough to create management strategies that will minimize methylmercury (MeHg) bioaccumulation in the Everglades, while fulfilling other management objectives such as nutrient reduction and natural hydroperiod restoration. Mercury 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 due to high Hg levels in fish tissues. Because virtually all Hg contained in edible fish is MeHg, acquiring a complete understanding of the processes controlling the environmental fate of MeHg is requisite to make responsible ecosystem management decisions. Necessary information includes, the precise locations and rates of MeHg production and destruction, environmental factors (such as water chemistry) that either exacerbate or mitigate MeHg production, and foodweb bioaccumulation pathways.

Synopsis – Phase I Studies (1995-1998)

The precise underpinnings of why wetlands, such as the Everglades, are susceptible to methylmercury production and bioaccumulation are not completely understood. High rates of microbial MeHg production in anaerobic, organic-rich sediments and advective flows of nutrient bearing water are probable causes. Previous work by the ACME project has revealed that mercury (Hg) 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 addition, *in situ* microbial processes and photochemical processes control MeHg levels at the ecosystem level. Mercury loads to the Everglades are dominantly derived from atmospheric sources, but toxicity is largely controlled by the relative rates of conversion to methylmercury, which in turn appears to be intimately associated with other complex biogeochemical cycles, such as the sulfate/sulfide cycle. Specific key finding of the ACME project are the following: (1) MeHg bioaccumulation is driven by internal MeHg production, mainly in surface sediments; (2) MeHg concentrations in all matrices (sediment, surface water, pore water, and biota) are maximal in the central Everglades (southern WCA2A, WCA2B and north-central WCA3); (3) MeHg is somewhat lower in more pristine areas like Everglades National Park and WCA1, and much lower in the most eutrophic areas of WCA2A and the constructed nutrient-retention wetlands; (4) The spatial MeHg pattern is not driven primarily by inorganic Hg concentration, although there is weak but significant relationship between Hg and MeHg concentrations in surface sediments; (5) Photochemical reduction and photo-demethylation are important mechanisms for removal of mercury and destruction of MeHg, respectively, over much of the Everglades; (6) Sulfur inputs from areas north of the Everglades have a large impact on MeHg production, but the magnitude and even direction of the impact varies with the sulfate and sulfide concentration; (7) Phosphate and nitrate generally had no direct effect on MeHg production rates in sediment cores; (8) Anaerobic microbial processes, including sulfate reduction, are key components of microbial organic carbon decomposition in Everglades sediment; (9) Microbial dissimilatory sulfate reduction (rather than assimilation by plants) appears to be the most important mechanism for reduced sulfur storage in Everglades peat; (10) Natural fires and extended periods of peat exposure can greatly exacerbate MeHg production (for example 10x increases in sediment MeHg levels), and this phenomenon appears to be driven by sediment oxidation and release of sulfate after re-inundation; (11) Bioaccumulation of MeHg in Gambusia appears to be facilitated by the movement of benthic invertebrates (insects and zooplankton) into the water column, and less importantly by direct grazing on surface sediments and periphyton; (12) Methylation occurs only in periphyton "mats" where microbial sulfur cycling occurs, and is most common in the less-calcareous periphyton found in eutrophic areas.

Plans – Phase II Studies (1999-2003)

In order to provide predictive capabilities of the potential effects of Everglades restoration efforts on Hg cycling, the complex relationships between loadings of Hg, sulfur, and nutrients on MeHg production and bioaccumulation need to be better understood. In the next phase of this research, we propose better quantify these individual relationships, and the interactions among these three key parameters, through amendments to *in situ* mesocosms. Short-term addition experiments are useful in examining processes, but may not predict long-term responses, for a number of reasons. Response of plant growth to nutrients is the obvious example, but other changes, like changes in Hg speciation and bioavailability over time, or development of microbial communities, are also important. An understanding of the relationship between Hg, S or nutrient loading and MeHg production and bioaccumulation requires a long-term, large-scale approach because there are many steps between the entry of "new" Hg to the ecosystem, its conversion to MeHg, and bioaccumulation in the foodweb.

We propose to use stable Hg isotope amendments to examine the relationship between Hg loading and MeHg production and bioaccumulation. This new approach will allow us to track the fate of newly deposited Hg separately from the larger existing pools, and to track the bioavailability of new Hg over time. The use of individual stable Hg isotopes will allow us to follow the cycle of new Hg added to the system, from initial partitioning, accumulation in vegetation, MeHg production and accumulation in sediments, fluxes and accumulation in the food web. We will also be able to trace burial, post-depositional reworking of Hg through sediments and plants, and Hg^0 formation. Important unknowns that stable isotopes will allow us to address are the availability of Hg in decaying plant material relative to newly deposited Hg adsorbed to sediments for methylation; and the recycling of buried Hg to the sediment surface through plant growth and decay. We also propose to make sulfur amendments as either a stable or radioisotope for the same reason. Sulfur isotope additions will allow us to find out how fast sulfide is turned over is sediments and made available again for sulfate reduction (through photosynthetic re-oxidation of sulfide), a key variable in modeling the relationship between sulfate load, sulfate reduction rate and sulfide accumulation in the oligotrophic Everglades. Isotopes will also allow us to track what fraction of newly added sulfate is retained in sediments.

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Nutrient Loading to Biscayne Bay and Water-Quality Trends at Selected Sites in Southern Florida

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During the early 1900's, water-management practices were undertaken to develop a highly managed hydrologic system consisting of levees, pump stations, gated control structures, and water-conservation areas in southern Florida. This complex hydrologic system was created for the purposes of flood control, water storage, replenishment of ground-water supplies, and retardation of saltwater intrusion. This man-made system has altered natural hydropatterns and degraded water quality in the Everglades ecosystem.

Plans for restoring the southern Florida and Everglades ecosystems to its predevelopment state requires filling canals, removing levees, and rechanneling canal discharges that currently enter Biscayne Bay. Biscayne Bay, a shallow subtropical estuary along the southeastern coast of Florida, provides an aquatic environment that is habitat to a diverse population of plant and animal species. As a result of agricultural and urban activities, increased nutrient loads in discharges from the east coast canals in southern Florida are a potential treat to the health of Biscayne Bay. An understanding of nutrient loading to Biscayne Bay is needed to assess the ecological health of the bay and to evaluate the water-quality impact of the diverted water to Everglades National Park. Restoring the southern Florida and Everglades ecosystem also requires an understanding of the changes in water quality that have occurred over time.

The U.S. Geological Survey, as part of its South Florida Place-Based Studies Program, initiated a project to document and define the concentration, distribution, and loading of nutrients to the bay from the coastal canal network. Water samples were collected from east coast canals in 1996-97 (primarily during the wet season) to determine concentrations of major organic and inorganic nitrogen and phosphorus species. Study results indicate that within the Biscayne Bay watershed, median concentrations of some nitrogen and phosphorus species were highest in selected land-use categories: (1) nitrite plus nitrate in the agricultural land-use category; (2) ammonia, total phosphorus, and orthophosphate in the urban land-use category; and (3) total organic nitrogen in the wetlands category.

Depth-integrated samples were dramatically different in total phosphorus concentration than 25 percent of grab samples at 1.0 meter depth and 33 percent of grab samples collected at 0.5 meter depth. No statistically significant differences were found for total nitrogen between grab and depth-integrated samples. Grab samples also were found to be biased low when compared to depth-integrated samples. A simple linear regression analysis was used to develop models for estimating total nitrogen and total phosphorus loads from the east coast canals to Biscayne Bay. Because of the large number of water samples collected over the years (1987-96), a log-linear model employing a minimum variance unbiased estimator was used to compute total nitrogen and total phosphorus loads for site S-26 in Miami.

Restoring and enhancing the natural ecosystem requires an understanding of how water quality has been affected over time by anthropogenic influences in southern Florida. Two U.S. Geological Survey daily discharge stations, one within the Big Cypress National Preserve (Tamiami Canal station) and one near Biscayne Bay (Miami Canal station), were analyzed for long- term (1966-94) trends in water quality to characterize prerestoration water quality and to document changes in water quality over time.

The principal tool used for the water-quality analysis was the Seasonal Kendall Trend (SKT) test, a nonparametric test that compares relative ranks of data values from the same seasons to negate variation caused by seasonality. To discern the anthropogenic influences that have affected water quality over the years, variation caused by discharge also should be negated. This was accomplished by performing the SKT on flow-adjusted concentrations (residuals) from statistically significant concentration/discharge relations developed using linear regression models. Long-term trends were determined at both sites for selected major inorganic constituents and physical characteristics; pH and dissolved oxygen; suspended sediment; nitrogen, phosphorus, and carbon species; trace metals; and bacteriological and biological characteristics.

Statistically significant (p-value less than 0.01) temporal trends for water-quality constituents at the Miami and Tamiami Canal stations were classified as indicators of either improvement or deterioration in water quality over time. Most downward trends indicate improvement in water quality over time; however, downward trends in pH and dissolved oxygen indicate deterioration over time and the potential for harmful effects on aquatic life. At the Miami Canal station, improvement in water quality was documented by 7 trends and deterioration in water quality was documented by 14 trends. At the Tamiami Canal station, improvement and deterioration in water quality were indicated by 4 and 9 trends, respectively. Median and maximum concentration concentrations at both sites were compared to the State of Florida freshwater standards; most concentrations were within these standards. However, the median concentrations of dissolved oxygen at the Miami and Tamiami Canal stations were 3.3 and 2.7 milligrams per liter, respectively, and did not meet the State freshwater standard of at least 5.0 milligrams per liter. Additionally, the median and maximum concentrations of total ammonia at both sites exceeded the State freshwater standard of 0.02 milligram per liter.

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Water Quality in the Everhglades and other South Florida Basins, 1996-98

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The environment in south Florida has been degraded by human activities. Native biota have been greatly reduced in abundance and diversity by drainage, development, alteration of water flows, wetland destruction, degradation of water quality, and the continuing invasions of exotic species. The Everglades ecosystem, which is adapted to water that has an extremely low phosphorus concentration, has been altered by agricultural activities that produce waters that contain high levels of phosphorus. Nutrient loading from the major rivers has contributed to enrichment of Lake Okeechobee and estuaries such as Charlotte Harbor. Mercury has accumulated in Everglades game fish and consumption of the fish poses a potential human health risk. Federal and State agencies and environmental groups have recently reached a consensus that south Florida, and the Everglades in particular, should be restored, to the extent possible, to its predevelopment condition. Restoration will require extensive changes in the water management system to restore predevelopment drainage patterns, improve water quality, and protect native biota.

The U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program is designed to provide nationally consistent data to assess trends in the Nation's water quality. Results for surface- and ground- water quality and biology that emerged from the southern Florida NAWQA study during 1996-98 are summarized below. The results are discussed in terms of regional issues and compared to water-quality conditions in other NAWQA studies nationwide. Results are explained in the context of national standards and criteria, such as those for drinking water quality and for protection of aquatic life. Information on the status of aquatic communities and the condition of aquatic habitats are included.

Results for surface-water quality and biology from the southern Florida NAWQA study include:

- Concentrations of total phosphorus (TP) at the south Florida NAWQA canal and river sites were above Everglades background levels (<0.004 mg/L) and exceeded the U.S. Environmental Protection Agency's Everglades water-quality standard of 0.01 mg/L.
- Agricultural fertilizer is a major source of the additional phosphorus. Natural phosphorus sources and phosphate mining also contribute to high concentrations of TP in the Peace River, one of the south Florida NAWQA river sites. Total phosphorus concentrations in south Florida tended to decrease from west to east along an 80-mile section of the Tamiami Trail, possibly due to differences in surficial geology. Sulfate concentrations were low along the Tamiami Trail except where agriculture or marine water influenced concentrations.
- Concentrations of dissolved organic carbon (DOC) in south Florida waters were relatively high compared with those in other waters of the Nation. High DOC concentrations provide food for bacteria to grow, reduce light penetration in the water, and enhance transport and cycling of pesticides and trace elements, such as mercury.
- Pesticides were detected in all but one south Florida NAWQA sample, but most concentrations were below aquatic-life criteria. However, the criteria do not address potential synergistic effects of mixtures of pesticides and their degradation products, which commonly occurred. Organochlorine pesticides, such as DDT and its degradation products, are still prevalent in bottom sediment and fish tissue at the south Florida NAWQA sites even though most uses of these compounds have been discontinued. The mobilization of these pesticides with reflooding

of farmlands, planned as part of the Everglades restoration, could lead to food-web contamination.

- Methylmercury, the most biologically available form of mercury, is enriched in sediment and biota of the Everglades. South Florida has the second highest ratio of methylmercury-to-mercury in sediment of 21 NAWQA basins nationwide. Methylmercury has accumulated in the Everglades food web because of natural conditions and human influences: atmospheric deposition rates are high and provide an important source of mercury; and water/sediment chemistry in the Everglades enhances methylation of mercury to its organic form, accelerating accumulation in the food web.
- The biological community at the NAWQA sites in south Florida includes species of fish, invertebrates, and algae that are tolerant of low water velocities, low dissolved-oxygen concentrations, nutrient enrichment, and habitat alteration. The incidence of external anomalies (lesions, ulcers, and tumors) on fish collected at two south Florida agricultural canal sites was in the top 25 percent of 144 NAWQA sites sampled nationwide for fish anomalies. Anomalies can be indications that fish are stressed by contamination. Exotic animals and plants are a threat to native biota. Ten of the 54 exotic fish species established in the region were collected at the south Florida NAWQA sites. Several herbicides used to control exotic plants were detected in surface water.

In much of the south-Florida region, ground water in the surficial aquifers, such as the Biscayne aquifer, is of good quality and usually meets Federal and State drinking water-quality standards. Contaminants such as nitrate, arsenic, pesticides, and volatile organic compounds (VOCs) are usually in low concentrations, presumably due to rapid flushing and recharge. Flushing and recharge are rapid because of high annual rainfall (about 55 inches) and because aquifers and permeable limestone are shallow and surface water and ground water can easily interchange. However, because of the shallow aquifers and permeable limestone, ground water is susceptible to surface contamination and to salt-water intrusion.

Results on ground-water quality from the southern Florida NAWQA study include:

- Nitrate concentrations were below the drinking water standard (10 mg/L) in the 108 wells sampled by the southern Florida NAWQA study, except for two shallow wells in the citrus land-use area (generally not a drinking water source).
- Pesticides were detected in more than 85 percent of the south Florida NAWQA wells and beneath every type of land use studied, but no concentrations exceeded any U.S. Environmental Protection Agency or State of Florida drinking-water standards.
- Pesticides, VOCs, and trace elements detected in shallow ground water were associated with specific land uses. For example, the herbicides bromacil and norflurazon were detected almost exclusively in citrus areas. Metolachlor and simazine were commonly detected in mixed agricultural areas near the southern Everglades. VOCs were commonly detected in water from shallow and deep wells in the Biscayne aquifer. Concentrations of one industrial VOC, vinyl chloride, exceeded the U.S. Environmental Protection Agency's maximum contaminant level (MCL, 2 μg/L) for drinking water in two samples.
- Radon-222 radioactivity exceeded the MCL of 300 pCi/L in the majority of samples from the Biscayne aquifer, including untreated water from the public-supply wells.

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Poster, Water Quality and Water Treatment Technologies

South Florida Water Quality Protection Program

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Interagency Management Committee:
Seminole Tribe of Florida
South Florida Water Management District
Florida Department of Agriculture and Consumer Services
US Environmental Protection Agency
Broward County
US Army Corps of Engineers
Miami-Dade County
Florida Department of Environmental Protection

The Water Quality Protection Program (WQPP) is an interagency effort that was established to recommend priority corrective actions and compliance schedules to address point and nonpoint source pollution and restore and maintain the chemical, physical and biological integrity within the south Florida ecosystem.

The WQPP will support sound decision-making at all levels of government and in the private sector. These changes will result in a better return on public and private investments in monitoring, environmental protection and natural resources management as well as protect human health, preserve and restore healthy ecological conditions and sustain a viable economy. This program will ratify and encourage ongoing efforts and/or change the ways water quality management strategies are defined, prioritized, conducted and funded.

This effort will be implemented through a three-phase effort. During Phase I information was compiled on existing water quality protection strategies and impacts in South Florida. Phase II is focusing on the development of a comprehensive restoration and enhancement plan with costs. In the final phase, Phase III, the comprehensive plan will be implemented.

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Modeling the Assimilative Capacity for Phosphorus through the Canal System of the Big Cypress Seminole Indian Reservation

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As a result of human activities, low nutrient wetland systems have been greatly affected by increased nutrient concentrations. This is particularly evident for phosphorus from agricultural activities in southern Florida. The Big Cypress Seminole Indian Reservation (BCSR), which receives a large amount of phosphorus from adjacent agricultural lands, is the location of our study. Our aim is to determine if phosphorus is assimilated during transit along the west and north feeder and the L-28 interceptor canals that traverse the BCSR, where it is being sequestered, and how much phosphorus is removed from the water column. We are attempting to correlate the movement of phosphorus within the canal system with several abiotic and biotic parameters in order to address the underlying mechanisms of phosphorus movement. To construct a model of phosphorus movement, we are utilizing water chemical, hydrological, and meteorological data collected from 1988 through 1995 at several locations throughout the BCSR as well as adjacent lands. The model developed from this data will then be validated with data collected from 1995 through 1998. Understanding the mechanisms of phosphorus movement is essential for wetland restoration, particularly for ecosystems such as the Everglades that historically evolved in oligotrophic conditions.

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Assessment of Sediment Toxicity in the St. Lucie River Watershed and Everglades Agricultural Area

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A two-year investigation funded by South Florida Water Management District is being conducted to evaluate sediment toxicity in the St. Lucie River Watershed (SLR) and Everglades Agricultural Area (EAA). Vegetable and citrus agriculture represent a large proportion of land use in the SLR and EAA. Currently used insecticides, herbicides and organochlorine compounds have been measured and concentrations have exceeded acute toxicity exposure concentrations for aquatic organisms. The problem gains in importance because of the frequency of use and diversity of pesticides applied during the South Florida growing season. Results will be presented from the first year of the investigation on the use of microbial toxicity as an initial screening procedure for whole sediment toxicity along with analytical data. Species sensitivity distributions will be defined comparing toxicity endpoints and actual exposure concentrations in water and sediment. The second year includes toxicity testing and a sediment TIE.

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Benthic Nutrient Fluxes near Florida Bay's Mangrove Ecotone

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

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

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

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

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Assessment of Methylmercury Risk to Three Species of Wading Birds in the Florida Everglades

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Mercury contamination is one of the more serious problems facing Everglades restoration. Currently, the Everglades is under human health advisories for limited or no fish consumption because of methylmercury (MeHg). In the Everglades, high concentrations of MeHg have also been found in top predators like raccoons, alligators, wading birds and Florida panthers. This case study reports on a risk assessment that used both deterministic and probabilistic methods to provide managers with estimates of risk while explicitly quantifying uncertainties. The objectives of this risk assessment were two fold: (1) to provide an Everglades-wide perspective of MeHg risk to wading birds, and (2) to address specific stakeholder concerns regarding possible adverse effects from restoration efforts currently under way in the Everglades. The latter objective was achieved using a well-studied oligotrophic site in WCA 2A as a reference for post-restoration conditions for mercury methylation and bioaccumulation. Exposures were based on measured tissue levels during 1997 – 1999 in fish species known to be consumed by wading birds. Toxicity reference values (TRV) were obtained from the published literature. Results suggest that birds foraging in the central basin were at greatest risk, with 86% of the great egret population expected to exceed the TRV. By comparison, only 46% of the egrets foraging at the post-restoration reference site in WCA 2A were predicted to exceed the TRV. Model-predicted egg and nestling feather mercury levels exceeded measured concentrations by a factor of 1.4 and suggest that the Monte Carlo model overestimates mercury exposure to the birds. Together with other lines of evidence, including reproductive studies, these results support the conclusion that the restoration effort will not increase MeHg risks to wading birds to unacceptable levels. Alternatively, MeHg risk to wading birds foraging preferentially in WCA 3A, particularly when near MeHg "hot spots", are of potential concern and warrant further studies.

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Toward Integrated Water Resource Quality Monitoring in South Florida Estuaries

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This poster documents on-going efforts of the South Florida Water Management District to integrate water quality monitoring in south Florida estuaries. Monitoring activities of several resource agencies and academic institutions are being melded into a coordinated, comprehensive program. Effective communication among federal, state and local coastal resource agencies is vital to the success of this effort; successful collaboration with academic researchers, non-profit organizations and the public is also essential. The development and implementation of this multi-objective program for water quality monitoring are described. Innovative approaches to network optimization, cost savings, and data sharing are explained. Current goals and activities of a newly established, regional water quality consortium, and projected monitoring challenges/opportunities of the 21st century are also described.

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Status of Water Quality Criteria Compliance in the Everglades Protection Area

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The Everglades Forever Act (EFA; Section 373.4592(1)(a), Florida Statutes) found that "*the Everglades ecological system is endangered as a result of adverse changes in water quality, and in the quantity, distribution, and timing of flows, and, therefore, must be restored and protected*." As a part of the Everglades Program provided in the EFA, the Florida Department of Environmental Protection (Department) and the South Florida Water Management District (SFWMD) are required to "*evaluate existing water quality standards applicable to the Everglades Protection Area and EAA* (Everglades Agricultural Area) *canals*." As a component of this evaluation the Department and SFWMD prepared Chapter 4 (Status of Water Quality Criteria Compliance in the Everglades Protection Area) of the 2001 Everglades Consolidated Report. This chapter provides an update to previous reports concerning the water quality status of the Everglades for WY2000 (*i.e.*, May 1, 1999 through April 30, 2000). It builds on the water quality analyses previously presented in past Interim and Consolidated Reports and includes a simplified analysis of the water quality parameters not meeting the water quality criteria specified in Section 62-302.530, F.A.C., and a discussion of any temporal or spatial trends observed for the parameters identified as Concerns or Potential Concerns. Unlike previous reports, the chapter provided a discussion of the factors contributing to excursions from applicable water quality criteria and an evaluation of the natural background conditions where existing standards may not be appropriate for conditions in the Everglades.

Excursion analyses revealed that constituent excursions varied greatly for different regions of the Everglades Protection Area (EPA). Most importantly, the vast majority of EPA water quality data were found to meet numeric water quality criteria. However, excursions were recorded for eight parameters including dissolved oxygen, alkalinity, conductivity, iron, pH, turbidity, lead and un-ionized ammonia. Additionally, the pesticides DDT, DDE, DDD, endosulfan, and diazinon each exceeded either Class III criteria or chronic toxicity values on one occasion.

A review of contributory factors revealed that the majority of dissolved oxygen, pH, and alkalinity excursions were the result of natural conditions within the marsh. The Department recognizes these conditions to be natural characteristics of the EPA, and thus, does not consider the excursions to be violations of State standards. Additionally, excursion rates for several other parameters (e.g., conductivity, turbidity, iron, lead) were likely influenced by factors, including groundwater infiltration, construction, pumping activities, and sample contamination, which affected data interpretation and ultimately compliance determination.

In recognition of background dissolved oxygen conditions, the Department has developed a Site Specific Alternative Criterion (SSAC) for Everglades dissolved oxygen. Application of the SSAC, to Water Year 2000 data, substantially reduced the excursion rate in all of the EPA and provided a more accurate assessment of which sites are adversely impacted with respect to dissolved oxygen. Establishment of the SSAC will require further peer review, public notice and hearing, and approval by the Secretary of the Department.

Overall, water quality with the during Water Year 2000 exhibited similar conditions as in Water Year 1999 and a historic period comprised of Water Years 1978 through 1998. Since many of the observed Class III excursions can be attributed to natural marsh conditions, they do not represent an ecologic threat to the Everglades. The Department, with assistance from the SFWMD, intends to continue evaluation of background water quality in the EPA as it relates to current standards.

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Optimal Conditions for the Determination of Total Phosphorous in Water

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The conditions affecting the determination of total phosphorus in water after digested by persulfate or sulfuric-nitric acid using the method of Murphy and Riley (1962) were studied. There was an inverse relationship between the formation rate of phosphoantimonylmolybdenum blue color and the final acid concentration; and formation rate varied directly with phosphorus concentration. Color was less stable at higher digestate persulfate concentrations, and color developed from the neutralized sulfuric-nitric acid digested samples was least stable. There was a maximum absorbance plateau within the final acid concentration interval ($0.36N \leq N_P \leq 0.56N$) for persulfate digested samples, and neutralization was not required before blue color development if the final acid concentration of the sample was within this range. Salinity had no significant effect on total phosphorus determinations using the persulfate digestion method, and this method was able to completely recover phosphorus from organic phosphorus compounds and sediment mixed samples with organic carbon content up to 100 ppm. There was no significant difference between total phosphorus determined using persulfate and sulfuric-nitric acid digestion methods. However, persulfate digestion yielded more precise data than the sulfuric-nitric acid digestion method. Total phosphorus concentrations from 15 ml sample digestion volumes were lower than those from 40 ml or 90 ml volumes using a graduated cylinder sub-sampling method for water samples with relatively high suspended solids content, and the precision of the results increased with the sample digestion volume. There was no significant difference between total phosphorus measurements from a 15 ml sample digestion volume using pipette sub-sampling and from 40 ml or 90 ml sample digestion volumes using graduated cylinder for sub-sampling. For samples with relatively high solids content, at least one hour of settling time was required before transferring an aliquot of the supernate from digested samples for total phosphorus analysis, or the blank correction method should be used to prevent overestimation of total phosphorus, even when there are no visible particles in the digested samples.

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Meeting Room Assignment Guide

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Session II: AM & PM

River of Grass Ballroom – Salons F & I (Level One)

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Immokalee (Level Three)

Session IV: AM & PM

Chokoloskee (Level Two)

Session V: AM (Friday Only)

Goodland Room (Level Two)