FCE II YEAR THREE
ANNUAL REPORT FOR NSF AWARD DBI-0620409

FLORIDA COASTAL EVERGLADES LTER

Florida International University

Submitted September 2009

<u>Principal Investigators</u>
Evelyn Gaiser
Mike Heithaus
Rudolf Jaffé
Laura Ogden
René Price

CONTENTS

I. PARTICIPANTS

A. Participant Individuals

Principal Investigators:
Evelyn Gaiser

Co Principal Investigators:
Mike Heithaus, Rudolf Jaffé, Laura Ogden, René Price

Senior personnel:
William Anderson, Anna Armitage, Mahadev Bhat, Joseph Boyer, Henry Briceno, Randolph Chambers, Daniel Childers, Tim Collins, Carlos Coronado, Susan Dailey, Stephen Davis, Frank Dazzo, Bob Doren, Vic Engel, Sharon Ewe, Jack Fell, Carl Fitz, James Fourqurean, Jose Fuentes, Jennifer Gebelein, Hugh Gladwin, Anne Hartley, James Heffernan, Darrell Herbert, Gail Hollander, Krish Jayachandaran, Lynn Leonard, William Loftus, Jerome Lorenz, Christopher Madden, Melissa Memory, Christopher Moses, Greg Noe, Steve Oberbauer, Jeff Onsted, Mark Rains, Jennifer Rehage, Jennifer Richards, Victor H. Rivera-Monroy, Mike Robblee, Michael Ross, Rinku Roy Chowdhury, Dave Rudnick, Jay Sah, Colin Saunders, Margo Schwadron, Len Scinto, Norm Scully, Marc Simard, Fred Sklar, Ned Smith, Tom Smith, Helena Solo-Gabriele, Gregory Starr, Serge Thomas, Joel Trexler, Tiffany Troxler, Robert Twilley, Evan Variano, Kevin Whelan, Joseph Zieman

Post-docs:
Tom Frankovich, Robinson Fulweiler, Amartya Saha, Jessica Schedlbauer, Jeremy Stalker, Tiffany Troxler, Anna Wachnicka, Jeff Wozniak, Youhei Yamashita

Graduate students:
Jose Bazante, Robin Bennett, Ross Boucek, Edward Castaneda, Meilian Chen, Yan Ding, Kendra Dowell, Katherine Dunlop, Brett Gallagher, Rebecca Garvoille, Patrick Gibson, Daniel Gomez, Elizabeth Harrison, Kelly Henry, Kristine Jimenez, Michael Kline, Greg Koch, Josette La Hee, David Lagomasino, Sylvia Lee, Kung-Jen Liu, Vivian Maccachero, Philip Matich, Lauren McCarthy, Jay Munyon, Emily Nodine, Adam Obaza, Danielle Ogurcak, Oliva Pisani, Carrie Rebenack, Adam Rosenblatt, Clifton Ruehl, Michelle Sanchez, Katherine Segarra, Christina Stringer, Suresh Subedi, Pamela Sullivan, Travis Thyberg, Xavier Zapata

Research Experience for Undergraduates:
Katya Cabeza, Jose Javier, Daniel Sarmiento

Undergraduate students:
Allison Cornell, Yilmael Diaz, Roger Lopez, Greg Losada, Tatiana Marquez, Rachel Tennant, Mary White, James Wilson

Pre-college teachers:
Nick Oehm, Teresa Casal, Carlos Escobar, Catherine Laroche

High school students:
Brian Aguilar, Heidy Abreu, Fey Akinnifeisi, Sommer Carabuccia, Giselle Castellanos, Vanessa Castellanos, George Delafe, Naureen Fasihi, Erikamarie Gil, Ben Giraldo, Geovanna Kamel, Christopher Sanchez

Technicians, programmers:
Robin Bennett, Daniel Bond, Alex Croft, Kevin Cunniff, Jeana Drake, Brett Gallagher, Chuck Goss, Rafael Guevara, Imrul Hack, Steve Kelly, Mark Kershaw, Greg Losada, Amanda McDonald, Jennifer Mellein, Alaina Owens, Christina Pisani, Linda Powell, Damon Rondeau, Mike Rugge, Pablo Ruiz, Timothy Russell, Olga Sanchez, Brooke Shamblin, Adele Tallman, Franco Tobias, Rafael Travieso, Josh Walters

B. Partner Organizations

- College of William & Mary: Collaborative Research; Personnel Exchanges
- Ecology and Environment, Inc.: Collaborative Research; Personnel Exchanges
- Everglades National Park: Collaborative Research; Personnel Exchanges
- Florida Gulf Coast University: Collaborative Research; Personnel Exchanges
- Harbor Branch Oceanographic Institute: Collaborative Research
- Indiana University: Collaborative Research
- Louisiana State University: Collaborative Research; Personnel Exchanges
- Miami-Dade County Public Schools: Collaborative Research; Personnel Exchanges
  Two of our Education and Outreach coordinators (Susan Dailey and Nick Oehm) have taught and given FCE LTER presentations at Miami-Dade County Public Schools. Our Research Experience for Teachers (RET) and Research Experience for Secondary Students (RESSt) programs have included teachers and students from Miami-Dade County Public schools.
- Michigan State University: Collaborative Research; Personnel Exchanges
- National Aeronautics and Space Administration: Collaborative Research; Personnel Exchanges
- National Audubon Society: Collaborative Research; Personnel Exchanges
- Nova Southeastern University Oceanographic Center: Collaborative Research; Personnel Exchanges
- The Pennsylvania State University: Collaborative Research; Personnel Exchanges
- South Florida Water Management District: Financial Support; In-kind Support; Collaborative Research
- Sam Houston State University: Collaborative Research
- Texas A&M University Main Campus: Collaborative Research; Personnel Exchanges
  Collaborations with Stephen Davis.
- Texas A&M University at Galveston: Collaborative Research; Personnel Exchanges
- U.S. Department of the Interior: In-kind Support; Facilities; Collaborative Research
- Department of Interior U.S. Geological Survey: In-kind Support; Collaborative Research

- University of Alabama: Collaborative Research; Personnel Exchanges
- University of Colorado: Collaborative Research; Personnel Exchanges
- University of Florida: Collaborative Research; Personnel Exchanges
- University of Miami: Collaborative Research; Personnel Exchanges
- University of Miami Rosenstiel School of Marine & Atmospheric Science: Collaborative Research; Personnel Exchanges
  Jack Fell through a separately funded NSF grant.
- University of North Carolina at Chapel Hill: Collaborative Research; Personnel Exchanges
- University of North Carolina at Wilmington: Collaborative Research; Personnel Exchanges
- University of South Florida: Collaborative Research; Personnel Exchanges
- University of Virginia: Collaborative Research; Personnel Exchanges
- Miami-Dade County, Department of Planning and Zoning: Collaborative Research

C. Other collaborators

We have maintained important collaborative partnerships with 5 federal agencies (Everglades National Park, USGS, NOAA, EPA, and NASA-JPL) during the third year of the FCE II LTER Program. We also partner with 1 state agency (South Florida Water Management District), 1 NGO (National Audubon Society), and 18 other universities (Louisiana State University, College of William & Mary, Texas A&M University, and University of South Florida through subcontracts).

Some examples of specific collaborations include:

- The FCE Human Dimensions group is collaborating with Miami-Dade County's Department of Planning and Zoning to develop a methodology to incorporate historic zoning data into a GIS platform.
- The FCE Human Dimensions group co-organized (along with CAP, PIE and BES LTERs) and participated in the cross-LTER site meeting "Socio-ecological dynamics of residential landscape: a multi-site workshop," held during Feb 18-19, 2009 at Arizona State University in Tempe, AZ.
- Dr. Mark Rains of USF used a Supplemental Grant for International Collaboration to support cross-site collaboration between the FCE-LTER and the Ecosistemas Arrecifales del Pacifico program of the Mexican ILTER.
- FCE researchers Dr. René M. Price (FCE LTER II-PI) and her graduate student (Jeremy Stalker) along with FCE LTER collaborator Victor Rivera-Monroy of LSU, joined Dr. Jorge Herrera-Silveira of CINVESTAV in Merida Mexico, and his graduate student Sara Morrales for a sampling trip in Celestún Estuary, Yucatan, Mexico in the summer of 2009. This was the second sampling trip to the Celestún Estuary, and was funded through a supplemental grant for International Collaboration to support cross-site collaborations between FCE LTER and Coastal Ecosystems in the Yucatan Peninsula program (ECOPEY) of the Mexican LTER.

- Through our Education and Outreach program, we have developed strong working relationships with: Felix Varela Senior High School; Miami Dade County Public Schools; Miami Dade College Department of Biology, Health, and Wellness; Miami Dade College School of Education; Science Approach, LLC; and the Everglades Digital Library. We also work closely with CEMEX USA aggregate mining corporation and the Ft. Lauderdale Museum of Discovery and Science as our primary community partners.
- Joe Boyer collaborated with Linda Amaral-Zettler at International Census of Marine Microbiology, (ICoMM) (icomm.mbl.edu), Marine Biological Laboratory. He received NSF funding to support massively-parallel, 454-based tag sequencing strategy that allows extensive sampling of marine microbial populations (PNAS 103: 32 p. 12115-12120). Sequencing of hypervariable regions of the SSU rRNA gene allows measurement of both relative abundance and diversity of dominant and rare members of the microbial community thereby allowing efficient comparison of the structure of microbial populations in marine systems. The aquatic component of this project began last fall at 4 sites in FCE during wet and dry season.
- Joe Boyer collaborated with Ryan Penton at Michigan State University to sample marine sediments in Florida Bay for metagenomic profile using massively-parallel, 454-based tag sequencing strategy. Preliminary analysis suggests that FL10 is drastically different from 9 and 11. Looking at the database, it seems like FL10 has much lower DOC and is a more refractory site. The proportion of observed OTUs and Chao1 ratios indicate that FL9,10, and 11 are all relatively phylum poor in contrast with the richest communities observed at barrow canyon (Alaskan maritime), Juan de Fuca (Pacific) and Cascadia basin (Pacific).

II. ACTIVITIES AND FINDINGS

A. Research and Education Activities

The second phase of Florida Coastal Everglades (FCE) research (FCE II) focuses on understanding how dissolved organic matter (DOM) from upstream oligotrophic marshes interacts with a marine source of phosphorus, the limiting nutrient, to control estuarine productivity in the estuarine ecotone. We also now incorporate a socio-ecological theme t our work, aimed at understanding how land use changes affect local ecological dynamics in south Florida. Our 15 ecological research sites are located along freshwater to marine transects in the Shark River Slough (SRS), and the Taylor Slough/Panhandle (TS/Ph) regions of Everglades National Park, in addition to a land use transect that cuts across southern suburban Miami-Dade County. FCE II research is organized into 4 working groups (Primary Production, Organic Matter Dynamics, Biogeochemical Cycling, Trophic Dynamics and Community Structure) and 4 cross-cutting themes (Hydrology, Human Dimensions, Climate and Disturbance, Modeling and Synthesis). We include summaries of the third year of research by FCE II working groups, cross-cutting theme groups, education, and information management activities below.

1. Primary Production

Phytoplankton

Phytoplankton biomass (as chlorophyll a) and primary productivity (as quantum yield) were quantified monthly at all LTER sites using pulse amplitude modulated (PAM) fluorometry. PAM fluorometry allows us to discriminate biomass and activity of the major functional guilds: cyanobacteria, green algae, and brown algae. These data are coupled with measurements of nutrient availability, DOM, and other biotic and abiotic parameters to determine hydrologically-driven trends in limiting resources across the land-ocean margin ecosystem.

Periphyton - Controls on periphyton productivity

We continue to measure periphyton biomass, productivity composition at FCE LTER sites. We are interpreting long-term trends in relation to those gathered from joint large-scale landscape surveys in the Everglades and Florida Bay and field and laboratory experiments. These data are being combined into models that predict changes in periphyton biomass, composition and nutrient content from hydrologic, water chemistry and other abiotic and biotic variables. Effects of variability in periphyton abundance, composition and quality on consumer standing stocks and composition continue to be examined using these surveys and linked experimental work in collaboration with Joel Trexler and the Trophic Dynamics group. We are also pursuing an understanding of mechanistic linkages between periphyton attributes to variability in hydrology, light, nutrients and vegetation through field and lab experiments, conducted mainly by FCE graduate students. In particular, manipulations of periphyton in laboratory chemostats have been revealing triggers for the pervasive inverse relationships of periphyton production to nutrient availability. Species-based models that predict salinity, nutrient availability and habitat structure are being used to environmentally calibrate sediment cores from the ecotone and Florida Bay so that modern fluctuations apparent in FCE data can be placed in a long-term context. Through a joint DOE-NCCR project, we have been manipulating periphyton and plant production to determine controls on CO_2 sequestration or evasion in peat and marl-forming environments, and these findings will be interpreted with respect to atmospheric eddy covariance data obtained from our two marsh flux towers. Our 2006 ILTER supplement supported comparisons of periphyton and consumer standing stocks and composition between FCE and karstic wetlands of the Yucatan peninsula and Belize. Visits supported by NSF in 2006-07 were supplemented by FIU-SERC foundation support in 2007-08, so we now have two years of wet and dry season data from these sites.

Periphyton - Primary production of periphyton-dominated ecosystems

Because accurate productivity estimates are key to understanding ecosystem response to changes in climate and water management in the Everglades, we are conducting a whole ecosystem chamber-based study of ecosystem productivity in conjunction with eddy covariance estimates of carbon flux at two sites of contrasting hydroperiod in Everglades National Park. Site TS/Ph1b is an infrequently flooded wet prairie site while Site Shark River Slough 2 is a permanently flooded marsh; both are part of the Florida Coastal Everglades Long Term Ecological Research program that supplies ancillary data about the sites. We performed monthly measurements of CO2 flux in 5 replicate plots using an LI-840 infared gas analyzer connected to a clear, polycarbonate chamber. Measurements were taken every second for one minute in light and dark.

Sawgrass
We continue to measure *Cladium* biomass on a bimonthly basis and calculate annual net aboveground productivity at freshwater slough sites TS/Ph1b, 2, 3 and 6 and SRS1-3. We have been exploring relationship of *Cladium* productivity to hydrologic and nutrient drivers.

Seagrass ecosystems
We continue to assess primary production of the seagrass ecosystems in the FCE-LTER domain every 2 months. On these trips, we have been measuring seagrass leaf productivity using standard hole punch methods and periphyton productivity as described above since 2000. We are continuing long-term fertilization experiments, documenting the changes that occur in seagrass ecosystems as phosphorus, the limiting nutrient, is added to the ecosystem. This year we initiated a modeling project that uses statistical relationships between benthic community structure and water quality to forecast potential changes in the plant communities of Florida Bay in response to changes in freshwater flow.

Mangrove Ecosystems - The effects of hurricane-deposited sedimentary phosphorus on mangrove growth
In Year 1 of FCE II (October 2006), we initiated a small-scale fertilization experiment with collaborators from LSU and FIU to better understand how carbonate sediment from derived from Florida Bay (a potential source of inorganic P) controls dwarf *R. mangle* productivity and biomass allocation. This was done to simulate the effects of hurricane-induced sediment deposition—something we observed with Hurricanes Wilma (2005) and Irene (1999). Work by others has shown dramatic effects of nutrient addition (typically P) on dwarf *R. mangle* growth, insect herbivory, mangrove physiology, and nutrient-use efficiency. So, we hypothesized that this sediment-associated source of P would represent a long-term, available supply of P to the presumed P-limited mangroves growing in this region.

Mangrove Ecosystems - Mangrove root zone research
In this study we investigate the spatial and temporal patterns of belowground biomass and productivity of two Florida Coastal Everglades (FCE) mangrove systems – Shark River estuary and Taylor River Slough. We estimated standing stock root biomass and productivity and root distribution with depth (top: 0-45 cm, bottom: 45-90 cm) in all FCE mangrove sites using the sequential coring and the ingrowth core techniques. Root cores were randomly collected in each of the sites using a PVC coring device (10.2 cm diameter x 45 cm length). All root cores were stored in Ziploc bags at 4ºC and brought to the laboratory for further analyses. All samples were processed separately and initially rinsed with water through 1-mm synthetic mesh screen to remove soil particles. Samples were then transferred to plastic containers with water and live roots were separated by hand picking and flotation. Live roots were sorted into diameter size classes of <2 mm, 2-5 mm, and >5 mm (fine, medium, and coarse roots, respectively), oven-dried at 60 ºC to a constant weight, and weighed.

Ingrowth cores (10.2 cm diameter x 45 cm length) made of flexible synthetic mesh material and filled with pre-sieved Sphagnum peat moss were installed in each of the cored holes for standing root biomass. Ingrowth cores were retrieved at different intervals and the subsequent root growth within the ingrowth core was used to estimate annual root production. After each harvest, ingrowth cores were processed separately following the same protocol as in the standing root biomass section. Root turnover rate was calculated as annual root productivity divided by standing stock biomass. We hypothesized that patterns of belowground root allocation are regulated by nutrient limitation (P) and longer hydroperiods at the Taylor River sites compared to Shark River sites. We expected that mangrove forests along Taylor would have the greatest root biomass allocation and the lowest root production due to increased root longevity resulting in lower turnover rates.

Mangrove Ecosystems - CO_2 Fluxes and Energy Balance (V. Engel, J. Barr, J. Fuentes)
Tower-based eddy-covariance (EC) measurements of CO2 and H2Ov fluxes and energy balance have been made above the mangrove forest at SRS 6 since 2004. The objective is to relate ecosystem function to climatic and environmental drivers. In 2009, this work received funding from the National Institute of Climate Change Research (NICCR). In addition to the EC measurements, soil respiration rates are currently being measured quarterly, and a CO2 vertical profiling system is being tested for installation. Prop root and stem respiration rates will also be measured. Data on CO2 fluxes collected prior to hurricane Wilma in 2005 have recently been summarized in two publications (Barr et al. 2009 JGR- Biogeosciences; Barr et al. 2009 submitted Global Change Biology). Upcoming work will focus on coupling the measurements of CO2 sequestration with biometric data on above- and belowground productivity, and on examining the response of the system to tropical hurricane disturbance. A large source of uncertainty in the mangrove forest carbon budget relates to the amount of dissolved and particulate carbon removed from the system thru tidal activity. A tracer-based Lagragian study of carbon transport and in-situ transformation in the estuary surrounding the site is being planned to address this uncertainty.

2. Organic Matter Dynamics

For FCE-LTER 2, one of the central research questions for the organic matter working group is: *How are organic matter dynamics (DOM, "floc" and soils) in the oligohaline ecotone controlled by local processes versus allochthonous freshwater, marine and groundwater sources?*

Mangrove Group (R. Twilley et al).
Isotope signatures of mangrove leaves can vary depending on discrimination associated with plant response to environmental stressors defined by gradients of resources (such as water and nutrients limitation) and regulators (such as salinity and sulphide toxicity). We tested the variability of mangrove isotopic signatures ($\delta^{13}C$ and $\delta^{15}N$) across a stress gradient in south Florida, using green leaves from four mangrove species collected at six sites. Mangroves across the landscape studied are stressed by resource and regulator gradients represented by limited phosphorus concentrations combined with high sulfide concentrations, respectively. Sampling was carried out in FCE-LTER sites in May and October 2001; and January, May and October 2002. Mature, fully developed green leaves were removed manually from the canopy of the trees (1.5 to 2 m heights) at each site. Senescent leaves (yellow leaves free of structural damage) were collected from branches and from the forest floor. Fresh litter samples (brown leaves) and decayed litter (black leaves with loss of structural integrity) were collected from the soil surface. For each mangrove species, we collected at least 10 leaves of each stage (green, senescent, litter, decayed) and then obtained a mixed sample by species and decomposition stage.

Soil Biogeochemistry Group (R. Chambers et al.)
For FCE-LTER 2, one of the central research questions for the organic matter working group is: *How are soil dynamics (nutrient and organic matter content, peat accumulation, sedimentation) in the oligohaline ecotone controlled by water source and hydrologic residence time?* Our synoptic-scale sampling and characterization of surface soils has provided a description of the existing range in nutrients and organic matter content both at the oligohaline ecotone and from transect locations upstream and downstream of the ecotone. Although the ecotones of both Shark River Slough (SRS) and Taylor Slough (TS) transects exhibit similar peaks in aquatic productivity, the soils are in fact quite different. Beyond characterization will be the long-term changes in soil nutrient and organic matter content associated with natural and human-derived modifications to ecosystem hydrology.

Paleoecological and soil accretion studies (C. Saunders et al.)
Several ongoing paleoecological investigations by FCE researchers are being used to reconstruct past changes in vegetation, hydrology, salinity, water quality, soil accretion and soil nutrient accumulation in freshwater, mangrove, and estuarine environments of the southern Everglades. Paleoecological investigations include an analysis of fossil diatom records to reconstruct past salinity and water quality in Florida Bay and Biscayne Bay (Anna Wachnicka, FIU); vegetation and vegetation-inferred hydrologic changes in the freshwater portions of Shark Slough using a macrofossils, biomarkers, phytoliths, and macrofossil stable isotopes (Evelyn Gaiser, William Anderson, Colin Saunders, Chris Sanchez, Sebastian Diaz, and Nia Brisbane); a physiological and paleoecological study of vegetation and soil accretion changes along the Taylor Slough coastal ecotone; and a literature review of all radiometric-based (210Pb, 137Cs, 14C) estimates of soil accretion over the greater Everglades and including FCE sites (Colin Saunders, Carlos Coronado, Dave Rudnick, Fred Sklar, Debra Willard, and Charles Holmes). These studies provide important long-term (decadal to millennial) time series data on vegetation and soil dynamics, and are important components of the calibration/validation datasets used for several FCE models: ELM, SCAT, NUMAN, and SEACOM.

Organic Geochemistry Group (Jaffé et al.)
Our group has focused on the determination of the dynamics of 'floc'. Specifically, we have worked on (1) characterizing the OM sources of floc using the analyses of biomarkers (lipids) and chemotaxonomy (pigment based) to assess specific microbial sources of OM in floc and attempted to correlate the later with similar measurements in life periphyton. This has been done at both freshwater marsh and fringe mangrove sites. (2) We have attempted to determine both the bio- and photo-reactivity of floc from both freshwater marsh and mangrove sites. The former resulted in clear spatial differences, but the methodology used was not adequate due to high S/N values. We are now reassessing this experiment using a different methodology. With regards to photo-reactivity we have used floc suspensions in waters collected from the sampling sites and exposed them to simulated solar irradiance, observing significant photo-dissolution for both freshwater and mangrove floc.

With regards to dissolved organic matter (DOM) it is clear that floc photo-dissolution may be an important source. However, we have continued to investigate other traditional sources, on both spatial and temporal scales. As Such we have now completed 4 years of monthly determinations of DOM fluorescence characteristics for the FCE-LTER. In particular, the application of 3D fluorescence, or excitation emission matrix (EEM) fluorescence in combination with parallel factor analysis (PARAFAC) has been found to be particularly useful in assessing both source and diagenetically-induced changes in this detrital OM component. In this respect, we have also investigated the potential exchange of DOM between surface waters and ground waters both in the freshwater marshes of Taylor Slough and Florida Bay.

3. Biogeochemical Cycling

Baseline Water Quality
For both SRS and TS, collections of samples for water quality, primary productivity, soil nutrients/physical characteristics, and physical data (rainfall/water level) are used to help answer key FCE-LTER questions. Dissolved and total nutrient analyses were carried out at all LTER sites in conjunction with SERC Water Quality Monitoring Network.

Microbial Dynamics
Three procedures were performed each month for all FCE II sites: bacterial production, bacterial enumeration, and the measurement of pigment, quantum yield, and excitation characteristics of phytoplankton using Phyto-PAM. Heterotrophic bacterial production is determined using tritiated thymidine uptake within 24 hours of collection. Bacterial enumeration was determined through epifluorescence microscopy using DAPI. Algal dynamics were determined through PAM (pulse-amplitude modulation) fluorescence within 24 hours of collection. Algal energetics samples were analyzed using PAM fluormetry for chl a content and productivity irradiance curves.

Microbial Metagenomics of Floc
Floc samples have been collected for DNA analysis at 6 LTER sites: SRS 1, 2, and 6, and TS 1, 2, and 6. Thus far, samples have been collected in May and September 2007. DNA is extracted from the samples using a FastDNA SPIN kit (for soil) and the extracted DNA is then amplified through PCR T-RFLP analysis.

Biogeochemical Cycling
Upstream/downstream sampling of mangrove ecotone - As part of a project funded by NOAA, collaborators from TAMU, LSU, and FIU have been looking at the influence of salinity and season on nutrient dynamics along the stretch of Taylor River, between TS-Ph6 and 7. Thus far, we've conducted sampling trips in January 2007 and 2008 (early dry season), May 2007 and 2008 (late dry season), and August 2006 and 2007 (wet season) to quantify the downstream flux and benthic exchange of N, P, and OC in this system. During each 1-week sampling, water temperature, salinity, pH, and dissolved oxygen are measured at each sampling station hourly with a calibrated sonde. We also sample surface water at each site every six hours and analyze for nitrogen (total and inorganic) and the phosphorus (total and inorganic) content.

Sediment core flux studies - Beginning in January 2007, we initiated a set of experiments to quantify the vertical exchanges of nutrients (N and P) and DOC between the benthos and water column at various sites along Taylor River. During this first set of pilot incubations, we collected sediment/soil cores from two inland (TS/Ph 7 and Pond 1) and two bay sites (Little Madeira Bay east and west of Taylor River mouth). The surrounding of TS/Ph 7 is vegetated with dwarf mangrove. Both Little Madeira Bay sites were covered with seagrass (*Thalassia testudinum*). These samplings have been repeated through the May 2008 sampling. Beginning in May 2007, we also began amending the water column (in a separate set of incubations) with 1 µM P (> 10X ambient concentrations) in order to understand the effects of limiting nutrient additions on benthic exchanges. Intact sediment cores were contained in the lower part of core tubes with overlying site water. Ten replicate cores from same study site were carefully placed in water bath tank to control water temperature. 20 L site water was pre-filtered with 0.2 mm pore size filter prior to incubation. Sediment cores were incubated in the water bath and overlying site water was replaced with filtered site water. Magnetic stirrers maintained the overlying filtered water in a homogeneous state without disturbing the sediment. Prior to the initiation of each incubation, we measured initial dissolved oxygen (DO) and took water samples for analysis of nutrients and DOC. At the conclusion of each incubation (approximately 4 hours), we measured final DO and took samples for analysis of nutrients and DOC. DO was recorded with a YSI Oxygen Sensor through the sampling port of each core. NO3+NO2, NH4, SRP, and DOC samples were analyzed according to the methods described above.

4. Trophic Dynamics and Community Structure

Spatiotemporal dynamics in the fish and macroinvertebrate community in the Shark River (SRS)

We sampled fish and macroinvertebrates to assess their spatiotemporal dynamics in relation to hydrological conditions. This research aims to understand the mechanistic links among functional diversity, predator-prey interactions and ecosystem function. We are particularly interested in how hydrological variation (both anthropogenic and natural) creates context-dependency in functional diversity and species interactions. Sampling was conducted at 10 locations in the upper estuary (SRS3 and 4) in the wet, early dry, and late dry seasons using electrofishing and minnow trapping. We also sampled the entire estuarine portion of the SRS transect (SRS 3 to 6) to examine how palaemonid shrimp segregate along the estuary seasonally in relation to freshwater inflow and salinity regimes. We installed and sampled drop traps at two sites in the upper estuary (Fig. 4.1), which will allow us to obtain measures of prey density in the upper estuary that will be directly comparable to other parts of the ecosystem (Fig. 4.2). This will allow us to better estimate

Fig. 4.1. Aerial image of three newly-installed 3 x 3 m drop traps used to sample small-bodied fishes (<5cm standard length) in the vicinity of SRS3 at the marsh mangrove ecotone (Photo courtesy of L. Oberhofer).

Fig. 4.2. Example of freshwater small fish taxa (< 5 cm standard length) collected in traps during the dry season at the SRS ecotonal sites.

secondary production and its seasonal variation.

Factors influencing movements and trophic interactions of large predators in the Shark River Slough
We continued telemetry studies of four species in the Shark River Slough. We have maintained and downloaded our array of 43 VR2 monitoring systems in the Shark River quarterly. To date, we have deployed acoustic transmitters on 35 American alligators, 49 bull sharks, 16 snook and 18 Florida gar. We have collected tissue samples from all of these individuals, and any others captured but not tagged with acoustic transmitters, for stable isotopic analyses. Quantitative fishing to investigate factors influencing the distribution of bull sharks has continued to be able to investigate the influence of marsh dry-down and enhanced upstream prey availability on shark abundance and habitat use. In addition, we have begun sampling the distribution of juvenile bull shark predators (larger sharks) with drumlines and will soon initiate prey sampling with crab and fish traps, and DIDSON sonar. Finally, we have stomach contents sampling of bull sharks and alligators to complement our isotopic studies aimed at understanding the degree of individual specialization in the populations.

Fish and invertebrate communities of upstream marshes.
We continued gathering fish and macroinvertebrate density estimates at SRS 2 and 3 and TS 2 and 3 to contribute to the growing FCE-LTER database on consumer density. Samples were collected in February, April, July, October, and December, similar to all past years of the project. We put special emphasis on data QA/QC this year and are submitting updated versions of all of our data with some minor errors corrected.

Community dynamics of Florida Bay.
Complex links between the top-down and bottom-up forces that structure communities can be disrupted by anthropogenic alterations of natural habitats. We used relative abundance and stable isotopes to examine changes in epifaunal food webs in seagrass (Thalassia testudinum) beds following six months of experimental nutrient addition at two sites in Florida Bay (USA) with different ambient fertility.

5. Hydrology

We initiated a new geochemical and geophysical project in cooperation with the Drs. Chris Smith and Peter Swarnzenski of the U.S. Geological Survey. The objective of the project was to determine the location and amount of groundwater discharge in both Shark and Taylor Sloughs during the dry season of 2009. The Shark Slough survey was conducted between May 29, 2009 and April 5, 2009 while the Taylor Slough survey was conducted in April 28-May 1, 2009. In this project, radioisotopes of radon and radium were measured in the surface water of the sloughs and compared with surface water values of salinity and pH. Time series measurements of ^{222}Rn were made at three sites in Shark and two sites in Taylor and compared with tidal fluctuations in water levels. Groundwater samples were also collected in both regions for nutrients, major cations and anions, trace metals, as well as for ^{222}Rn and radium isotopes. Finally, continuous resistivity surveys were conducted in both sloughs to identify the depth of the seawater mixing zone as well as karst features within the Biscayne Aquifer. Plans were made to conduct this sampling again during the wet season of 2009 in conjunction with other tracer experiments using temperature with collaborator Mark Rains of USF, and SF_6 with Dr. David Ho from the Univ. Hawaii, and Vic Engel of ENP.

The project initiated last year aimed at estimating the major water budget parameters in Taylor River continued throughout this year by M.S. student Xavier Zapata. Groundwater and surface water samples were collected at the FCE sites TS/Ph-7b, TS/Ph-6b, TS/Ph-3 as well as surface water from the mouth of Taylor River on a monthly basis. Salinity, temperature, DO, and pH were determined in the field. Water samples were analyzed at FIU for stable isotopes of oxygen and hydrogen, anions, cations, and total and dissolved nutrient concentrations. In addition, pressure transducers were installed in the surface water at TS/Ph-7b and TS/Ph-6b as well as in some of the groundwater wells at both of those sites. Four In-Situ Inc. The Aqua Troll 200 pressure transducers (5psi) were vented to the atmosphere and record water level, temperature, and conductivity/salinity every 30 min.

Our collaborators at Louisiana State University, Victor Rivera-Monroy, B. Michot, Robert Twilley, and E. Meselhe developed a hydrodynamic model for the Taylor River region including the FCE-LTER sites TSPh-6 and TSPh-7. The model domain was based on bathymetry, canal cross sections, elevations and vegetation differences across Taylor River. Boundary conditions were tentatively established based on freshwater inflow and open water characteristics (i.e. water stage, salinity). Elevation data and main channel cross sections were acquired inside the region using Real-Time Kinematic (RTK) GPS. Hydrologic data including water levels, discharge, flow rates, and salinity were gathered from the USGS, ENP, the FCE_LTER and other sources. The data sets were used to establish boundary conditions for model calibration.

The Hydrology Working Group in conjunction with the Modeling and Synthesis Group hired a postdoctoral researcher, Dr. Amarty Saha, to assist in ecohydrological modeling for the FCE LTER. Dr. Saha has developed a monthly and annual water budget for all of Shark Slough 2002-2008. Inputs considered were surface water inflows (S12s and S333) and rainfall, while outputs consisted of discharge to the Gulf of Mexico (Lostman, Shark, Broad, Harney and North rivers) and evapotranspiration. Data for inflows, rainfall and discharges were obtained from the FCE-LTER database as well as data from our collaborators at the USGS, ENP and SFWMD. Using a mass balance approach, monthly change in volume of surface water in Shark Slough was determined from water level changes, and was equated to the sum of the inputs, outputs and a residual term.

Surface water flow rates and levels that were monitored in northeast Shark Slough resulted in a publication submitted to the journal Wetlands: He G, Engel VC, Leonard L, Croft A, Childers D, Laas M, Deng Y, and Solo-Gabriele H. *Factors controlling surface water flow in a low gradient subtropical wetland*. Upon conclusion of that project, the surface water station that was originally located at Frog City was moved to SRS-2 in June 2009. Surface water flow rates and levels are now monitored along the SRS transect at SRS-1d, Gumbo Limbo tree island and SRS-2.

Seawater intrusion along the coastline of south Florida continued to be monitored. Our collaborators at the USGS, Dr. Thomas Smith III and Gordon Anderson, monitored seawater intrusion along the Shark, Harney and Lostman's Rivers. We continued to monitor seawater intrusion in the Taylor River at sites TS/Ph-3, TS/Ph-6 and TS/Ph-7. Furthermore, seawater intrusion and groundwater discharge along the Atlantic coastline was monitored by FIU Ph.D. graduate student, Jeremy Stalker. The results of his research was recently published as Stalker, J C, R. M. Price, P.K. Swart, *Determining Spatial and Temporal Inputs of Freshwater, Including Groundwater Discharge, to a Subtropical Estuary Using Geochemical Tracers, Biscayne Bay, South Florida,* Estuaries and Coasts, 32(4), 694-708, 2009.

Vic Engel of ENP, and Dr. Marc Stieglitz of Georgia Tech University are experimenting with applying a spatially-explicit hydrologic, nutrient and dynamic vegetation model, originally developed for analyzing pattern formation in arctic systems, to the ridge and slough topography of ENP. For this project, the model would be parameterized using LTER field data on sawgrass productivity, surface water flow velocity, water quality and soil biogeochemistry. Simulations would focus on the effects of water management, climate variability, and salt water intrusion on the development and maintenance of the ridge and slough habitat.

Our collaborators at ENP produced hydrologic data and water level maps for the FCE-LTER. Hydrologic data such as water levels, rainfall amounts, and surface water discharge is collected by ENP and has been provided to us for use in many of the hydrology working group projects. Most recently, ENP personnel have produced water level contour maps from the USGS Eden database. These maps were constructed for the wet and dry seasons from 2000 through March of 2009.

Hydrology Working Group International Collaborations

The hydrology working group was very active this past year in cross-site collaborative research with the Mexican LTER. Science objectives for this research involved water budgets as they related to salinity and the transport of nutrients to coastal mangroves and estuaries. Three regions of Mexico visited this past year include: 1) Pacific Coastline; 2) Celestún Estuary of the Yucatan, and 3) Sian Ka'an Biosphere Reserve of the Yucatan.

Dr. Mark Rains of USF used a Supplemental Grant for International Collaboration to support cross-site collaboration between the FCE-LTER and the Ecosistemas Arrecifales del Pacifico program of the Mexican ILTER. In the summer of 2008, Dr. Rains and undergraduate and graduate students from USF joined Francisco de Asís Silva Bátiz and Enrique Godínez Domínguez of the Universidad de Guadalajara to collect surface-water and ground-water samples from three lagoons and their associated mangroves. Lagoons located at La Manzanilla, Barra de Navidad and La Veina were sampled. Samples were analyzed for dissolved constituents and stable isotopes. These data were combined with previously-collected data and used to better constrain mass-balance mixing models that quantify the proportional contributions of ocean water and fresh water to the mangroves and lagoons. A broader impact of this collaborative effort was to strengthened the relationship between Rains of USF and de Asís Silva Bátiz and Godínez Domínguez of the Universidad de Guadalajara. This strengthened relationship has led to an NSF Integrative Graduate Education and Research Traineeship (IGERT) pre-proposal now under development, the focus of which is the development of strategies for balancing limited water resources in coupled human-natural systems in the US, Latin America, and the Caribbean Basin.

FCE researchers Dr. René M. Price (FCE LTER II-PI) and her graduate student (Jeremy Stalker) along with FCE LTER collaborator Victor Rivera-Monroy of LSU, joined Dr. Jorge Herrera-Silveira of CINVESTAV in Merida Mexico, and his graduate student Sara Morrales for a sampling trip in Celestún Estuary, Yucatan, Mexico in the summer of 2009. This was the second sampling trip to the Celestún Estuary, and was funded through a supplemental grant for International Collaboration to support cross-site collaborations between FCE LTER and Coastal Ecosystems in the Yucatan Peninsula program (ECOPEY) of the Mexican LTER. The first trip occurred in the spring of 2008 during the dry season in the Yucatan. This second sampling occurred during the wet season in the Yucatan. Water samples were collected and analyzed for the stable isotopes of hydrogen and oxygen, major cations, and anions at FIU, and for total and dissolved concentrations of nitrogen, phosphorus, carbon and silica at CINVESTAV. A mass balance mixing model was developed to determine the dominant sources of water (seawater, fresh groundwater, and brackish groundwater) to the estuary.

Dr. René Price (FCE-LTER II-PI), is a co-PI on a newly created NASA project: *WaterSCAPES: Science of Coupled Aquatic Processes in Ecosystems from Space.* This 5-year, $5M project established a University Research Center (URC) based at FIU to develop a quantitative understanding of how wetland ecosystems are changing over time and space. The objective of *WaterSCAPES* is to quantification the stocks and fluxes of water, nutrients and biomass as they couple and aggregate into the spatial and temporal organization and adaptation mechanisms of vegetation at the ecosystems level. The research and education activities in this URC are performed on two wetland ecosystems: the Everglades of South Florida and the Sian Ka'an Biosphere Reserve in the Yucatan peninsula of Mexico. Dr. René Price and other researchers from *WaterSCAPES* visited Sian Ka'an in the spring of 2009. During that meeting, *WaterSCAPES* researchers met with the director of Sian Ka'an as well as an associated NGO to discuss future research activities. Findings from this ancillary research project will be directly applicable to the main goals and hypotheses of the FCE LTER.

6. Human Dimensions

The FCE Human Dimensions (FCE HD) research centers on understanding the human dimensions of land use change as it affects local ecological dynamics in south Florida. This research aims to: (1) develop spatial models of land use decision-making, (2) connect FCE ecological research within Everglades National Park to regional land use/cover dynamics, and (3) adopt a methodology that facilitates cross-LTER site comparisons. Here we outline activities for two related FCE HD projects.

Our first in-depth analysis focuses on land use/cover change in southern Miami-Dade County, a critical buffer zone located between two national parks. For this work, we have been examining the processes of rapid suburbanization as agricultural lands transition to residential development. Associated with such transformations is the proliferation of the residential lawn, also under study in other LTER sites (PIE, CAP, and BES). Strategies to slow suburbanization at local and regional scales include growth management policies and zoning regulations. In particular, zoning ordinances serve as the primary method for lessening and prevent the conversion of agricultural and forested lands—though zoning has also been implicated in increased landscape fragmentation. To understand the role of zoning in shaping (or not) the conversion of agricultural lands into residential lands in southern Dade we have been engaged in the following activities:

1) Collaborating with Miami-Dade County's Department of Planning and Zoning to develop a methodology to incorporate historic zoning data into a GIS platform
2) Acquiring and cleaning up zoning data for southern Dade-County. The period we are analyzing is from 1992 through 2008. All zoning data is being geo-referenced to the parcel. This year, we edited the zoning files to reflect zoning requests.
3) Incorporating other data into our GIS parcel-level analyses. These include parcel boundaries (and changing boundaries), assessment and sale amounts over time, comprehensive plan classification, land use zoning, and census-derived socioeconomic data.
4) Acquiring high-resolution remotely-sensed GeoEye imagery to help us quantify green vegetation, classify prevailing land use/covers (including lawns) and derive indices of landscape structure for the study site. FCE HD members are working with other LTER sites to employ common approaches to analyze these data (e.g., using object-oriented classification approaches for high-resolution land cover characterization).
5) Held a planning meeting at Clark University in October 2008 to develop a cross-site approach to studying the social and ecological consequences of the conversion of rural lands to residential lawns.
6) Co-organized (along with CAP, PIE and BES LTERs) and participated in the cross-LTER site meeting "Socio-ecological dynamics of residential landscape: a multi-site workshop," held during Feb 18-19, 2009 at Arizona State University in Tempe, AZ. The primary objectives of the workshop were to (1) share and coordinate approaches to current research on social-ecological dynamics of residential landscapes across LTER sites, (2) identify opportunities and challenges associated with cross-site, long-term social-ecological research; and, (3) establish an information-sharing network and collaborations in comparative long-term social-ecological research. The workshop facilitated an assessment of core capacities-datasets, models, protocols and infrastructure to support cross-site networked research on human ecological system dynamics related to residential landscapes, focusing on existing capabilities and planned capacity building at the following LTER sites: CAP, BES, FCE, PIE, JRN, CWT, LUQ, CDR, KNZ, HBR.
7) Acquired and scanned historic US Works Projects Administration (WPA) land use surveys of Miami Dade County from the 1930s. The WPA was a federal program under the New Deal. This archive includes hand-written surveys for each property in Miami-Dade County and describes land use, property characteristics, soil information, and demographic information for home and landowners. We completed scanning this archive so that it can be geo-referenced into our GIS parcel layers. We anticipate this archive will provide a critical baseline for our understandings of land use change and an important contribution to our overall understandings of the region's history and growth.

Our second (and related) project examines the role of hurricanes in landuse/cover change in southern Miami-Dade County. For this project, we are examining how Hurricane Andrew, in

1992, acted as a “pulse” event that reconfigured the landscape in heterogeneous ways. This heterogeneity, we hypothesize, stems from ongoing press processes that produces uneven resilience to pulse events among different communities. For this project, we are building upon the conceptual model developed for the LTER Decadal Research Plan. Activities associated with this second project include:

1) Collaboration and writing with FCE ecological scientists to develop a theoretical framework that incorporates the regime change and resilience literature (from ecology) and the disaster, vulnerability, and environmental justice literatures (from the social sciences). We held a week-long workshop in March 2009 to analyze census data for this project
2) Analyzing the response differences within these communities to Hurricane Andrew. Variables we are analyzing include changes in demographics (ethnicity/race, income, home ownership variables), land use, and community character and quality of life issues.
3) Analyzing differences within these communities that contributed to their resilience (or lack of) to Hurricane Andrew. These variables include type and degree of homeowner insurance (strongly correlated to ethnicity), home ownership variables, income and community governance.

7. Climate and Disturbance

The Climate and Disturbance Working Group has just completed its 3rd year in the FCE organizational structure. At the 2009 ASM, we presented our immediate research goals for the next year and recent results. One of the main goals of the working group was to conduct a LIDAR survey of the study sites, and this was complete finally this summer and that data is being worked up by Dr. Zhang. Additionally, the group has hired a post-doc to help with out climate focus, and to work on time-series analysis of modern and paleo climate data bases and teleconnection indices affecting the greater Everglades system. Presented below are the main activities for the working group ranging from paleo studies to research within the modern FCE system:

Physiological and paleoecological study of plant communities, TS ecotone (Saunders)
FCE collaborators Sharon Ewe, Tiffany Troxler, and Colin Saunders have initiated a combined physiological and paleoecological study to examine past and current plant community and physiological changes along Taylor Slough coastal ecotone. Research activities in the past year have included collection of soil cores from five sites spanning TS/ph-3 (freshwater sawgrass marsh) to TS/Ph-7, three of which are co-located with TS/Ph-3, -6 and -7 and with existing sites where Sediment Elevation Tables (SETs) are being employed to quantify soil elevation changes. Cores are being radiometrically dated using 210Pb and 137Cs profiles and analysed for macrofossil profiles macrofossil isotopic composition (e.g., sawgrass seeds, sawgrass leaf and root fragments). Vegetation changes inferred from macrofossil profiles and species-specific isotopic varation (downcore) will provide a means to understand past physiological responses to past changes in hydrology and salinity encroachment. In addition to characterizing the pre-drainage system, these data will be important in calibrating the SCAT model, which will be used

to hindcast decadal to centennial marsh vegetation and soil accretion changes along the coastal ecotone.

REU - Using mineral-magnetism to gauge the intensity of past fires in the Everglades (Sah)
Jose Javier, an undergraduate student in the Department of Earth Sciences, carried out a study examining the effects of wildfires on the magnetic properties of soils in the Everglades. The project consisted of two parts. In the he first part Jose had analyzed thirty soil samples that had been collected at vegetation survey sites within the Cape Sable seaside sparrow (CSSS) habitat in southern Everglades by Jay Sah's group of South Florida Terrestrial Lab in Southeast Environmental Research Center. In the second part of the study, Jose analyzed the soil samples collected from CSSS vegetation survey sites after 2008 fires.

Impacts of pending changes in water management and long-term effects of sea-level rise (Davis)
The oligohaline zone of Taylor River is controlled to a great extent by seasonal patterns of freshwater flow, storm events, and frontal passages. In order to assess the impacts of pending changes in water management (i.e., restoration) and long-term effects of sea-level rise, we have continuously tracked variations in water quality at a number of locations along the mangrove ecotone. As part of this work, we've conducted intensive seasonal samplings of water quality at locations upstream and downstream the mangrove ecotone in Taylor River. Thus far, we have completed six samplings, one in August 2006, three in 2007 (January, May, and August) and two in 2008 (January and May). Each sampling was made over a one-week period of time and was intended to capture the short-term hydrological and biogeochemical variability associated with wind and tide forcing and precipitation-driven runoff during these periods. The August samplings were designed to capture early wet season conditions (low salinity, strong outflow from Everglades to Florida Bay) in the mangrove ecotone of Taylor River. The January samplings were planned to capture the transition period between the wet season and the dry season, and the May samplings were designed to capture conditions that typify the peak of the dry season, when salinity levels and water residence times are high.

Mangrove Zone Research (LSU group, Rivera-Monry et al.)
The distribution of mangrove biomass and forest structure along Shark River estuary in the Florida Coastal Everglades (FCE) has been correlated with elevated total phosphorus concentration in soils thought to be associated with storm events. The passage of Hurricane Wilma across Shark River estuary in 2005 provided an excellent opportunity to test this hypothesis and to assess the role of these pulsing events in regulating soil biogeochemistry and forest community structure and productivity in mangroves of south Florida. In this report we present a comprehensive analysis of the chemical properties and spatial patterns of hurricane sediment deposits in mangrove forests of FCE. We sampled from multiple points along transects at Broad Creek (December 2005), at SRS6 (December 2005), and across the Buttonwood Ridge near Taylor River (October 2006). We also sampled from fixed vegetation plots at SRS6 and TS/Ph8. All soil-sediment cores were collected with a piston corer (2.5 cm diameter x 15 cm length), sectioned into two layers, top (storm deposits; variable depth) and bottom (mangrove soils; surface10 cm) layers, and the depth of each layer registered. The storm layer was easily distinguished from the mangrove soil layer because of its gray color, fine sand texture, and organic-free deposits. Samples were stored in Ziploc bags at 4 ºC and brought to the laboratory for further analyses.

Paleolimnological/paleoecological study of Lake Annie (Gaiser)
We continue to study climate and disturbance patterns at 'reference' locations of low disturbance in our ecosystem, including Lake Annie, at the headwaters of the Everglades. Lake Annie exists on the undisturbed property of Archbold Biological Station, is considered one of the most pristine lakes in the state and has one of the longest continuous limnological records. Because it is in the same watershed, climatological signals reflected in long-term observational and paleolimnological records of Lake Annie can be used to inform similar records from more disturbed settings at FCE sites in the Everglades and Florida Bay. We are analyzing both observational (Gaiser et al., 2009 a, b) and paleolimnological records (Quillen, 2009) to extract climate signals and have contributed to a collaborative, pending DMUU proposal with University of Central Florida to determine if these signals are present in FCE records. In addition, high frequency aquatic sensors have been deployed contemporaneously in Lake Annie (Gaiser, unpubl.) and lakes of the southern Everglades (Koch, unpubl.) in order to detect system-scale influences of climatological variability in South Florida.

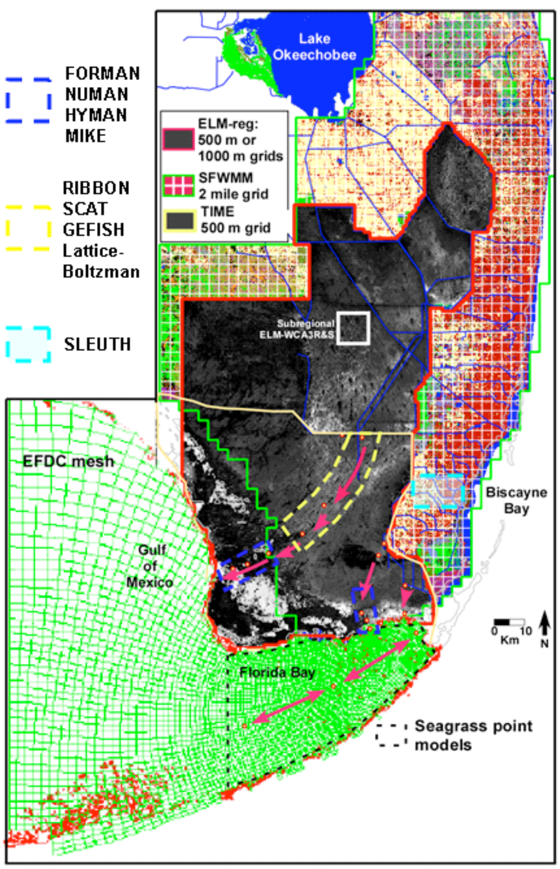
Isotope hydrology and precipitation (Price)
Rainfall continued to be collected from the roof of a building at FIU for stable isotopes of oxygen and hydrogen since October 2007. The rain is collected in a wet-dry collector manufactured by Aerochemetrics, Inc. Approximately once a week, the amount of rainfall in the wet collection bucket is recorded, and then a subsample of the rain water is collected and analyzed for the stable isotopes of oxygen and hydrogen on a Los Gatos Liquid Water Analyzer.

Multiscale Analysis and Probabilistic Projections of Sea Level Rise for the Everglades (Engel et al.).
This research project (*with* Dr. Upmanu Lall and Christina Karamperidou, Columbia University) will develop a systematic analysis of the historical data on regional sea level and winds and relate this to larger-scale climatic drivers. This is being approached in the context of a formal statistical model of sea level rise scenarios for S. Florida using all sources of available information, such as IPCC General Circulation Models (GCMs) of global ocean heat content, sea level pressure and wind fields, and historical data on local sea level, and regional pressure, temperature, and wind fields. The approach will address biases in GCM projections, as well as systematic and subjective uncertainties associated with the sea level projections at each of the time scales of interest to the LTER hypotheses, and to ENP restoration and management efforts. This project will look at each of the mechanisms associated with sea level fluctuations at a particular time scale of variation (daily, seasonal, inter-annual) and develop a conceptual model for those variations in terms of climatic parameters that can be established from the associated physics and historical and model-derived climate data fields. The biggest issue is of course the uncertainty associated with the global sea level projections related to thermal expansion of the oceans and the projected changes in salinity and land ice melt. These will be addressed using both subjective and objective probabilistic analysis. The composite uncertainty analysis across scales will be used to inform a risk assessment for selected Everglades ecosystem attributes from sea level variations.

Pine rock land response to Hurricane Wilma (Anderson and Ross)
We are continuing our study of the effects of Hurricane Wilma on the coastal plants. In order to better predict how future sea-level rise will affect coastal systems, we have been studying the effects of Hurricane Wilma's storm surge on Big Pine Key. Last, September, Anderson travel to the WSL in Switzerland to measure the tree-rings from these samples with Paolo Cherbuni.

8. Modeling and Synthesis

General coordination activities
A total of 18 modeling and synthesis projects are currently being used to address FCE II research hypotheses (Figure 8.1). After the 2008 FCE ASM, our group arranged a series of meetings, including a 3-day workshop in Key Largo, FL (June 15-17, 2009), aimed at improving integration and dialogue among these modeling and empirical research activities. Follow-up tasks from this meeting include (1) development of work plans for using multiple FCE models (and data synthesis) for addressing priority research questions for the FCE; (2) the initiation of one of these proposed synergies using ELM and SEACOM models; and (3) a review paper outlining this integrative modeling approach and its application toward Everglades restoration and management. Other types of synergistic activities being explored include generating standardized boundary conditions and driving variables to allow consistency checks in inputs/outputs among models, or conversely, highlight important discrepancies among models, and thus areas for future research.



Model Name(s) or Synthesis Project	Spatial Domain & Resolution	Temporal Domain & Resolution	Principal Outputs
SFWMM	Regional, South Florida (km)	decades (daily)	managed water depths, "grand experiment" hydrology
ELM	Subregional to all Everglades (m to km)	decades to centuries (daily)	hydrology, bio-geochemistry, biology, salinity, groundwater
TIME (ASICS)	Subregional (m to km)	years (daily)	groundwater and surface water hydrology, salinity
RIBBON, SCAT, Lattice-Boltzman	Subregional, Ridge-Slough (m to km)	days to millennia (hr -month)	biogeochemistry; vegetation & peat dynamics; surface water flow
FORMAN, NUMAN, HYMAN, MIKE	Mangroves (m)	century (daily - yearly)	biogeochemistry, succession, water quality
SEACOM (+ TIME EFDC, FATHOM)	Florida Bay (m to basin)	years (hr - daily)	seagrass and phytoplankton biological responses
ODFISH, GEFISH	theoretical landscape (m)	years (daily)	fish community responses to seasonal wetting & drying, elevation gradients
SLEUTH	Urban landscape (property units)	years (monthly)	urban growth, zoning laws, land use change
Hydrology FCE data and literature review	Subregional (m to km)	years (hr - daily)	subregional and landscape variation in hydrology
Soil accretion literature review	All Everglades (m to km)	decades to millennia (yr – decadal)	subregional and landscape variation in accretion

Figure 8.1. Overview of the geographic domains and objectives of FCE modeling and synthesis activities

Large-Scale Hydrology Models

SFWMM

The South Florida Water Management Model (SFWMM) is a regional-scale computer model that simulates the hydrology and management of south Florida water resources from Lake Okeechobee to Florida Bay. Developed by the South Florida Water Management District, the model simulates all the major components of the hydrologic cycle in southern Florida on a daily basis using climatic data for the 1965-2000 period. The SFWMM is widely accepted as the best available tool for analyzing regional-scale structural and/or operational changes to the complex water management system in southern Florida. Several FCE models, most notably ELM, rely on products generated by the SFWMM. Over the past year, new developments to this model include the full implementation of a Position Analysis (PA) probability function, which benefit water management by providing (1) an assessment of future risks associated with operational plans and deviations for a basin (e.g. Lake Okeechobee, WCAs) over a period of several months; (2) simulations of a large number of possible rainfall events using current conditions as the initial values for modeling; and (3) incorporation of a broad range of meteorological conditions that may occur in the future.

TIME

The Tides and Inflows in the Mangrove Ecotone (TIME) model is a landscape-scale hydrologic model developed by researchers at the USGS to simulate the duration, timing and extent of wetland inundation and salinities along the freshwater-saltwater interface. It encompasses the entire weltands of Everglades National Park. Everglades National Park has begun funding a project to use TIME to simulate hydrology given a 6”, 1’, 2’ and 3' rise in sea level and alternate sets of boundary conditions at Tamiami Trail based on current (baseline) conditions, future with restoration (CERP), and future without CERP. Results of this project will be an important addition toward providing standardized boundary conditions, driving variables and consistency checks for FCE ecological and hydrological models in evaluating system responses to restoration scenarios.

Freshwater Ecosystem models

ELM

Carl Fitz (University of Florida) has completed the development and documentation of a fine-scale (500 m grid resolution) application of the Everglades Landscape Model (ELM v2.8), in the regional domain ranging from the northern freshwater Everglades to the border of Florida Bay and Gulf of Mexico. The output variables include water depths and flows, water column and soil phosphorus, water column chloride, soil accretion, and periphyton and macrophyte distributions. This year FCE collaborators Carl Fitz and SFWMD researchers Christopher Madden and Amanda MacDonald initiated a project to link FCE models ELM and SEACOM (Seagrass Ecosystem Assessment and Community Organization Model). Fostered by discussions and break-out sessions during our June 2009 workshop, this project aims to understand impacts of processes within the freshwater landscape (from ELM) on estuarine processes downstream (SEACOM) and to provide a consistency check between the outputs and inputs of these models. For this study, ELM outputs provide driving variables and boundary conditions for the

SEACOM model, which simulates seagrass/phytoplankton and nutrient dynamics in Florida Bay and ponds located within the mangrove ecotone. ELM outputs include a future baseline case and a future scenario with increased (tripled) inflows into the southern Everglades through one structure (S-332D) upstream of the Taylor River region.

SCAT
The Sediment Carbon Accumulation and Transport model (SCAT), developed by FCE collaborators Colin J. Saunders (SFWMD) and Daniel L. Childers (FIU/ASU), is a simulation model of ridge-slough vegetation and soil accretion within the marsh ecosystems of Shark Slough. During 2008-2009, a simplified version of the model was developed to determine the extent to which downcore profiles of fossil sawgrass seeds could be simulated as a function of past interannual variability in water depths and empirical relationships between water depth, sawgrass biomass, and sawgrass seed production provided by a synthesis of FCE LTER macrophyte and water gage data. This approach was developed so that models simulating long-term (multiple decades to centuries) vegetation changes could be directly tested against long-term paleoecological data. This first phase of this modeling was aimed at evaluating the extent to which Shark Slough vegetation has responded to past climate variations (1895 to present) and how water management effects have altered that relationship.

LBM (Lattice-Boltzman models)
In low-energy wetland systems such as the Everglades, the effects of vegetation distributions and water management on surface water flow patterns are difficult to measure. A better understanding of these relationships is necessary to address fundamental questions related to plant community ecology, nutrient cycling, and carbon budgets. Simulations of flow vectors using finite element models at the scale of individual landscape features are computationally expensive and require extensive parameterization. Lattice Boltzmann models, developed by FCE Hydrology co-lead Vic Engel (ENP) and Dr. Michael Sukop and Shadab Anwar at FIU, provide an alternative to simulate hydrodynamics in complex heterogeneous media such as the Everglades ridge and slough habitat. In this application, high resolution aerial imagery of the habitat is pixilated to generate the model domain. Flow vectors are derived as a function of the input boundary head gradients and the vegetation resistance. An objective parameter optimization subroutine (PEST) is used to calibrate the model using the results from several large-scale surface water tracer releases (Ho et. al. 2009 and Variano et al. 2009). A partial proposal for this work was funded by the South Florida Water Management District in 2008. A full proposal was submitted to Everglades National Park in 2009. This work will be useful for analyzing nutrient fluxes and water residence times in the freshwater marshes along the SRS transect and will also occur in parallel with SF6 tracer measurements of large-scale surface water flow patterns (see Hydrology WG activities).

Mangrove Models

HYMAN
Mangrove trees play an important role in the maintenance and sustainability of coastal wetlands due to their ability to adapt and survive in a wide range of saline and tidal conditions. Hydrologic processes (e.g., inundation frequency) and salinity are important regulators controlling the

growth and productivity of mangrove forests. To quantify how changes in landscape-level hydrology will influence these regulators in mangrove forests, FCE collaborators from LSU (Victor Rivera-Monroy, B. Michot, Robert Twilley, and E. Meselhe) have applied the mangrove hydrology model (HYMAN) to three FCE-LTER sites (SRS-4, -5 and -6) along the Shark River estuary, each with distinct tidal forcings.

MIKE-NUMAN

A major need for operational and restoration planning is to determine how passage of Everglades water through the mangrove ecotone influences salinity and nutrient loading to Florida Bay. The ecotone has a dynamic role as a sink, source, and transformer of nutrients and discharge from the ecotone is a large source of N and C for Florida Bay. A hydrologic/water quality model (MIKE 21) is being developed by SFWMD and Louisiana State University that is applicable to FCE for analysis of ecotone system dynamics along lower Taylor River. The model will be utilized as a tool to evaluate how potential changes in water flow (including water management scenarios) will affect the salinity, biogeochemistry and water balance within the ecotone and influence water and materials loading to Florida Bay at Taylor mouth. It will become part of the southern Everglades-Florida Bay model integration suite that includes ELM, SCAT, Ribbon, NUMAN SEACOM which will work together to create the ability to track nutrient, salt and water transport and transformation and shifts in the major plant community zones within the ecotone and the estuary. The mangrove ecotone model's spatial domain has been established based on pond bathymetry, creek channel cross sections and wetland elevations in Taylor Slough and includes wetland surface, groundwater and creek flows. Boundary conditions are established at Argyle Henry upstream and Taylor River mouth downstream and driven by USGS gauge data and the TIME model as inputs.

CONSUMER modeling

Using information theoretic framework, FCE researchers Joel Trexler (FIU), Charles Goss (FIU), Raúl Urgelles (FIU) and Robin Bennet (SFWMD) are employing model selection methods on time series data to understand long-term dynamics of consumer populations. Ongoing projects include assessment models (Trexler and Goss, 2009); analysis of dragonfly naiad dynamics (Urgelles, MS); aquatic fauna population and community dynamics incorporating disturbance and migration.

Complementary to the statistical modeling, a basic food web model, Greater Everglades Fish model (GEFISH), has been developed by Don DeAngelis (University of Miami), Joel Trexler (FIU), Fred Jopp (Frei Universitnät, and Univ. Miami), and Doug Donalson (ENP). The objective of the model is to describe the spatio-temporal dynamics of small fish biomass in a spatially explicit domain, typical of an Everglades landscape. Model drivers include seasonal rise and fall of water levels and a limiting nutrient, phosphorus. The model structure includes primary producers (periphyton), detritus, invertebrate detritivores, fish consumers, and nutrients, which are recycled within the system. The model is spatially explicit on a 100 × 100 grid of square cells (though this size can be increased if needed) representing a segment of the Everglades hydroscape, each cell assumed to be 100 × 100 meters. For example, the overall modeled landscape could consist of an area resembling the east-southern Taylor Slough in the Everglades.

Florida Bay / seagrass modeling

SEACOM

Collaborators Chistopher Madden (SFWMD), Amanda McDonald (SFWMD), Pat Gilbert and Cindy Heil (US Fish and Wildlife Service) have continued development of a mechanistic simulation model of seagrass-water column interactions for Florida Bay ecosystem studies within FCE. The model describes the biomass, production, composition and distribution of SAV- *Thalassia*, *Halodule*, and *Ruppia* and a mixed phytoplankton community. Model development is aimed toward understanding the effect of hydrologic and salinity restoration via managed adjustments of the timing and amount of freshwater discharge on the SAV and phytoplankton communities. The Seagrass Ecosystem Assessment and Community Organization Model (SEACOM) is calibrated for nine basins in the bay and describes biological and nutrient dynamics with a timestep of 3 hr.

The model is parameterized from experimental data in the field, mesocosms, bioassays, and monitoring. The SAV portion of the model has been updated to include the growth dynamics and recruitment of *Ruppia,* a low-salinity species expected to expand with additional freshwater inputs to northern Florida Bay. It has been calibrated for several bay regions with seagrass, phytoplankton, and nutrient cycling data, light and residence time, and other physical parameters specific to each sector. The preliminary phytoplankton module is fully functional and has been integrated into the core SAV model.

Other recent updates include the use of the models EFDC and SICS (Southern Inland and Coastal Systems; Eric Swain, USGS) for water quality boundary conditions and the FATHOM model for coarse-scale water transport and salinity determination. The model is also being calibrated for two mangrove ponds of Taylor River. The latter is an important step toward linking SEACOM with other FCE models and improving our ability to address FCE II hypotheses on coastal ecotone dynamics.

Human Dimensions modeling / SLEUTH

Researchers in the Human Dimensions working group are currently developing the SLEUTH model (a cellular automata model developed by Keith Clarke, UCSB) to simulate urban growth and land use change in the South Florida urban landscape. In the model, each cell is affected by the current state (land-use type or land zoning) of nearby cells which may cause state changes—e.g., urban, transportation, shade/natural. Empirical investigations on land zoning changes and changes in residential lawns currently ongoing within the urban study area (Homestead) are planned to be integrated into the operation of the model. The model also forecasts impervious surfaces and water draw, features that lay the groundwork for incorporating socioeconomic drivers into existing FCE ecohydrological models.

Other Synthesis

Hydrology review
Understanding and restoring the Everglades, a hydrologically-controlled ecosystem, requires a reasonably accurate quantification of the inflows, storage and outflows of water. As mentioned in the Hydrology WG section of this report, a joint Hydrology/Modeling post-doc (Dr. Amartya Saha) has developed an annual water budget of Shark Slough for 2002-2008. In addition to providing an understanding of the major contributors to the water budget, this project budget lays the groundwork for improved integration among FCE modeling by (1) allowing comparisons of water budgets in other parts of the Everglades and with other models (e.g., SFWMM, TIME) and (2) providing a standardized set of boundary conditions and hydrological drivers for the different smaller scale FCE ecosystem models (e.g., SCAT, Ribbon, FORMAN/HYMAN, SEACOM). The addition of water flow data to the water budget will permit the calculation of water residence times in different areas of the SRS as well as seasonal variation in residence times. Residence time information is directly necessary for models predicting particulate and nutrient transport, water and nutrient availability for productivity as well as salinity fluctuations in the ecotone and FL Bay.

Paleoecological and soil accretion studies
Several ongoing paleoecological investigations by FCE researchers have been used to reconstruct past changes in vegetation, hydrology, salinity, water quality, soil accretion and soil nutrient accumulation in freshwater, mangrove, and estuarine environments of the southern Everglades. Long-term (decadal to millennial) time series obtained from these studies provide calibration/validation data used by several FCE models: ELM, SCAT, NUMAN, and SEACOM. Paleoecological investigations include an analysis of fossil diatom records obtained from sediment cores to reconstruct past salinity and water quality in Florida Bay (~4600 years ago to present) and Biscayne Bay (~660 years ago to present) (Anna Wachnicka, FIU). Second, an ongoing collaboration between FCE researchers at FIU (Evelyn Gaiser, William Anderson), SFWMD (Colin Saunders) and Felix Varela high school (Chris Sanchez, Sebastian Diaz, Nia Brisbane) has quantified vegetation and vegetation-inferred hydrologic changes in the freshwater portions of Shark Slough using a combination of macrofossils, biomarkers and most recently phytoliths (Chris Sanchez, Evelyn Gaiser). In 2008, FCE collaborators Sharon Ewe, Tiffany Troxler, and Colin Saunders initiated a physiological and paleoecological study to examine past and current variation in marsh plant communities and sawgrass physiological stress along Taylor Slough coastal ecotone. Finally, a literature review of all radiometric-based estimates of soil accretion over the greater Everglades (and including FCE sites) is being conducted by colleagues from SFWMD (Colin Saunders, Carlos Coronado, Dave Rudnick, and Fred Sklar) and USGS (Debra Willard, Charles Holmes) to quantify the primary abiotic and biotic determinants underlying regional and habitat-specific variation in soil accretion.

9. Information Management

The Florida Coastal Everglades (FCE) Information Management System (IMS) saw a change to its Information Manager's (Linda Powell) station location as she has relocated 405 miles northwest of Miami in Tallahassee, Florida. The FCE internal executive board (IEC) understood the importance of maintaining consistency in its IMS and agreed to approve a plan which allows Linda to work 'remotely' via the Florida International University VPN. Linda has visited her FCE Office at FIU (Miami) at quarterly intervals and is in constant contact with the group via telephone, emails, and conference calls.

The FCE LTER office has also relocated to new office space on the campus of Florida International University. The office space has expanded to include work stations for the information manager, project manager, education & outreach representative and a visiting scientist. With a larger office footprint, room has been made for a conference table, computer server housing and small reception area.

The FCE IMS continues to facilitate the site's scientific work and to ensure the integrity of the information and databases resulting from the site's coastal Everglades ecosystem research. The web-based query interface tool linked to FCE physical and chemical research results, stored in their FCE Oracle10g database, is finished and is currently being vetted by the FCE Information Management Advisory Committee (IMAC) and its internal executive board (IEC). The new web interface will simplify data discovery and data access for FCE and LTER network scientists as signature FCE chemical and physical data, togther with over 4 million physical and chemical data values from outside agencies (Everglades National Park, South Florida Water Management District and the USGS) have also been added to the FCE Oracle10g database.

Our focus over the past couple months has been directed towards the FCE web site enhancement. Small changes to the FCE 'Data' web page structure will allow users to more easily choose between FCE data products like our signature research datasets, LTER core research data and the FCE physical/chemical online database. Links to important LTER Network and outside agency data resources remain an important part of the FCE website 'Data' section.

The FCE IMS is an active participant in LTER network level activities. Data contributions have been made regularly to the following LTER network databases: 1) ClimDB, 2) SiteDB, 3) All Site Bibliography, 4) Personnel, 5) Metacat XML database and 6) Data Table of Contents. The FCE IMS group is also a data contributor to the EcoTrends project managed by the Jornada Basin LTER.

The FCE information manager, Linda Powell, continues to serve as an IM representative on the LTER Network Information Systems Advisory Committee (NISAC). She will be attending the annual LTER Information Management Committee meeting held during the LTER Network All-Scientists Meeting in Estes Park, Colorado in September 2009.

10. Education and Outreach

In 2008, the primary objective for FCE LTER Education and Outreach was to address the strategic initiatives and goals of *The Decadal Plan for LTER*. Our approach for addressing the *Decadal Plan* was to expand the scope of our existing programs to include other LTER sites, establish international relationships, enhance and expand our community partnerships, and to continue to support educational programs that promote scientific literacy.

We have implemented and continue to support the following programs in order to address the Strategic Initiatives and Goals for Education & Outreach as outlined in *The Decadal Plan for LTER*. Using the educational goals framework of the decadal plan as an outline, we report our continued efforts for the 2008-2009 period.

Conduct Research, Develop Environmental Literacy and Inclusion

Developing learning progressions leading towards environmental science literacy
FCE Research Experience programs work towards developing environmental literacy by including students from Kindergarten through graduate school (K-20) in our research. In addition to the our traditional graduate and undergraduate research training, we have developed programs in which elementary, middle, and high school students works side by side with our RETs, REUs, and other FCE researchers. These programs target specific learning groups and are modeled after the REU and RET programs.

Primary, Middle Grades, and Secondary Education
Over the past several years FCE has adapted the REU program to include high school and middle school students in our RESSt and REMS programs, respectively.

The FCE Research Program for pre-college students began in 2002 with a single high school student enrolled in our Research Experience for Secondary Students (RESSt) program. Since then FCE researchers have worked with over 33 students on an individual basis and an additional 30 in small group settings. Throughout FCE II we have continued to provide ongoing support for our *RESSt* internships and last year we placed an additional nine students to work directly with FCE researchers.

In 2008-2009 we have continued to improve both our RESSt and Research Experience for Middle School (REMS) programs while our participants have gained international recognition for their research. In his third year working as an RESSt intern with Drs. Evelyn Gaiser and Colin Saunders, high school student Christopher Sanchez was awarded *Second Place* in *Plant Science* at the 2009 Intel International Science and Engineering Fair. Christopher received a $1500 cash award, a minor planet named in his honor (see http://www.azstarnet.com/sn/education/300136.php and http://www.societyforscience.org/intelisef09/intelisef09gao.pdf for additional information) and he was offered an internship to work with a leading phyotlith researcher at the University of Nevada. Prior to receiving his awards at *Intel*, Christopher also received *Superior* in the *Botany* division at the *54th South Florida Regional Science and Engineering Fair* where he was awarded *Best Biological* project and received the *George Avery Award* by the Florida Native Plant

Society. In addition, he was one of 12 senior high students to represent Miami Dade County Public Schools at the *54th State Science and Engineering Fair of Florida*, where he received *Second Place* in the *Botany* division and a $40,000 scholarship to the Florida Institute of Technology. Christopher also received the *Baush & Lomb Award* in science and *Outstanding Junior* by the Science Department at Felix Varela Senior High School and named *2009 National Hispanic Merit Scholar* by the College Board. In March 2009, Chris presented his results in a poster at our annual ASM meeting and has since continued his research with plans to compete again on the 2010 Science Fair circuit.

In her second year as an RESSt intern, Erikamarie Gil received one of thirty Planet Connect Grants from the National Environmental Education Foundation. Erikamarie was the *only* Florida recipient and will use the $1000 award to raise awareness about south Florida native plants. Erikamarie is working with FCE staff to identify plants and construct a dichotomous key, photographic identification guide and GIS map for students and teachers to use at the habitat restoration area created as a joint venture between FCE and the CEMEX Florida East Coast Quarry.

Our Research Experience for Middle Schools (REMS) continues to expand and is largely supported through the financial support of CEMEX. FCE continues to work with CEMEX in expanding a habitat restoration area at one of their inactive limestone quarries that is adjacent to the Everglades. This restoration area provides us with an ideal location and outdoor learning laboratory that is safe, easily accessible, and does not impact our study sites. Through our partnership with CEMEX they have provided materials, transportation, lunches, and substitute coverage for classes that visit the site. In 2007-2008, we planted over 7500 native grasses, trees and shrubs at the 0.63 acre restoration area which includes a wetland marsh, pineland, hammock and tree island. This year our RESSt students conducted short FCE Everglades ecology lessons with over 150 middle school students and constructed 100 bird nesting boxes.

Pre-Service and Professional Service Teacher Education

FCE also works directly with both pre- and professional service teachers through our RET program. Last year, FCE was the first of four sites to participate in *Coastlines, an* NSF *Information Technologies for Students and Teachers (iTEST)* grant (award # 0737706). Through *Coastlines* FCE worked with Science Approach (SA), LLC of Tucson, Arizona and Alison Whitmer (SBC & MCR) to provide Florida teachers with professional development and instruction in LTER science and GIS technology. In 2008-2009, we continued to support our partnership with SA by providing Webinar presentations on LTER science and through RET participation in the *Coastlines II Summer Institute* in Washington DC, with BES. Second year participants and FCE RETs, Teresa Casal and Catherine Laroche provided input with an FCE perspective while receiving an additional 24 hours of online training; 80 hours of face-to-face professional development; and 16 hours of implementation support.

Following their participation in the *2008 Coastlines I Summer Institute*, our RETs developed additional FCE GIS lessons and provided professional development for teachers. Our first RET, Teresa Casal, developed and pilot tested FCE GIS water quality lessons plans that include the use of MyWorld GIS software with150 Honors/Gifted Chemistry students.

Through our partnership with Felix Varela Senior High School and Miami Dade County Public Schools, Catherine Laroche used her RET to tailor *Coastlines* GIS lessons to FCE and provide teachers with professional development supported through *Project Rewards and Incentives for School Educators (RISE)*. Project RISE is a five-year grant funded by the US Department of Education (Award # S374A070132; http://opi.dadeschools.net/Project_Rise/) designed to improve student learning by improving teacher's instructional skills. As a Project RISE Coordinator, Catherine offered FCE related professional development workshops using her FCE GIS lessons. In addition, she mentored and provided instructional support to both teachers and students through the implementation of her GIS lessons with the potential of impacting up to 600 Earth Space Science students.

FCE Education and Outreach Staff worked with Catherine to secure the funds to purchase 9 Pasco GLX Explorer interface units, probes and software to collect weather and water quality from the Everglades National Park. Through a separate donation, FCE Staff hosted 25 *Coastlines I* students on a field trip to Everglades National Park where they mentored new students in the collection of data using the Pasco GLX and generating GIS maps using the MyWorld software.

FCE Education and Outreach Staff have also worked as *Content Area Experts* in authoring questions and designing the teacher certification exams in the State of Florida for Middle School Science, Earth Space Science, Biology, and Chemistry subject exams.

In 2008, we have continued to expand our relationship with Miami Dade College. This year, Teresa Casal has begun to introduce FCE lessons and FCE datasets to pre-service Math and Science teachers enrolled in the School of Education at Miami Dade College. Over 40 undergraduates enrolled in Teresa's *EME 3410 Instructional Technology in Mathematics and Science* were introduced to FCE lessons and download two FCE datasets for use with *Google Earth* and *My World GIS.* She also plans to introduce additional FCE lessons and datasets to students enrolled in her data analysis course during the Fall 2009.

Our relationship with Miami Dade College has grown to include their School of Education and Everglades National Park (ENP). As collaborators in ENP's *Parks as Resources for Knowledge (PARK)* project*,* FCE is providing support as their scientific advisor. The program is modeled after similar project entitled "*Rip Rap Geology"* at Golden Gate National Park. Through the Everglades *PARK* program, pre-service teachers will work with Everglades and FCE staff in developing hands on, laboratory activities while studying Everglades fire ecology in relation to soil and water characteristics.

Nick Oehm, Education and Outreach Coordinator, presented information about FCE and the Everglades to 70 of his biology students. In addition, Nick, Teresa, and our Catherine gave FCE presentations to an additional 336 students at Felix Varela Senior High School.

Including and learning from diverse people and perspectives

In an effort to establish international Education & Outreach partnerships, we have begun discussions with Dr. Victor Rivera Monroy (FCE and MexLTER) about establishing a sister Education & Outreach program with the MEX LTER. Our hope is to begin connecting

American students with our Mexican counterparts with interactive curriculum and research experiences for teachers and students.

In a recent visit to Asia, our Education & Outreach Coordinator has begun contacting schools in Taiwan and China in order to begin establishing a network of English language schools to partner with FCE. Our goal is to develop and share lessons with these schools by including the Taiwan Ecological Research Network (TERN) and the Chinese Ecological Research Network (CERN) in order to allow students from around the globe to collect, share, and discuss the reasons for differences among common forms of data.

We also worked to include other fields of study in our education curriculum beyond the sciences of earth science, biology, chemistry, and environmental studies. This year we involved high school stagecraft classes in lectures on FCE ecosystems and critical habitats for wildlife of the region. The stage classes followed the learning activity by building bird boxes at CEMEX.

Developing programs for working with specific constituent groups

Work at undergraduate and graduate levels to improve training
In addition to over 40 graduate students, FCE has numerous undergraduates working in our laboratories and participating in our REU programs. In 2008-2009, FCE offered three REUs in which all students presented the results of their projects in manuscripts, posters and/or talks at meetings. FCE is actively improving our undergraduate and graduate program through ongoing mentoring and training through Research Assistantships and the REU program. In addition, Drs. Laura Ogden and Evelyn Gaiser have offered workshops and reading groups to FCE students that focus on LTER readings and data analysis.

Work with K-12 schools to promote environmental literacy
FCE continues to promote environmental literacy in K-12 schools through our RET, RESSt, and REMS programs. In the coming year, we will continue to develop programs geared towards our K-5 citizens in elementary school through a new partnership with Kimberly Allen at the newly opened Gateway Environmental K-8 Learning Center. Together with Ms. Allen we will continue developing our Research Experience for Elementary Students (REES) program. Our current plan is to coordinate REES program with the expansion of the CEMEX restoration area and work on a habitat restoration area at the school site.

Engage citizens and leaders with LTER research
The inclusion of community leaders and policy makers intrinsic to our research program and has played a major role in FCE since inception. Our research collaborators include governmental organizations such as the South Florida Water Management District, Everglades National Park, National Park Service South Florida Caribbean Network, United States Geologic Survey Florida Integrated Science Center and National Research Program. In addition, we interact and collaborate with researchers from NGOs including Harbor Branch Oceanographic Institute, National Audubon Society Tavernier Science Center, and the private firm Ecology and Environment, Inc.

Through our Education and Outreach program we have developed strong working relationships with: Felix Varela Senior High School; Miami Dade County Public Schools; Miami Dade College Department of Biology, Health, and Wellness; Miami Dade College School of Education; Science Approach, LLC; and the Everglades Digital Library. We also work closely with CEMEX USA aggregate mining corporation and the Ft. Lauderdale Museum of Discovery and Science as our primary community partners.

B. Findings

1. Primary Production

Phytoplankton
The extraction of climatic signals from time series of biogeochemical data is complicated in estuarine regions because of the dynamic interaction of land, ocean, and atmosphere. We explored the behavior of potential global and regional climatic stressors to isolate specific shifts or trends, which could have a forcing role on the behavior of biogeochemical descriptors of water quality and phytoplankton biomass from Florida Bay, as an example of a sub-tropical estuary (Briceño and Boyer 2009). We performed statistical analysis and subdivided the bay into six zones having unique biogeochemical characteristics. Significant shifts in the drivers were identified in all the chlorophyll a time series. Chlorophyll a concentrations closely follow global forcing and display a generalized declining trend on which seasonal oscillations are superimposed, and it is only interrupted by events of sudden increase triggered by storms which are followed by a relatively rapid return to pre-event conditions trailing again the long-term trend

Periphyton - Controls on periphyton productivity
High rates of periphyton productivity continue to be measured in the freshwater marsh that results in thick floating and epilithic mats that average 4800 ml m^{-2} in wet biovolume, 210 g m^{-2} in dry mass and 60 g m^{-2} ash-free dry mass. Rates of periphyton ANPP were lower in the predominantly floating mats of SRS than for the epilithic mats of TS (mean 2001-2004 = 21 g m^{-2} yr^{-1} vs. 1400 g m^{-2} yr^{-1}, respectively). Within the SRS transect, the highest rates of periphyton production occurred during the wet season of each year, with values being highest in the central slough (SRS 2, 3) and lowest at the SRS 1a and b, close to the Tamiami Canal. Movement of this site in 2005 and 2006 to areas further from the S-12 water delivery structures dampened this trend. There was a general negative relationship between periphyton production and phosphorus availability (Fig. 1.1) and decreased production with inceasing water depth (Fig. 1.2), a trend reported extensively in this study and throughout the Everglades (Gaiser et al., 2006). Within the TS transect, periphyton production is highly variable, with highest rates occurring just after seasonal inundation of previously dry mat (Iwaniec et al., 2006). The relationship of periphyton production to P availability along this transect is positive, but the gradient was within the natural range of variation exhibited in the Everglades rather than reflecting excess P income that instigates the disintegration of the mat matrix (Gaiser et al., 2005). Epiphyte accumulation rates in Florida Bay were lower than those for the marsh. Rates are significantly higher at TS/Ph-11 than TS/Ph-9 and 10 at all times of the year and these epiphytes contain a higher concentration of phosphorus than those at the two upstream sites (Fig. 1.3). Compositional differences in the

epiphytic diatom flora were also pronounced among the three Florida Bay sites and were related to gradients in salinity and phosphorus availability (Frankovich et al., 2006).

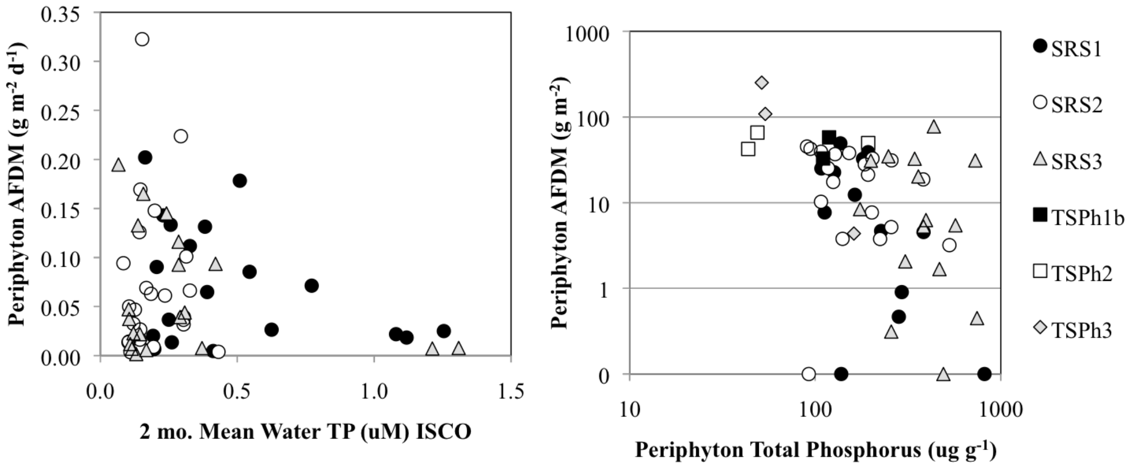


Fig. 1.1. Negative relationships between biomass and production of periphyton with phosphorus concentrations in water and periphyton at FCE sites.

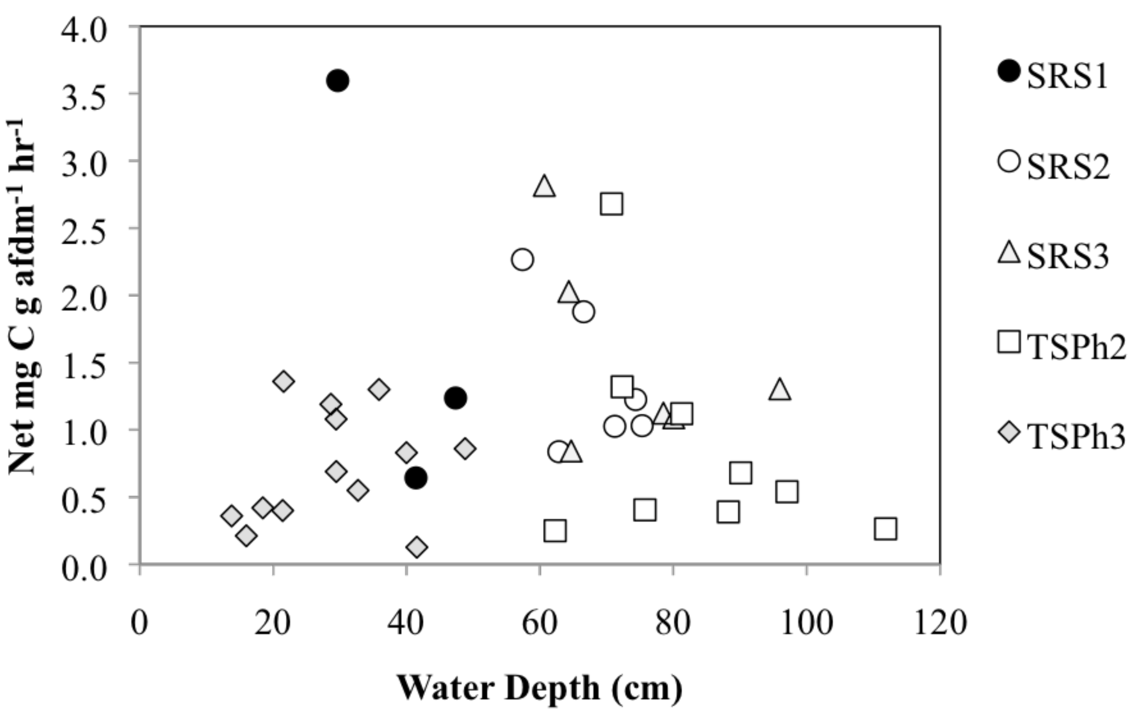


Fig. 1.2. Periphyton productivity tends to decrease with water depth across sites.

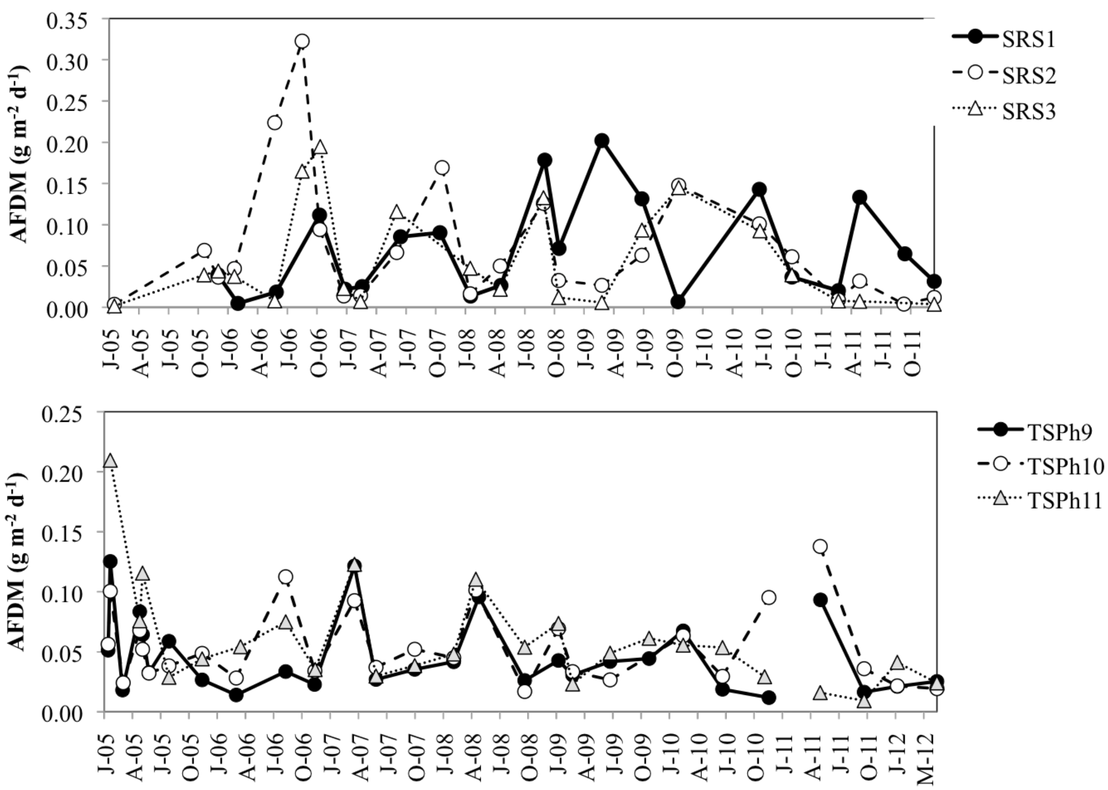


Fig. 1.3. Periphyton accumulation rates follow a wet-dry season pattern, with highest production in the wet season

Collaborative mapping efforts to determine landscape scale distribution of periphyton in the Everglades are showing similar trends in production, relative to water quality, salinity and hydrologic gradients in the system. These relationships have been modeled and are being used to indicate ecosystem status, using an assessment approach that accounts for climate-driven inter- and intra-annual variability and builds upon those used for other sensitive organisms in this system (Gaiser et al., 2008). One exciting result of these large-scale mapping surveys has been the appearance of elevated periphyton phosphorus values throughout the ecotone, lending support to FCE hypotheses that coastal sources of phosphorus impact not just the estuaries but the adjacent marshes, as well, and enabling us to evaluate the seasonality of this response in a rapidly responding community. The cascading influence of periphyton productivity and composition on consumer dynamics were examined in a path analysis using data from these surveys (Seargent et al., In Press) and manipulative experiments (Ruehl et al., Submitted) (Fig. 1.4).

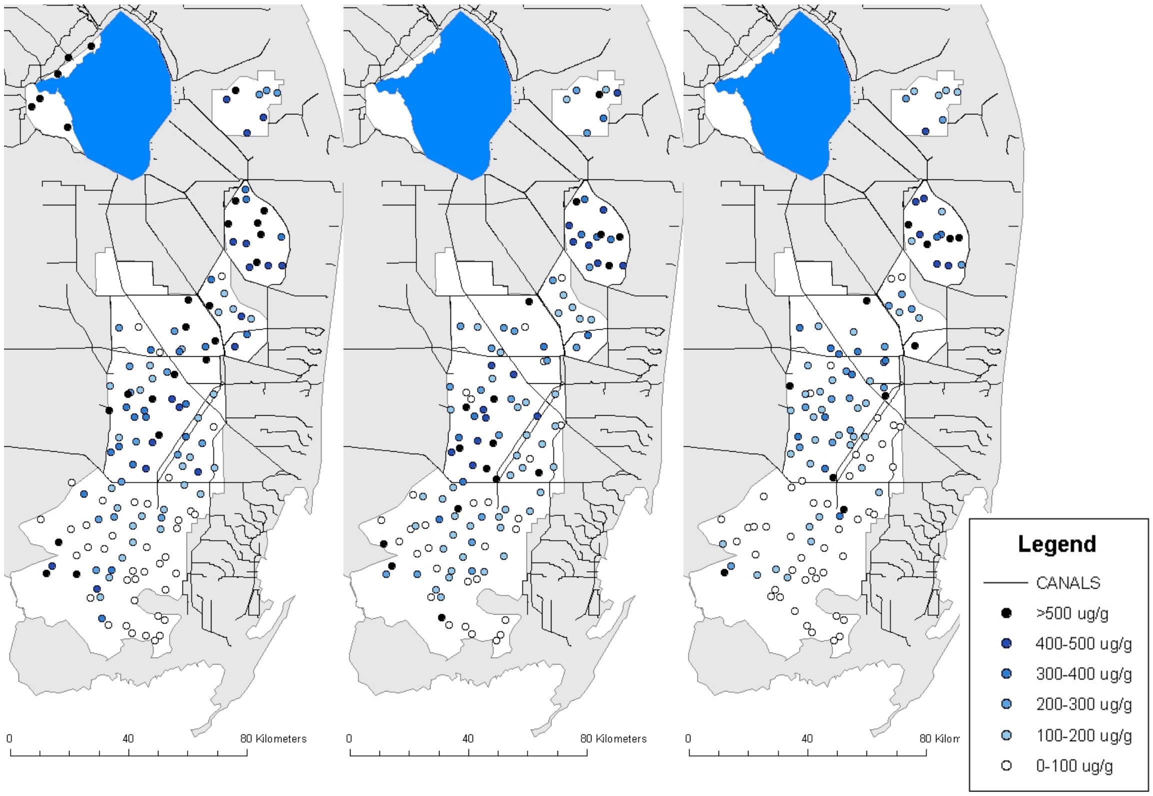


Fig. 1.4. FCE long-term data are used to inform interpretations of changes in periphyton total phosphorus concentrations from landscape assessment program

Periphyton - Primary production of periphyton-dominated ecosystems
We found maximum annual NEP values at Taylor Slough 1b (291 g C m^{-2} yr^{-1}) and maximum annual ER values (-366 g C m^{-2} yr^{-1}) showing annual net heterotrophy. Maximum annual NEP values at Shark River Slough 2 (385 g C m^{-2} yr^{-1}) and maximum annual ER values (-34 g C m^{-2} yr^{-1}) showing annual net autotrophy. Temporal changes showed NEP at Taylor Slough 1b decreased significantly when inundated during the wet season ($P < 0.05$) while ER showed no significant changes over time ($P > 0.05$). NEP and ER at Shark River Slough did not show significant intraannual pattern. Together with estimates from associated eddy covariance towers, these CO2-based estimates will indicate if there is a net flux of inorganic carbon into or out of the marsh ecosystem. (Figs 1.5)

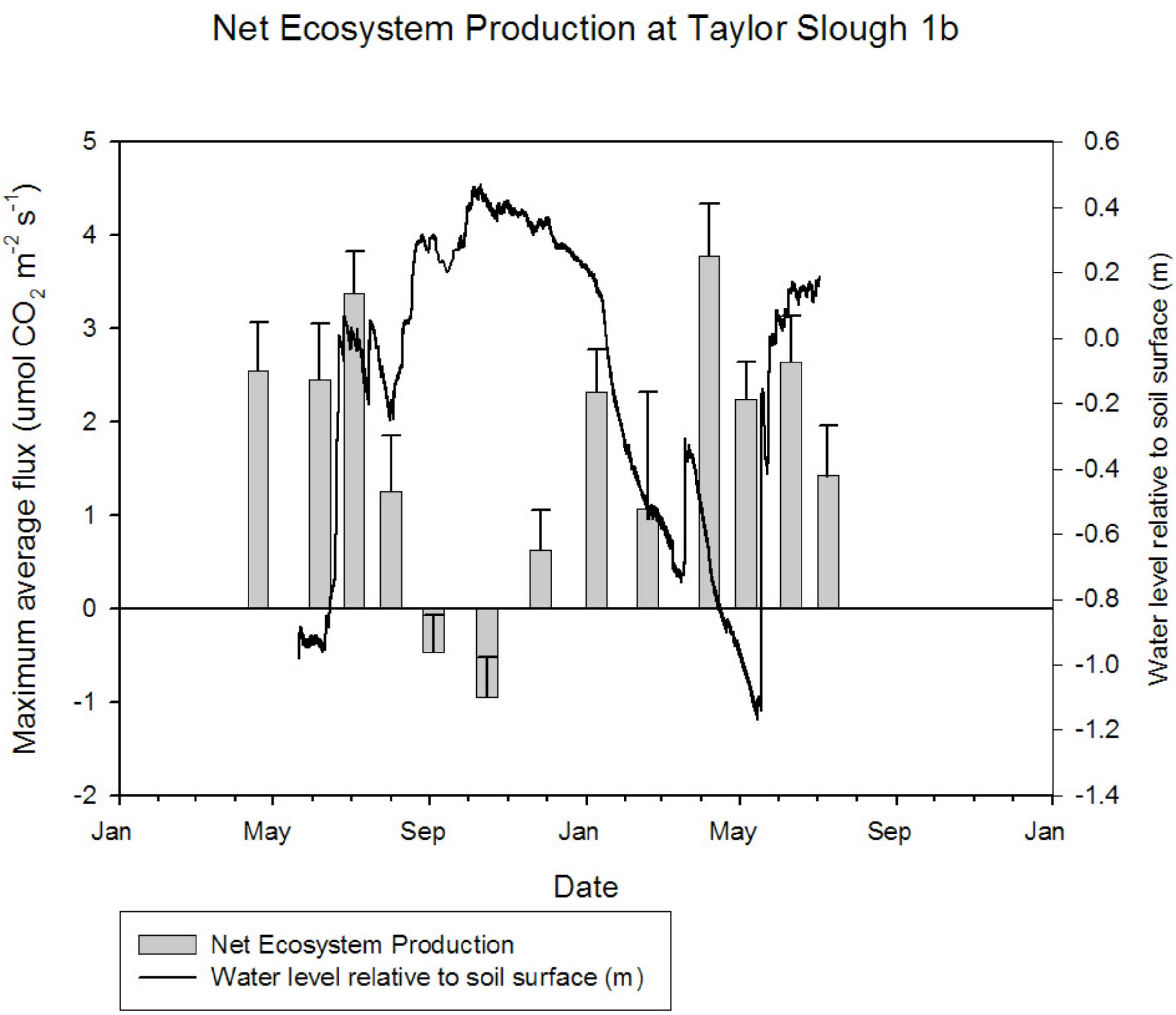


Fig. 1.5. CO2 flux in whole-ecosystem chambers at TSPh1b

Seagrass ecosystems - Projected Reorganization of Seagrass Communities in Response to Altered Freshwater Flow in Florida Bay

A statistical discriminant function model that associates seagrass community type with water quality was applied to modeled changes in freshwater flow from the Everglades to Florida Bay for the purpose of assessing how the changes in the salinity climates of the bay might alter seagrass community composition and distribution upon implementation of the Comprehensive Everglades restoration Plan (CERP). Salinity climates were simulated with the hydrological model FATHOM(Cosby et al. 1999, Nuttle et al. 2000), calibrated to the period of January 1991 through December 2000. Average monthly freshwater flow rate was then increased in a stepwise manner by a factor of 0.5 (0.5x) in nine simulations beginning with 1.0x flow rate and ending with 5.0x flow rate. The discriminant function model and was constructed with the same data sources for seagrass community composition and water quality as in an earlier analysis by Fourqurean et al. (2003). Improvements to the model increased the predictive accuracy from 56.7% to 69.1%. Seagrass communities types described by the model include sparse *Thalassia* *testudinum, dense T. testudinum*, *Halodule wrightii*, *Syringodium filiforme*, *Halophila decipiens*, dense mixed species, *Ruppia maritima-H. wrightii*, and bare sand. Predictors used to classify community type were salinity, salinity variability, % light reaching the benthos, sediment depth, and four commonly measured water quality variables; total organic carbon, total phosphorus, nitrate, and ammonium. To provide relevance to CERP the results were aggregated by feasibility study zones (Figure 1.6).

Increases in freshwater flow produced large decreases in salinity climate that were accompanied by large increases in salinity variability in northern and eastern Florida Bay. In both regions decreased salinity was accompanied by an increase in the probability of *H. wrightii* and sometimes *Ruppia-Halodule* communities at the expense of *T. testudinum* communities. The predicted seagrass community type was highly sensitive to any increase in freshwater flow in northern Florida Bay where the probability *H. wrightii* increased to 100% with a 2.5x flow rate. Northeastern Florida Bay was similarly sensitive but required a 4.0x flow rate or greater for the 100% shift to *H. wrightii*. An exception was Barnes Sound, which experienced smaller changes in salinity climate because of connectivity with Biscayne Bay. The eastern bay had some of the largest absolute changes in salinity and is sensitive to all increases in freshwater flow rate. However, all of the community types present at the 1.0x flow rate remain at the highest flow rate. The probability of *H. wrightii* increased with each increase in flow rate and there was a low probability of *Ruppia-Halodule* at the 2.0x and 2.5x flow rates. The magnitude of change in the salinity climate declined toward the west. Increased freshwater flow continued to favor an increase in the probability of *H. wrightii* in the north-central bay but predicted community type was relatively insensitive to increased freshwater flow, even at the 5.0x flow rate. Further west to the boundary of Florida Bay there was little or no change in salinity of the predicted probability of seagrass community types.

The overall response of seagrass ecosystems across Florida Bay suggest that any increase in freshwater flow rate from the Everglades will cause an increase in the probability of *H. wrightii* communities. In the north a 50% increase in flow rate will maintain all community types, while a 100% increase in flow rate will cause a large shift toward dominantly *H. wrightii* communities throughout the region. In the northeast the distribution of community types will be little affected by a 150% increase in flow rate, while in eastern and western regions of Florida Bay the distribution of community types will remain little changed with a 200% increase in freshwater flow rate from the Everglades.

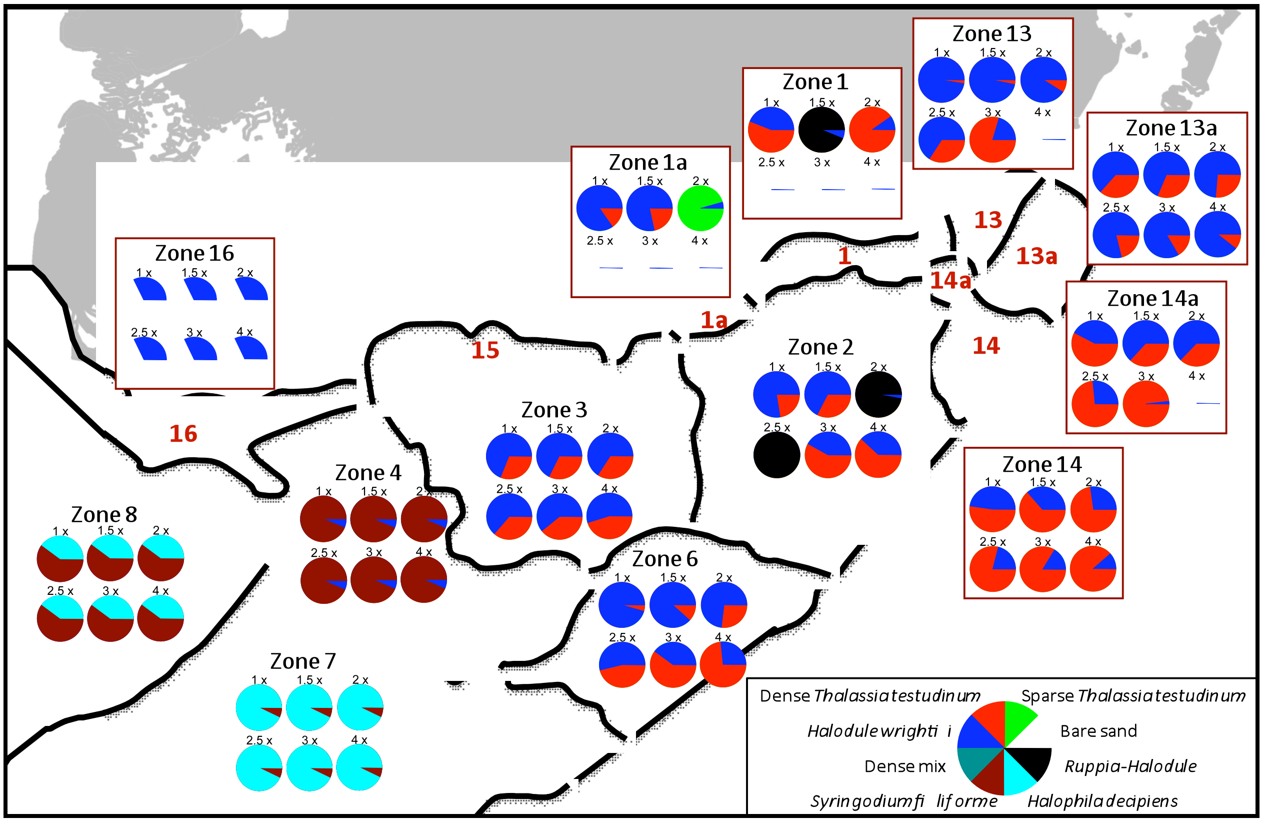


Figure 1.6. The probability of eight seagrass community types predicted by the discriminant function model after salinity and salinity variability were adjusted to reflect changes modeled by FATHOM. CERP feasibility study zones are indicated by number.

Seagrass ecosystems - Benthic Metabolism in Florida Bay is Controlled by Phosphorus Availability

Seagrass community composition and cover at six experimental nutrient enrichment sites in Florida Bay have been monitored and evaluated for more than six years. Nitrogen (N) and phosphorus (P) were applied in complete factorial combination to six sites in Florida Bay distributed from Duck Key (25° 10' N, 80° 29') in the northeast to Sprigger Bank (25° 54' N, 80° 56' W) in the southwest. After six years of P addition *Halodule wrightii* had colonized most P-addition plots in the four easternmost sites, displacing the formerly dominant *Thalassia testudinum*, and in the three easternmost sites there were clear increases in cover and biomass (Armitage et al. 2005). To test if these nutrient driven changes in ecosystem structure were accompanied by changes in ecosystem function (primary production), benthic metabolism was measured in treatments at all sites.

Dissolved oxygen (DO) production and consumption was measured simultaneously in three replicates of each treatment in 20 L chambers with a well-mixed DO environment. Benthic respiration and net benthic DO production were measured as the rate of DO change in chambers that were sequentially darkened then illuminated with ambient light. Gross benthic DO production was estimated as the sum of DO consumed in the dark and DO produced in the light. Incubation periods in the light and dark were between 90 to 160 minutes, depending on the rate of DO change. Incident PAR was measured at one minute intervals near the top of the seagrass canopy with a LI-COR spherical quantum sensor. Incubations were conducted in October 2008, February 2009, and June 2009. For all sites and seasons there were no clear effects of N fertilization on benthic metabolism so the analysis was reduced to -P and + P treatments for increased statistical power.

Gross DO production was lowest in winter and highest in summer in all sites with the exceptions of Bob Allen Keys and Sprigger Bank, where summer incubations were conducted in low ambient light (Figure 1.7). In eastern regions of the bay (Duck Key, South Nest Key, Bob Allen Keys) DO consumption rates were comparable in summer and fall and low in winter, while in the westernmost site (Sprigger Bank) DO consumption changed little from season to season. DO consumption at Rabbit Key Basin and Nine Mile Bank was highest in summer and may be associated with high loads of plant necromass. Net DO production was generally highest in summer with the exception of afore mentioned Bob Allen Keys and Sprigger Bank.

In the eastern regions of the bay P enrichment caused an increase in DO consumption, net DO production, and gross DO production in all seasons. Benthic metabolism was elevated in P treatments at Rabbit Key Basin in fall, but not in winter or summer. Further east, P additions elevated DO consumption at Nine Mile Bank and Sprigger Bank, which was occasionally accompanied by increased gross DO production. Elevated gross production in P treatments may reflect increased photosynthetic mass but may also indicate increased photosynthetic efficiency. Preliminary mass-based analyses suggest that both mechanisms are in effect and that the increase in efficiency can be attributed to replacement of *T.* testudinum by *H.* wrightii. Elevated respiration in P treatments can be attributed to increased biomass and/or an effect on the heterotrophic community.

Fall and winter 24-hr net benthic metabolism was approximately balanced to net heterotrophic in the eastern sites, balanced to net autotrophic at Rabbit Key Basin, and net autotrophic at the westernmost site, Sprigger Bank. Very large loads of seagrass necromass at Nine Mile Bank may have been supporting a large decomposer community, causing the site to become net heterotrophic in the winter. In summer, all western bay sites were net autotrophic while eastern Florida bay sites remained balanced to net heterotrophic. Phosphorus additions drove the eastern sites to net autotrophy. The pattern suggests that much of the eastern bay is a net carbon (C) source in winter and fall, a net C sink in summer, and that P additions change the way that Florida Bay functions.

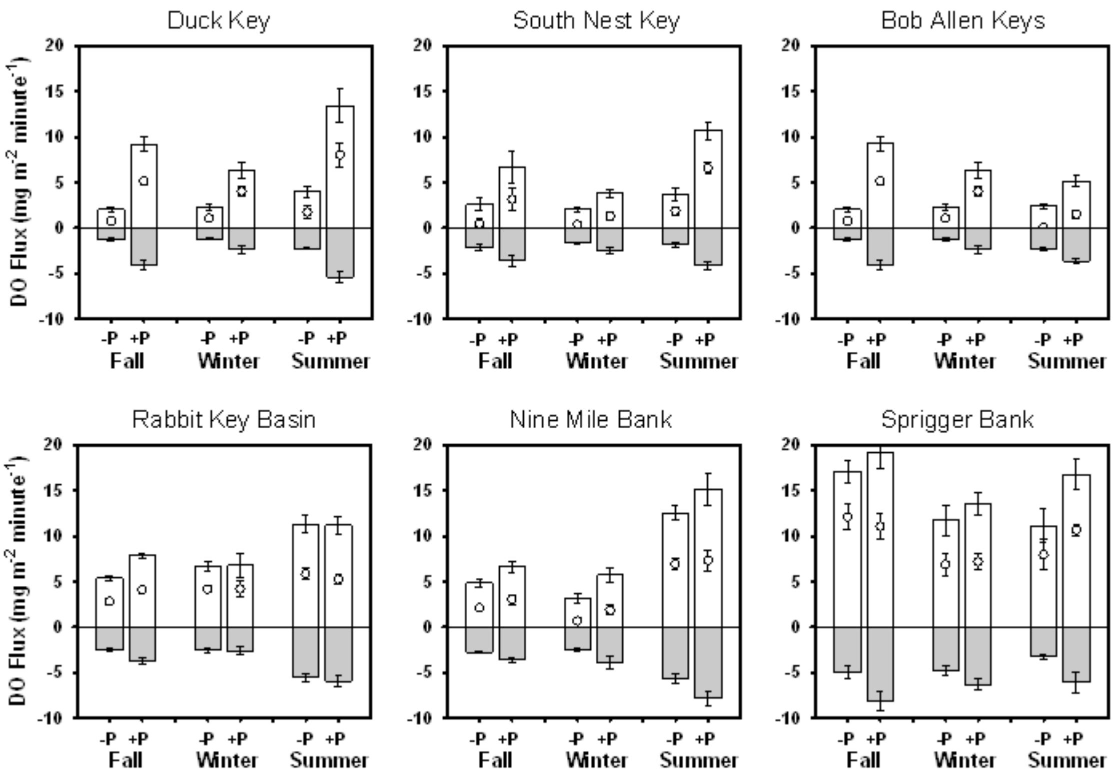


Figure 1.7. Dissolved Oxygen fluxes measured in closed chambers in situ. Bars above the zero-reference represent gross O_2 production in full daylight. Bars below the zero reference represent O_2 consumption in the dark. Bullets represent net O_2 production. Whiskers represent 1 SE.

Sawgrass - Freshwater marsh ANPP (Aboveground net primary productivity)
We have been quantifying aboveground net primary productivity (ANPP) by the dominant macrophyte—sawgrass (*Cladium jamaicense*)—at eight FCE LTER sites for approximately a decade. Specifically, we present sawgrass ANPP data for TS/Ph-1, 2, and 3 in Taylor Slough for 2000-2008, for TS/Ph-4 and 5 in the C-111 Basin for 1998-2006 (when these sites were discontinued as part of FCE II), and for SRS-1, 2, and 3 for 2001-2008. Childers et al. (2006) present the methods used in these measurements and the statistical models used in calculating ANPP. Over the entire decadal record, there were significant differences in mean ANPP rates across the sites (Fig. 1.8a) and in long hydroperiod (SRS sites) vs. short hydroperiod (TS/Ph sites) marshes (Fig.1.8b). Interestingly, the southernmost site in the Taylor Slough transect (TS/Ph-3) more closely resembles a long hydroperiod marsh than the other short hydroperiod marshes in its basin. This is likely because this site is considerably wetter than the other TS/Ph sites. It is also notable that the overall ANPP mean at the northernmost SRS site (SRS-1), which is considerably drier than the other sites in this basin, most closely resembles the shorter hydroperiod TS/Ph marsh locations.

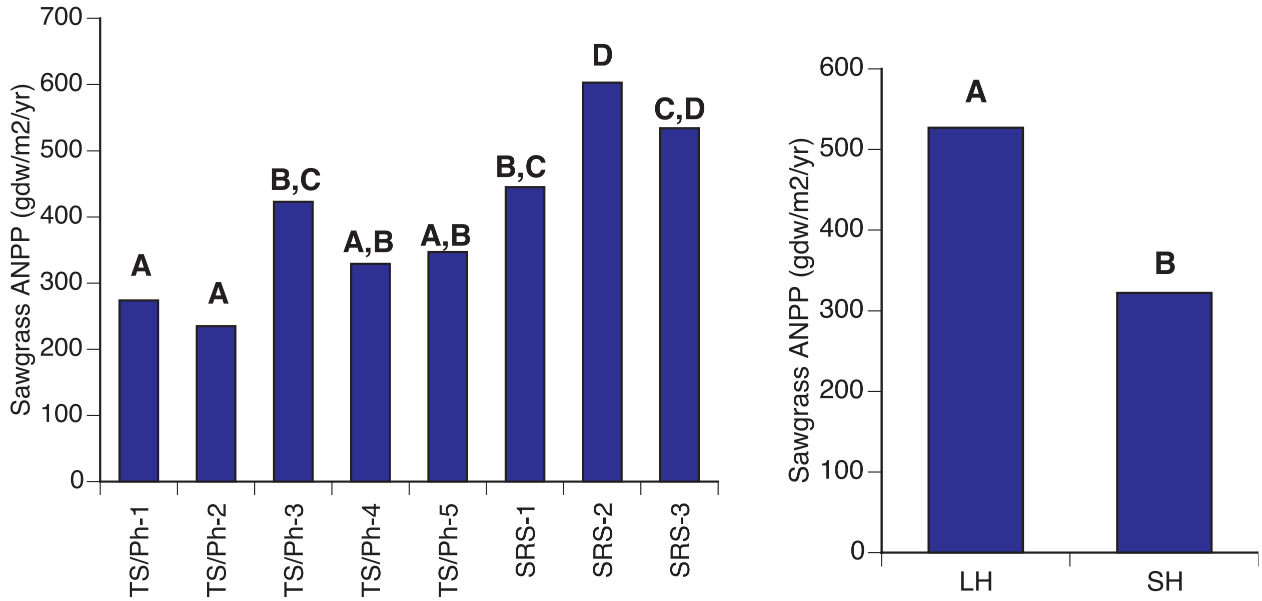


Figure 1.8. Overall time-series mean ANPP by site (A) and by hydroperiod (B; LH = long hydroperiod; SH = short hydroperiod). All differences are significant to p<0.0001.

The annual time-series of ANPP shows considerably more detail and provides critical information about interannual variability at the eight sites, across the 3 FCE basins, and in short versus long hydroperiod marshes (Fig. 1.9). We found highly significant differences in temporal patterns of ANPP among sites (Repeated Measures ANOVA time effect p<0.0001; time*site p<0.0001), among basins (RMANOVA time effect p<0.0001; time*basin p=0.014), and between short and long hydroperiod marshes (RMANOVA time effect p<0.0001; time*hydropd p=0.003). The two TS/Ph sites in the C-111 basin followed a very similar pattern of interannual variability (Fig. 1.9, green symbols) while the Taylor Slough TS/Ph sites did not (Fig. 1.9, blue symbols). The longer hydroperiod sites in SRS also showed relatively little consistency in interannual variability (Fig. 1.9, red symbols).

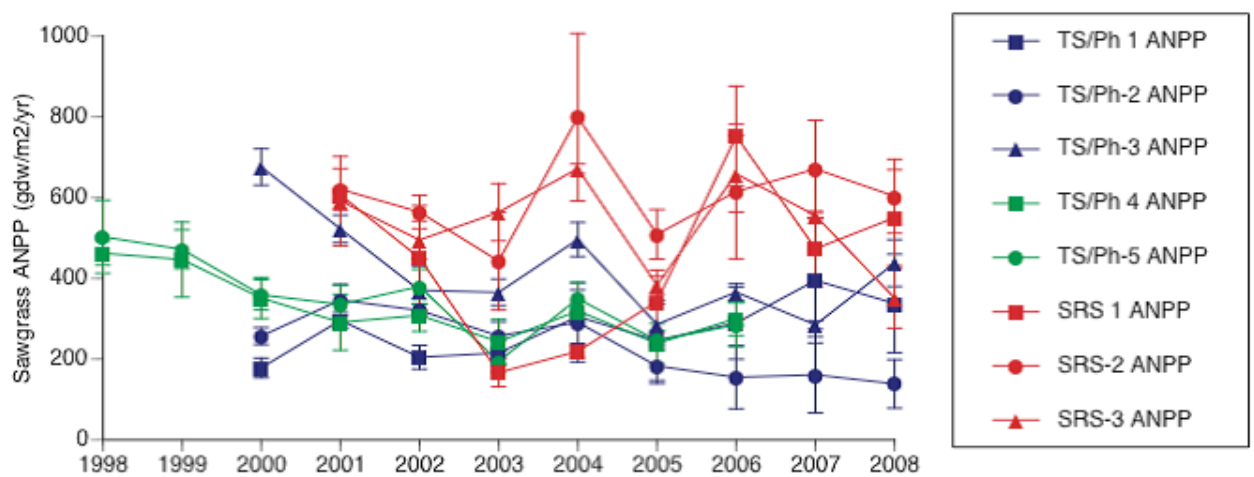


Figure 1.9. Time-series of ANPP by site and by basin (C-111 in green, Taylor Slough in blue; Shark River Slough in red).

We investigated several possible explanations for these decadal patterns in sawgrass ANPP, including logical and well-documented relationships with various measures of hydrologic conditions and with soil phosphorus (P) content. Based on the analysis presented by Childers et al. (2006), we hypothesized a negative relationship between sawgrass ANPP and: a) hydroperiod; b) mean annual water depth, and; c) depth-days, which is a hybrid variable that combines hydroperiod and mean water depth and is analogous to degree-days in climatology (see Childers et al. 2006 for details). We also hypothesized a positive relationship between sawgrass ANPP and soil P, based on numerous publications supporting this relationship. Finally, we hypothesized that a multivariate explanation that included both soil P and some measure of hydrologic condition (e.g. depth-days) would explain the most variation in sawgrass ANPP.

The results of this multivariate approach were mixed and not anticipated. We found no relationship between sawgrass ANPP and soil P with all sites combined (Figure 1.10). Various measures of the hydrologic environment did explain significant portions of the interannual variation in sawgrass ANPP, and the best relationship was a curvilinear response of ANPP to depth-days with all sites and all years pooled together (r^2=0.43; intercept $p<0.001$; Depth-Days $p<0.0001$; (Depth-Days)^2 $p=0.018$; Fig. 1.11). This relationship suggests a "wetness maximum" in either water depth, hydroperiod, or both, at which sawgrass is most productive. This result is not what we expected, based on Childers et al. (2006) where they found a negative relationship between Depth-Days and sawgrass ANPP. That analysis was based only on short hydroperiod sites, though, and only on data from 1998 – 2004. This more complete ANPP and hydrology dataset may, in fact, present a clearer picture of how sawgrass responds to inundation and is more in keeping with the autecology of the species. Notably, we were unable to find any multivariate relationships in which both hydrology and soil P contributed significantly to explaining ANPP dynamics. Again, in all cases soil P was insignificant in explaining ANPP variability.

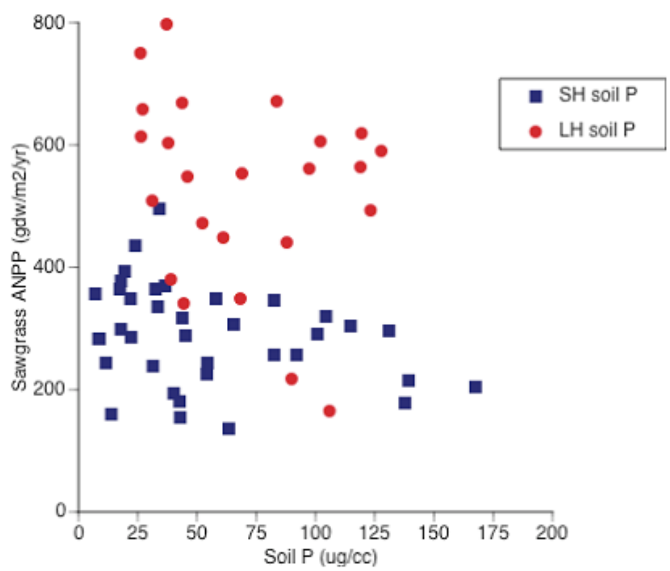


Figure 1.10. Time-series of ANPP by site and by basin (C-111 in green, Taylor Slough in blue; Shark River Slough in red).

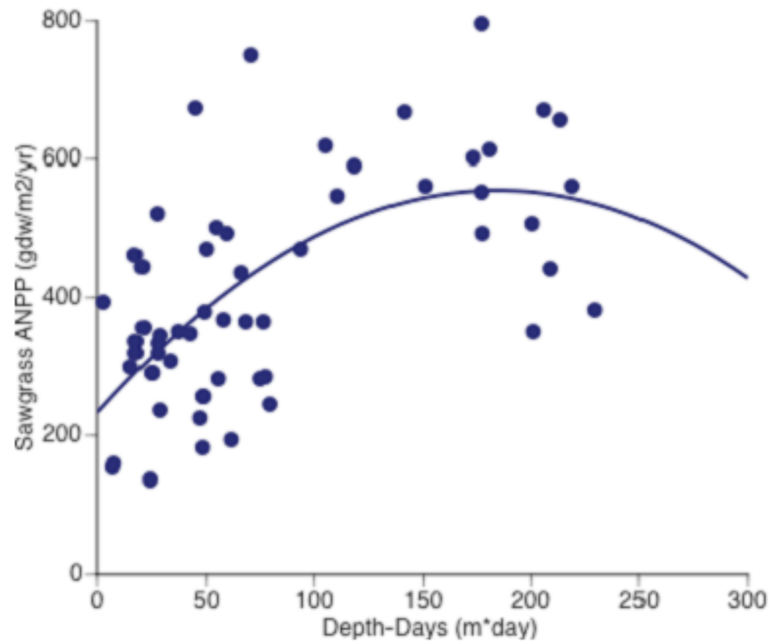


Figure 1.11: Relationship between ANPP and the hybrid hydrologic variable depth-days. Overall $r^2=0.43$ and $p<0.0001$. $ANPP=2.1(Depth\text{-}Days)-0.011(Depth\text{-}Days)^2+282$.

Mangrove Ecosystems - Primary production of mangrove forests

From June to August 2001 and from May to June we studied the ecophysiology of red mangrove (*Rhizophora mangle L.*) i*n situ* (Barr et al. 2009). Physiological measurements were made using environmentally controlled gas exchange systems. The field investigations were carried out to define how regional climate constrains mangrove physiology and ecosystem carbon assimilation. In addition, maximum carboxylation and photosynthetic active radiation (PAR) limited carbon assimilation capacities were investigated during the summer season to evaluate whether ecophysiological models developed for mesophyte plant species can be applied to mangroves. Under summertime conditions in the Florida Everglades, maximum foliar carbon dioxide (CO_2) assimilation rates reached 18 μmol CO_2 m^{-2} s^{-1}. Peak molar stomatal conductance to water vapor (H_2O) diffusion reached 300 mmol H_2O m^{-2} s^{-1}. Maximum carboxylation and PAR-limited carbon assimilation rates at the foliage temperature of 30°C attained 76.1 ± 23.4 μmol CO_2 m^{-2} s^{-1} and 128.1 ± 32.9 μmol (e^-) m^{-2} s^{-1}, respectively. Environmental stressors such as the presence of hypersaline conditions and high solar irradiance loading (>500 W m^{-2} or >1000 μmoles of photons m^{-2} s^{-1} of PAR) imposed sharp reductions in carbon assimilation rates and suppressed stomatal conductance. On the basis of both field observations and model analyses, it is also concluded that existing ecophysiological models need to be modified to consider the influences of hypersaline and high radiational loadings on the physiological responses of red mangroves.

Mangrove Ecosystems - The structure of mangrove forests

Hurricanes have shaped the structure of mangrove forests in the Everglades via wind damage, storm surges and sediment deposition (Smith et al 2009). Immediate effects include changes to stem size-frequency distributions and to species relative abundance and density. Long-term impacts to mangroves are poorly understood at present. We examine impacts of Hurricane Wilma on mangroves and compare the results to findings from three previous storms (Labor Day, Donna, Andrew). Surges during Wilma destroyed ≈ 1,250 ha of mangroves and set back recovery that started following Andrew. Data from permanent plots affected by Andrew and Wilma showed no differences among species or between hurricanes for % stem mortality or % basal area lost. Hurricane damage was related to hydro-geomorphic type of forest. Basin mangroves suffered significantly more damage than riverine or island mangroves. The hurricane by forest type interaction was highly significant. Andrew did slightly more damage to island mangroves. Wilma did significantly more damage to basin forests. This is most likely a result of the larger and more spatially extensive storm surge produced by Wilma. Forest damage was not related to amount of sediment deposited. Analyses of reports from Donna and the Labor Day storm indicate that some sites have recovered following catastrophic disturbance. Other sites have been permanently converted into a different ecosystem, namely intertidal mudflats. Our results indicate that mangroves are not in a steady state as has been recently claimed.

Mangrove Ecosystems - The effects of hurricane-deposited sedimentary phosphorus on mangrove growth

Thus far, there has not been a continuous effect of sediment addition over the duration of the experiment. Overall we've seen net positive growth in each tree clump, although at a small level typical of this growth form of *R. mangle*. Following our most recent sampling in November 2008, we have begun to see an indication of "sediment effect" on stem growth (Figure 1.12). This may be an artifact of the small sample size, but we will continue to monitor the effects in a future sampling. Also of interest, there is noticeably more *Eleocharis* that has become established on areas amended with carbonate sediment—suggesting that this is a more suitable substrate for this oligohaine species.

Figure 1.12. (left) Photo of Dr. Sharon Ewe taking initial leaf and stem measurements on a dwarfed *Rhizophora mangle* at TS/Ph 6a prior to carbonate sediment amendment at the base of the tree (right).

Mangrove Ecosystems - Mangrove root zone research

Total root biomass (top 45 cm of soils) differed significantly among sites for the period of study (Fig. 1.13). Total biomass was greater at the Taylor River region (3265 ± 531 g m^{-2}) compared to Shark River region (2477 ± 528 g m^{-2}). On averaged, coarse roots (> 5 mm) accounted for 60%

of the total biomass for all sites, while fine and medium roots contributed with 18 and 20% of the total, respectively (Fig. 1.14). Mean root biomass was significantly higher in the top section (1953 ± 277 g m^{-2}) compared to the bottom section (968 ± 205 g m^{-2}) of mangrove soils at all sites. Variation in fine root biomass (top 45 cm of soils) was also examined among sites, given that this root size class distribution accounts for most of the nutrient uptake. Fine root biomass varied significantly among mangrove sites and ranged from 199 ± 40 g m^{-2} (TS/Ph7) to 471 ± 75 g m^{-2} (SRS4; Fig. 1.14). The Shark River sites showed a distinct trend in fine root biomass that increase with distance from the mouth of the estuary (Fig. 1.14). SRS6 (244 ± 37 g m^{-2}) had the lowest fine root biomass compared to SRS4 (471 ± 75 g m^{-2}; Fig. 1.14).

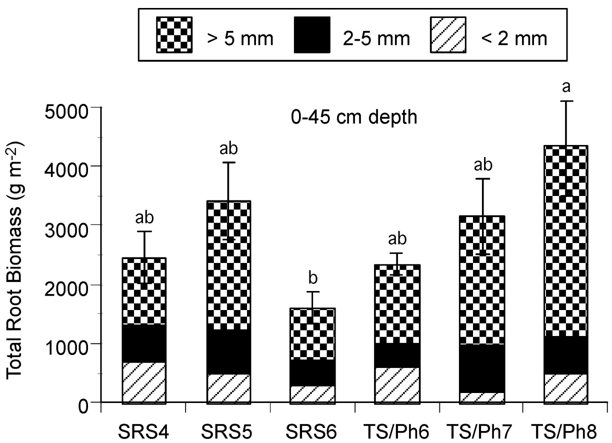


Fig. 1.13. Total root biomass (to a depth of 45 cm) and root size class distribution in mangrove forests of Everglades National Park. Means (± 1 SE) followed by different letters are significantly different ($p < 0.05$) among sites

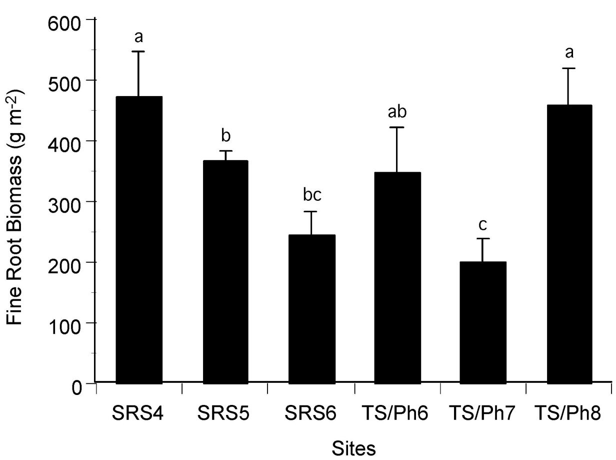


Fig. 1.14. Mean (± 1 SE) fine root biomass (to a depth of 45 cm) in mangrove forests of Everglades National Park. Different letters indicate significant differences ($p < 0.05$) among sites

Total root productivity ranged from 193 ± 59 g m^{-2} yr^{-1} (SRS6, year 1) to 1949 ± 307 g m^{-2} yr^{-1} (SRS5, year 2; Table 1), with no significant differences in root productivity among mangrove sites after 1 year. Root productivity was highly variable after two years and increased 2 to 2.5 times at all sites, except at TSPh/8 (1581 ± 411 g m^{-2} yr^{-1}) and SRS5 (1949 ± 307 g m^{-2} yr^{-1}) where root estimates were up to 4.6 and 9.2 times greater compared to year 1, respectively. The variation in fine root productivity (top 45 cm of soils) was significant among sites (Fig. 1.15), with the highest root estimates at the Shark River sites (159 ± 11 g m^{-2} yr^{-1}) compared to Taylor River sites (56 ± 8 g m^{-2} yr^{-1}; Fig. 1.15). Root turnover rates decreased as the root size class distribution increased from < 2 mm to > 5 mm for most of the sites, except at the Taylor River sites where no significant differences were observed among size classes (Fig. 1.16). Overall, mean turnover rates of fine and medium roots were higher at the Shark River sites (0.484 ± 0.061 and 0.269 ± 0.052 yr^{-1}, respectively) compared to Taylor River sites (0.167 ± 0.014 and 0.196 ± 0.050 yr^{-1}, respectively). In contrast, mean turnover rate of coarse roots was higher at the Taylor sites (0.178 ± 0.055 yr^{-1}) and lower at the Shark River sites (0.105 ± 0.006 yr^{-1}).

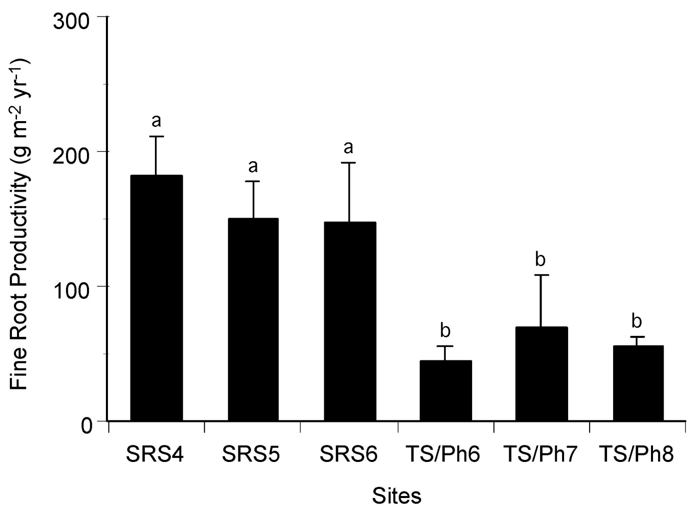


Fig. 1.15. Mean (± 1 SE) fine root productivity (to a depth of 45 cm) in mangrove forests of Everglades National Park. Different letters indicate significant differences ($p < 0.05$) among sites

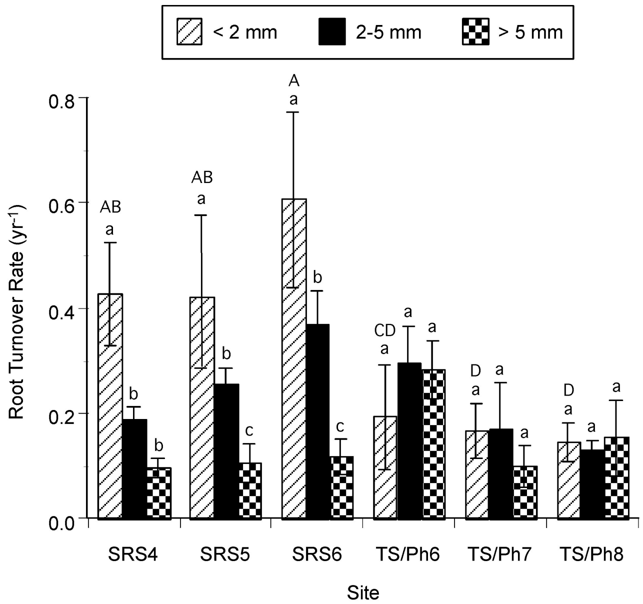


Fig. 1.16. Mean (± 1 SE) turnover rate of root size classes in mangrove forests of Everglades National Park. Different small letters indicate significant differences ($p < 0.05$) among root size classes within each site. Different capital letters indicate significant differences ($p < 0.05$) in fine root turnover among sites

We also found a significant relationship of fine root biomass and productivity with soil TP concentrations (Fig. 1.17), suggesting a strong control of nutrient availability on belowground root allocation. Our results support our hypothesis that sites with more limiting P conditions such as Taylor sites, have lower turnover rates of fine roots and longer root longevity (the inverse of root turnover) spans compared to Shark River. The relative increase in root life span in the Taylor River sites compared to Shark River could be an adaptation of mangroves to nutrient loss. This is particularly significant given that the P-limited condition and the likely greater expenditure of energy in foraging the limiting nutrient in the Taylor sites, at expenses of growth, could add a physiological cost in maintaining root growth and higher turnover rates.

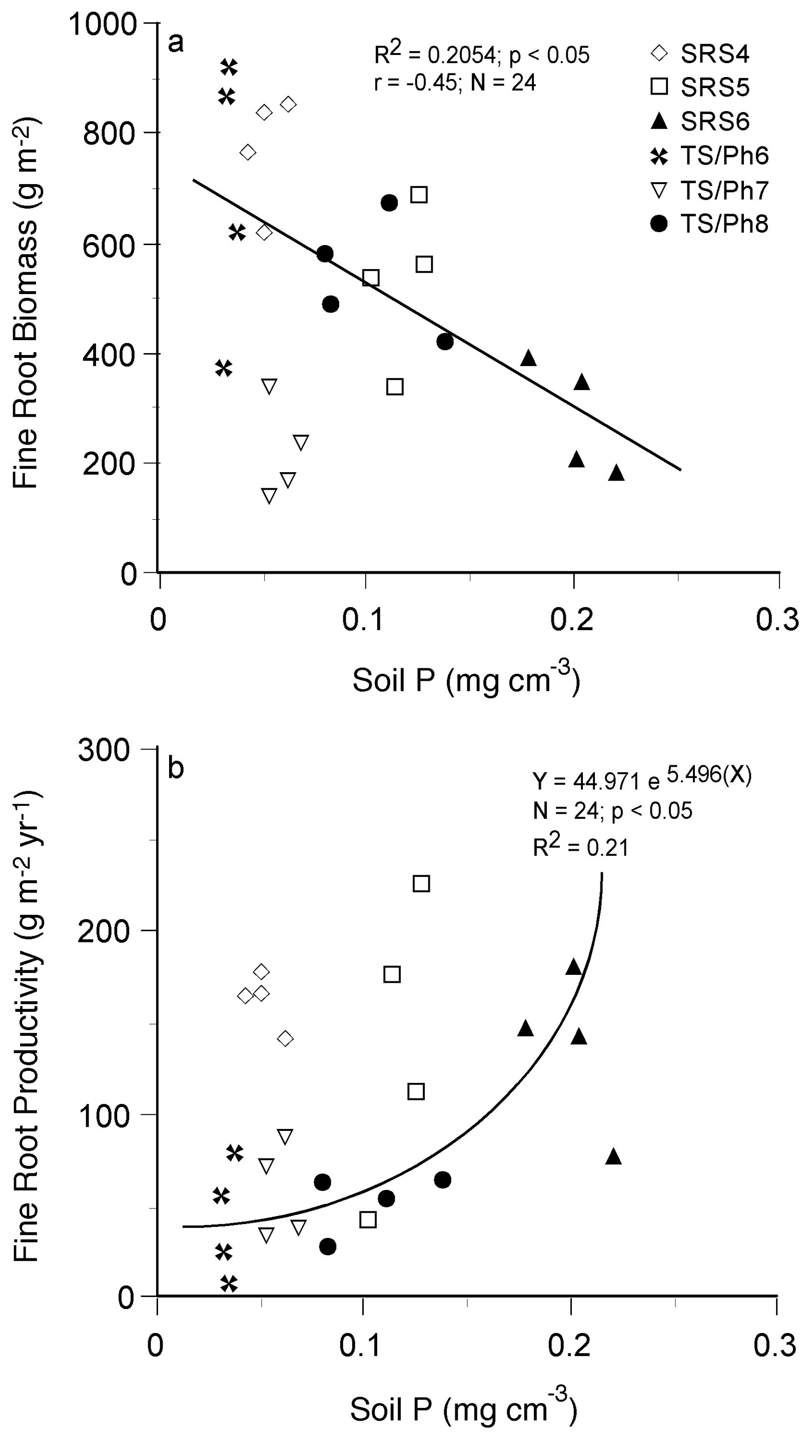


Fig 1.17. (a) Linear relationship between fine root biomass and soil P concentrations in mangrove forests of Everglades National Park. Standard parameters of the linear model are indicated. (b) Nonlinear relationship between fine root productivity and soil P concentrations in mangrove forests of Everglades National Park. Standard parameters of the exponential model are indicated

2. Organic Matter Dynamics

Mangrove Group (R. Twilley et al.)

Foliar $\delta^{13}C$ ratios exhibited a range from -24.6 to –32.7‰, and multiple regression analysis showed that 46% of the variability in mangrove $\delta^{13}C$ composition could be explained by the differences in dissolved inorganic nitrogen, soluble reactive phosphorus, and sulfide porewater concentrations. ^{15}N discrimination in mangrove species ranged from –0.1 to 7.7‰, and porewater N, salinity, and leaf $N:P_a$ ratios accounted for 41% of this variability in mangrove leaves. The increase in soil P availability reduced ^{15}N discrimination due to higher N demand. Scrub mangroves (≤1.5 m tall) are more water-use efficient, as indicated by higher $\delta^{13}C$; and have greater nutrient use efficiency ratios of P than do tall mangroves (5 to 10 m tall) exising in soils with greater P concentration. The high variability of mangrove $\delta^{13}C$ and $\delta^{15}N$ across these resource and regulator gradients could be a confounding factor obscuring the linkages between mangrove wetlands and estuarine food webs. These results support the hypothesis that landscape factors may control mangrove structure and function, so that nutrient biogeochemistry and mangrove-based food webs in adjacent estuaries should account for watershed-specific inputs.

Soil Biogeochemistry Group (R. Chambers et al.)

SRS soils generally are higher in organic content and grade from low to high bulk density along the gradient from freshwater to the coastal ocean. Concomitantly, soil phosphorus (P) increases along the SRS transect and is closely correlated with bulk density (Figure 2.1). Given that the suspected source of elevated P is carbonate-bound P derived from marine sediments (a source confirmed by measurement of P-rich carbonates deposited during Hurricane Wilma during FCE-LTER 1), the gradient in soil phosphorus associated with both bulk density and proximity to the coastal ocean along the SRS transect is in sharp contrast to the pattern observed along the TS transect. The correlation between bulk density and soil P along the TS transect is not significant (Figure 2.1); further, the carbonate-rich sediments all along the TS transect are relatively low in soil phosphorus. With the proposed increased delivery of freshwater through Shark River Slough, increased inputs of low-nutrient freshwater should enhance oligotrophy by decreasing sediment and phosphorus deposition within the ectone.

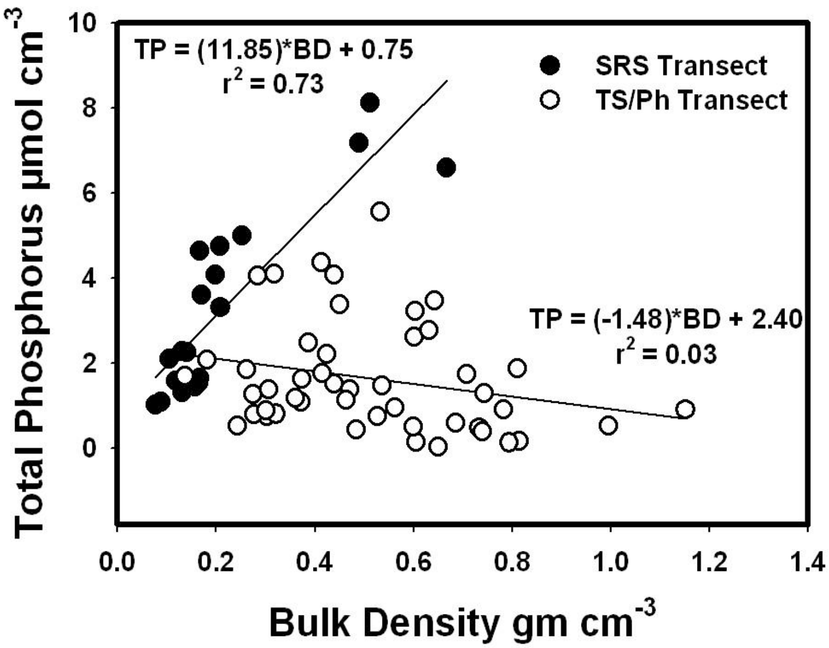


Figure 2.1. Relationship between soil bulk density and total phosphorus along Shark River Slough (SRS) and Taylor Slough (TS/Ph) transects (data from 2008). synoptic soil sampling).

Paleoecological and soil accretion studies (C. Saunders et al.)
Evidence of macrofossils from soil cores (Figure 2.2) collected along ridge-to-slough transects throughout Shark Slough and WCA-3B have demonstrated deeper water conditions and habitats currently dominated by sawgrass and spikerush were previously dominated by water lily species. These methods demonstrate the utility of using macrofossil (mainly seeds and plant fragments) to delineate past habitat boundary shifts and their potential impacts on soil formation.

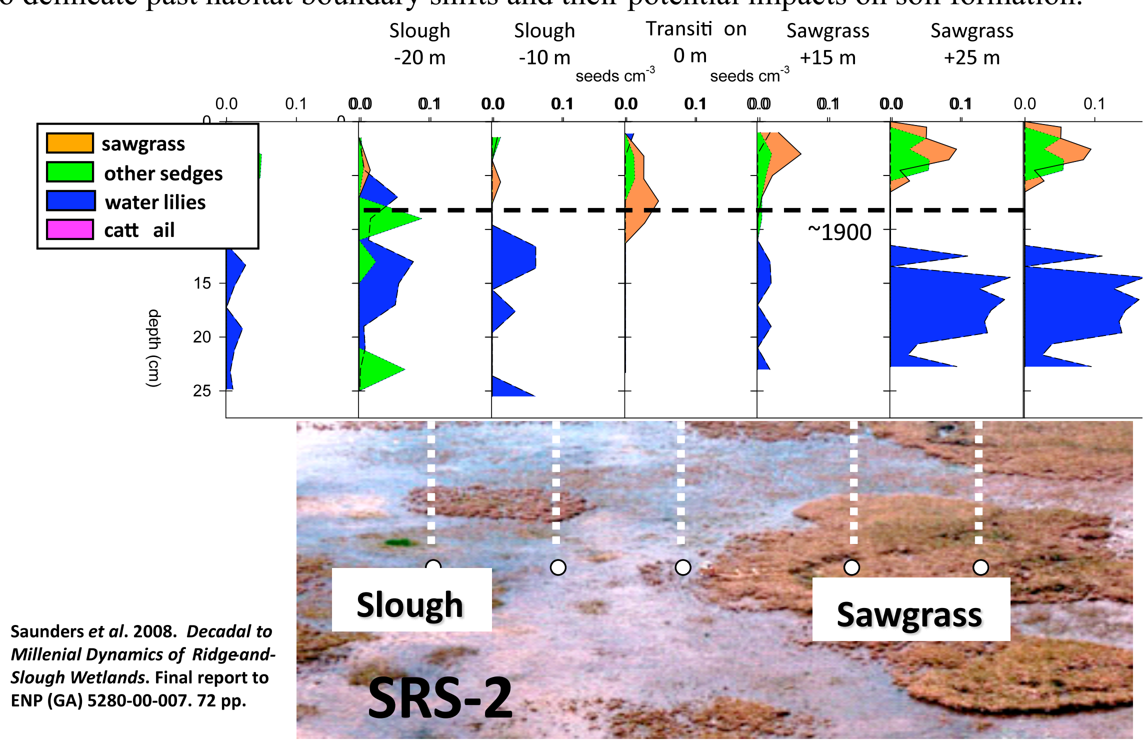


Figure 2.2. Macrofossil profiles taken along a 45 m transect spanning the shallow slough (dominated by spikerush) and sawgrass community at permanent FCE LTER site SRS-2.

The literature review of Everglades soil accretion studies, based on radiometric dating, is still in progress, but our preliminary results show that landscape variation in accretion rates show a correspondence with the landscape variation in soil loss based on repeated surveys over the 20th century (Figure 2.3). Soil accretion data compiled for Shark Slough thus far also indicates that in the SRS-3 conceptual landscape, accretion in deep sloughs has been outpacing sawgrass accretion, potentially reflecting a loss in microtopography.

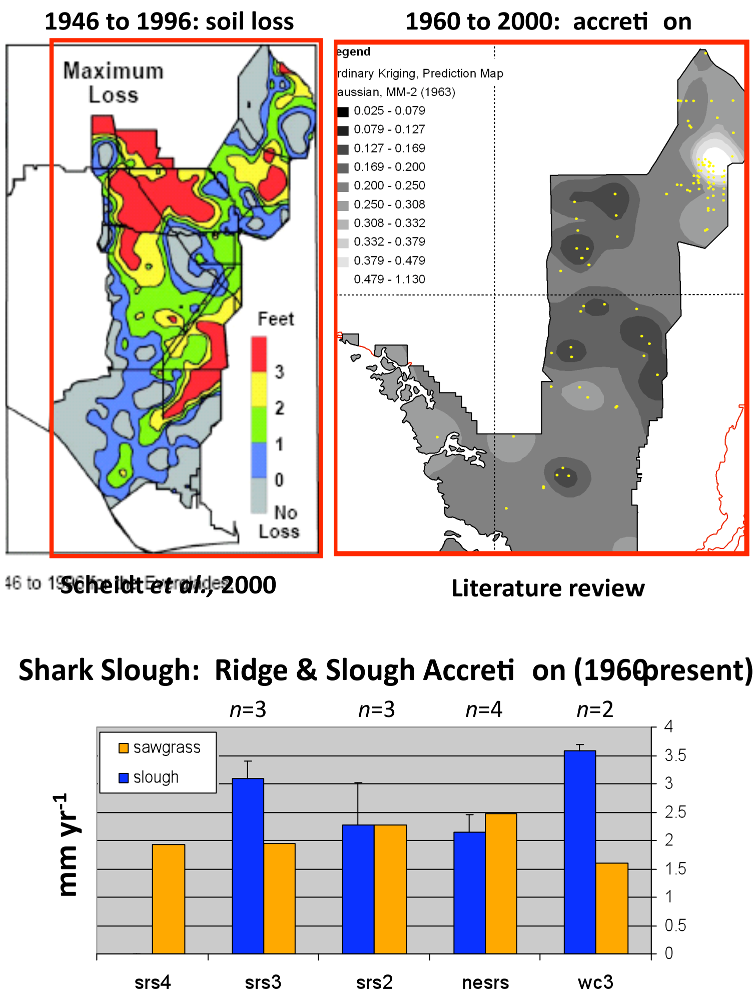


Figure 2.3. (Top panels) Spatial variation in soil loss from 1946 to 1996 documented by Scheidt et al., 2000 compared with spatial variation in soil accretion based on radiometric dating (210Pb and 137Cs) of soil cores taken throughout the Everglades. (Bottom panel) Literature review data specific to ridge and slough accretion rates in Shark Slough, from upstream (WCA-3) down to SRS-4 (no slough accretion rates are measured at SRS-4).

Organic Geochemistry Group (Jaffé et al.)

Our data suggest that some lipid biomarkers such as the C20 highly branched isoprenoid seem to be produced by cyanobacteria and as such might be applicable as a marker for such organisms in floc when pigments are no longer usable for chemotaxonomic purposes. With regards to floc reactivity, both freshwater marsh and mangrove floc seemed to be highly reactive to UV-Visible irradiance resulting in significant photo-dissolution of this detrital matter.

As shown below, DOC levels after several days of exposure increased by about a factor of 10. As such, floc may be an important source of DOM in the Everglades ecosystem. This process is under further investigation!

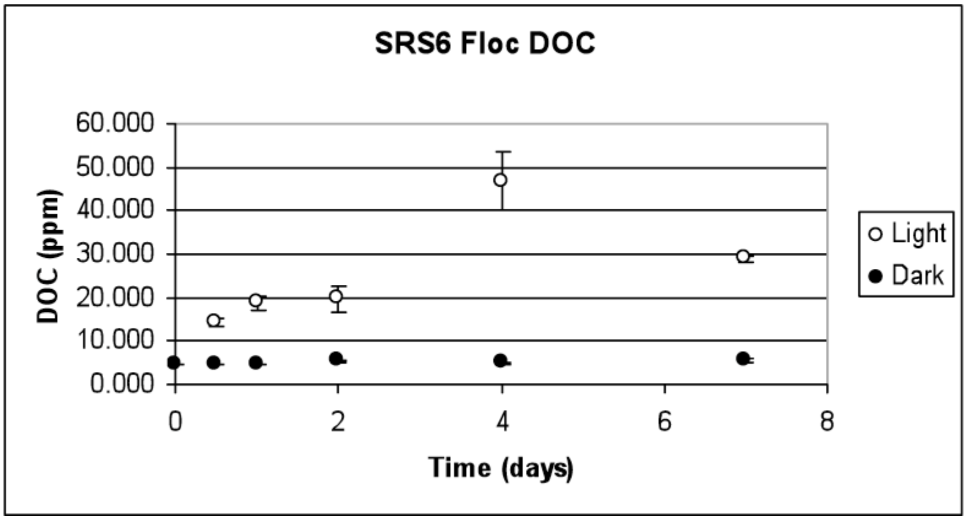


Figure 2.4. Example of photo-induced dissolution of floc under solar simulation for samples collected at a fringe mangrove site (SRS6).

The data collected on DOM suggest that there is significant exchange of DOM between surface and groundwater for both locations, but that fringe areas of the Bay seem mostly influenced by higher plant/mangrove derived DOM while only the central Bay was primarily influenced by OM mainly derived from seagrass communities, however, with a strong 'terrestrial' signature associated to it. Fringe areas in the Florida Keys seemed optically similar to those in the Taylor Slough and mangrove areas as such are likely influenced by local higher plant, terrestrial vegetation including mangroves.

3. Biogeochemical Cycling

Microbial Dynamics
We have noticed an overall decline in bacterial production since beginning fall of 2005 with no statistical decline in bacterial numbers. These changes seem related to hurricane impacts of extremely active 2005 season.

Biogeochemical Cycling
Upstream/downstream sampling of mangrove ecotone - We see considerable differences in water quality and constituent concentrations between TS/Ph 6 & TS/Ph 7 and across samplings, indicating strong spatial and seasonal controls on water quality and materials exchange in this region. During 2008 and 2009 samplings, SRP was low and averaged 0.07 µM at both sites. This is expected during the wet season, when flows are predominantly from the oligotrophic Everglades. Overall, TP, SRP, TSS, salinity, and pH were higher near the mouth of the river (TS/Ph 7) and seemingly highest during the dry season or the transition from the wet to the dry season. Within each sampling, we also saw noticeable differences in water quality and nutrients as a result of wind forcing and precipitation events that affected salinity, temperature, pH, and DO concentrations at these sites. These trends indicate processing of materials at the landscape level, as concentrations increase or decrease from one end of the river to the other (e.g., significant DOC increase from TS/Ph 6 to TS/Ph 7 in August 2008) or the ratios of

inorganic:total nutrients change from one end to the other (e.g., P in May 2009). The former reflects a mangrove source of DOC during the wet season, while the latter reflects a possible transformation of organic P to inorganic P or a new source of inorganic P at the lower end of the river during the dry season.

Sediment core flux studies - In order to evaluate the role of season and surface water quality in affecting benthic nutrient (N and P) exchange across lower Taylor Slough, we have conducted core incubation experiments for the past two years on control cores and cores that have enhanced P availability in the water column. Seasonal experiments have included wet season, dry season, and wet-dry transition incubations in each year and cores collected at TS/Ph 7b and nearby locations. These other sites include: Taylor River Pond 1 (pond 1), West of Taylor River mouth in Little Madeira Bay, and East of Taylor River mouth in Little Madeira Bay. The latter two sites were selected as a way to consider the different bottom type and water chemistry found in each. In total, all sites represent the range of soils and sediments (peat soil, marl/floc, and carbonate mud) throughout the lower mangrove ecotone in Taylor Slough that may exhibit different patterns in benthic fluxes of nutrients.

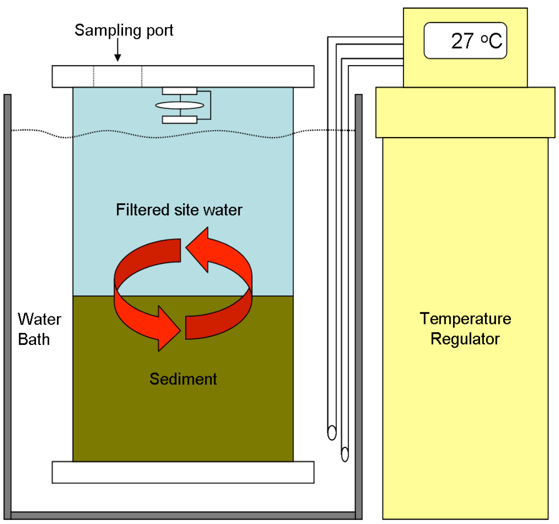


Figure 3.1. Illustration of core incubation scheme used to measure nutrient exchange along the Taylor River mangrove ecotone. The photo on the right is of a set of sediment cores collected from a mangrove pond near TS/Ph-7 (Pond 1).

In each incubation (see Figure 3.1), we measure initial dissolved oxygen (DO) and take water samples for analysis of nutrients and DOC. At the conclusion, (approximately 4 hours), we measure the final DO concentration and take final samples for nutrients and DOC. Significant DO removal has occurred at all sites indicating net heterotrophy in the peat-dominated soils and sediments (Figure 3.2). Consistent $NO_3 + NO_2$ uptake and NH_4 release from soils and sediments suggest denitrification via microbial activity in addition to ammonification of organic material contributing to release of reduced inorganic nitrogen. DOC consumption supported this. In control conditions, we have observed weak, but significant PO_4 uptake from the water column to the sediment. Enhanced PO_4 uptake by sediments was found after the addition of 1 μM of PO_4 in the water column (Figure 3.2). Intensified PO_4 removal from water column may be due to the stronger gradient between the water column and sediment or may have contributed to microbial demand for this limiting element. Leading up to our most recent sampling (October 2008), we observed a gradual increase in the rate of P uptake in the P-addition treatment at each site over time—especially at TS-Ph 7b and Eastern Little Madeira Bay. The cause of this is currently unknown, but we hypothesize that it may be a result of recent storm activity that affected soils and sediments in this region of the Everglades. Data from October 2008 showed that this trend ceased at all sites and reverted back to levels observed at the beginning of the study.

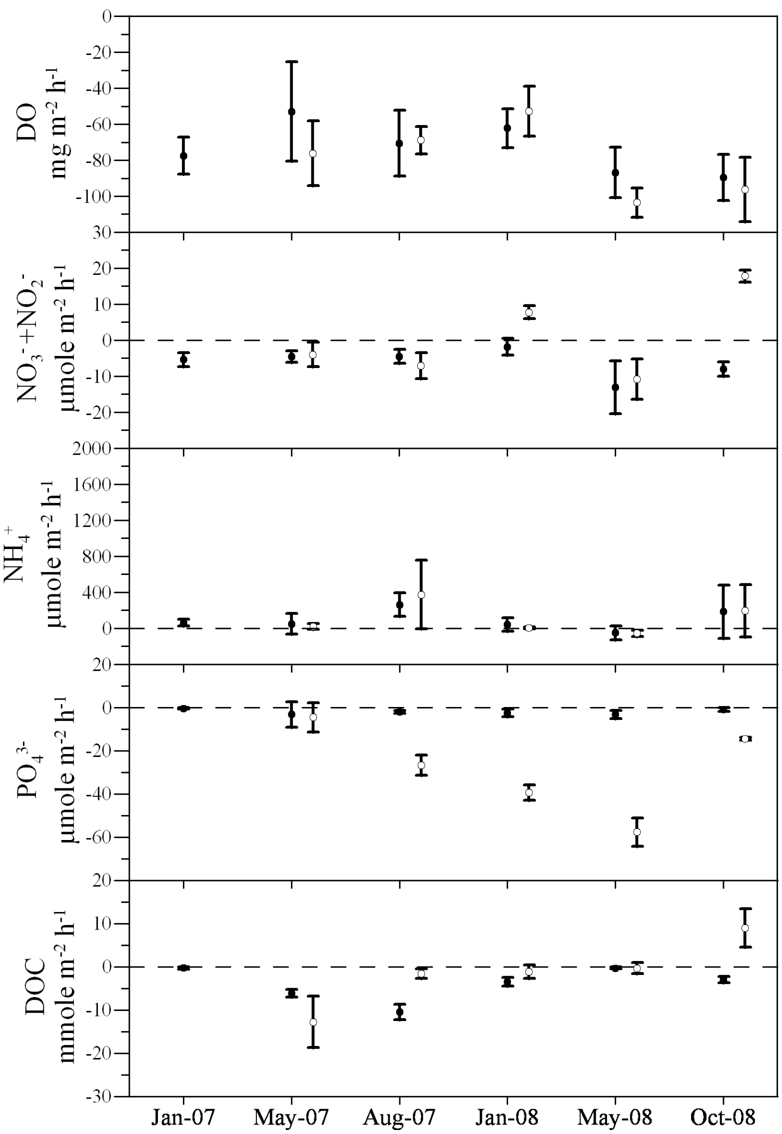


Figure 3.2a. Plot of mean fluxes (±SD) of DO, NO_3+NO_2, NH_4, SRP, and DOC from soil cores collected at TS-Ph 7b. ● as Control, and ○ as P addition. N = 10 in Jan. 2007 and 5 thereafter.

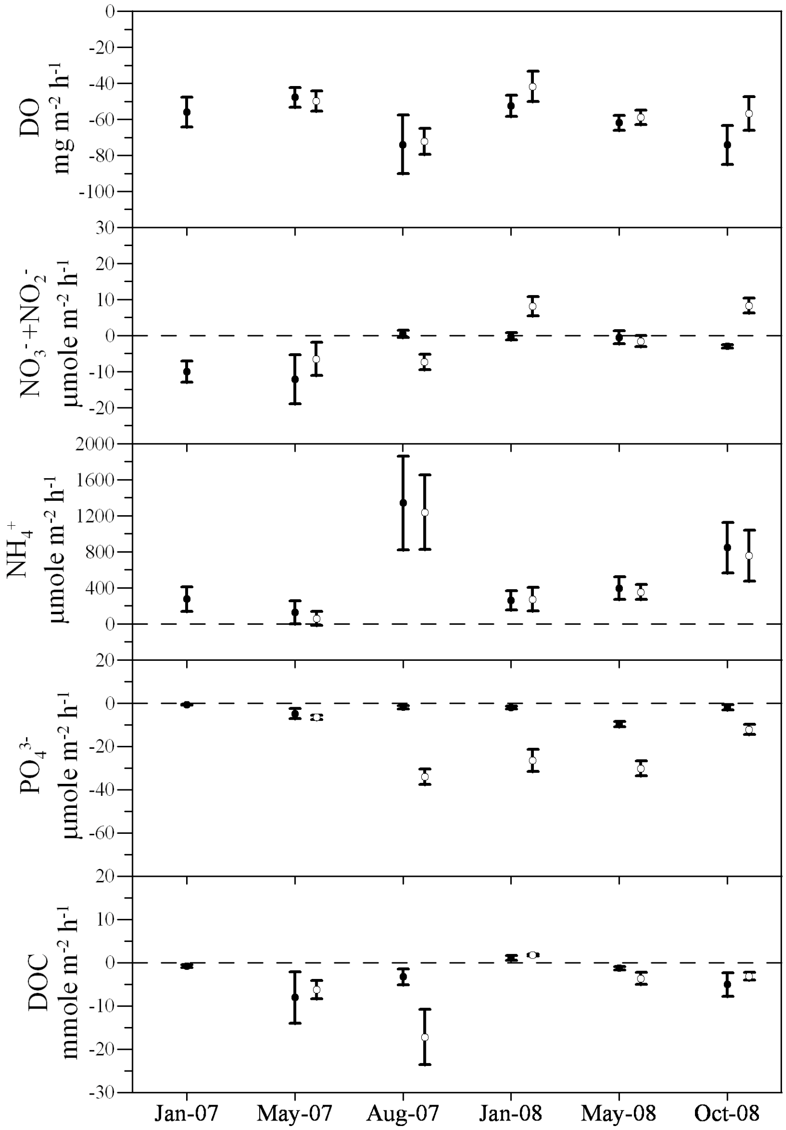


Figure 3.2b. Plot of mean fluxes (±SD) of DO, NO_3+NO_2, NH_4, SRP, and DOC from sediment cores collected at Pond 1. ● as Control, and ○ as P addition. N = 10 in Jan. 2007 and 5 thereafter.

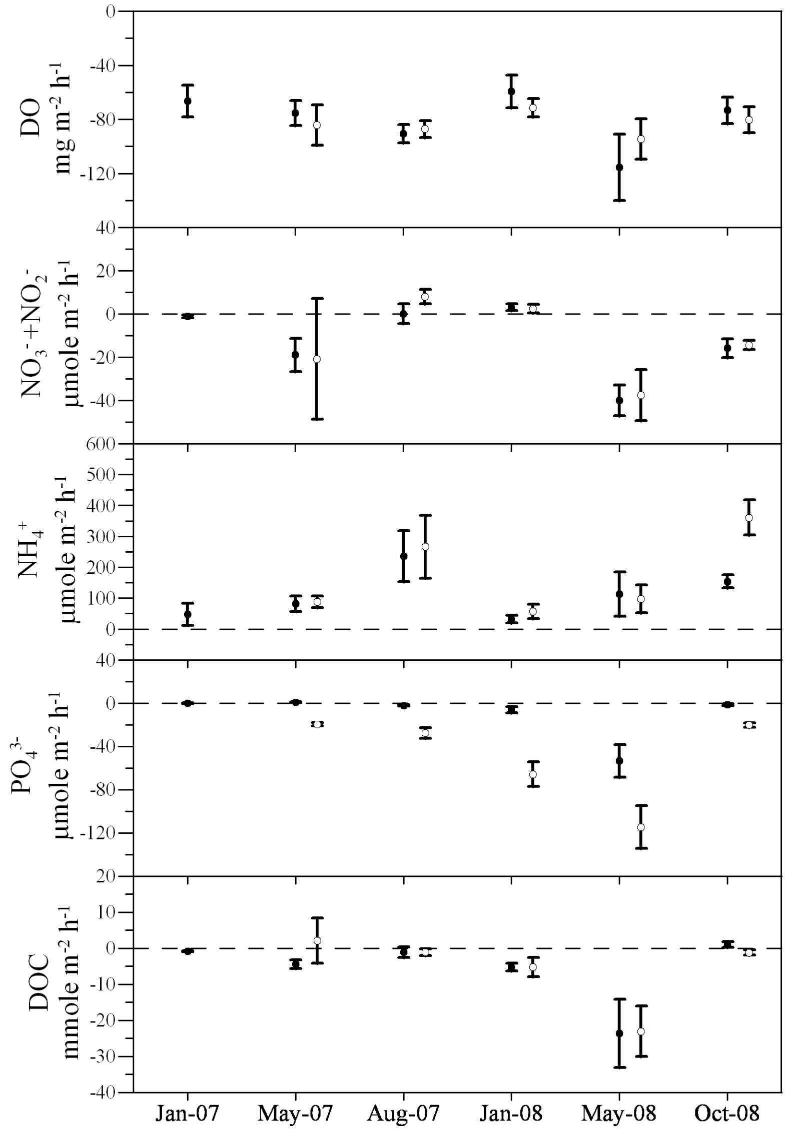


Figure 3.2c. Plot of mean fluxes (±SD) of DO, NO_3+NO_2, NH_4, SRP, and DOC from sediment cores collected at Eastern Little Madeira Bay. ● as Control, and ○ as P addition. N = 10 in Jan. 2007 and 5 thereafter.

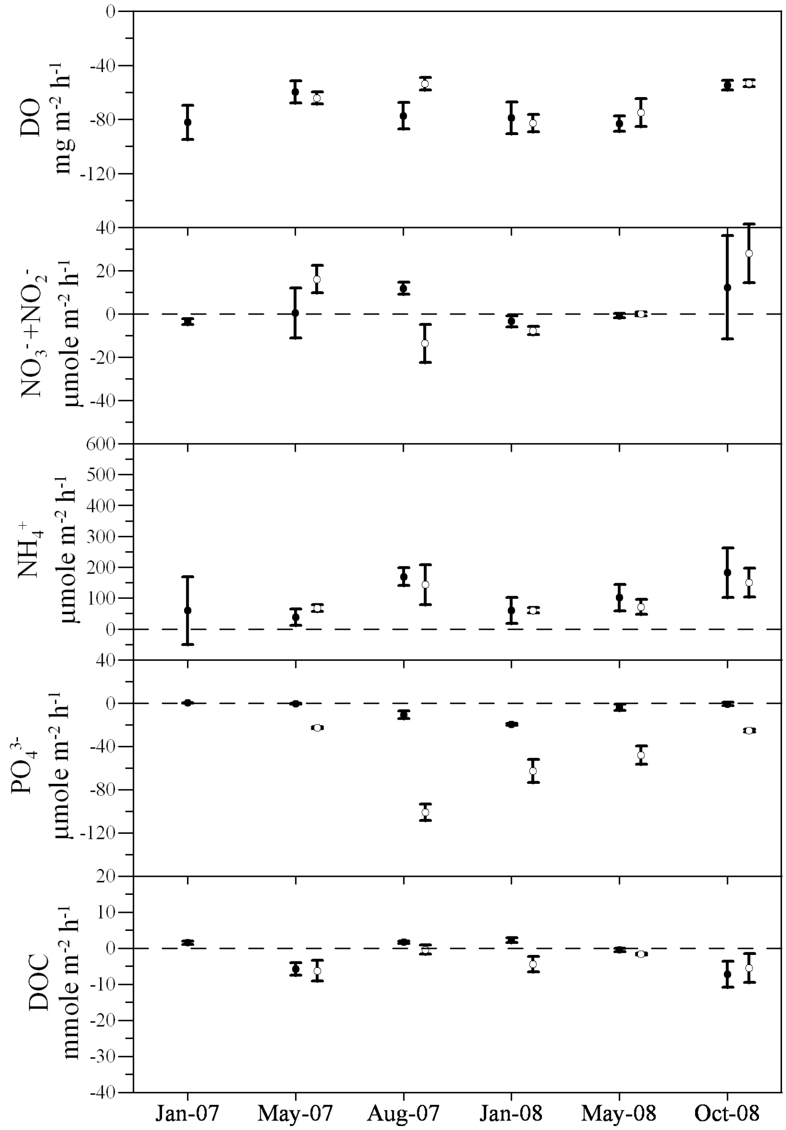


Figure 3.2d. Plot of mean fluxes (±SD) of DO, NO_3+NO_2, NH_4, SRP, and DOC from sediment cores collected at Western Little Madeira Bay. ● as Control, and ○ as P addition. N = 10 in Jan. 2007 and 5 thereafter.

4. Trophic Dynamics and Community Structure

Spatiotemporal dynamics in the fish and macroinvertebrate community in the Shark River (SRS)

Our five years of sampling show that the upper Shark River estuary is inhabited by a diverse and dynamic fish community composed of transient marsh species, resident estuarine species, and transient marine taxa (e.g., 37 fish species were collected via electrofishing since 2004, Fig. 4.3). Patterns of fish abundance vary markedly yearly and seasonally, and are closely tied to marsh hydrology upstream (Fig. 4.4), as well as to local abiotic conditions in the estuary, particularly salinity and dissolved oxygen.

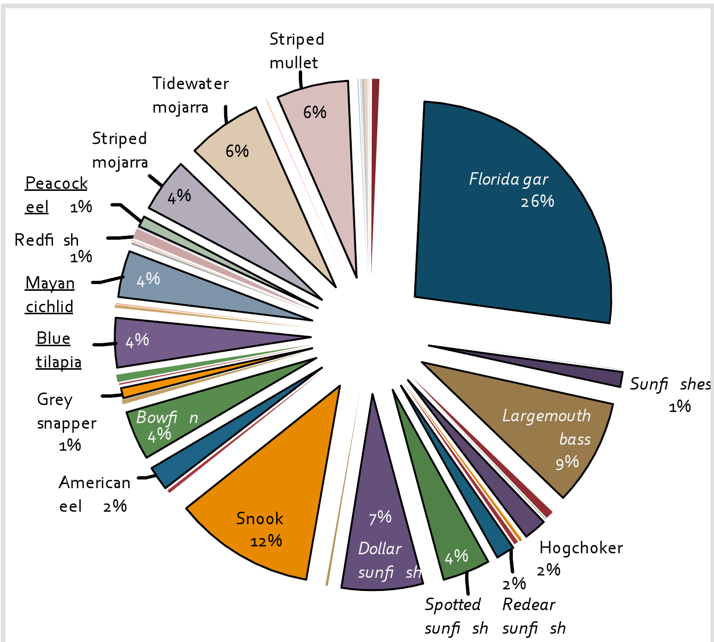


Figure 4.3. Species composition in electrofishing samples across all sites and sampling years (marsh fishes are shown in italics, estuarine/marine taxa in regular text, and non-natives are underlined).

Catch per unit effort (CPUE) generally peaked in the drier months of sampling, reflecting a pulse of freshwater taxa into creeks as marshes upstream dry (Fig. 4.5). These marsh species that move into the estuary remain in the upper most sites, perhaps limited in distribution by the higher salinity of the estuary in the dry season (Fig. 4.4). Along with the increases in freshwater fish taxa (both predators and prey) in the upper estuary, we also detect increases in the abundance of marine predators (i.e., snook, tarpon and redfish) that are synchronous. The timing of these increases in fish abundance is closely tied to the pattern of water recession in upstream marshes (Fig. 4.4), and may have important implications for marsh prey availability and thus to wading bird foraging and nesting success. Fish abundance generally peaked early in the dry season in years where marshes wet season levels were lower and they dried earlier (2004-05, 2006-07, and 2007-08); whereas in years with rather wet seasons (i.e., 2005-06 and 2008-09; shown in shades of green in Fig. 4.5) catches peaked later.

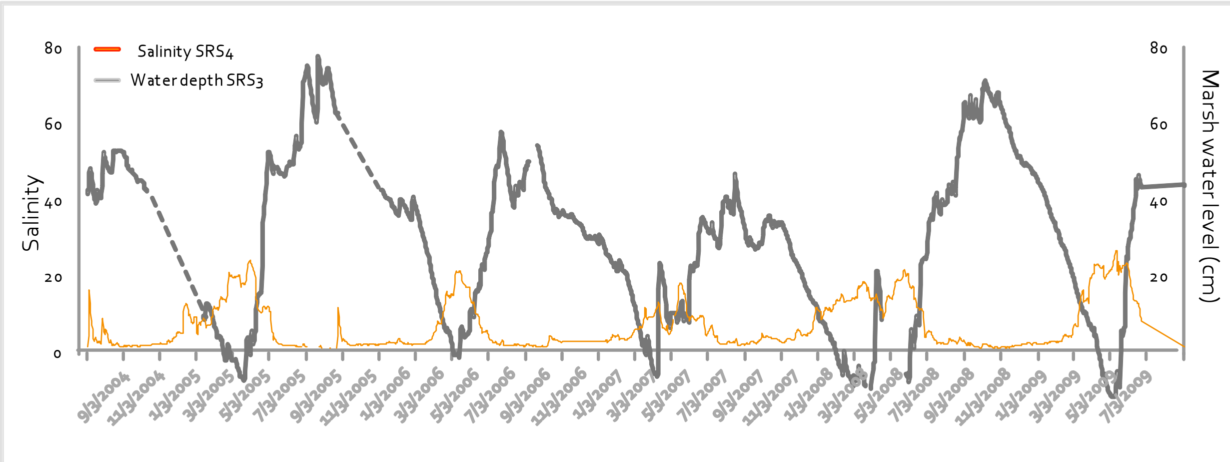


Figure 4.4. Daily salinity at SRS3 and daily marsh water level (cm) at SRS4 plotted over the period of the study (9/2004 to 7/2009). Data are from hydrological stations SH1 and SH2 (USGS).

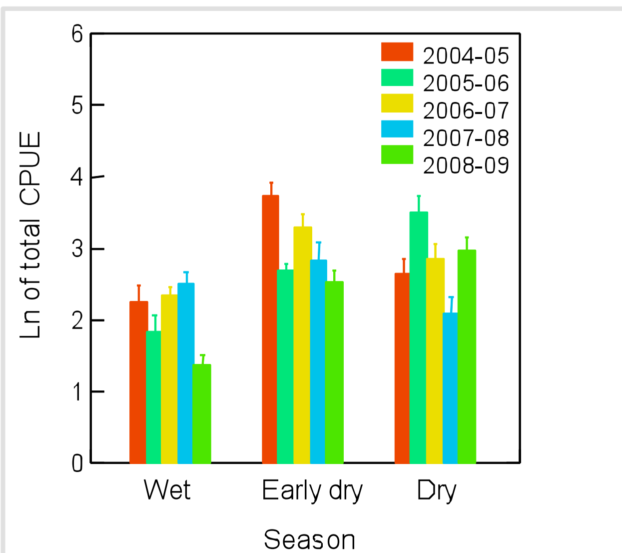


Figure 4.5. Total catch per unit effort (CPUE) in electrofishing data plotted as a function of season and sampling year.

In these dry years, high catches seen early in the dry season are typically followed by decreases in fish abundance, suggesting that some of that fish biomass that moves intro creeks in response to early marsh dry-down may be readily consumed by piscine predators, instead of remaining on the marsh surface where it may be available to wading bird predators. This is of critical importance to Everglades restoration since a major performance measure for restoration is wading bird nesting success, particularly in the historical coastal mainland rookeries in the vicinity of our SRS sites.

Our minnow trapping throughout the estuary showed that five palaemonid shrimp species occur throughout, and their distribution and abundance varies seasonally. CPUE was dominated by *P. paludosus,* and the distribution of this common marsh species expanded significantly downstream at low salinities in the wet season. At the downstream end of the estuary, composition was dominated by *Palaemon floridanus,* while multiple species co-occurred in the mid-estuary (i.e., Tarpon Bay). Salinity and other physiochemical variables had little explanatory power when examining variation in CPUE. We suspect this is due to their broad broad salinity tolerances. Stable isotope analyses suggest that these shrimp species have similar functional roles, but have varying food resources throughout the estuary particularly in the dry season. Patterns of N and C enrichment match those detected by previous studies, which are thought to result from variation in freshwater input and primary production across the estuary.

In summary, our data suggest that the seasonal hydrology of the Everglades ecosystem is altering functional diversity both temporally and spatially in the Shark River Estuary, as well as the strength and magnitude of predator-prey interactions among fishes in the upper estuary. The effects of this variability on ecosystem function are not fully understood and deserve further study.

Factors influencing movements and trophic interactions of large predators in the Shark River Slough

We have discovered several surprises in our investigations of the trophic position of large predators. First, alligators appear to occupy a lower trophic position that we had originally thought and feed at a trophic level considerably below those occupied by the smaller-bodied snook, Florida gar, and bull sharks (Figure 4.6). Both bull sharks and alligators show a considerable degree of individual specialization in their diets. Analysis of isotopic signatures of slow-turnover tissues reveals that individual bull sharks may specialize in feeding in marine food webs, estuarine/freshwater food webs, or a mix of the two (Figure 4.7). All three foraging tactics are found throughout the SRS – up to 25+km upstream (Figure 4.8). Analysis of rapid-turnover tissues suggests that these specializations are stable through time. Analysis of bull shdark movements suggests that there is considerable individual and inter-annual variation in residence times and short-term movements. Analyses are ongoing.

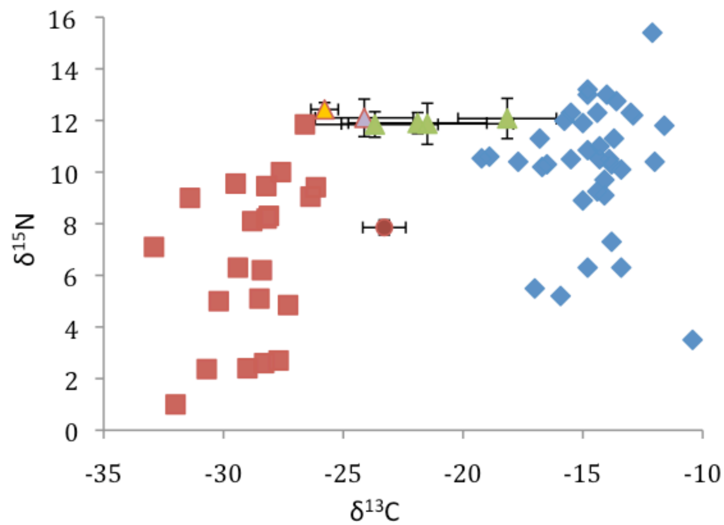


Figure 4.6. Isotopic signatures of representative freshwater and estuarine taxa (red) and marine taxa (blue) relative to bull sharks captured from the river mouth to upstream (green triangles), Florida gar (orange triangle), snook (purple triangle) and alligators (red circle).

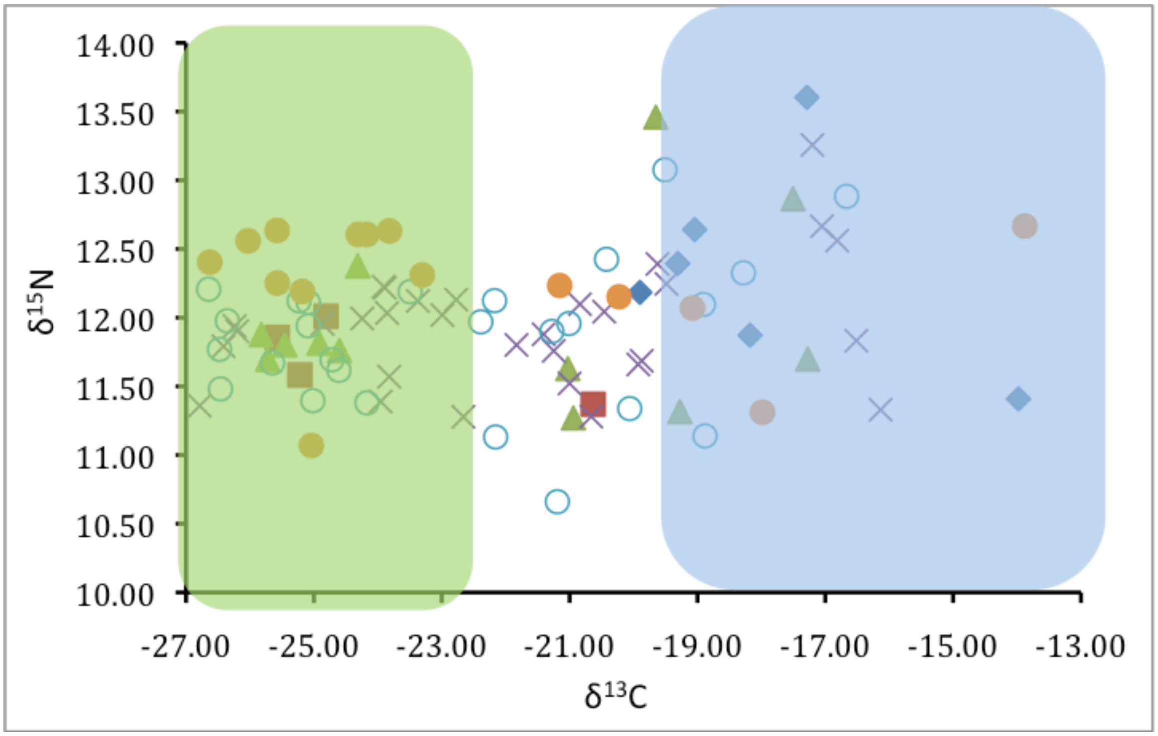


Figure 4.7. Individual variation in isotopic signatures of juvenile bull sharks. Sharks show relatively marine and freshwater/estuarine signatures regardless of capture location. Different symbols represent sharks captured near the river mouth in dry (diamond) and wet (squares) seasons, at SRS5 (triangles), in Tarpon Bay (X), Otter Creek (open circles) and Rookery Branch (closed circles).

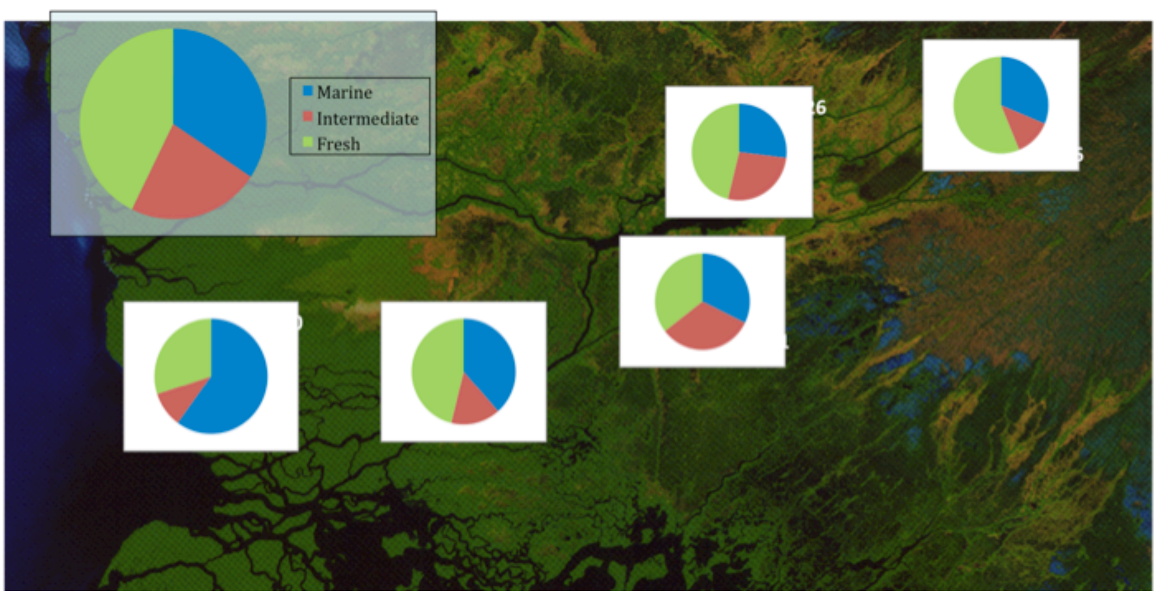
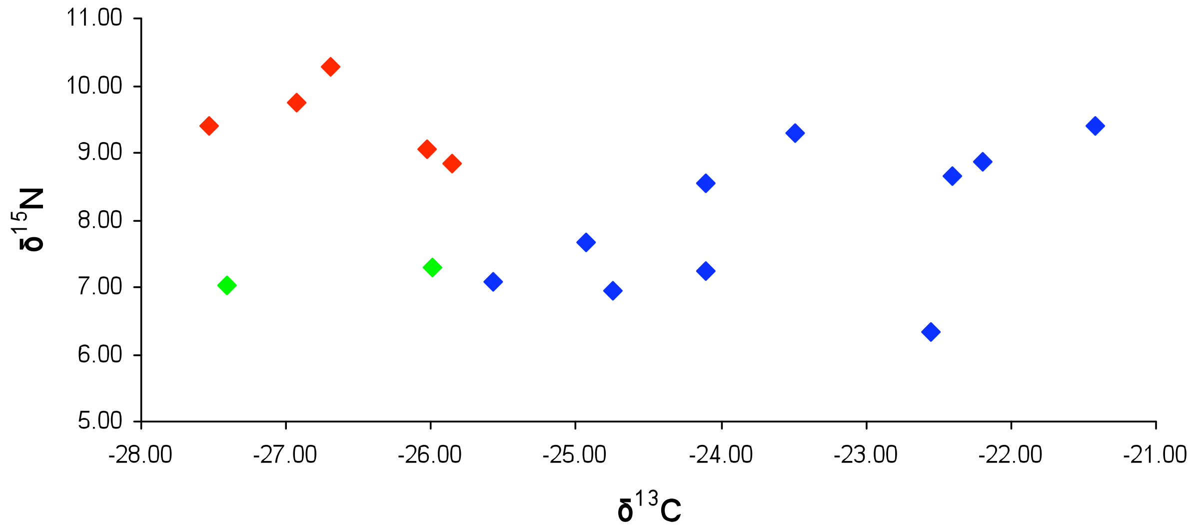


Figure 4.8. Distribution of bull shark foraging patterns within the Shark River Estuary.

For alligators, trophic interactions appear to be related to movement tactics. Individual alligators appear to adopt either a residential or "commuting" movement tactic. Residential alligators remain in the same basic region (either upstream or mid-estuary) throughout the year while commuters will remain upstream during the dry season but during the wet season make numerous trips to the mouth of the river. Over a three day period, they commute from upstream areas (~18km from the mouth of the river) to the Gulf of Mexico and back and then repeat the movement several days later. Isotopic signatures of commuting individuals suggest a greater reliance on marine food webs than those that remain resident upstream.



Movements of gar and snook are less dramatic than those of bull sharks and alligators, and stable isotopic analyses suggest much less specialization in feeding with an almost exclusive reliance on freshwater and estuarine food webs (Figure 4.6).

Fish and invertebrate communities of upstream marshes.

We have found that applying dynamic targets, based on abundance data gathered over a wide range of environmental conditions, are critical for predicting how marsh communities will respond to water management strategies.

Community dynamics of Florida Bay.

At a eutrophic site, nutrient addition did not strongly affect food web structure, but at a nutrient-poor site, enrichment increased the abundances of crustacean epiphyte grazers, and the diets of these grazers became more varied. Benthic grazers did not change in abundance, but shifted their diet away from green macroalgae + associated epiphytes and towards an opportunistic seagrass (Halodule wrightii) that occurred only in nutrient addition treatments. Benthic predators did not change in abundance, but their diets were more varied in enriched plots. Food chain length was short and unaffected by site or nutrient treatment, but increased food web complexity in enriched plots was suggested by increasingly mixed diets. Strong bottom-up modifications of food web structure in the nutrient-limited site and the limited top-down influences of grazers on seagrass epiphyte biomass suggest that in this system, the bottom-up role of nutrient enrichment can have substantial impacts on community structure, trophic relationships, and, ultimately, the productivity values of the ecosystem.

5. Hydrology

During the geochemical and geophysical surveys conducted in both Shark and Taylor Sloughs by the USGS, higher radon activity was observed in the surface water coincident with lower pH values (Fig. 5.1). More acidic surface waters were observed along narrower stretches of the river, reflecting either surface drainage of the acidic wetland soils or groundwater discharge which had an average pH of 6.95. Groundwater discharge could also have been occurring throughout the entire stretch of the river, but dilution may have been obscuring the low pH and radon inputs in the wider channels.

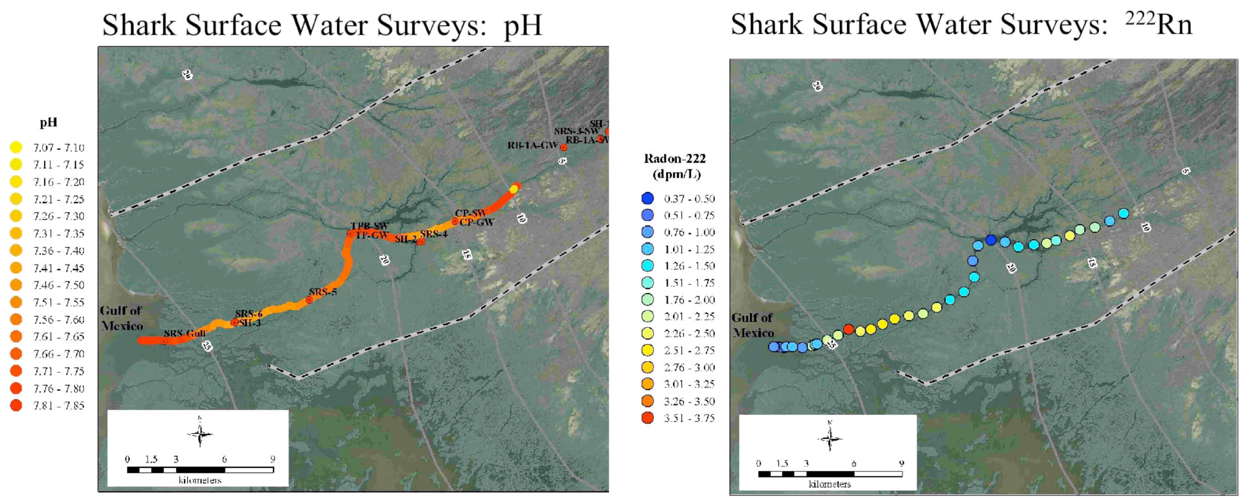


Figure 5.1. Surface water pH (left) and ^{222}Rn (right) activity measured in Shark Slough between May 29, 2009 and April 5, 2009. Higher ^{222}Rn levels tended to co-occur with lower pH values, possibly indicating groundwater discharge.

Surface water radon activity appeared to be partially controlled by tidal variations at both SRS-4 and SRS-6. At SRS-4, surface water radon activities increase during the flood-tide following the lowest-low in the tidal cycle and reach their highest values (~16 dpm/L) at the following low-high tide. During the subsequent tidal modulations, the radon activity decreased to a near constant value of 12 dpm/L. At SRS-6 radon activities increased during the flood tide following the lowest-low, but unlike at SRS-4, activities remained elevated during the subsequent ebb and flood tides. It was not until the highest high tide that radon activities were suppressed back to approximately 10 dpm/L. The highest discharge rates (~ 25 cm d-1) lagged low tides by approximately 4 hrs. Groundwater inputs to the system were also qualitatively indicated by short-lived radium isotopes. From the samples collected, fresh surface water (RB-1A SW), fresh groundwater (SH-1 GW), and saline gulf water (SRS-Gulf) end-members could be established. Samples collected from surface water sites SRS-5 and SRS-6 were elevated relative to the conservative mixing line established between fresh and saline surface water. This suggested that at salinities between 20 and 35, there was an additional input of Ra to the surface water. Higher $^{223,224}Ra$ activities from groundwater near these sites further suggested that this source could be a groundwater input.

We further examined the behavior of select metals and nutrients within the groundwater mixing zone along the Shark River. Calcium-enrichment was observed in all brackish ground waters relative to mixing fresh groundwater and Gulf of Mexico sea water, suggesting the dissolution of the carbonate aquifer was an important geochemical process within this subterranean estuary. Dissolution may have also account for a slight enrichment of strontium and phosphate in some of the groundwater samples. Barium demonstrated non-conservative release within the subterranean estuary; however, barium enrichment occurred at a lower salinity (< 10) than does maximum calcium enrichment (15 – 20). Uranium exhibited a non-conservative removal across the large-scale mixing zone. Dissolved iron (Fe) and manganese (Mn) concentrations were fairly constant in all groundwater samples (1.8 and 1.2 μM, respectively) and did not show a systematic source/sink behavior across the salinity gradient. Thus, Fe and Mn redox-cycling may be less influential in this carbonate subterranean estuary than has been typically observed in siliciclastic, redox controlled systems. Similar magnitudes of calcium enrichment and uranium depletion in the surface waters reflected the strong coupling between the surface and ground water system in the ENP.

For the Shark Slough water balance, evapotranspiration (ET) was estimated using a simple net radiation based model (Abteu 2006), and was found to closely track ET values obtained by the FAO-Penman Montieth equation using data from the 4 meteorological towers operated by FCE researchers. Net radiation was found to be similar at the 4 sites (SRS1, SRS2, TSPh1 and TSPH7b), hence permitting the use of the net radiation based model across all of Shark Slough. Preliminary results for the time period between 2002 and 2008 indicate that rain was the largest input to Shark Slough, accounting between 19 and 26% of the total water budget (Table 5.1). The discharge of surface water from Shark Slough to the Gulf of Mexico exceeded the inflow from the S12s and S333 structures each year. The change in water levels across Shark Slough accounted for only 1 – 4% of the annual water budget. The residual term was positive each year, and varied between 16 to 27% of the annual water budget. A positive residual suggested that an additional source of water, possibly groundwater discharge, was needed in Shark Slough to complete the water balance. However, a detailed analysis of the error associated with each of the water balance parameters is needed to assess the relative magnitude of the residual term.

Table 5.1. Components of the annual water budget (2002-2008) for SRS expressed as percentages of the total water budget.

Year	ET %	Rain %	Inflow %	Outflow %	Annual Level Change %	Residual %	Total
2002	32	19	10	18	1	20	100
2003	37	19	15	11	1	17	100
2004	31	20	7	20	1	21	100
2005	27	20	11	22	1	19	100
2006	33	26	6	18	1	16	100
2007	39	20	1	12	1	27	100
2008	31	24	5	14	4	21	99

As part of a CERP RECOVER project with funding from ENP, ACOE, USFWS, and SFWMD, FCE researchers J. P. Sah, M. S. Ross, P. Minchin, S. Saha and K. Bradley investigated long-term water levels in the upper reaches of Taylor Slough. They used multiple linear regression analysis to determine that surface water levels in the upper reaches of Taylor Slough were affected by water pump operations associated with the S332 structures. A precipitation-based-only hydrologic model was developed for water level data obtained prior to the construction of the S332 structures (1961-1980) period. This baseline precipitation-based-only model was then forecasted to estimate water levels during the S332 construction (1980-1999) and S332D construction (2000-2008) periods. The result was that the precipitation-based-only model results predicted significantly lower water levels than were observed in both periods (Fig. 5.2). In both the S332 and S332D periods, the water level in Taylor Slough was strongly related to deliveries from the pumping stations. Water delivery from S332 was relatively low (3.8 million m^3/month) between 1980 and 1991, but delivery significantly increased after 1991 (13.6 million m^3/month), resulting in water levels 20 cm higher in the 1990s than in the 1980s, and, in general, 25-50 cm higher than they would have been in a precipitation driven system. After 2000, even though water was not directly delivered into the slough, as it was during the operation of S332 pumping station, the water level in the slough was 15-40 cm higher than it would have been in a precipitation-driven system, suggesting a strong influence of the S332D system. The effects of this structure were particularly evident in the dry season when seasonal mean water levels at Taylor Slough Bridge (TSB) coincided with the amount of water delivered through S332D (Fig. 5.2). These results indicated that the marl prairies in the upper reaches of the Taylor Slough basin had become wetter in recent years, most likely due to the increased water deliveries from the S332 structures.

Despite the uncertainties in the LSU hydrodynamic model of the mangrove ecotone in Taylor Slough, the model performance was considered satisfactory in capturing the overall salinity patterns and trends in the target model area (Fig. 5.3). The largest uncertainties in the model arose from the unknown overland flow component during the wet season, and from bathymetry errors in the dry season. The model will be further calibrated using time series salinity data collected along Taylor River.

At the TS/Ph-7b transect, monthly surface water salinity varied between 3 and 44 psu between April 2008 and June 2009. During the same period groundwater salinity remained relatively stable between 26 and 32 psu. Close to the river, groundwater and surface water salinities were similar between March and July, suggesting a possible interaction between the two. During the rest of the year, surface water salinity was significantly lower than the groundwater. Further along the transect, away from the river, there was little evidence for groundwater-surface water interactions. Surface water salinity at TS/PH-6b was also variable (1-50 psu). Low salinity values (<5 psu) were observed between Sep. 2008 and Feb. 2009. Groundwater salinities at the two sites located close to the main river channel, tended to be more stable throughout the monitoring period with average salinity values of 22 and 19 psu. Groundwater salinity further from the main river channel tended to be higher with an average of 30 psu.

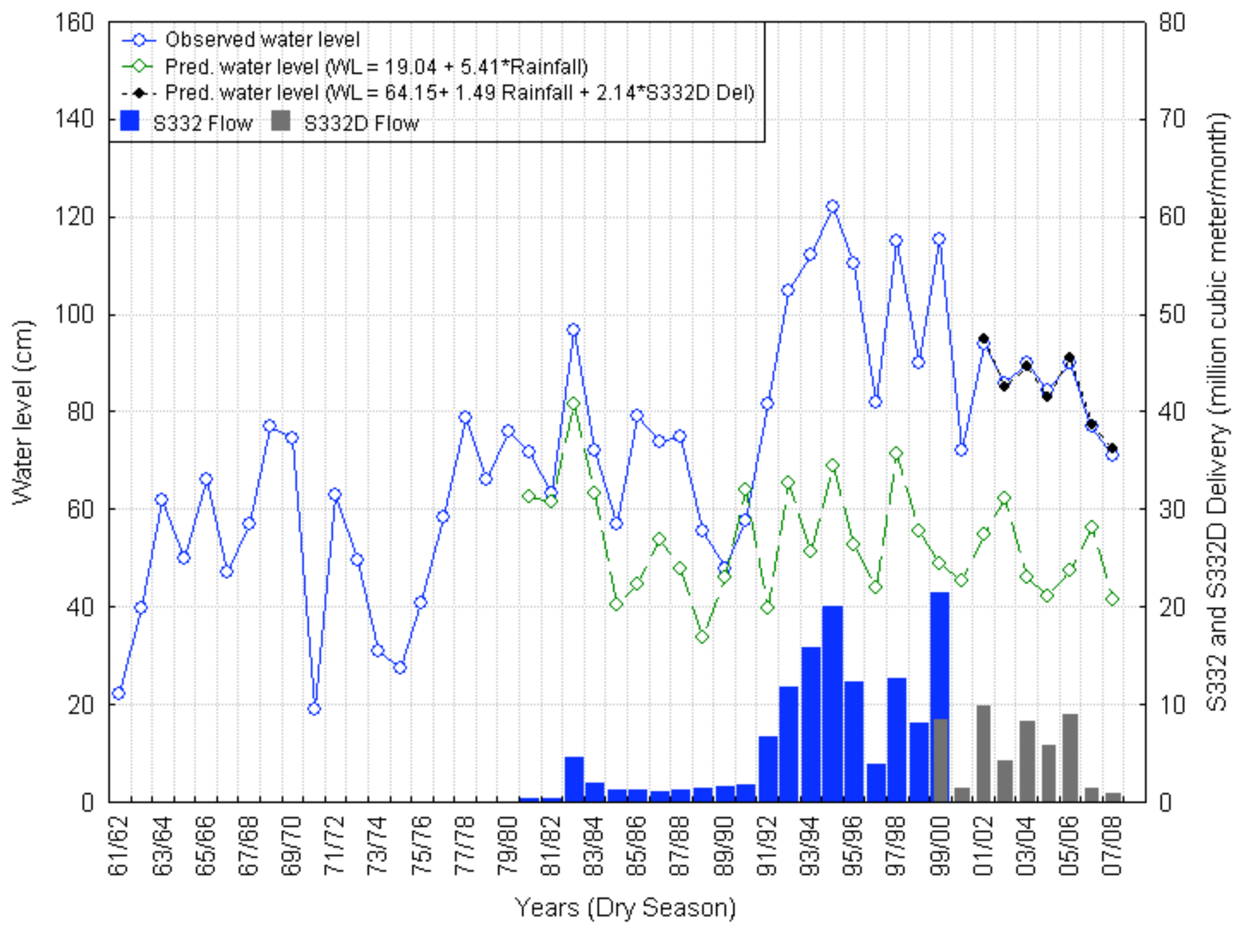


Figure 5.2. Observed and predicted water level at the TSB stage recorder and water flow through S332 and S332D during the 1961-2009 dry seasons.

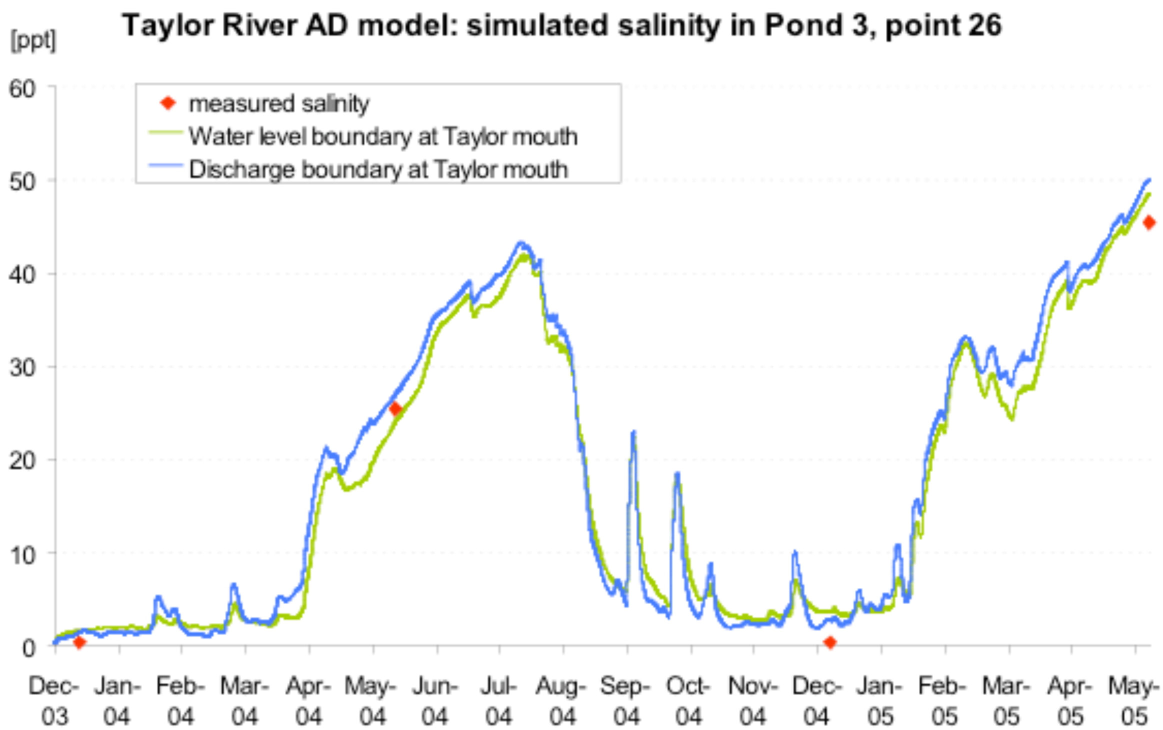


Figure 5.3. Salinity simulation in Taylor River Pond #3 for the period December 2003 – May 2005.

Hydrology Working Group International Findings

A key finding of the Mexico Pacific study was that the contribution of fresh water to each of the lagoons and mangrove regions varied with geomorphology. The proportion of freshwater contribution to the lagoon was highest (>80 %) for a closed-mouth lagoon, and lowest for an open-mouth bay (Fig. 5.4). Surface water in a spring-fed river was made up of about equal contributions of ocean water and fresh water. The results of this research indicated that fresh groundwater, which is increasingly used for local and regional water-supply purposes, could be quite a large contributor of water to some coastal mangrove and lagoons.

Three dominant sources of water were identified as contributing to water in the Celestún estuary during the Spring 2008. These source waters included : 1) seawater (SW) from the Gulf of Mexico; 2) Upper Celestún surface water (UCSW) that discharges to the headwaters of the estuary, and 3) fresh groundwater (GW) (Fig. 5.5). The UCSW was brackish with salinities varying between 19 and 20 psu and may be characterized as a mixture of fresh groundwater and seawater that discharged to the upper reaches of Celestún. Seawater from the Gulf of Mexico had salinity values close to 36 psu while the fresh groundwater had a mean salinity value of 3 psu. Using a 3 component mixing model of strontium and salinity, seawater was determined to be the largest contributor of water to the Celestún estuary was seawater (50%). The remaining 50% was divided between the UCSW (31 %) and fresh groundwater (20%). Nutrient concentrations of nitrate and total phosphorus were found to be highest in the fresh groundwater, and may be responsible for elevated concentrations of these nutrients within the estuary.

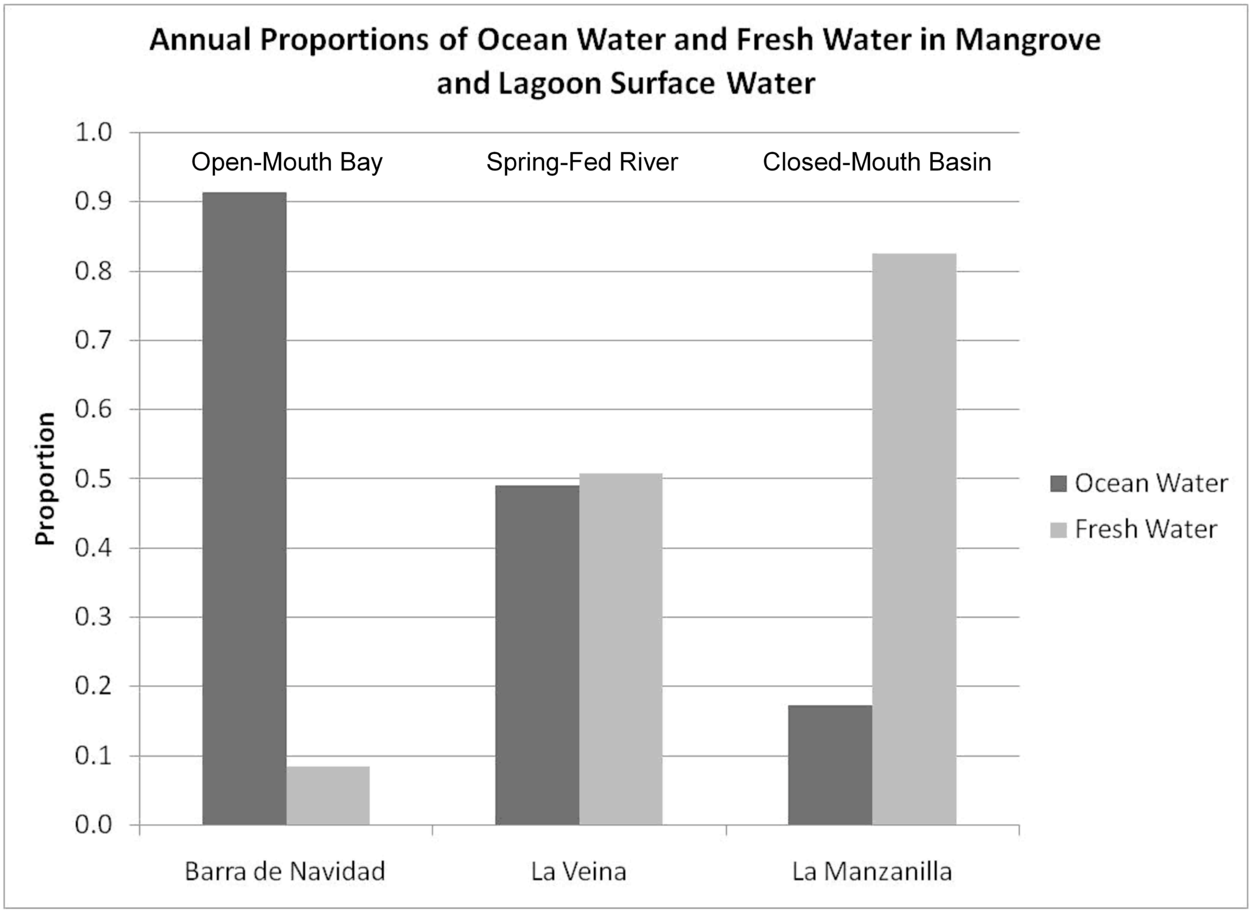


Figure 5.4. The proportions of ocean water and fresh water that contribute to three lagoon and mangrove areas in the central western Pacific area of Mexico.

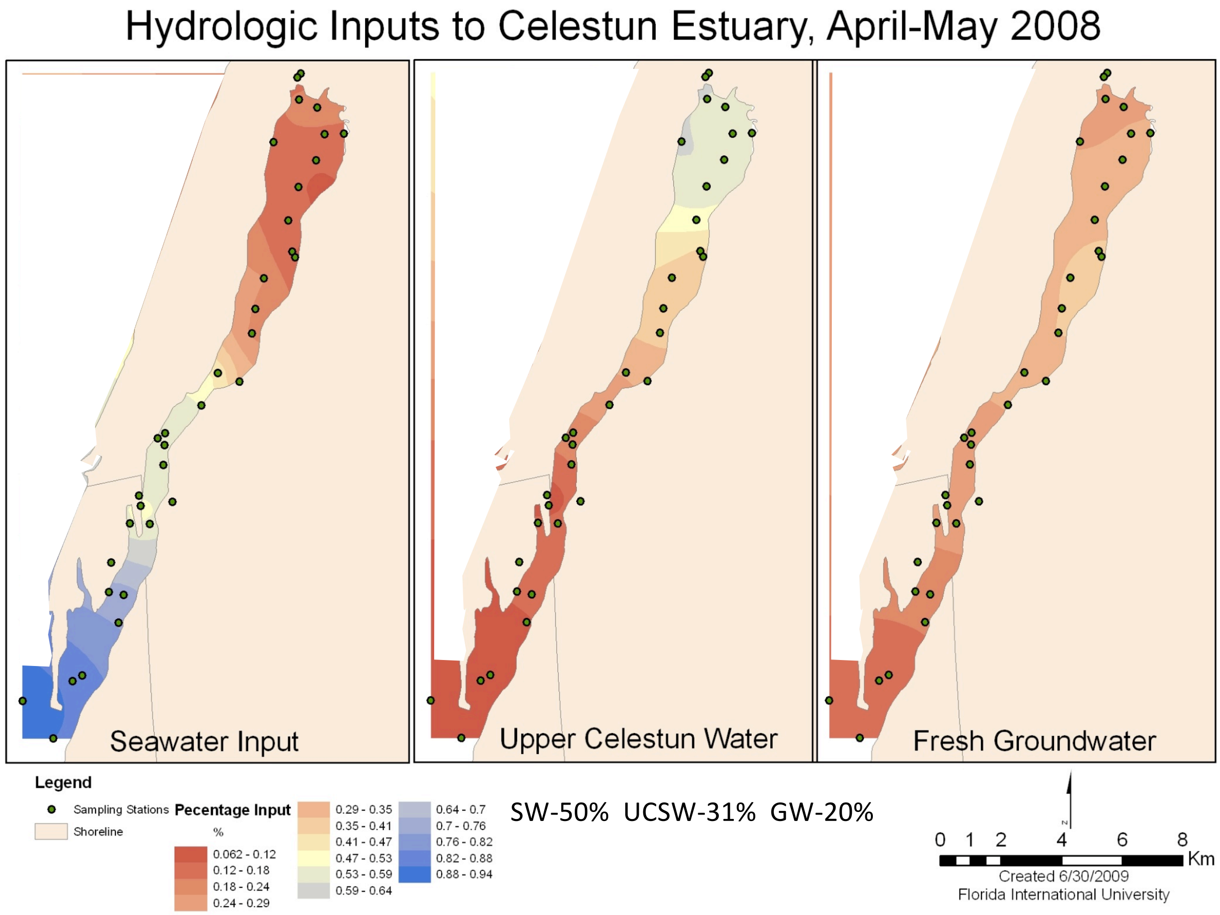


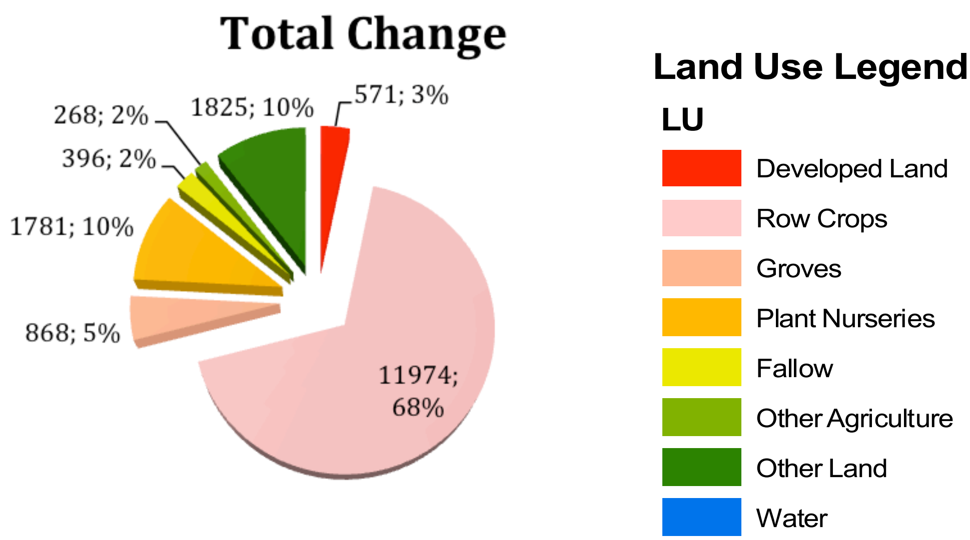
Figure 5.5. Proportions of seawater (SW), Upper Celestun surface water (UCSW), and fresh groundwater (GW) to Celestún estuary, Yucatan, Mexico.

6. Human Dimensions

1) Refined data layers for the larger study site. This data enables us to locate properties with lawns in relation to other properties in the south Miami-Dade county area. Land use classification of properties (from the County Tax Assessor data—1992-94 pre/post Hurricane Andrew and current 2007) allows analysis of both changes in land use between agricultural and residential (mapping growth/sprawl, among other variables) and GIS positioning of properties in relation to other data layers we are adding.
2) During the course of our land use and zoning analyses, we discovered several phenomena, particularly in regard to zoning and land use change. First, simply zoning a parcel of land as “agriculture” does not guarantee that parcel can remain an economically viable farm, as nearby landscapes and land uses, along with economic opportunities and disincentives, can strongly outweigh the effects of zoning alone. Second, the rezoning of lands from agriculture to residential, commercial, or some other form of development

hastens the conversion (and the prerequisite zoning change) of nearby lands still zoned for agriculture. Third, the greater number of edges an area of agriculturally zoned land has with land zoned for development affects how quickly that land will also be rezoned for development. Lastly, allowing subdivision of agriculturally zoned lands into five acre lots discourages agricultural food production and encourages instead nurseries or non-productive "ranchettes." At the very bottom, below, are two snapshots in time that reveal land use change in Miami-Dade County, zoning changes, and zoning requests made by the landowners.

We have also discovered that, when examining change within agriculture, a great deal of row and field cropland is being converted to nurseries and low density developments in many parts of Miami-Dade County. By rasterizing shapefiles, concatenating them and examining change within each cell, we have discovered that parcels above 5 acres are in greater danger of being converted to nurseries than those that are smaller. Also, and surprisingly, land that is zoned for interim uses has a greater retention of row and field cropland than land specifically zoned for agriculture. Directly below are greater specific details regarding this analysis:

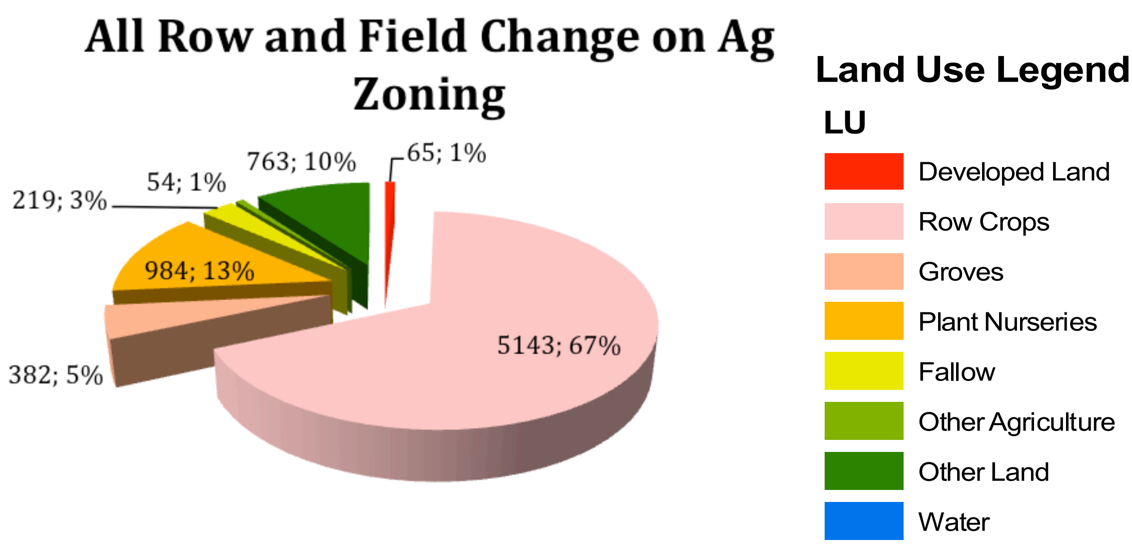


Each pie wedge above reveals the number of cells that it represents as well as the pie percentage of the slice. Each cell is 0.9 acres.
As you can see, overall, Row and Field Croplands greatest conversion threat was to "Other Land" and "Nurseries." Other Land is mainly the Water Management Authority as well as the Everglades NPS. All of this happened in the extreme West of the area.

However, when breaking it down by size of 2007 parcel we learn a bit more.

Parcel Size	Retention %	Greatest Threat
Under 5 Acres	58%	Development
5 to 10 Acres	65%	Nurseries
10 to 20 Acres	67%	Nurseries
20 to 40 Acres	79%	Other Land
40 to 80 Acres	71%	Other Land
80 to 160 Acres	76%	Other Land
160 to 320 Acres	93%	Other Land
Over 320 Acres	67%	Other Land

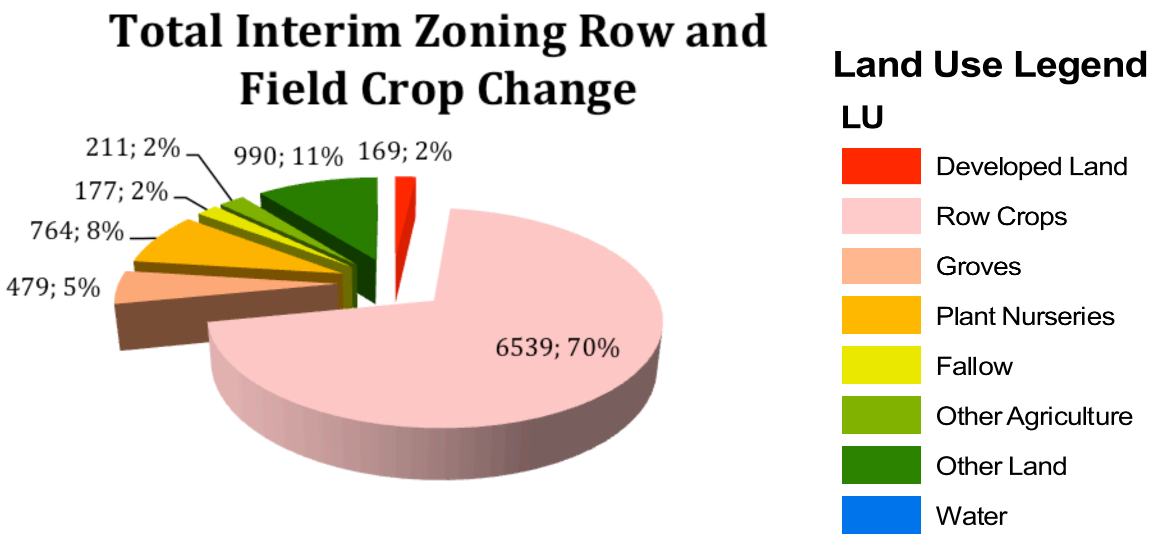
Now if we just look at Row and Field Cropland in areas zoned for agriculture. 67% retention with the greatest threat being nurseries.



Parcel Size	Retention %	Greatest Threat
Under 5 Acres	64%	Nurseries
5 to 10 Acres	65%	Nurseries
10 to 20 Acres	72%	Nurseries
20 to 40 Acres	85%	Nurseries
40 to 80 Acres	73%	Other Land
80 to 160 Acres	67%	Other Land
Over 160 Acres	4%*	Other Land

*There were only two parcels of that size that were zoned for agriculture and they were almost entirely taken over by the Water Management Authority.

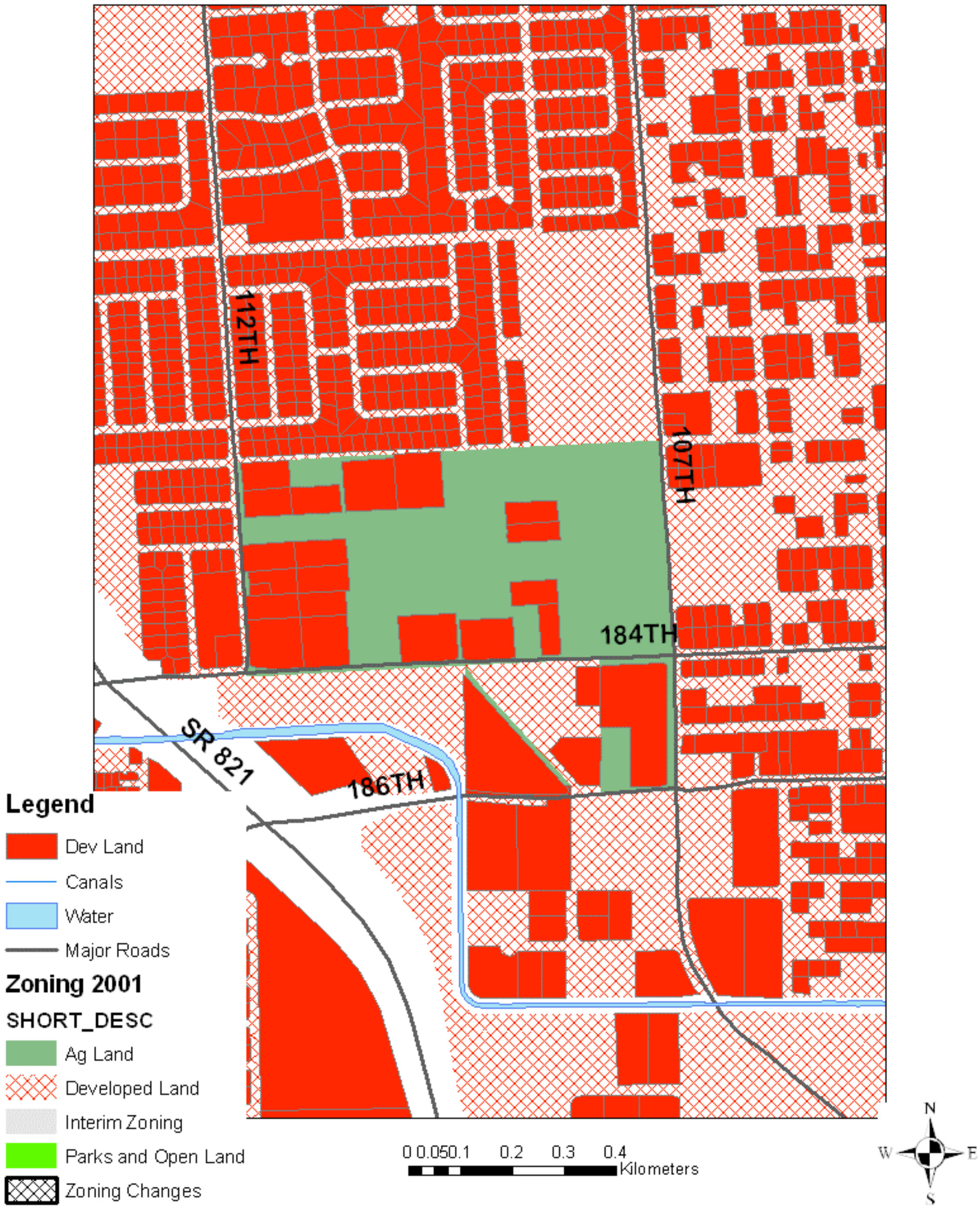
As for land that was in Interim Zoning in 2001: There was 70% retention. Greatest threat: Other Land.



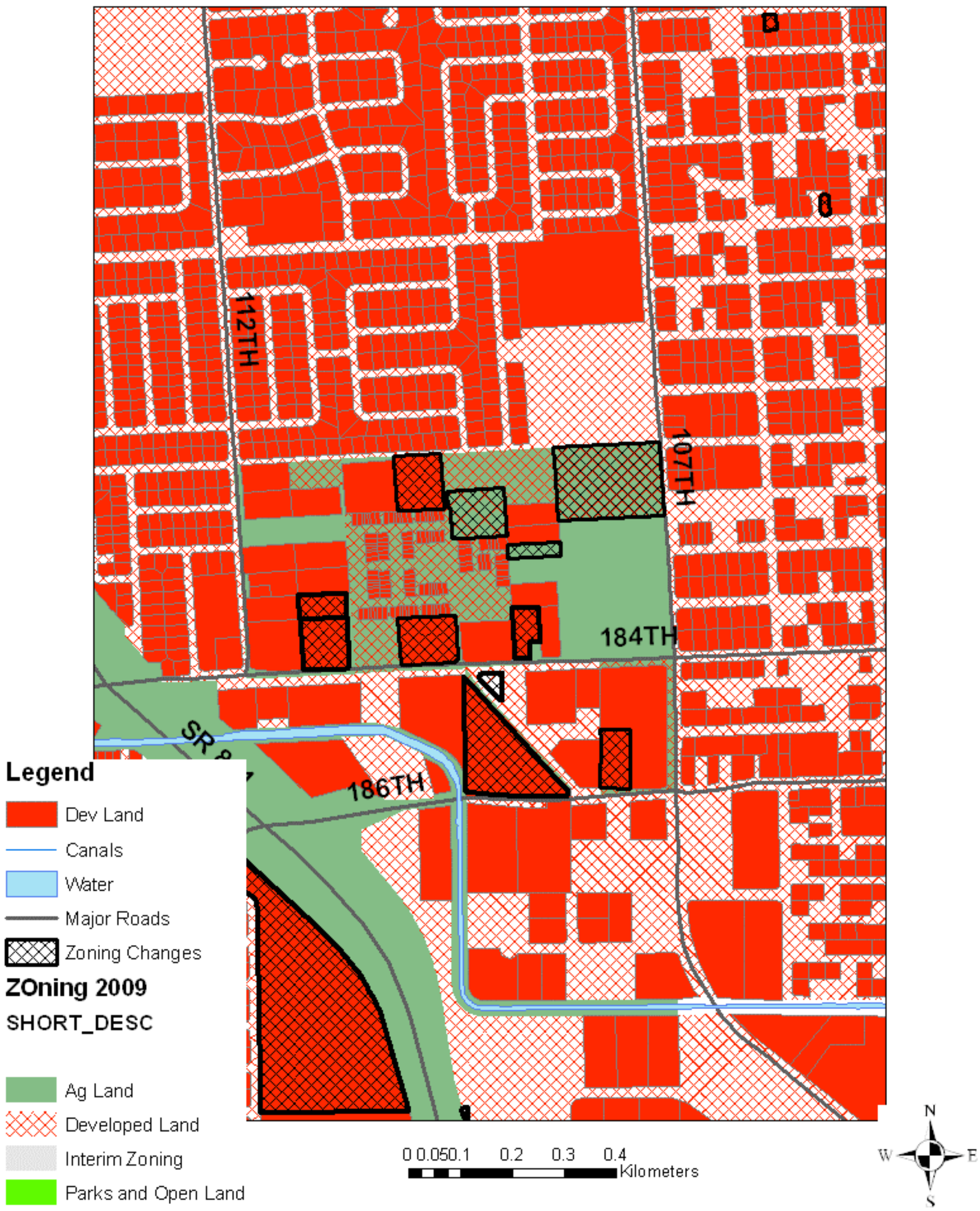
Parcel Size	Retention %	Greatest Threat
Under 5 Acres	59%	Other Land
5 to 10 Acres	65%	Nurseries
10 to 20 Acres	65%	Other Land
20 to 40 Acres	77%	Other Land
40 to 80 Acres	69%	Other Land
80 to 160 Acres	80%	Other Land
160 to 320 Acres	94%	Other Land
Over 320 Acres	98%	Other Land

Other findings: Row and Field Cropland zoned for agriculture between 5 and 10 Acres revealed the greatest vulnerability to Nurseries as 19% of this land became nurseries in 2006.
On land zoned for agriculture row and field crop retention increases with larger parcels, peaking with parcels that are 20 to 40 acres, then steadily decreases with increasing size.
On interim zoned land retention increases, decreases, then increases again with increasing parcel size. Also of interest, row and field cropland on interim zoned land overall had higher retention than land specifically zoned for agriculture. 70% for interim zoned land and 67% for ag zoned land.

1992 Dev. Land and Zoning Changes (w/2001 Zoning)



2006 Dev. Land and 2008 Zoning Changes (w/2009 Zoning



3) Preliminary findings for our research into the role of hurricanes, as pulse events, into land use/cover change in our study site suggest the following:
   a. The pulse of Hurricane Andrew exacerbated pre-existing historically constituted social inequalities.
   b. More specifically, communities and neighborhoods with higher percentages of African-American residents were less resilient to Hurricane Andrew, as a pulse

event. African-American households were characterized as being underinsured for the disaster, less likely to be homeowners, and were less able to rebuild after the pulse event.

c. Household resilience, in the case of Andrew, was predicated on a household's ability to relocate after the storm. Ability to relocate was largely a factor of quality of homeowner insurance. Those households that were underinsured (primarily African American) lacked critical capacity to relocate and therefore had less resilience to the storm event.
d. The greatest changes occurred in neighborhoods with the highest degree of vulnerability to press events. These post-Andrew changes include shifts in demographics and community character (housing type, for instance).

7. Climate and Disturbance

REU - Using mineral-magnetism to gauge the intensity of past fires in the Everglades (Sah)
Soils at sites that were extensively burned exhibited a pronounced surface magnetic enhancement effect with magnetization of surface samples up to 16 times greater than that observed at depth (> 7cm) at these sites. The increase in magnetization results from an increased abundance of a low-coercivity phase (maghemite) that occurs at the expense of the abundance of a high-coercivity phase (goethite). These results indicate that fire-induced heating caused goethite in the surface soils to convert into a more magnetic, low-coercivity phase, such as maghemite. Goethite is an excellent adsorber of phosphorous, and therefore the destruction of goethite as a result of burning may have important implications for phosphorous cycling in the Everglades ecosystem.

Impacts of pending changes in water management and long-term effects of sea-level rise (Davis)
Throughout the study, we've seen considerable differences in water quality and constituent concentrations between samplings sites and across samplings, indicating strong spatial and seasonal controls on water quality and materials exchange in this region (Figure 7.2). Our most recent data from May 2008 support trends observed thus far in that surface water P concentrations are typically highest during the dry season, and inorganic N, TN, and DOC are quite low. Total suspended solids were unusually high in May 2008 and may have been the result of low discharge and long water residence times that favored the development of high algal biomass. Salinity in May 2008 was the highest we measured in this study (> 30 ppt) and dissolved oxygen concentrations were quite low (avg. < 4 mg/l) at the TS-Ph 6 site during this period as well (Figure 7.1).

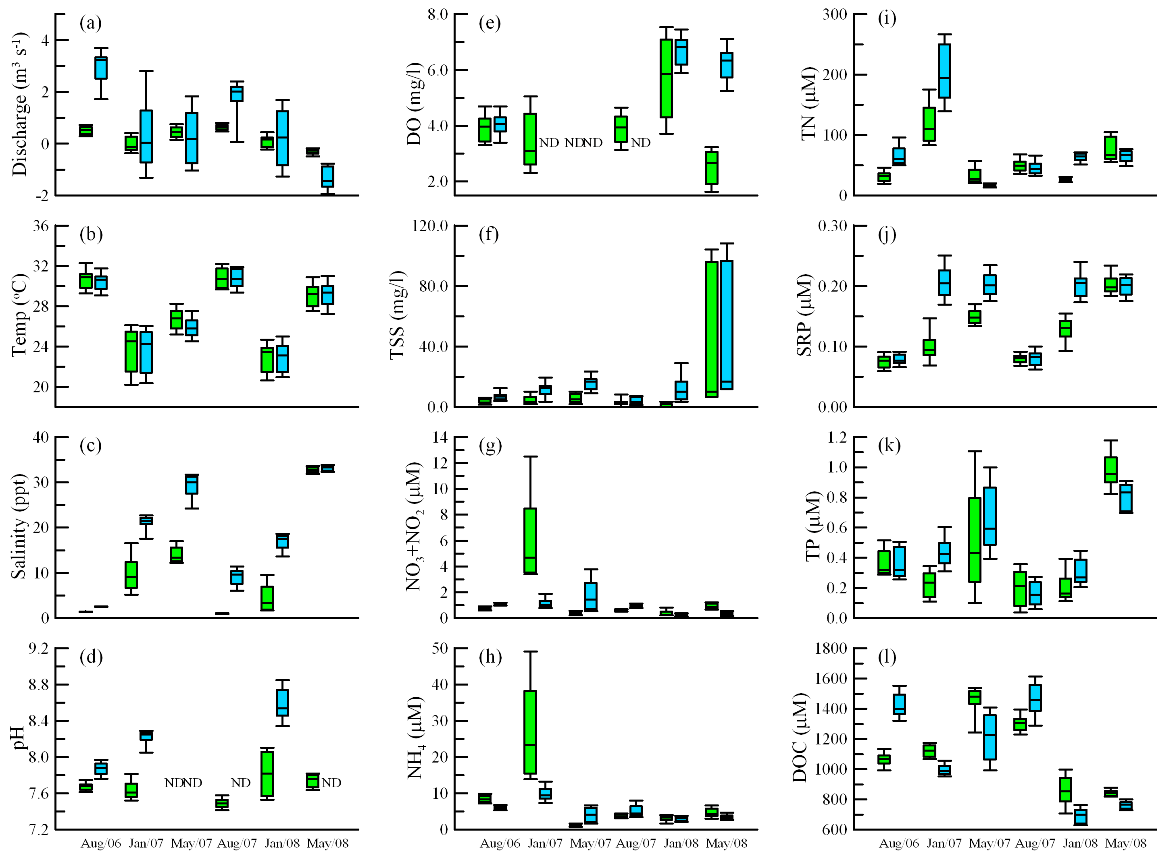


Figure 7.1. Box-and-whisker plots illustrating the distributions in water quality and constituent concentration data collected in upstream (TS/PH-6a) and downstream (TS/Ph-7a) sampling sites in Taylor River. Each plot includes data from samplings conducted in Aug. 2006, Jan. May & Aug. 2007, and Jan. & May 2008.

In the first wet season sampling (August 2006), salinity, TN, and NO_3+NO_2 concentrations were low at both sites. NH_4 concentrations were also low overall but higher at the upstream site, indicating uptake of NH_4 along the axis of Taylor River. In the dry season samplings, increased (more dynamic) salinity at both sites was found due to lower freshwater inputs. An inverse pattern between salinity and dissolved inorganic nitrogen (DIN = NO_3+NO_2+NH_4) at TS/Ph-6 may be due to increased marine influence at the mouth site. DIN was higher at TS/Ph-6, but TN was higher at TS/Ph-7. During the January 2008 sampling, DIN was low at both sites, but SRP was quite high, particularly near the mouth of Taylor River. This was the same pattern observed for upstream-downstream concentrations of SRP during the January 2007 sampling. During August 2006 and 2007 samplings, SRP was lower and averaged 0.07 µM at both sites. This is expected during the wet season, when flows are predominantly from the oligotrophic Everglades. Overall, TP, SRP, TSS, salinity, and pH were higher near the mouth of the river and seemingly highest during the dry season or the transition from the wet to the dry season. See Figure 3 for box-and-whisker plots of water quality data from minisondes and TSS, DOC, N, and P concentrations from surface water samples collected at both stations during both samplings.

Mangrove Zone Research (LSU group, Rivera-Monroy et al.)
The storm surge caused by Wilma showed a distinct pattern along Shark River estuary. Water level within mangroves was ~3 m at the mouth of the estuary (SRS6) and decreased to 0.5 m at the upper mangrove sites (SRS4). Overall, the storm surge in our mangrove sites last approximately 7-8 h, based on data recorded by the instruments. Associated with the storm surge, large amounts of mineral sediment from the coastal shelf were redistributed and deposited across mangrove forests of our study sites. This large-scale sediment deposition (0.5 to 4.5 cm) varied spatially within each mangrove site, with maximal deposition in areas adjacent to the water edge and lower deposition in the interior forest. Along Shark River, sediment deposition was maximal at SRS-6, close to the Gulf of Mexico, and decreased upstream as no deposition was evident in SRS-4 (18.2 km from the mouth of the estuary).

Storm deposits were characterized with higher bulk densities (650.4 ± 30.9 mg cm^{-3}) compared to pre-existing surface mangrove soils (top 10 cm of soil = 366.2 ± 11.8 mg cm^{-3}). Organic matter content showed an opposite trend, with lower concentrations in storm sediments (84.5 ± 7.2 mg cm^{-3}; 15% AFDW) compared to surface soils (top 10 cm = 118.3 ± 7.3 mg cm^{-3}; 50% AFDW). Mean TP concentrations in storm deposits differed significantly from mangrove soils, with higher TP in the storm layer (0.36 ± 0.02 mg cm^{-3}) compared to pre-existing mangrove soils (0.22 ± 0.02 mg cm^{-3}). The contribution of TP from this hurricane event to the total P pool in the top 10 cm of mangrove soils ranged from 7% (Taylor Ridge) to 56% (TS/Ph8). When comparing the chemical P fractions of hurricane deposits, the Ca-bound P_i fraction was the most significant fraction and accounted for up to 25-29% of total P, while the labile P_i fraction was the second largest pool in all sites, comprising 11-23% of total P. The P fractions in mangrove soils showed a similar trend among sites as storm deposits, although values were lower (Fig. 4). The higher Ca-bound portion of TP in storm sediment deposits compared to surface mangrove soils suggests that allochthonous mineral inputs from adjacent coastal waters during the passage of Wilma is significant contribution to nutrient density of P. In addition, the lower residual P (44-61%) as per cent of TP of storm deposits compared to surface mangrove soils (70-75%) also reflects the contribution of mineral sediments to mangrove peat-dominated soils during a hurricane event. Moreover, vertical accretion resulting from this hurricane event was 8-17 times greater than the annual accretion rate (0.30 ± 0.03 cm yr^{-1}) averaged over the last 50 yrs for FCE mangroves. Accordingly, these mineral inputs from Hurricane Wilma represent a critical source of sediment that determine soil vertical accretion rates and nutrient resource gradients in mangroves of southwestern Everglades. Patterns of P deposition to mangrove soils associated with this storm event are particularly significant to forest development due to the P-limited condition of this carbonate ecosystem. This source of P may be important adaptation of Neotropical mangrove forests to projected impact of sea-level rise.

Paleolimnological/paleoecological study of Lake Annie (Gaiser)
We are examining long-term observational and paleoecological datasets for evidence of cyclical dynamics related to climate oscillations. We found signals of cyclical dynamics in a 'reference' (un-impacted by development) site in the upper Everglades watershed (Gaiser et al., 2009; In Press; Fig. 7.2) and in the Southern Everglades estuaries (Briceno et al., In Press). Multi-billion dollar hydrologic restoration plans for South Florida have only just started to encompass recent entry into an AMO warm phase that is projected to continue to bring more rainfall and storms

through Florida. Perhaps because the AMO modulates climate in an opposite pattern to the rest of the continental United States, the majority of the South Florida restoration planning period in the 1980s and 1990s did not take the AMO into account. The critical discrimination of cyclical from directional climate controls on long-term changes observed in South Florida lakes, wetlands and estuaries will require commitment to long-term data collection programs.

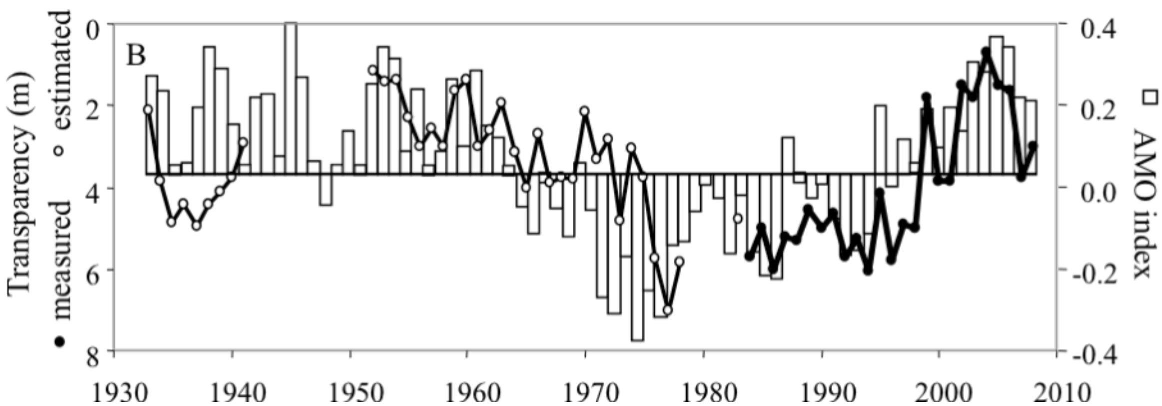
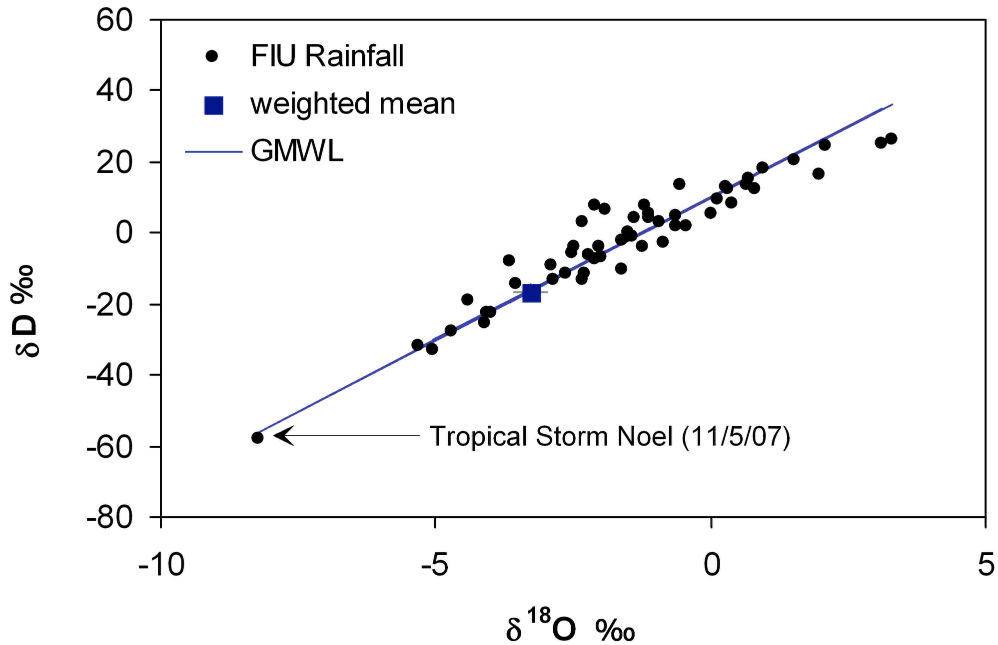


Fig. 7.2. Synchronous trends in water transparency and the Atlantic Multi-Decadal Oscillation Index in Lake Annie, FL, used as an un-impacted reference site in the Everglades watershed (Gaiser et al., 2009). Trends are driven by hydrologic controls on DOC concentration, similar to those observed in the southern estuary FCE sites (Briceno et al., 2009).

Isotope hydrology and precipitation (Price)

The weighted-mean values of $\delta^{18}O$ and δD of the rainfall collected at FIU was -3.27 ʟ and -16.41 ʟ, respectively. The lowest isotopic values ($\delta^{18}O$= -8.24 ʟ and δD=-58.03 ʟ) were obtained during the week of Nov. 5, 2007 associated with the passage of tropical storm Noel. Other tropical storms have since passed across the region, including Hurricane Fay (August 24, 2008) and Hurricane Ike (Sept. 2008). However, the rainfall collector was removed from the roof of the building during the advance of these hurricanes, and rainfall was not collected.



8. Modeling and Synthesis

Workshops and coordination activities

Our modeling/synthesis workshop in June focused on three objectives (1) summarizing the current state—i.e., the successes and limitations—of FCE modeling and synthesis in addressing the FCE II central hypotheses; (2) highlighting potential synergies among FCE modeling and synthesis; and (3) drafting an outline for a review paper on FCE modeling/synthesis activities.. For objective 1, we rated each modeling/synthesis activity in terms of the extent to it addresses the 6 general research questions of FCE II. This matrix, summarized graphically in Figure 8.2, showed that while some research questions are the focus of multiple, fully calibrated, and completed modeling or synthesis projects (questions 1, 2, 4 and 5), other research questions are only partly addressed or in the planning stage. This exercise helped clarify the need for greater focus on general research questions 3 (consumer impacts in the ecotone), 6 (ecotone boundary shifts) and 7 (socioeconomic impacts on Everglades hydrology) (Fig 8.2).

GENERAL QUESTION 1: interaction of surface and groundwater, tidal, seawater, rainfall, ET, and increasing freshwater controls hydrology in oligohaline ecotone

GENERAL QUESTION 2: seasonal, inter-annual variability in water source (surface, groundwater, rainfall, and marine inputs) and P availability control primary productivity/allocation in the ecotone

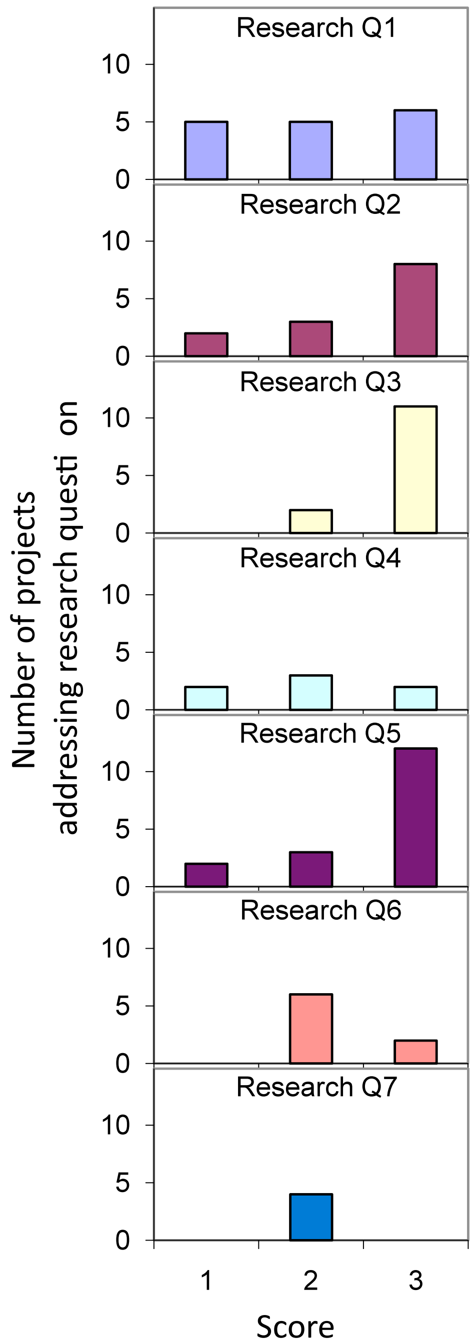
GENERAL QUESTION 3: implications of increased freshwater and detrital OM inputs for consumers in the oligohaline ecotone, and impacts on food webs in the greater estuary

GENERAL QUESTION 4: water residence time and nutrient inputs (primarily from freshwater inflows, marine inputs, and groundwater) control ecotone nutrient concentrations and cycling rates

GENERAL QUESTION 5: organic matter dynamics (DOM, "floc", and soils) in the oligohaline ecotone altered by local processes versus allochthonous freshwater, marine, and groundwater sources

GENERAL QUESTION 6: the location and extent of the oligohaline ecotone controlled by changes in climate, freshwater inflow (management, restoration), and disturbances (SLR, hurricanes, fire)

GENERAL QUESTION 7: social and economic processes driving land use change in areas adjacent to FCE and how these changes affect the quantity and quality of water flowing along FCE transects



Scores defined as follows: 1 = model or synthesis project directly addresses a specific FCE research question and associated models are fully developed and calibrated; 2 = project only partially focuses on the research question; 3 = project is in still in development or planning phase (e.g., model coding, conceptualizing).

Figure 8.2. Histograms showing the degree to which research questions are being addressed by FCE modeling and synthesis activities. General research questions paraphrased as statements in this figure.

For the second objective, we completed a matrix of all potential synergies (Leavesley et al., 1996) among FCE modeling and synthesis, in addition to those ongoing (e.g., integration SFWMM and ELM; integration of EFDC, FATHOM, TIME within SEACOM), and highlighted those critical to address current gaps in FCE modeling/synthesis (Fig 8.2). As an example, the workshop generated a multi-modeling approach (Figure 8.3) addressing FCE General Question 6 (ecotone boundary shifts). Currently there is no means of moving coastal ecotone boundaries in FCE models. A landscape model such as ELM is required but at this time ELM is best suited for freshwater habitats. Usually habitat boundaries are modeled as "pixel switches" from one habitat type to another. But boundaries move in a gradient that is not well captured by a binary transformation. To address this issue, we propose using SFWMM, TIME and ELM models for boundary conditions to (e.g., water transport, P inflow) smaller-scale ecosystem models: SCAT and ribbon for marshes and sloughs; HY-FOR-NU-MAN and MIKE mangrove habitats; and SEACOM for Florida Bay and mangrove ponds. The small-scale models may be linked with each other (e.g., providing driving variables and/or boundary conditions), and ultimately selected algorithms from each model may provide a new "hybrid" models of ecotone habitat change. The "hybrid" models may in turn provide new mechanisms of vegetation, soil and nutrient dynamics to subsequently incorporate into a landscape model such as ELM. Finally, integration and synthesis of data, including potentially new studies, will be required for calibration/validation. Critical data are expected to include soil accretion and elevation change; primary production; decomposition and soil chemistry; paleoecological analyses; and analyses of historic aerial imagery.

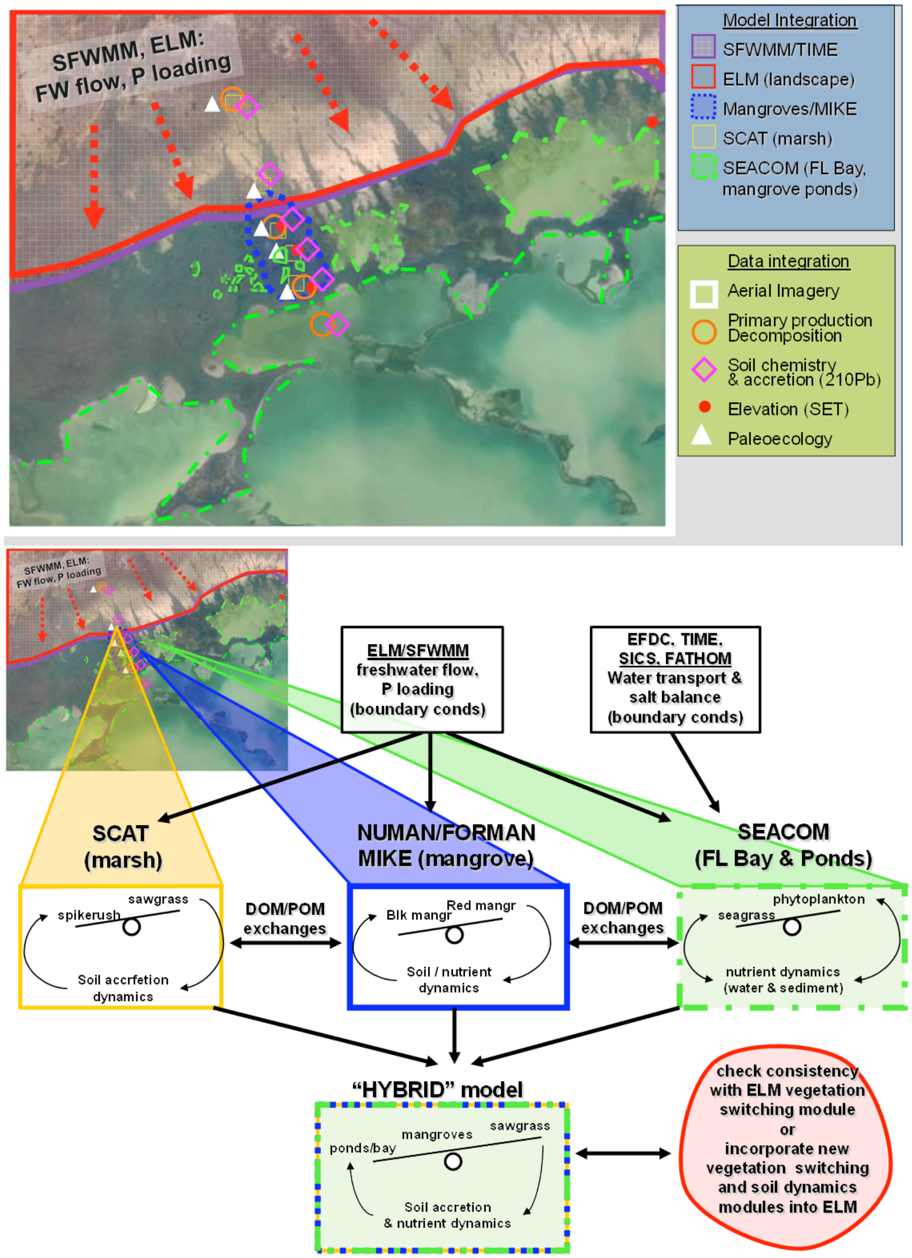


Figure 8.3. Conceptual work plan for a multi-modeling approach to address the extent and magnitude of ecotone boundary shifts (FCE II General Question 6).

The third accomplishment from our workshop was an outline for a review manuscript on FCE modeling/synthesis activities and their application toward Everglades restoration and management: "A strategy for integrating ecohydrological models of the Florida Everglades: Advances and limitations in the context of the restoration." This paper will summarize the products of our workshop and teleconferences and serve as a road-map for long-term goals and objectives of FCE modeling/synthesis. Importantly, it will provide the scientific community an example on how to improve integration of models with varying (but related) goals and objectives toward regional ecological restoration and management. Our plan is to have a completed draft of this paper in the coming year.

Freshwater ecosystem models

ELM and linked ELM-SEACOM

For the 20-year calibration/validation simulations, hydrologic performance of the ELM v2.8 improved over that of ELM v2.5, with a median (across 82 monitoring stations) bias of 0 cm for comparisons of daily observed and simulated stage data. The simulated and observed phosphorus concentrations were very closely related, with a seasonal median bias (across 78 stations) of 0 ug L^{-1} in both the marsh and the canal stations. During the 36-yr future scenarios, the scenario with increased upstream inflow resulted in substantial increases in P outflows from the freshwater Everglades into Florida Bay, relative to the base run (Figure 8.4). SEACOM was then run for ten year futurecast scenarios using ELM output of TP from the Taylor Slough site as the input for the Little Madeira Model Basin (Figure 8.5). The simulated P outflows were input as direct file inputs to the SEACOM model with no feedback on cross-boundary flows. TP was run at the ELM baseline level, 2X and 3X. SAV responded by generally lower biomass, although non-linearities are apparent in the seagrass response (e.g. year 7-8).

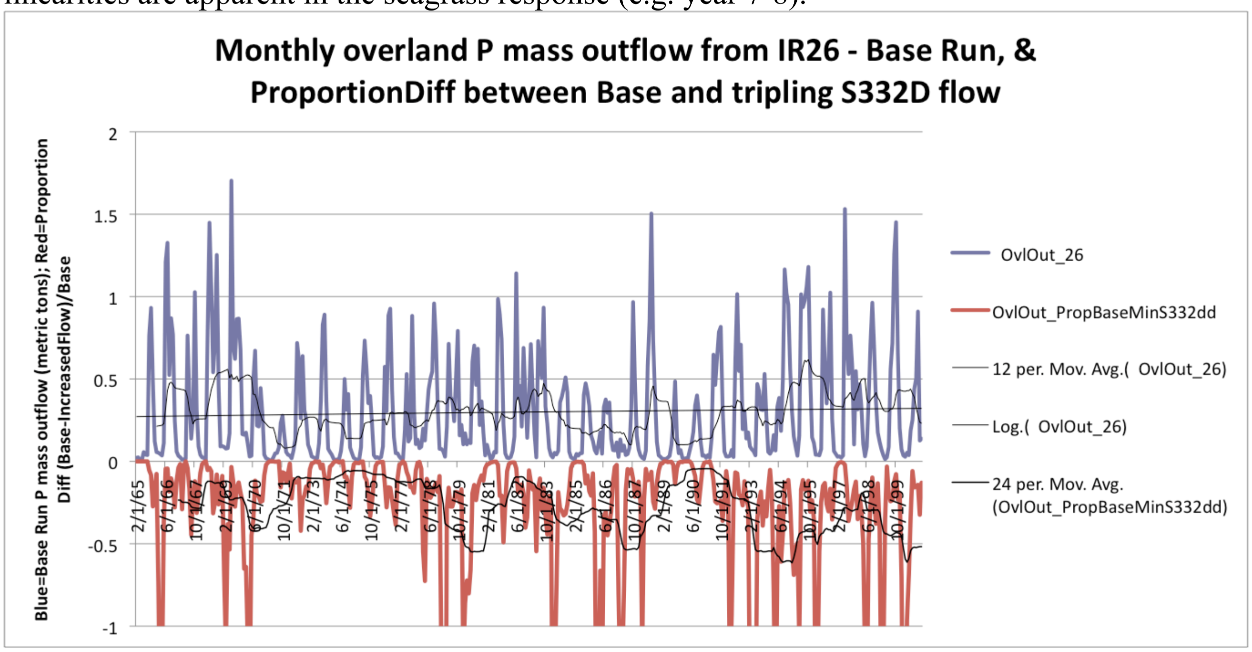


Figure 8.4. Proportional differences between ELM simulated P outflow for a future baseline case versus that of a future scenario with increased (tripled) inflows into the southern Everglades (through one structure (S-332D) upstream of the Taylor River region**).**

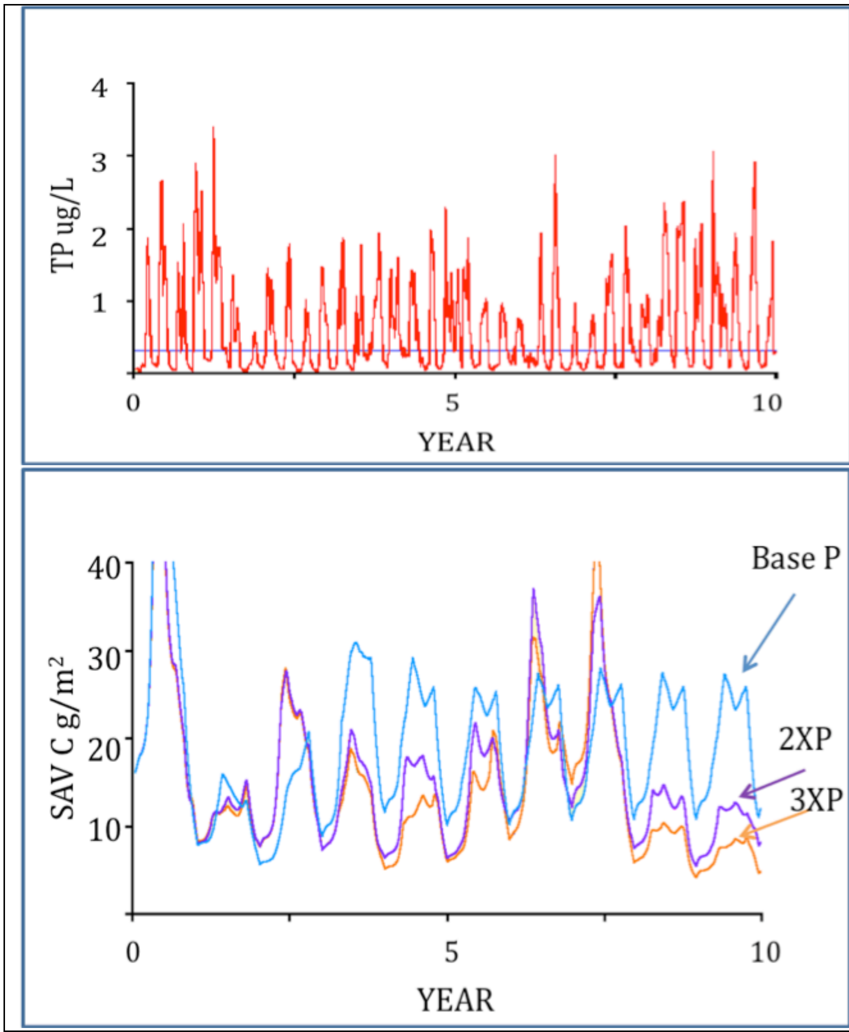


Figure 8.5. Top panel shows the ELM Total P output times a factor of three (high scenario) in red and a blue line at the static TP concentration used in the unlinked model. Lower panel shows SEACOM output of SAV response to three P scenarios: Baseline ELM output, 2X and 3X.

SCAT

A simplified version of the SCAT model (conceptual diagram shown in Figure 8.6) is used to simulate sawgrass seed profiles. The model was simulated for sawgrass marshes at SRS-2 and SRS-3 and the slough community at SRS-3 over the period from 1895 to 2004. Water depths were based on water gage records, rainfall records and an assumption (based on the NSM/SFWMM model runs) of a 30-cm decrease in water stage starting in 1930. Model runs (Figure 8.6) successfully reproduced the downcore variation and overall magnitude of sawgrass seed profiles in the wetter site (SRS-2) and the drier site (SRS-3). Improvements in simulated seed profiles (versus observed) at the SRS-3 slough site were achieved only after including the assumption of horizontal advection, preferentially depositing seeds from marshes upstream into the slough (downstream). Successful simulations of these model simulations provide a consistency check among several lines of FCE data and models, including paleoecological, biomass and seed production data from FCE and FCE-related studies; water stage and rainfall records; and NSM/SFWMM simulations of pre-drainage water levels in Shark Slough.

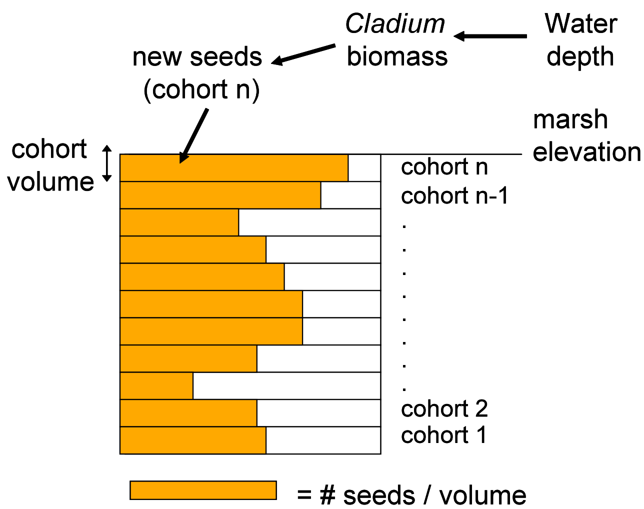
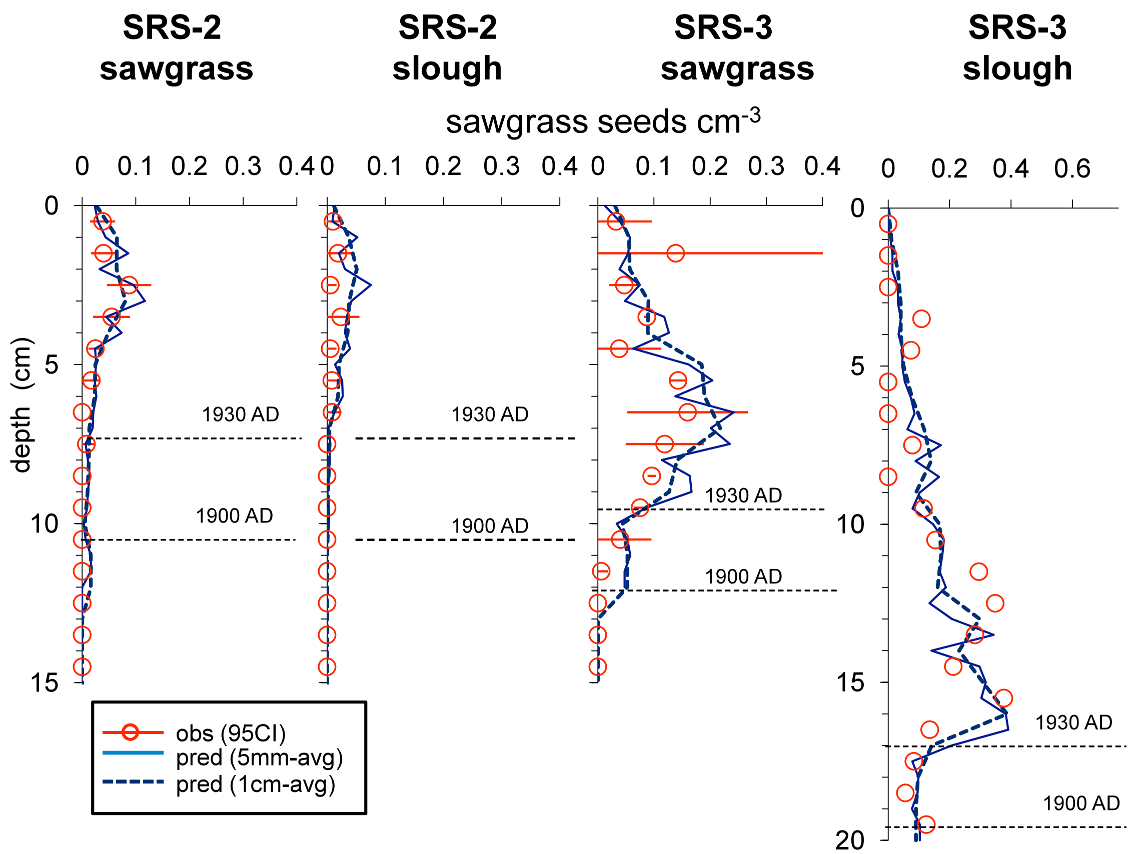


Figure 8.6. (Upper left) Conceptual model for hindcasting sawgrass seed profiles. (Lower Graphs) Predicted and observed seed profiles for sawgrass and slough habitats at SRS-2 and SRS-3. SRS-3 slough model assumes horizontal advection of sawgrass seeds (produced upstream) into the slough (downstream).



Mangrove Models

HYMAN

The HYMAN model uses mass balance equations to determine daily water and salt budgets as the combined effects of inputs from precipitation and tide, and losses through evapotranspiration, seepage, and runoff. Statistical relations of surface water depths in each forest were developed as as a function of channel water elevations. Other model inputs such as evapotranspiration and seepage were calculated from observed data. The simulated values of pore water salinity (insterstitial) for each site can reasonably match the corresponding observation trends and consist with its distance to the estuary mouth. Based on the sensitivity test, the best-fit parameters were determined for each site and most of the simulated results fell within a reasonable range comparing to the discrete measured values (Figure 8.7). In addition, most of the observed discrepancies can be correlated to certain corresponding hydrologic signals.

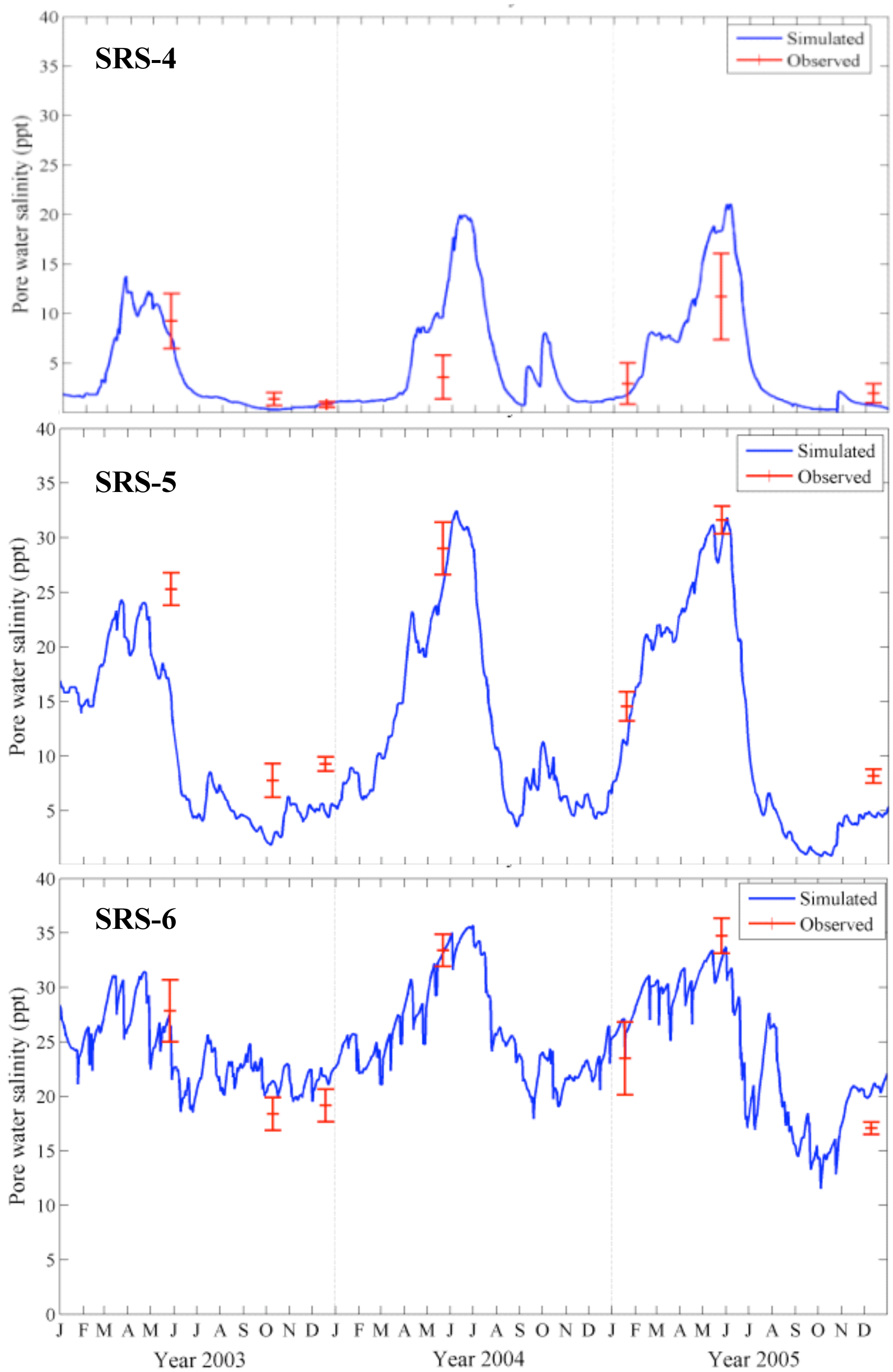


Figure 8.7. HYMAN simulation outputs at SRS-4, -5 and -6 showing simulated and observed salinity values (interstitial).

MIKE/NUMAN

The MIKE21 and MIKE11 modeling in the Taylor River region is in the process of being calibrated and has demonstrated the capability to predict observed salinity throughout the domain during both the wet and dry seasons. A salinity calibration example (Pond 3, an area midway between the two boundary sites) is provided in Figure 8.8. The largest uncertainties in the model arise from the unknown overland flow component during the wet season, and from bathymetry errors in the dry season. Improvement in the simulation quality will require more detailed information on model area elevations, especially at the northern boundary where most inflow occurs. Surveying the area east and west of the Taylor upstream gage site and collecting velocity data at a few locations are strong recommendations to improve model performance.

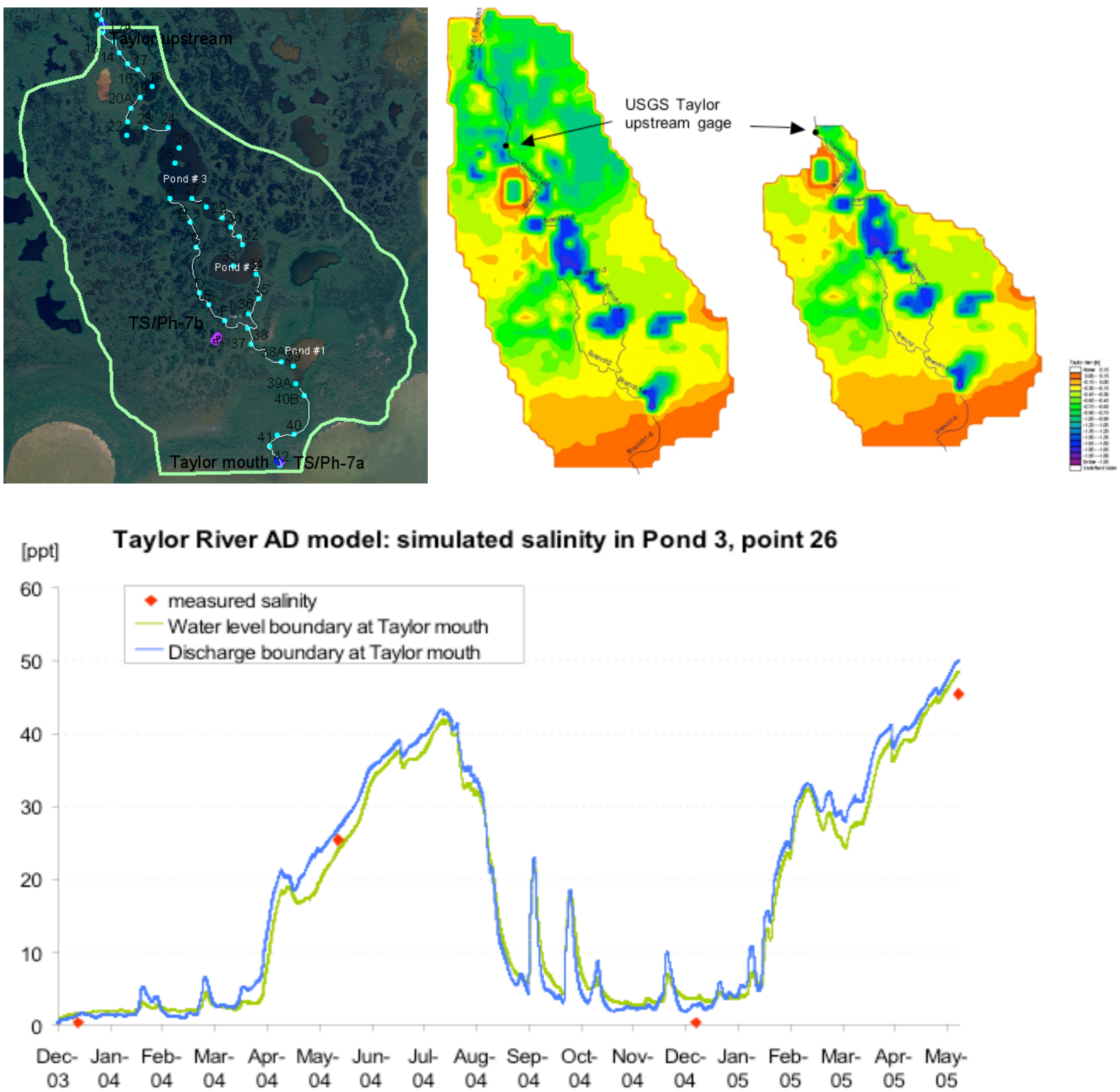


Figure 8.8. Upper left: Location of salinity measurements along Taylor River. Upper right: bathymetry setups including the original and (right) reduced model area (50 x 50 m MIKE21 grid with connected MIKE11 channel). Lower figure: Simulated salinity in Pond #3.

Consumer models

GEFISH

The objective of the GEFIH model is to describe spatio-temporal dynamics of small fishes on the model landscape. The basic food web structure of GEFISH model is shown in Figure 8.9 (top). In the model, fish functional types move seasonally, up the hydrologic gradient during floods and down the gradient during falling water. At the time, the model is able to simulate patterns of biomass change for six food web species through a year across an elevational gradient for a given water level amplitude (Figure 8.9). Future plans for the GEFISH model is to apply it to different scenarios: (1) The lower elevation end of a marsh landscape is bordered by a canal containing piscivorous fish, with varying carrying capacity for the piscivorous fish; (2) a new piscivorous fish is introduced that can move from the canal into the relatively shallow marsh areas of the landscape; (3) spreader swales are introduced and will form permanent refuges for smaller fish, but also increase potential habitat for piscivorous fish. Within each of these classes of scenarios, the effects of numerous variations of seasonal water patterns will be studied.

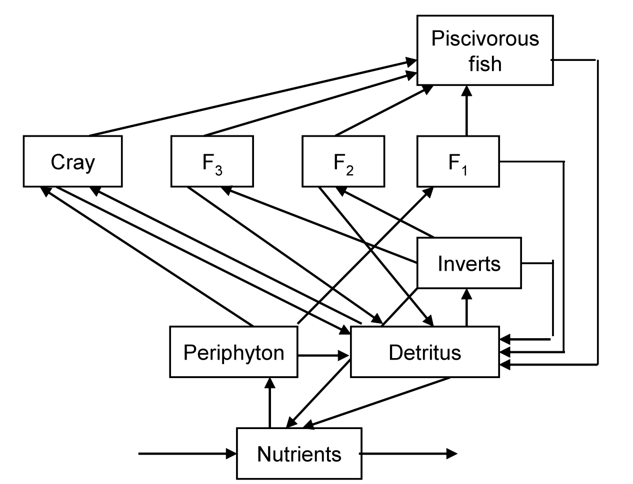
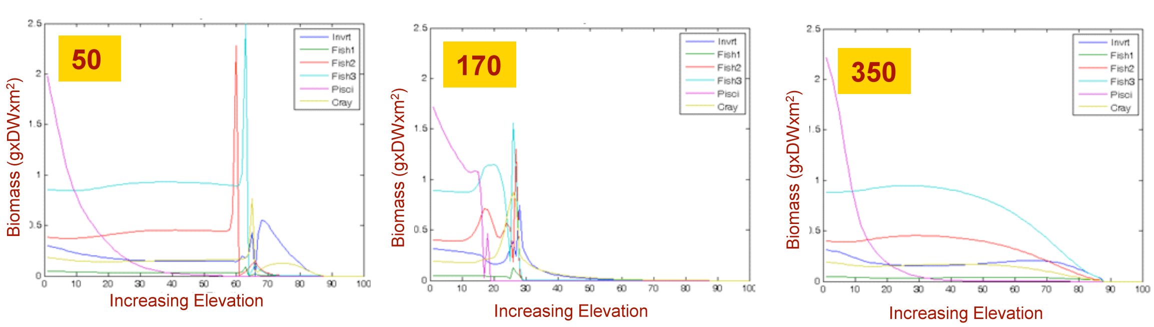


Figure 8.9. (Left) Food web structure of the GEFISH model. Cray=crayfish, F1= intermediate fish spp., F2=good disperser fish spp., F3= good resource exploiter fish spp. (Below) Mean biomass of six food web species along an elevation gradient in the last simulation year (year 10). Starting from day 50 (a) to day 170 (c), until the end of the simulation on day 350 (f). The water level amplitude during this simulation run was 0.6 meters.



Seagrass / Florida Bay models
In addition to the linked ELM-SEACOM modeling exercise (Figure 8.5**,** above), the SEACOM model is being applied to simulate the phytoplankton bloom that occurred in the eastern bay from 2005-2008, and is useful in research planning and restoration strategy assessment. The model demonstrates that a single injection of phosphorus, similar to that observed in late summer 2005, is sufficient to sustain phytoplankton blooms for months to years from internal recycling. The model is being used to test hypotheses about various flushing rate and P recycling rate scenarios, their effect on the plankton community, light regime and ultimately the SAV community.

The model is being prepared for use in refining calculations of freshwater inputs from the Everglades watershed required to maintain SAV existing communities and ecosystem health. It will also be used to evaluate the response of phytoplankton and SAV to pulsed nutrient inputs such as from tropical storm runoff, as well as a variety of climate change scenarios involving temperature and water level increase. Model runs of SEACOM to test the effects of changing nutrient cycling rates and basin residence time (Figure 8.10) reveals thresholds or "tipping points" of ecosystem change where the system switches from SAV-dominant to algal bloom-dominant. Longer water residence times, efficient nutrient retention, and pulsed nutrient inputs can push the ecosystem toward algal dominance.

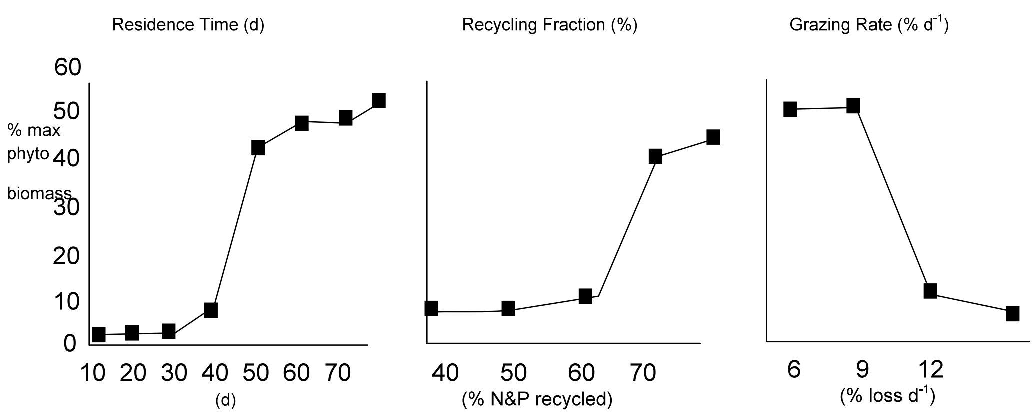


Figure 8.10. Model analysis of factors affecting phytoplankton biomass. Results of multiple scenario runs of SEACOM showing parameter thresholds for state change in phytoplankton biomass from nominal

C. Training and Development

Education, Outreach, and Diversity Activities

In 2008-2009 we have continued to improve our Research Experience for Secondary Students (RESSt) program while our participants have gained international recognition for their research. Last year we placed an additional nine students to work directly with FCE researchers. In his third year working as an RESSt intern with Drs. Evelyn Gaiser and Colin Saunders, high school student Christopher Sanchez was awarded *Second Place* in *Plant Science* at the 2009 Intel International Science and Engineering Fair. In her second year as an RESSt intern, Erikamarie Gil received one of thirty Planet Connect Grants from the National Environmental Education Foundation.

Our Research Experience for Middle Schools (REMS) continues to expand and is largely supported through the financial support of CEMEX. FCE continues to work with CEMEX in expanding a habitat restoration area at one of their inactive limestone quarries that is adjacent to the Everglades. This restoration area provides us with an ideal location and outdoor learning laboratory that is safe, easily accessible, and does not impact our study sites. This year our RESSt students conducted short FCE Everglades ecology lessons with over 150 middle school students and constructed 100 bird nesting boxes.

FCE has numerous undergraduates working in our laboratories and participating in our REU programs. In 2008-2009, FCE offered three REUs in which all students presented the results of their projects in manuscripts, posters and/or talks at meetings. FCE is actively improving our undergraduate and graduate program through ongoing mentoring and training through Research Assistantships and the REU program. In addition, Drs. Laura Ogden and Evelyn Gaiser have offered workshops and reading groups to FCE students that focus on LTER readings and data analysis.

In an effort to establish international Education & Outreach partnerships, we have begun discussions with Dr. Victor Rivera Monroy (FCE and MexLTER) about establishing a sister Education & Outreach program with the MEX LTER. Our hope is to begin connecting American students with our Mexican counterparts with interactive curriculum and research experiences for teachers and students.

In a recent visit to Asia, our Education & Outreach Coordinator has begun contacting schools in Taiwan and China in order to begin establishing a network of English language schools to partner with FCE. Our goal is to develop and share lessons with these schools by including the Taiwan Ecological Research Network (TERN) and the Chinese Ecological Research Network (CERN) in order to allow students from around the globe to collect, share, and discuss the reasons for differences among common forms of data.

Graduate Student Activities and Productivity

The FCE Affiliated Students Group includes over 40 graduate, undergraduate, and high school students who are members. The group meets once a month for meetings. They host seminars and social activities with other graduate student organizations. FCE students earned 1 MS thesis and 4 Ph.D. dissertations from December 2008 to September 2009.

Theses and Dissertations

Evans, Samantha. 2009. Carbon and Nitrogen Stable Isotope Patterns in South Florida Coastal Ecosystems: Modern and Paleoceanographic Perspectives, Ph.D. dissertation, Florida International University.

Quillen, Amanda Kay 2009. Diatom-Based Paleolimnological Reconstruction of Quaternary Environments in a Florida Sinkhole Lake. Ph.D. dissertation, Florida International University.

Sanchez, Michelle. 2009. Distribution of Particle Organic Material in Biscayne Bay, MS thesis, Florida International University.

Stalker, Jeremy. 2008, Hydrological Dynamics Between a Coastal Aquifer and the Adjacent Estuarine System, Biscayne Bay, South Florida, Ph.D. dissertation, December 2008, Florida International University.

Wachnicka, Ania. 2009. Quantitative Diatom-Based Reconstruction of Paleoenvironmental Conditions in Florida Bay and Biscayne Bay, U.S.A.. Ph.D. dissertation, Florida International University.

Tatiana Marquez, B.A. Environmental Sciences, conducted an undergraduate research project on the Phosphorus Content in Limestone from the Biscayne Aquifer under the supervision of Dr. Rene Price. She finished her project with a poster presentation at the LTER ASM in March 2009.

D. Outreach Activities

There are many ways in which FCE scientists, students, and staff interact with the greater public. Outreach often takes the form of presentations at forums such as community group meetings, publicized events, and secondary schools, or of specific training activities for students, teachers, or others. If a FCE scientist discusses their LTER research in such a presentation, we record that presentation as FCE outreach. The FCE Education and Outreach staff (including FCE high school interns) gave numerous presentations to schools in south Florida. FCE researchers also gave 104 presentations from December 2008 - September 2009.

The FCE information manager, Linda Powell, gave a talk about the Florida Coastal Everglades LTER Program to students in the enhanced education class at Conley Elementary in Tallahassee, Florida in May of 2009.

J.S. Rehage gave guest lectures at Miami Beach Senior High on the results of this study. She also attended several meetings of the CERP Monitoring and Assessment Plan (MAP) Greater

Everglades Module and assisted in preparation of the 2009 System Status Report to go to the U.S. Congress and provide an update on the progress of restoration efforts.

Members of the Heithaus lab gave talks at the International Game Fishing Hall of Fame (Marine Camps) and to science classes at a local middle school.

Joel Trexler was an Invited instructor, Marine Protected Areas course taught at Instituto de Ciencias del Mar y Limnología, Puerto Morelos, Quintana Roo, Mexico. Offered jointly by Universidad Nacional Autónoma de México and FIU, 2006-09

Joel Trexler was an Invited instructor, Monitoring in Coastal Wetlands. A 3-day course taught at Unidad Multidisciplinaria de Docencia e Investigación, Sisal, Yucatán, Universidad Nacional Autónoma de México, 2008 & 2009

We had a visit by Lisa Giles and her 7th grade class from Key Largo Elementary School. Ms. Giles created the Everglades, Keys, and Ocean (EKO) dropout prevention program to identify at-risk students early in their careers and provide them with a year-long environmental research project aimed at rekindling their love of learning. The curriculum involves hands-on oceanography and marine ecology activities and outdoor expeditions educate students about their local environment while helping them excel in school. Students share the data they collect with a national science database, which also helps boost their self-esteem. The program culminates with a special Science Night during which students present the results of their studies to members of the scientific community. Ms. Giles, has received the DCAT "Making a Difference Award, which was presented by the National Science Teacher Association.
During their time at FIU, they visited the Nutrient Analysis Lab, Microbial Ecology Lab, and Seagrass Lab where they received research instrument demonstrations and hands-on training.

Dr. Rene Price provided expert geochemical/hydrological advise to the South Florida Water Management on matters related to the effects of Florida Power and Light's (FP&L) cooling canal system at the Turkey Point Power Plant in Homestead, Florida on the local groundwater and surface water chemistry. The result of a small study conducted by Dr. Price, Post Doc Jeremy Stalker and other scientists from FIU and the University of Miami, led an oversight panel of water managers from the SFWMD, Florida Department of Environmental Protection, and Biscayne National Park to suggest to FP&L to increased groundwater and surface water monitoring in the vicinity of the cooling canals. FP&L responded with an extensive plan for additional monitoring.

Hugh Gladwin served on the Miami-Dade Climate Change Advisory Task and the Steering Committee, Local Mitigation Strategy, Office of Emergency Management and Homeland Security, Miami-Dade County, Florida.

Water management and climate variability (Gaiser). We have been attempting to interpret water management-derived changes in solute delivery and productivity on a backdrop of climate variability in order to effectively communicate to policy makers (1) the value of long-term data series in extracting water management changes from natural variability in ecological systems and (2) the extent to which temporal changes are controlled by water management. To this end, the

FCE published a special issue of Ecological Indicators (Doren et al., 2009) that documents our conceptual approach and provides examples of application and modeling, and is coordinating with the South Florida Ecosystem Restoration Task Force to annually produce a glossy "stoplight" reporting document for distribution to Congress and other agencies to communicate the extent of ecological change derived from water manipulations.

The FCE LTER Program also reaches out to the public is through our web site and web statistics have shown that we have been reaching a steadily growing number of new web clients, suggesting a strong positive trajectory for our web-based public outreach. We continue to receive general questions from our visitors and requests for schoolyard visits and presentations. Additionally, visitors to the data section of our website downloaded 309 datasets from September 2008 thru July 2009.

III. PUBLICATIONS AND OTHER SPECIFIC PRODUCTS

A. Publications

Books

Ogden, L. (In Press). The Bill Ashley Jungles: Landscape Ethnography and the Politics of Nature in the Florida Everglades. University of Minnesota, Minneapolis, MN.

Book chapters

Cooper, S., E.E. Gaiser, A. Wachnicka. (In Press). Estuarine paleoecological reconstructions using diatoms . In Smol, J.P., E.F. Stoermer (eds.) The Diatoms: Applications in Environmental and Earth Sciences. Cambridge University Press, New York.

Davis, S.E., D. Lirman, J. Wozniak. (In Press). Nitrogen and phosphorus exchange between tropical coastal ecosystems . In Nagelkerken, Ivan (ed.) Ecological Connectivity Among Tropical Coastal Ecosystems. Springer.

DeAngelis, D.L., J.C. Trexler, D.D. Donalson. (In Press). Competition dynamics in a seasonally varying wetland: importance of temporal variability and spatial heterogeneity . In Cantrell, S., C. Cosner, S. Ruan (eds.) Spatial Ecology. Chapman Hall/CRC Press, .

Gaiser, E.E., K. Ruhland. (In Press). Diatoms as Indicators of Environmental Change in Wetlands and Peatlands . In Smol, J.P., E.F. Stoermer (eds.) The Diatoms: Applications in Environmental and Earth Sciences. Cambridge University Press, New York.

Trexler, J.C., D.L. DeAngelis. (In Press). Modeling the evolution of complex reproductive adaptations in poeciliid fishes: Matrotrophy and superfetation . In Uribe, M.C., H.J. Greer (eds.) Viviparous Fishes II. New Life Publications, Homestead, FL.

Trexler, J.C., D.L. DeAngelis, J. Jiang. (In Press). Community assembly and mode of reproduction: predicting the distribution of livebearing fishes . In Evans, J., A. Pilastro, I.

Schlupp (eds.) Ecology and Evolution of Poeciliid Fishes. University of Chicago Press, Chicago, IL.

Twilley, R.R., V.H. Rivera-Monroy. 2009. Ecogeomorphic Models of Nutrient Biogeochemistry for Mangrove Wetlands . Pages 641-675 In Perillo, G.M.E., E. Wolanski, D.R. Cahoon, M.M. Brinson (eds.) Coastal Wetlands: An Integrated Ecosystem Approach. Elsevier.

Journal articles

Balcarczyk, K.L., J.B. Jones Jr., R. Jaffe, N. Maie. 2009. Stream dissolved organic matter bioavailability and composition in watersheds underlain with discontinuous permafrost. Biogeochemistry , 94: 255-270.

Barr, J.G., J.D. Fuentes, V. Engel, J.C. Zieman. 2009. Physiological responses of red mangroves to the climate in the Florida Everglades. Journal of Geophysical Research , 114: G02008.

Boyer, J.N., C.R. Kelble, P.B. Ortner, D.T. Rudnick. 2009. Phytoplankton bloom status: Chlorophyll a biomass as an indicator of water quality condition in the southern estuaries of Florida, USA . Ecological Indicators , 9(6): S56-S67 .

Briceno, H.O., J.N. Boyer. 2009. Climatic Controls on Phytoplankton Biomass in a Sub-tropical Estuary, Florida Bay, USA. Estuaries and Coasts, doi:10.1007/s12237-009-9189-1

Browder, J.A., M.B. Robblee. 2009. Pink shrimp as an indicator for restoration of everglades ecosystems. Ecological Indicators , 9(6): S17-S28.

Castaneda-Moya, E., R.R. Twilley, V.H. Rivera-Monroy, K. Zhang, S.E. Davis, M.S. Ross. (In Press). Spatial patterns of sediment deposition in mangrove forests of the Florida Coastal Everglades from Hurricane Wilma. Estuaries and Coasts

Chin, D.A., R.M. Price, V.J. DiFrenna. 2009. Nonlinear Flow in Karst Formations. Ground Water , Early View.

Doren, R.F.. 2009. Editorial. Ecological Indicators , 9(6): S1.

Doren, R.F., J.C. Trexler, A.D. Gottlieb, M. Harwell. 2009. Ecological Indicators for System-wide Assessment of the Greater Everglades Ecosystem Restoration Program. Ecological Indicators , 9(6): S2-S16.

Doren, R.F., J.C. Volin, J.H. Richards. 2009. Invasive exotic plant indicators for ecosystem restoration: An example from the Everglades restoration program. Ecological Indicators , 9(6): S29-S36.

Doren, R.F., Jennifer H. Richards, J.C. Volin. 2009. A conceptual ecological model to facilitate understanding the role of invasive species in large-scale ecosystem restoration. Ecological Indicators , 9(6): S150-S160.

Frederick, P.C., D.E. Gawlik, J.C. Ogden, M.I. Cook, M. Lusk. 2009. The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. Ecological Indicators , 9(6): S83-S95.

Gaiser, E.E.. 2009. Periphyton as an indicator of restoration in the Everglades. Ecological Indicators, 6(1): S37-S45.

Gaiser, E.E., N. Deyrup, R. Bachmann, L. Battoe, H. Swain. (In Press). Multidecadal climate oscillations detected in a transparency record from a subtropical Florida lake. Limnology and Oceanography.

Gaiser, E.E., R. Bachmann, L. Battoe, N. Deyrup, H. Swain. (In Press). Effects of climate variability on transparency and thermal structure in subtropical, monomictic Lake Annie, Florida. Fundamental and Applied Limnology.

Glibert, P.M., J.N. Boyer, C. Heil, C.J. Madden, B. Sturgis, C.S. Wazniak. (In Press). Blooms in lagoons: Fundamentally different from those of riverine-dominated estuaries. Estuaries and Coasts.

Harwell, M., B. Sharfstein. 2009. Submerged aquatic vegetation and bulrush in Lake Okeechobee as indicators of greater Everglades ecosystem restoration. Ecological Indicators , 9(6): S46-S55.

Heithaus, M.R., B. Delius, A.J. Wirsing, M. Dunphy-Daly. 2009. Physical factors influencing the distribution of a top predator in a subtropical oligotrophic estuary. Limnology and Oceanography , 54(2): 472-482.

Herbert, D.A., J.W. Fourqurean. 2008. Ecosystem structure and function still altered two decades after short-term fertilization of a seagrass meadow. Ecosystems, 11: 688-700.

Herbert, D.A., J.W. Fourqurean. 2009. Phosphorus availability and salinity control productivity and demography of the seagrass Thalassia testudinum in Florida Bay. Estuaries and Coasts, 32: 188-201.

Ikenaga, M., R. Guevara, C. Pisani, A. Dean, J.N. Boyer. (In Press). Changes in community structure of sediment bacteria along the Everglades marsh, mangrove forest, and Florida Bay seagrass meadows gradient. Microbial Ecology

Jaffe, R., D. McKnight, N. Maie, R. Cory, W.H. McDowell, J.L. Campbell. 2008. Spatial and temporal variations in DOM composition in ecosystems: The importance of long-term monitoring of optical properties. Journal of Geophysical Research - Biogeosciences, 113: G04032.

Lorenz, J.J., B. Langan-Mulrooney, P. Frezza, R.G. Harvey, F.J. Mazzotti. 2009. Roseate spoonbill reproduction as an indicator for restoration of the Everglades and the Everglades estuaries. Ecological Indicators , 9(6): S96-S107.

Madden, C.J., D.T. Rudnick, A.A. McDonald, K.M. Cunniff, J.W. Fourqurean. 2009. Ecological indicators for assessing and communicating seagrass status and trends in Florida Bay. Ecological Indicators, 9S: S68-S82. doi:10.1016/j.ecolind.2009.02.004.

Mazzotti, F.J., G.R. Best, L.A. Brandt, M.S. Cherkiss, B.M. Jeffery, K.G. Rice. 2009. Alligators and crocodiles as indicators for restoration of Everglades ecosystems. Ecological Indicators , 9(6): S137-S149.

Ross, M.S., P.L. Ruiz, J.P. Sah, E. Hanan. 2009. Chilling damage in a changing climate in coastal landscapes of the sub-tropical zone: a case study from south Florida. Global Change Biology, 15(7): 1817-1832.

Ross, M.S., J.J. O'Brien, G. Ford, K. Zhang, A. Morkill. 2009. Disturbance and the rising tide: the challenge of biodiversity management on low-island ecosystems. Frontiers in Ecology and the Environment , e-View: doi: 10.1890/070221

Sargeant, B., J.C. Trexler, E.E. Gaiser. (In Press). Biotic and Abiotic Determinants of Intermediate-Consumer Trophic Diversity in the Florida Everglades. Marine & Freshwater Research

Simoneit, B.R.T., Y. Xu, R. Neto, J. Cloutier, R. Jaffe. 2009. Photochemical alteration of 3-oxygenated triterpenoids: Implications for the origin of 3,4-seco-triterpenoids in sediments. Chemosphere, 74: 543-550.

Smith, T.J., G. Anderson, K. Balentine, G. Tiling, G.A. Ward, K. Whelan. 2009. Cumulative Impacts of Hurricanes on Florida Mangrove Ecosystems: Sediment Deposition, Storm Surges and Vegetation. Wetlands, 29(1): 24-34.

Stalker, J.C., R.M. Price, P.K. Swart. 2009. Determining Spatial and Temporal Inputs of Freshwater, Including Submarine Groundwater Discharge, to a Subtropical Estuary Using Geochemical Tracers, Biscayne Bay, South Florida. Estuaries and Coasts, 32(4): 694-708.

Trexler, J.C., C. Goss. 2009. Aquatic fauna as indicators for Everglades restoration: Applying dynamic targets in assessments. Ecological Indicators , 9(6): S108-S119.

Volety, A.K., M. Savarese, S.G. Tolley, W.S. Arnold, P. Sime, P. Goodman, R.H. Chamberlain, P.H. Doering. 2009. Eastern oysters (Crassostrea virginica) as an indicator for restoration of Everglades Ecosystems. Ecological Indicators , 9(6): S120-S136.

Williams, C.J., J.N. Boyer, F.J. Jochem. 2009. Microbial activity and carbon, nitrogen, and phosphorus content in a subtropical seagrass estuary (Florida Bay): evidence for limited bacterial use of seagrass production. Marine Biology, 156(3): 341-353.

Yamashita, Y., R. Jaffe. 2008. Characterizing the Interactions between Trace Metals and Dissolved Organic Matter Using Excitation-Emission Matrix and Parallel Factor Analysis. Environmental Science & Technology, 42(19): 7374-7379.

B. Other Specific Products

Presentations at Professional Conferences

The FCE LTER Program has not generated any tangible economically-valuable products to date. However, we view the dissemination of our results at professional scientific conferences as a tangible intellectual product. FCE scientists and students have made 104 such presentations during the third year of FCE II.

We continue to dedicate FCE resources to provide travel support for FCE scientists, students, and educators to attend professional conferences. This is important for their professional development, but is also important as a mechanism for disseminating products of FCE LTER research. Disseminating this intellectual product is critical to helping guide the science of Everglades Restoration.

Data or databases

We have 383 FCE and historical Everglades datasets. Datasets include climate, consumer, primary production, water quality, soils, and microbial data as well as other types of data. An Oracle10g relational database has been designed to accommodate the diverse spatial and temporal heterogeneous core data and accompanying metadata submitted by the FCE researchers. Datasets are available for public download from the data section of the Florida Coastal Everglades LTER website at http://fcelter.fiu.edu/data.

C. Internet Dissemination

The url of the main FCE LTER Program website is http://fcelter.fiu.edu.

IV. CONTRIBUTIONS

A. Contributions within Discipline

Several FCE scientists participate in large-scale high-density monitoring programs in the Everglades compliment FCE-LTER research. This includes the REMAP program of the Environmental Protection Agency, which collects and analyzes periphyton, vegetation and consumer data from 125 sites throughout South Florida every 3 years in conjunction with abiotic and other biotic data. Similar mapping occurs through support through the Comprehensive Everglades Restoration Monitoring and Assessment Program funded through the South Florida Water Management District. Evelyn Gaiser and Joel Trexler are collecting periphyton, consumers and plants from more than 400 sites per year, distributed throughout the Everglades, and analyzing patterns relative to water quality and hydrology gradients. Monitoring in Biscayne Bay, Florida Bay and the Florida Keys continues through support from the Southeast Environmental Research Center, University of Virginia and South Florida Water Management District.

Joe Boyer collaborated with Linda Amaral-Zettler at International Census of Marine Microbiology, (ICoMM) (icomm.mbl.edu), Marine Biological Laboratory. He received NSF funding to support massively-parallel, 454-based tag sequencing strategy that allows extensive sampling of marine microbial populations (PNAS 103: 32 p. 12115-12120). Sequencing of hypervariable regions of the SSU rRNA gene allows measurement of both relative abundance and diversity of dominant and rare members of the microbial community thereby allowing efficient comparison of the structure of microbial populations in marine systems. The aquatic component of this project began last fall at 4 sites in FCE during wet and dry season.

Joe Boyer collaborated with Ryan Penton at Michigan State University to sample marine sediments in Florida Bay for metagenomic profile using massively-parallel, 454-based tag sequencing strategy. Preliminary analysis suggests that FL10 is drastically different from 9 and 11. Looking at the database, it seems like FL10 has much lower DOC and is a more refractory site. The proportion of observed OTUs and Chao1 ratios indicate that FL9,10, and 11 are all relatively phylum poor in contrast with the richest communities observed at barrow canyon (Alaskan maritime), Juan de Fuca (Pacific) and Cascadia basin (Pacific).

Laura Ogden served as Contributing Editor for the Anthropology and Environment Section of *Anthropology News*. She also served on the Executive Board of the Anthropology and Environment Section, American Anthropological Association.

Stiefel, J.M., A.M. Melesse, M.E. McClain, R.M. Price, E.P. Anderson, and N.K. Chauhan, Effects of rainwater harvesting induced artificial recharge on the groundwater of wells in Rajasthan, India, Accepted and in press in Hydrogeology Journal.

Dr Rene Price and other FCE LTER researchers were contributing authors to the 2009 South Florida Environmental Report (2009 SFER) Prepared by the South Florida Water Management District for the State of Florida

Alber, M., J. Moore, J. Onsted, R.G. Pontius Jr., N. Sayre, L. Schneider and J.Thompson. "White Paper: Modeling Socio-Ecological Systems in LTER. A Common Denominator: Modeling Land and Water Use Change in LTER sites." Currently under review by LTER Steering Committee. Forthcoming.

Jeff Onsted participated in the following workshops:

- Future Directions for Cross-site, Socio-Ecological Research: Animating the ISSE Framework for the LTER Network Workshop (October 23 – 24, 2008 Clark University)

- LTER Working Group: Design Challenges and Solutions for Establishing a Network of Socio-Ecological Research Sites (December 15 – 19, 2008 University of Puerto Rico)

- FCE Modeling and Synthesis Workshop, June 15th thru June 17th Key Largo, FL. This workshop began the arduous task of bringing together the many different models being applied in the FCE LTER site.

B. Contributions to Other Disciplines

Joe Boyer attended the following meetings and workshops:

- FKNMS Sanctuary Advisory Committee. Ocean Reef, FL – Oct. 21, 2008.
- DERM and BNP Biscayne Bay SWMM Model Meeting. Miami, FL – Oct. 30, 2008.
- Southern Everglades and Florida Keys Ecosystem Restoration Workshop. Tavernier, FL Nov. 18, 2008.
- South Florida Ecosystem Restoration Task Force, Science Coordination Group. Coral Springs, FL – Dec. 11, 2008.
- Southern Association of Marine Laboratories. Baltimore, MD – Apr. 27-29, 2009.

- NOAA Coral Reef Conservation Program Atlantic/Caribbean CREIOS Workshop. Puerto Rico – May 12-14, 2009.
- FKNMS Sanctuary Advisory Committee Meeting. Marathon – June 16, 2009.

Roy Chowdhury, Rinku, Laura A. Ogden, Rebecca Garvoille., Millennium Conference Organizing Committee, "Water-Ecosystem Services, Drought & Environmental Justice," Ecological Society of America.

Several FCE scientists participate as advisors to the South Florida Ecosystem Restoration Task Force for establishing Vital Sign Indicators of Everglades restoration. This team is using FCE LTER and other large, long-term datasets to assess and evaluate the trajectory of Everglades restoration projects. This includes participation in bi-monthly workshops, modeling efforts and synthesis of long term datasets. This group published their findings in a special issue of the journal *Ecological Indicators* in 2008.

Several FCE scientists participate as advisors to the REstoration COordination and VERification (RECOVER) team for the Comprehensive Everglades Restoration program. This includes participation in quarterly workshops, reading and evaluating annual reports and proposals and synthesizing data for use in Everglades monitoring and protection.

Several FCE scientists participate as advisors to the South Florida Water Quality TOC Water Quality Evaluation Team which evaluates the compliance to water quality standards set for Everglades National Park and other federally protected land in South Florida. Participation includes presence at biannual meetings, reporting on water quality data (including FCE LTER findings) and evaluating reports to congress.

Evelyn Gaiser is a collaborator on an NSF Research Coordination Network grant for the Global Lakes Ecological Observatory Network. This is a grassroots network of limnologists, engineers and information specialists who aim to equip lakes and wetlands with high-resolution sensors and real-time global conveyance to evaluate large-scale patterns in ecological change in aquatic ecosystems. Participation in GLEON will facilitate future high-resolution sensor data collection and communication within the FCE LTER and a site at the head of the FCE watershed at Archbold Biological Station.

Evelyn Gaiser and Nick Oehm are on the planning committee for the 2009 Network ASM meeting in Estes Park, CO. Laura Ogden is presenting a plenary talk at this meeting.

Evelyn Gaiser, Jim Heffernan and Dan Childers participated on the LTER Science Coordination Committee at the annual meeting.

Evelyn Gaiser, Steve Davis and Victor Monroy-Rivera participated in the LTER Hurricane Research Coordination Network meeting in Merida, Yucatan supported by the 2008 supplement award to the Luquillo LTER. This meeting initiated a cooperative approach among US LTER and Mexico ILTER sites to the study of the effects of hurricanes on tropical forests. The meeting established a strong core group of researchers committed to establishing a network of sites and scientists to expand, improve, and synthesize research on hurricanes and their effects (see report at http://lno.lternet.edu/merida). Moreover, meeting participants agreed to develop two manuscripts, established working groups to prepare a proposal to the Research Coordination Network program, initiated a bibliography of research on Caribbean hurricanes, and began development of a web page that describes these achievements and the sites that will be involved in the new network. Additional 2009 supplement funding to FCE and LUQ will support a second meeting to 1) complete the manuscripts under development, 2) expand the working group to include additional ecologists and social scientists from the Greater Caribbean Basin, and 3) maintain the momentum that the first meeting provided until we obtain longer-term funding. This meeting will be held in Miami in December 2009.

Gail Hollander, Laura Ogden, Jim Heffernan, Michael Ross and Evelyn Gaiser wrote a proposal to the NSF ULTRA-Ex competition, with 20+ FCE and external collaborators, entitled "Double Exposures: Socio-ecological Vulnerabilities in the Miami-Dade Urban Region." The proposal was funded and will begin in September 2009. The ULTRA-Ex will integrate with and reciprocally augment the FCE-LTER, which is an NSF-funded multi-institutional program of science and education focused on understanding the long-term ecosystem dynamics of the Florida Everglades, particularly as influenced by the interactions of climate change and the politics of water management. The organizational framework for research in the FCE-LTER complements the ULTRA-Ex, with five pillars of research (hydrology, biogeochemistry, organic matter dynamics, primary productivity and food web dynamics) that are integrated by three cross-cutting themes (modeling and synthesis, climate and disturbance and human dimensions). We envision the ULTRA-Ex extending the pillars of research from the Everglades and its suburbanizing boundary into the urban system where decisions are made. Integration will be facilitated by extending the same cross-cutting themes across the expanded research realm. This ULTRA-Ex will be a critical to development of human dimensions research in the FCE, providing the means for understanding and possibly influencing the outcomes of a politically-charged urban-wildland dynamic that determines the future of this threatened Biosphere Reserve. The FCE-LTER will provide this ULTRA-Ex not only a research framework and foundation of science to evaluate urban-wildland dependencies, but also a developed network of collaborators, students, policy makers, information managers at the local and international scale to increase the efficiency of ULTRA-Ex program building.

International LTER supplemental funding from 2006/07 was used to support cross-system comparisons in the Sian Ka'an Biosphere Reserve in Quintana Roo, Mexico and New River Lagoon, Belize. The extensive wetlands occur on calcareous bedrock and support wet prairie habitat very similar to the Everglades. Joel Trexler, Evelyn Gaiser and William Loftus took FCE students Josette La Hée and Clifton Ruehl to these sites in Fall 2006 and Spring 2007 to compare the Eltonian biomass structure of these wetlands to that of the Everglades. Further support from FIU foundations supported their travel back to these sites in Fall and Spring 2008. Preliminary analyses show that these wetlands also support a very high biomass of periphyton which does not translate up the food web. The consumer community was depauperate and dominated by reduced community of gastropods and small fish as in the Everglades. Community analyses show a great deal of compositional overlap in the algal and plant communities but less so with the consumers, although biomass structure does appear consistent among sites.

C. Contributions to Human Resource Development

Eight undergraduate students at FIU gained experience in field sampling techniques working with bull sharks, snook, and gar. Three undergraduate students at FIU gained field experience working with alligators.

Ogden, Laura, A., Ted Gragson, Morgan Grove, Chris Boone. "From Yarksticks to Gyroscopes: Interdisciplinary Methods for Socio-ecological Research," Spring semester 2009. This course was video-assisted using a live interactive video-feed. All materials from the course (readings, video presentations, power point slides) are archived and available through the course website.

"Curriculum Enrichment, Instrumentation and Experiential Learning in Agroecology", August 2008 - August 2011, $290,000, USDA (Jeff Onsted, Co-PI). Funded.

"National Needs Fellows in Sustainable Sciences at Florida International University: An Interdisciplinary and Integrative Training Approach." September 2008- February 2012, $240,000, USDA (Jeff Onsted, Co-PI). Submitted and pending.

D. Contributions to Resources for Research and Education

Website

The FCE LTER website provides a variety of information, including data, educational activities, maps, project information, site information, publications, presentations, and photos. Visitors to the data section of our website downloaded 309 datasets from September 2008 through July 2009.

Wu, X., Y. Hu, H. He, R. Bu, J. Onsted, and F. Xi. "Using multiple methods to evaluate the performance of SLEUTH in the Shenyang metropolitan area." *Environmental Modeling and Assessment.* 14(2): 221-230, 2009.

"Limits to Growth in Agriculture and Emerging Sustainable Farming Systems in Developing Countries." May 2006 – April 2010, $100,000, USDA (Jeff Onsted became PI in July, 2008) Funded.

"Decision support tools for retention and success of small and medium sized farmers in Florida." January 2010 – December 2013, $333,000 USDA (Jeff Onsted, PI). Submitted and Pending.

E. Contributions Beyond Science and Engineering

Jeff Onsted assisted with the Agroecology Symposium on February 24th, 2009. He supervised the high school students as they toured the posters, assisted Lisa Wolf with her presentation, and made myself available throughout the day to assist with ad-hoc problems.

V. REFERENCES

Armitage, A.R., Frankovich, T.A., Heck, K.L. Jr., Fourqurean, J.W. 2005. Complexity in the response of benthic primary producers within a seagrass community to nutrient enrichment. Estuaries 28(3):422-434

DeAngelis, D. L., J. C. Trexler, C. Cosner, A. Obaza, F. Jopp. Fish population dynamics in a seasonally varying wetland. (Submitted to Ecological Modelling, July 2009)

Fourqurean, J.W., J.N. Boyer, M.J. Durako, L.N. Hefty, and B.J. Peterson. 2003. Forecasting responses of seagrass distribution to changing water quality using monitoring data. Ecological Applications 13:474-489.

Ho DT, Engel VC, Variano EA, Schmeider PJ, and Condon ME 2009. Tracer studies of sheetflow in the Everglades. Geophys. Res. Lett. doi: 10.1029/2009GL037355

Jopp, F., D. L. DeAngelis, and J. C. Trexler. Modeling seasonal dynamics of the small fish functional group in fluctuating freshwater marshlands. (Submitted to Landscape Ecology)

Leavesley, GH, S.L. Markstrom, M.S.Brewer, and R.J. Viger. 1996. The modular modeling system (mms) -- the physical process modeling component of a database-centered decision support system for water and power management *Water, Air and Soil Pollution* 90:303-311.

Nuttle, W.K., J.W. Fourqurean, B.J. Cosby, J.C. Zieman, and M.B. Robblee, 2000. Influence of net freshwater supply on salinity in Florida Bay. Water Resources Research 36:1805-1822.

Trexler, J.C. and C. Goss. 2009. Aquatic fauna as indicators for Everglades restoration: Applying dynamic targets in assessments. Ecological Indicators , 9(6): S108-S119.

Variano, E. A., D. T. Ho, V. C. Engel, P. J. Schmieder, and M. C. Reid (2009), Flow and mixing dynamics in a patterned wetland: Kilometer-scale tracer releases in the Everglades, Water Resources Research, 45, W08422, doi:10.1029/2008WR007216.