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FCE II Year Five Annual Report for NSF Award DBI-0620409 (2011)

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

FLORIDA COASTAL EVERGLADES LTER

Florida International University

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I. PARTICIPANTS

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B. Partner Organizations

- College of William & Mary: Collaborative Research; Personnel Exchanges
- Ecology and Environment, Inc.: Collaborative Research; Personnel Exchanges
- Everglades Foundation: Collaborative Research; Personnel Exchanges
- Everglades National Park: Collaborative Research; Personnel Exchanges
- Florida Gulf Coast University: Collaborative Research; Personnel Exchanges
- Florida State 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
- Portland 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 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 fifth year of the FCE II LTER Program. We also partner with 1 state agency (South Florida Water Management District), 2 NGOs (Everglades Foundation and the National Audubon Society), and 20 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:

- Greg Okin, University of California, Los Angeles – Modeling GPP and remote sensing of mangroves.
- Tom O'Halloran – Oregon State University and Sweet Briar College – Radiative forcing following mangrove disturbances
- 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.

II. ACTIVITIES AND FINDINGS

A. Research 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 to 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).

In this section, we include summaries of the fifth year of research by FCE II working groups, cross-cutting theme groups, and information management activities below. Our education and outreach activities are included in Sections C and D of this report.

1. Primary Production

The primary goal is of this working group is to understand how water source and nutrient availability influence above- and below-ground primary productivity across this gradient, with particular focus in the oligohaline ecotone. We continue all of our long-term productivity measurements across the freshwater-to-marine gradient. For this year's annual report, we highlight specific Year 5 projects, including an examination of the effects of nutrients, temperature and light environment on toxic phytoplanktonic cyanobacterial production, construction of quantitative models that predict long-term patterns of periphyton production and composition, experimental manipulations of temperature to examine thermal effects on periphyton, continued long-term measurements of effects of P-limitation on resource allocation in mangroves, and continued experimental research to determine controls on seagrass dynamics (which now includes manipulations of CO_2 availability). We also describe a newly funded FCE project that will explicitly examine effects of restored water flow into the upper reaches of the SRS transect, key to addressing our FCE II hypotheses.

Phytoplankton communities

We examined whether a common cyanobacterial member of the periphyton community, *Microcystis aeruginosa,* had allelopathic effects on other microalgae. Harmful algal blooms (HABs) are an increasing occurrence and threat to freshwater systems throughout the world. They are known to produce toxins that cause illness in humans and death to livestock that are exposed to the contaminated water. Most of these HABs species are cynaophycea and, when the conditions are right, they successfully compete with the other algal species, thus creating cyanobacterial blooms. The known mechanisms explaining the domination of these harmful cyanobacteria are generally linked to the right (often extreme) conditions such as i) excessive nutrient concentrations, ii) warm temperatures, iii) light and iv) less obvious competition mechanisms such as, but not limited to: faster nutrient uptake, efficient light uptake (e.g. creation of floating scum) and UV protective pigments as well as possibility to uptake CO_2 at high alkalinity (carbonic anhydrase enzyme). Beside competition, the allelopathic effect that these algae can have on the other algae has been largely overlooked. Hence, the capacity of *M. aeruginosa* (isolate from L. Trafford, Fl) to control at distance the photosynthesis of other algae through a telemediated dissolved chemical (ie. allelopathic) has been studied in spring 2011. The study examined the allopathic effect of *Microcystis aeruginosa* on the growth of four different Chlorophyceae *Staurastrum gracile, Pediastrum duplex, Kirchneriella contorta, Closterium littorale* and one Cyanophyceae *Aphanocapsa incerta*. Cultures of test algae were grown in DY-V medium for control, and 50/50 vol/vol DY-V and filtered DY-V medium in which *M. aeruginosa* was grown until this alga reached its stationary growth (=”toxic” medium). Total cholorophyll concentration and the photosynthetic capability of the algae were assessed over 29 days using the Pulsed Amplitude Modulation method (PAM) using a Phyto-Pam Phyto-ED apparatus.

Periphyton communities
We continue to measure periphyton biomass, productivity composition at all of the sites where periphyton is present. 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 (see Modeling section). 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 initiating new experiments to determine the cause of periphyton dissolution noted in the winter dry season months. This experiment includes new manipulations of water temperature in controlled laboratory chambers.

Mangrove ecosystems
We evaluated long-term (2001-2004) vegetation patterns (above- and belowground) and soil carbon (C), nitrogen (N), and phosphorus (P) storage in mangrove sites along two distinct estuaries: Shark River estuary (SRS-4, SRS-5, SRS-6) and Taylor River Slough (TS/Ph-6, TS/Ph-7, TS/Ph-8) in the Florida Coastal Everglades (FCE) before the passage of Hurricane Wilma (October 2005) across the study area. We tested the hypothesis that patterns of carbon and nutrient (N and P) storage in vegetation (i.e., leaf, wood, roots) and soil (top 45 cm) components are regulated by the interaction of environmental gradients with lower storage in scrub mangroves along Taylor River compared to riverine mangroves in the Shark River region. In December 2000, two 20 x 20 m permanent plots were established between 30-50 m from shoreline in each site to monitor forest structural attributes and soil biogeochemical properties. All trees with diameter at breast height (dbh) ≥ 2.5 cm were tagged within each plot and initially measured in May 2001 and re-measured every year until May 2004. Mangrove trees were not measured at TS/Ph-6 & 7 due to the stunted physiognomy (tree height ≤ 1.5 m) of the mangrove forest. We continue measuring mangrove forest structural attributes in all six sites up to today to

evaluate changes in carbon and nutrient storage and the resilience of mangroves as a result of hurricane disturbance in FCE.

Aboveground wood (trunk and branches) and leaf biomass was calculated for each individual tree tagged using species-specific allometric equations published for the study area. The annual net increase in wood and leaf biomass was calculated as the difference in biomass between years of each individual tree. Total (0-90 cm) root biomass was calculated for each of the six FCE mangrove sites during December 2000 and 2002. Root cores were collected in each site using a PVC coring device (10.2 cm diameter x 90 cm length). All root samples were processed separately and initially rinsed with water through 1-mm synthetic mesh screen to remove soil particles. Live roots were separated by hand picking those floating in fresh water, and sorted into diameter size classes of <2 mm, 2-5 mm, and 5-20 mm (fine, small, and coarse roots, respectively). Each root sample was oven-dried at 60 ºC to a constant mass, and weighed. Total root biomass estimates represent the sum of all size classes for each site. Soil C and nutrient (N and P) pools were analyzed in all six FCE mangrove sites. Soil cores were collected once at each site in May 2001 and January 2002.

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 have also been assessing the effect of addition of nitrogen and phosphorus to the benthic ecosystem across a natural fertility gradient in Florida Bay. Management of ecological disturbances requires an understanding of the time scale and dynamics of community responses to disturbance events. To characterize long-term seagrass bed responses to nutrient enrichment, we established six study sites in Florida Bay, USA. In 24 plots (0.25 m2) at each site, we regularly added nitrogen (N) and phosphorus (P) in a factorial design for 7 years.

We also modeled the effects of changes in water management and water quality on the distribution of seagrass communities in Florida Bay. Historic changes in water-use management in the Florida Everglades have caused the quantity of freshwater inflow to Florida Bay to decline by approximately 60% while altering its timing and spatial distribution. Two consequences have been (1) increased salinity throughout the bay, including occurrences of hypersalinity, coupled with a decrease in salinity variability, and (2) change in benthic habitat structure. Restoration goals have been proposed to return the salinity climates (salinity and its variability) of Florida Bay to more estuarine conditions through changes in upstream water management, thereby returning seagrass species cover to a more historic state. To assess the potential for meeting those goals, we used two modeling approaches and long-term monitoring data. First, we applied the hydrological mass balance model FATHOM to predict salinity climate changes in sub-basins throughout the bay in response to a broad range of freshwater inflow from the Everglades. Second, because seagrass species exhibit different sensitivities to salinity climates, we used the FATHOM-modeled salinity climates as input to a statistical discriminant function model that associates eight seagrass community types with water quality variables including salinity, salinity variability, total organic carbon, total phosphorus, nitrate, and ammonium, as well as sediment depth and light reaching the benthos.

This year we began also testing the response of CO_2-limited, oligotrophic seagrass ecosystems to a factorial manipulation of CO_2 availability and nutrients. Future climate change will likely represent a major stress to shallow aquatic and coastal marine communities around the world. Most climate change research, particularly in regards to increased pCO_2 and ocean acidification, relies on ex situ mesocosm experimentation, isolating target organisms from their environment. Such mesocosms allow for greater experimental control of some variables, but can often cause unrealistic changes in a variety of environmental factors, leading to "bottle effects." We developed an in situ technique of altering dissolved pCO_2 within nearshore benthic communities (e.g., seagrasses, algae, and/or corals) using submerged clear, open-top chambers. Our technique utilizes a flow-through design that replicates natural water flow conditions and minimizes caging effects. The clear, open-top design additionally ensures that adequate light reaches the benthic community.

We have also initiated a project in the northern areas of Shark River Slough to examine ecological responses to modifications of water flow along the Tamiami Trail, including a 1-mile bridge scheduled for completion by fall 2013 and several miles of additional bridging planned for 2014 and 2015. We have incorporated a full before-after control-interference design in order to increase the probability that FCE research will be able to document both upstream and downstream impacts of changes to water movement along the Shark River Slough transect.

Response of freshwater Everglades communities to water management activites
We have initiated a new FCE project with support from the Department of the Interior/Everglades National Park to explicitly examine effects of a new 1-mile bridge on ecosystem dynamics in northeast Shark River Slough. This study follows the Before-After-Control-Intervention design of FCE II but is intensively focused on the area immediately downstream of the initial smaller-scale bridging effort. A full suite of long-term research sites has been selected downstream of the bridge (to be completed in 2013) and in a control area just west of the construction. We will be examining effects of the restoration project on water quality, periphyton, macrophyte, soils and consumer dynamics at the plot and landscape scale. To most effectively design this study, we have been reanalyzing broad spatial scale data on macrophyte and periphyton communities in relation to other water control structures along the eastern boundary of Everglades National Park (Gaiser et al. 2008, Trexler et al. 2008) in order to establish the proper scale and resolution of sampling.

2. Organic Matter Dynamics

The organic matter-working group continues to focus its research efforts on determining and quantifying OM sources and transformations to soils and sediments, and characterizing the pools and identifying the spatial and temporal pathways for exchange of particulate and dissolved organic matter (OM) between soils and water in the south Florida landscape. Water affects ecosystem structure and provides connectivity among wetland and open water habitats of the south Florida region, ranging from freshwater to mangrove to marine environments occurring in both peat- and marl-dominated depositional areas. Our central objective for FCE II has been to determine how organic matter dynamics (POM and DOM in soils and water) in the estuarine ecotone are controlled by local production versus allochthonous inputs from freshwater and marine end-members.

Specifically in Year 5, we completed research to determine the effect of groundwater nutrient pulses on water column metabolism in estuary ponds using data from high-frequency monitoring buoys equipped with O_2, light and temperature sensors (Koch et al. 2011). We also completed tracer addition experiments to track POM transport in the dry and wet season in the Taylor Slough drainages. In addition, we are measuring rates rates of photo-degredation of this POM in estuaries during the tidal cycle. FCE research continues to document dynamics of DOM: we are now examining our long-term data on DOM quality to determine tidal, seasonal and storm-related patterns of change, including tracking a "black-carbon" component, as well as initiating new observational research to determine the source and transport of DIC. A new FCE project supported partly by the South Florida Water Management District, Everglades National Park and Everglades Foundation has allowed us to establish a new experimental facility for manipulating water source and quality to determine impacts on soil processes and the plant community.
We have also initiated a new project to determine the effects of elemental N:P ratios on organic matter processing in the oligohaline ecotone. Mangrove leaf and root decomposition studies were initiated in May 2009 at three of the FCE mangrove sites (SRS-4, SRS-5, SRS-6). Finally, we have integrated all of our carbon cycling research into a common conceptual framework that can be used to guide carbon budget research planned for FCE III.

3. Biogeochemical Cycling

The biogeochemical cycling working group conducts research to determine effects of changes in water source and flow on nutrient cycling, and the impact of changes in nutrient supply on microbial community dynamics. The group coordinates collections of baseline surface water quality data from all FCE sites, measures microbial dynamics with fluorometric and molecular tools, and facilitates studies of biogeochemical cycling, including examinations of the influence of salinity on cycling rates and nutrient exchanges among groundwater, peat soils, pore-water and surface water.

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 CHLA 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. 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.

Porewater biogeochemistry at mangrove sites
We investigated long-term (2001-2010) patterns of porewater biogeochemistry in mangrove sites along two Florida Coastal Everglades (FCE) estuaries: Shark River estuary (SRS-4, SRS-5, SRS-6) and Taylor River Slough (TS/Ph-6, TS/Ph-7, TS/Ph-8). In December 2000, two 20 x 20 m permanent plots were established between 30-50 m from shoreline in each site to monitor soil biogeochemical properties. Within each site, four repeated sampling stations were randomly established in each plot to measure porewater salinity, temperature (ºC), porewater nutrients and sulfide concentrations, and soil redox potential (Eh). Porewater samples were collected at 30 cm depth (McKee et al. 1988) during the dry (May) and wet (October-November) seasons from

2001 to 2010 in all sampling stations. One porewater aliquot was assayed for temperature and salinity using a portable YSI salinity-conductivity-temperature meter (model 30, YSI Incorporated, Yellow Springs, Ohio). A second sample was added to an equal volume of antioxidant buffer in the field and transported to the laboratory within 12 h to be analyzed for sulfide concentrations with a silver/sulfide electrode (model 9616BN, Orion Research, Beverly, MA). A third porewater sample was filtered using a GF/F filter and stored frozen until assayed for ammonium (NH4+), nitrite (NO2-), nitrate (NO3-), and soluble reactive phosphorus (SRP) using a segmented flow analysis Flow Solution IV autoanalyzer (OI Analytical, College Station, Texas). Nitrate concentrations were measured since 2004 due to analytical problems with the analysis during previous years. Soil Eh (0, 10, 45 cm depth) was measured by duplicate in situ using a multi-depth platinum probe (Hargis and Twilley 1994). Porewater sampling in the Taylor River sites was conducted up to 2006. Beginning on May 2010, we continued monitoring porewater chemistry on TS/Ph-6 & 7 sites; porewater sampling in TS/Ph-8 was cancelled after 2006.

Response of freshwater Everglades communities to water management activities
We have been collecting water quality samples from the region of Northeast Shark River Slough that will be impacted by restorative modifications on Tamiami Trail (see Primary Productivity Activities), including downstream of the location of a 1-mile bridge and existing culvert throughways. Water quality samples are collected monthly from a series of grab sample sites and daily by ISCO autosamplers. We are also comparing the response of water quality to changes in water delivery on the Tamiami Trail to those observed along the eastern boundary of Everglades National Park at the head of Taylor Slough.

4. Trophic Dynamics and Community Structure

The trophic dynamics group is focused on determining the flow of detritus through the food web, including in large animals as they move in and out of the ecotone. In Year 5, much progress has been made in tracking the spatiogemporal dynamics in macroinvertebrates, small fish and large consumers through a variety of methods including regular drop-trap sampling and telemetry studies. The group also received supplemental support for comparative research in Shark Bay, Australia, and reports initial findings from those investigations.

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, 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. This will allow us to better estimate 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 52 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. We initiated studies of spatial and temporal variation in the abundance and behavior of bottlenose dolphins. We conducted 1900 km of surveys (171 hours) resulting in 79 group sightings. Quantitative fishing to investigate factors influencing the distribution of bull sharks (80 longline sets) has continued to be able to investigate the influence of marsh dry-down and enhanced upstream prey availability on shark abundance and habitat use. We continued sampling the distribution of juvenile bull shark predators (larger sharks) with drumlines (1200 hook hours) from SRS4 to SRS 6 and Ponce de Leon Bay. We continued sampling mesoconsumer communities (prey for large predators) using crab traps, fish traps, and gill nets. Tissue samples have been obtained from all individuals and a subset have been retained for stomach contents analysis. In 2010-2011 we collected stomach contents using non-lethal techniques from an addition 36 alligators and conducted a laboratory feeding trial to determine the rate of turnover of isotopic values in multiple tissues of alligators. Finally, we used fatty acids to investigate feeding ecology of large consumers and mesoconsumers in upstream marshes and the Shark River Estuary.

Comparing trophic structure and organic matter dynamics between subtropical P-limited estuaries

Using Supplemental Funding, we initiated studies in Shark Bay, Western Australia to understand the dynamics of organic matter in sediments, black carbon, and trophic structure using fatty acid analysis. Data are currently being analyzed and will be compared to the dynamics of Florida Bay. A special issue of the journal Marine and Freshwater Research highlighting this research is forthcoming in 2012.

5. Hydrology

Over the past year the hydrology working group continued to investigate how changing inflows from the upstream Everglades affected the position of the salinity mixing zone and altered geochemical conditions in the ecotone by suppressing brackish groundwater discharge. New this year was an initial attempt at understanding how changing freshwater inflows affect the water residence times in the oligohaline ecotones of Taylor and Shark River Sloughs. Water budget parameters of rainfall, evapotranspiration, surface water flow and groundwater discharge continued to be monitored in both Shark and Taylor Sloughs. Research was conducted on determining how surface water levels throughout ENP varied with managed water releases, rainfall and sealevel rise.

Water Budgets of Taylor and Shark Sloughs

Pressure transducers installed in the surface water and groundwater at sites TS/Ph-7b and TS/Ph-6b continued to monitor water levels, conductivity/salinity and temperature every 30 min. These data were used to determine the position of the salinity mixing zone, and the timing and location of groundwater-surface water interactions within the oligohaline ecotone of Taylor Slough. The weather tower at TS/Ph-7b continued to operate and data collected from the weather tower was used to estimate rates of evapotranspiration, the largest loss of water from the Taylor Slough watershed. Three papers summarizing our water budget research in Taylor Slough were submitted this year, with the lead author of each paper a graduate student funded by FCE LTER research (Michot et al., 2011; Koch et al., 2011; Zapata-Rios and Price, 2011).

Dr. Amarty Saha, postdoctoral researcher supported between the Hydrology and Modeling and Synthesis groups completed a water budget of Shark Slough for the years 2002-2008. That time period served as a baseline for comparison of the effects of future restoration efforts expected within the next five years. Inputs to the water budget include surface water inflows via hydraulic structures and precipitation, while outputs consist of evapotranspiration (ET), discharge to the Gulf of Mexico and seepage losses to an eastern bordering canal. Using a mass balance approach, daily change in volume of SRS (from stage changes) is equated to the difference between input and outputs yielding a residual term, that includes error in each of the components as well as net groundwater exchange. The resulting water budget for Shark Slough was summarized in a manuscript currently under review in the Journal of Estuaries and Coasts (Saha et al., 2011), and presented at regional (GEER 2010; FCE LTER ASM 2011), national (AGU 2011 Fall meeting) and international (AGU 2010 Meeting of the Americas, Iguazo Falls, Brazil) meetings.

Temperature as a Tracer

Dr. Mark Rains of University of South Florida and his graduate student Victoria Spence continued their project aimed at using heat as a natural tracer to study groundwater discharge over the course of seasonal and tidal cycles in the mangrove ecotone regions of both Shark and Taylor Sloughs. Field data collection continued at the four FCE sites TS/PH-6b, TS/PH-7b, SRS-4 and SRS-6. Temperature was monitored at each site using two vertical columns of temperature sensors (107-L Temperature Probes, Campbell Scientific, Logan, Utah) connected to data loggers (CR1000 Dataloggers, Campbell Scientific, Logan, Utah) (Fig. 5.1). At each site, air temperature, water temperature and soil temperature have been monitored at 30 minute intervals since May 2010. Soil temperature is monitored at each site at multiple depths ranging from 25 to 50 cm intervals to the top of the bedrock. The model SUTRA-MS (*Hughes, and Sanford, 2005) was* used to determine groundwater flow directions. The first iteration of the model included no-flow boundaries to model conductive heat flow and to calibrate the temperature data in order to calculate the specific heat properties of the peat. Subsequent modeling efforts will include a head flux boundary at the bottom in order to model advective heat flow as a proxy for groundwater flow.

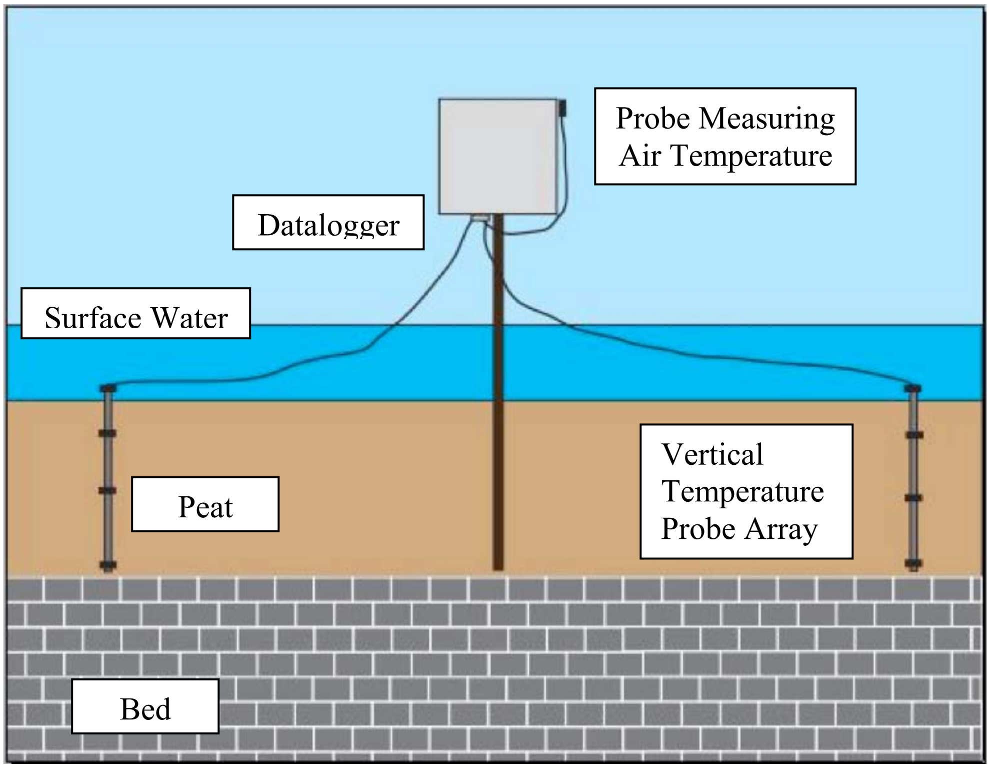


Figure 5.1: Generalized diagram of the temperature probe arrays for sites where bedrock is <2 m below the ground surface.

Geochemical Tracers
In order to determine the sources of water, the interactions between the sources of water as well as to calculate residence times of different water source reservoirs and evaporative enrichment, the surface water samples collected along the SRS and TS/Ph transects were analyzed for major anion and cation concentrations (i.e., Cl, SO_2, Ca, K, Mg, and Na) using a Dionex 120 ion chromatograph by Nicole Neira, an FIU undergraduate student, and Estefania Sandoval, an FIU graduate student. Each (1 L) sample that was collected by the ISCO 6172 autosampler was split in half in the laboratory, with one half analyzed for major cations and anions at FIUs hydrogeology laboratory and the other analyzed for total nutrient concentrations at SERCs Nutrient Laboratory. Prior to being analyzed for major cations and anions, the sample was filtered and split again with one half acidified with 10% HCl for the cations analysis. To date, Shark Slough samples collected from August 2008 through February 2010 have been analyzed. Taylor Slough samples collected between August 2008 to January 2011have been analyzed to date.

Water Residence Times in Shark and Taylor Sloughs
Water residence times along the SRS transect were estimated by postdoctoral researcher Amartya Saha as the volume of water in a segment of Shark Slough divided by the average flow velocity for that segment. A multiyear dataset of flow velocities (every 15 minutes) from SONTEKS placed in Shark Slough was analyzed to develop seasonal flow profiles along the SRS transect. Shark Slough was divided into segments centered around the position of the SONTEKS. The volume of water in each segment was estimated as the product of the area and water depth, with the water depth determined as the difference between water level (EDEN data)

and ground elevation (GIS digital elevation model). Inflows across Tamiami Trail and discharge data for the Shark River Slough (USGS) were used to check the above calculations. The water residence times were then used to calculate phosphorus loading and residence times along the transect using phosphorus concentration data from each of the transect stations.

Preliminary estimates of water residence times in Taylor Slough were made by two FIU graduate students: Greg Koch (Ph.D.) and Estefania Sandoval (M.S.). Greg Koch provided estimates of water residence times in small ponds in southern Taylor Slough located between TS/PH-6 and TS/PH-7 from 1999 to 2009 according to the equation:
WRT = Ap x Z=/(Q + ET x Ap), where Ap was the surface area of the pond, Z was water depth, Q was surface water discharge, and ET was evapotranspiration. Aerial photography via Google Earth was used to estimate pond area, while pond depth was estimated from USGS stage data at site TS/Ph-6. Surface water discharge from the ponds was assumed to be equal to the discharge measured at TS/Ph-6 by the USGS. ET estimates were obtained for the nearby site, Joe Bay, from the South Florida Water Management District DBHydro database. The results of this analysis was published in the Journal Estuaries and Coasts (Koch et al., 20110). M.S. student Estefania Sandoval provided estimates of water residence times throughout the Taylor Slough watershed located between the main park road and Florida Bay for the period between January 2008 and July 2009. Water residence times were estimated as the volume of water in Taylor Slough divided by the discharge. Volume estimates in the watershed were determined from EDEN water level data, while discharge was estimated as the sum of surface water outflow (Qout) at the mouth of Taylor Slough, ET and groundwater recharge (R). The estimates of Qout, ET, and R were obtained from the results of Zapata-Rios (2009).

Subsurface salinity monitoring in the southeastern Everglades "White Zone"
FIU researcher Tiffany Troxler has been monitoring soil salinity at 24 sites located across six N-S transects with the "White Zone" of Taylor Slough (Fig. 5.2). The "White Zone" is documented as a region of low productivity/degraded habitat (Ross et al. 2000) located inland of the mangrove ecotone. Dr. Troxler's research is aimed at investigating landscape soil salinity patterns and relationships with seasonal hydrologic variability in an attempt to better understanding the mechanisms for the formation and expansion of the "White Zone". At each site, surface water and porewater salinity, specific conductivity and dissolved nutrient and carbon concentrations were monitored 3-4 times/year. Using soil extractions, specific conductivity and salinity patterns were determined in early dry and wet seasons to contrast the influence of hydrologic variability on subsurface soil salinity patterns with depth and across the landscape.

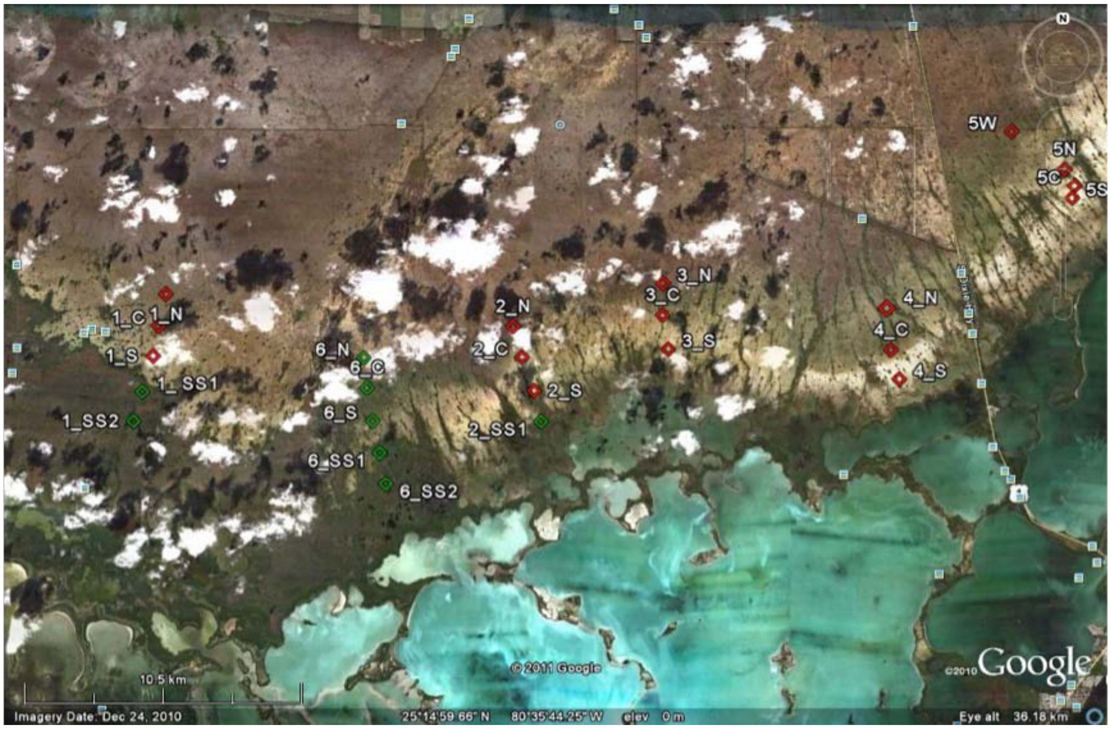


Figure 5.2: Location of soil salinity monitoring sites across the "White Zone" of Taylor Slough.

Field Spectroscopy and Remote Sensing of Mangroves

FIU Ph.D. student David Lagomasino initiated a new feasibility study aimed at determining coastal water quality (seawater intrusion) indirectly from the spectral responses of mangrove vegetation on a regional scale. Spectra-derived biophysical indices were used to assess various relationships between the spectral signatures of the 3 main mangrove species (i.e., *Avicennia germinans*, *Rhizophora mangle*, and *Laguncularia racemosa*) and the ionic and nutrient concentrations in porewater (i.e., 20cm and 100cm depths), surface water, and groundwater of the mangrove ecotone of ENP. Water samples from these sources were collected during the dry season, a transitional period, and the wet season at three sites in large, high-biomass mangroves along Shark River and two sites in dwarf, low-biomass, mangroves along Taylor River. Water samples were analyzed for major ions (e.g, Cl^-, SO_4^{2-}, Na^{2+}, Mg^{2+}, K^+, and Ca^{2+}) and nutrients (e.g., total organic carbon, N and P). The spectral responses of each of the mangrove species were collected in-situ within a few days of the water sampling.

Terrestrial Laser Scanning (TLS)/Ground-based LiDAR fieldwork

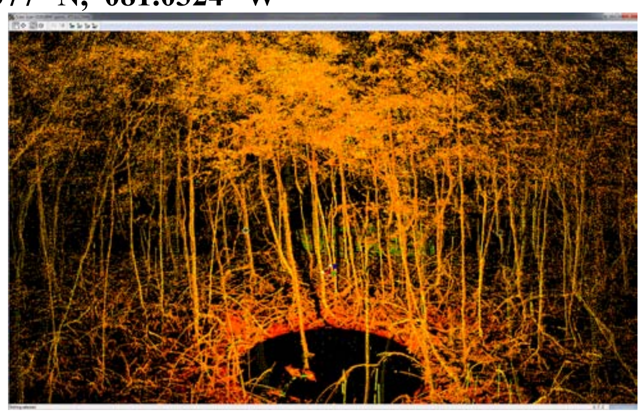
In order to calibrate Synthetic Aperture Radar satellite data for biomass and carbon estimation, TLS surveys were conducted in the Everglades National Park, specifically along Shark River Slough sites. The sites were: SRS 4 (Small size mangroves), SRS 5 (Intermediate size mangroves) and SRS-6 (Tall Mangroves). The first survey was done between March 28, 2011 - March 31, 2011 in the SRS-5 and SRS-6 sites. The second survey was done between April 20, 2011 - April 21, 2011 in the SRS-4 site. These LiDAR measurements enable us to acquire different parameters of the vegetation that are important for biomass estimation. These parameters are: Diameter Breast Height (DBH), first branch height, total tree height, canopy cover area, trunk volume, root and overall vegetation structure. DBH is an important parameter for biomass estimation. To verify this parameter in the LiDAR data, more than 100 DBH measurements were also acquired using a DBH special measuring tape. Also, an internal high-resolution camera in the TLS, enable us to identify different mangrove species (red, white and black).

Day	**Site**	**Scans**	**Data (GB)**
28/03/11	SRS-6	4	2.00
29/03/11	SRS-6	2	1.5
30/03/11	SRS-6	2	1.02
30/03/11	SRS-5	3	3.32
31/03/11	SRS-5	5	5.76
20/04/11	SRS-4	4	1.52
21/04/11	SRS-4	5	1.89
		25	**17.01**

Summary of the TLS Fieldwork:

SRS-4 (LTER site) – Small size mangroves

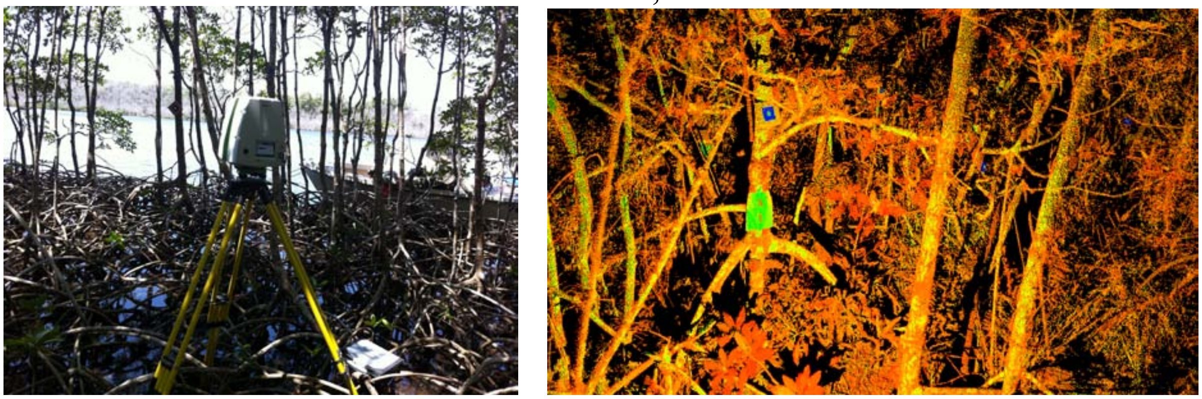
Coordinates: **25.377° N, 081.0324° W**



Figures 5.3a, 5.3b: Pictures of the small size mangrove, SRS-5 site. On the left, a photo of the SRS-4 site. On the right, a LiDAR point cloud of the SRS-4 site.

<u>SRS-5 (LTER site) – Intermediate Size Mangroves</u>

Coordinates: **25.410° N, 080.9653° W**



Figures 5.4a, 5.4b: Pictures of the intermediate size mangrove, SRS-5 site. On the left, the TLS scanner
in the site. On the right, a LiDAR point cloud of the SRS-5 site.

<u>SRS-6 (LTER site) – Tall mangroves</u>

Coordinates: **25.3646° N, 081.0779° W**

Figures 5.5a, 5.5b: Pictures of the tall mangrove, SRS-6 site. On the left, the a photo of the SRS-6 site showing mangrove tree identification. On the right, a LiDAR point cloud of the site.

Hydrology Working Group International Collaborations

FCE hydrology researchers, Dr. Rene Price (FIU), Dr. Fernando Mirrales-Wilhelm (FIU), David Lagomasino (FIU Ph.D. student) and Dr. Shimon Wdowinski (Univ. of Miami) continued to do research in the Sian Ka'an Biosphere Reserve in the Yucatan peninsula of Mexico through leveraged funding supported by the NASA WaterSCAPES project. Field work was conducted in December 2010, in which groundwater monitoring wells were installed in the coastal mangroves. Groundwater and surface water samples were collected and transported to FIU for chemical analysis of stable isotopes of oxygen and hydrogen, major cations and anions, and nutrients. In addition, to the field work, remotely sensed Synthetic Aperture Radar (SAR) amplitude and phase observations were used to determine relative water level changes in the vegetated wetlands of Sian Ka'an. A total of 56 RADARSAT-1 SAR acquisitions were used to calculate 38 interferograms and 13 flooding maps with 24 day and 48 day time intervals between July 2006 and March 2008. The results of the SAR analysis were published in Wetlands by Gondwe et al., 2010.

FIU researchers Drs. Rene Price, James Fourqurean, Rudolf Jaffe, and Michael Heithaus collaborated with researchers from the University of Western Australia (Drs. Gary Kendrick, Pauline Grierson, Diane Walker) on a new multi-disciplinary project investigating the sources of water and carbon within Shark Bay, Australia. Over 50 surface water and groundwater samples were collected from in and around Shark Bay for stable isotopes of oxygen and hydrogen in order to identify sources of water (rain, seawater, surface water, and groundwater). In addition, surface water, sediment, seagrass, algae, crustaceans, and fish were analyzed for carbon biomarkers. Finally, 10 sediment cores were collected for carbon content to determine the history of carbon sequestration within Shark Bay. The results of these studies will be compared to similar research being conducted within Florida Bay. In order to stimulate collaborate research between the University of Western Australia and FIU, a symposium was held at the University of Western Australia on 2 March 2011. Approximately 25 researchers from both universities as well as from governmental environmental organizations from Western Australia attended the meeting to discuss current research and future collaborative research in Shark Bay, Australia and Florida Bay, USA.

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, and (4) understand the impacts of sea level rise on social vulnerability. Here we outline activities for two related FCE HD projects.

In FCE-LTER Human Dimensions (FCE-HD) research, three core research questions directly concern the patterns and social processes linked to residential landscapes, within which are juxtaposed suburban lawns (grass cover), shrubs, trees and various proportions of impervious surfaces (including building footprints) and bare soils.

Much research on urban tree/vegetative cover in the US has focused on the distribution and ecology of land cover on public lands and parks in cities, and the social access to these environmental amenities for urban dwellers. However, most local-level decision-making about land management and vegetative cover in fact happens in privately managed residential spaces. Analyzing the cover patterns and social production of residential yard and landscapes is increasingly critical to deeper explanations of urban ecosystems and processes.

First, we ask: ***What are the spatial patterns and composition of (sub)urban landscapes in the FCE-HD study area?*** To answer this question, we are using land cover data derived from high-resolution GeoEye imagery to characterize the types and greenness of land covers using categorical data (classified cover) and continuous/quantitative data (e.g., indices of vegetation greenness such as NDVI—Normalized Difference of Vegetation Index) (see Fig. 6.1).

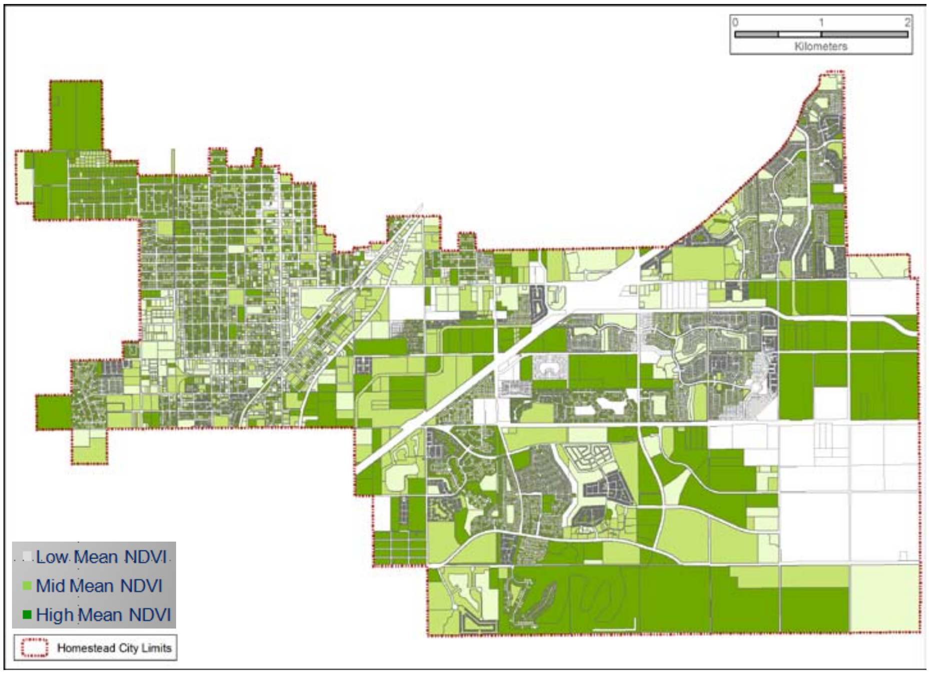


Figure 6.1: Relative greenness of land parcels in Homestead, Florida, derived from reflectance bands in 2009 GeoEye imagery. Greenness is depicted in three classes (low, medium and high) based on statistical breaks in mean parcel-scale NDVI values.

Secondly, we pose the question: ***What are the broad-scale social/structural/institutional determinants of those patterns?*** To address this second question, we are analyzing the aforementioned land cover data using spatially explicit GIS approaches that integrate high-resolution land cover with municipal zoning data (e.g., Fig. 6.2), and with neighborhood-scale socio-demographic characteristics derived from Claritas PRIZM market segmentation data (Fig. 6.3).

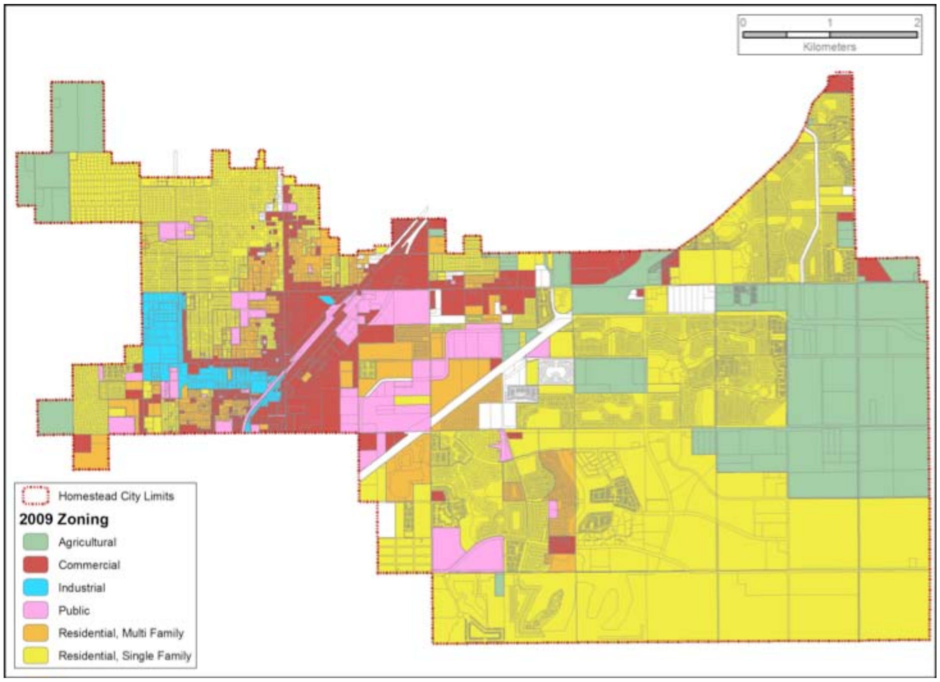


Figure 6.2: Municipal Zoning (2009) in Homestead, Florida. Note the majority of land area is under residential (~12,907 single family parcels) zoning, with large areas also zoned under agricultural land use. Public, industrial and commercial lands are the other main zoning categories.

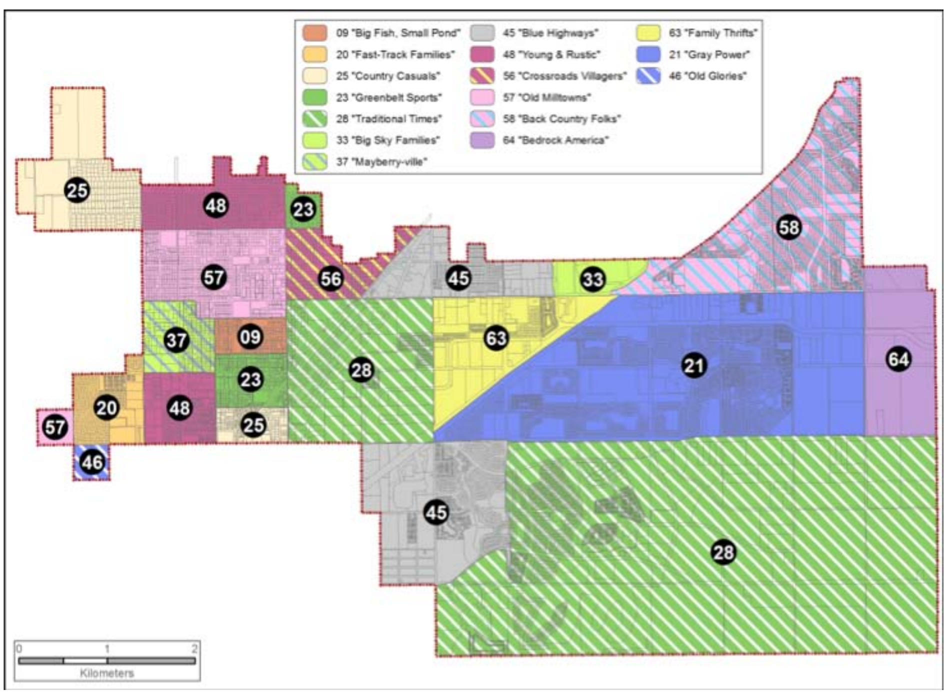


Figure 6.3: PRIZM socio-demographic groups in Homestead, Florida. For instance, approximately 20% or ~2580 residential land parcels each pertain to neighborhoods dominated by the "*Gray Power*" (#21), "*Traditional Times*"(#28) and "*Back-Country Folks*" (#58) PRIZM social groups.

Third, we are leading the systematic, comparative analysis of residential land cover across multiple LTER sites to address a third research question: ***Is (sub)urbanization homogenizing residential landscapes in America?*** To investigate this question, we are leading the analysis of cross-site data land cover and neighborhood-scale socio-demographic (PRIZM) data at four urban LTER sites (FCE, BES, PIE and CAP, see Fig 6.4). Specifically, we analyze the relation between socio-demographic groups common to residential neighborhoods in all four sites, and their associated land covers, landscape structure and spatial autocorrelation.

Finally, Rebecca Garvoille passed her doctoral candidacy exams in February 2011 and is now carrying out ethnographic and archival fieldwork in the southern Everglades for her dissertation entitled "The Cultural Politics of Everglades Restoration: Land, Identity and Nation in the Florida Everglades." Specifically, her dissertation research examines how south Florida's successive environmental restoration projects, including its national parks, have shaped the politics of identity, land and nation for Native Americans and rural glades peoples in the southern Everglades and how the legacies of these struggles inform contemporary Everglades restoration politics. Her dissertation research will make an important contribution to FCE the Human Dimensions Working Group.

As a Research Assistant for the FCE Human Dimensions Group, Rebecca is finishing up the data collection for a paper she is authoring with Dr. Laura Ogden that explores the process of suburbanization in FCE Human Dimensions Study Site. This paper draws on data collected through a yard observational survey and semi-structured interviews to analyze how the production of suburban yards and suburban subjects is an uneven and emplaced process shaped by historical memory and landscape legacies in the Homestead/Redland area. She plans to submit this manuscript for publication to the journal *Environment and Planning D: Society and Space* in fall 2011.

7. Climate and Disturbance

The Climate and Disturbance working group has continued research on: (1) Regional gradients in precipitation and temperature in response to climate teleconnections, (2) Mangrove forest disturbance and post Hurricane Wilma recovery, and (3) Paleoecological and paleoclimatologic results from Everglades and South Florida. We report specific Year 5 activities below. FCE post-doc Chris Moses moved on a new position at NOAA, and his replacement Anna Wachnicka continues moving the paleoclimate focus forward and is now collaborating with the USGS. Additionally, FCE members including several from the C&D Working Group are PI's on a newly funded NSF project, which is directly linked with the FCE funded through the Water Sustainability and Climate (WSC) program. On March 18-19, 2011, the project held an FIU/FCE sponsored workshop on "Linking freshwater inputs to ecosystem function and services provided by a large mangrove estuary". Our working group is also focusing on publishing a special issue of the *Journal of Paleolimnology*, on Everglades Paleoclimate Records. The first of several manuscripts are moving through the review process and are in press. Presented below are the results of the main activities of the working group ranging from the WSC workshop, paleo-based studies to recent in the mangrove zone/ecotone.

NSF WSC Workshop - Linking freshwater inputs to ecosystem function and services provided by a large mangrove estuary (Sukop, Jaffe, Rehage, Engle & Anderson)

This workshop was funded by a NSF-Category 1 Water, Sustainability, and Climate project and held in Miami on March 18 and 19, 2011. On the first day of the workshop eleven people participated in a field trip to the Shark River (ENP) and the adjacent Harney River. The second day of the workshop held at FIU, included more than 50 individuals. In addition to the FIU participants, there were representitives from both state and federal agencies (CERP, USGS, NOAA, ENP & SFWMD). Workshop presentations focused on: economic valuation strategies, hydrology, mangrove ecology, carbon cycling, and fisheries. These invited presentation/talks provided participants with a baseline understanding of the study region. Breakout groups considered specific data needs and ecosystem services and their linkages with hydrologic management of system. Breakout groups were followed by a panel discussion led by key participants (economists, managers, and scientists) which summarized the workshop.

NSF WSC tracer study – Shark River isotopic composition of TOC (Engle, Ho, Jaffe, Palya & Anderson)

As part of the larger NSF WSC funded project, an SF_6 tracer study was conducted in November of 2010 by working groups form ENP, FIU and Univ. of Hawaii. This work included the release of the tracer (SF_6), which was sampled in a lagrangian approach as the tracer "patch" moved from the fresh water portion of the system to the mangrove ecotone. The goal of this study was to measure carbon export through the system. Annie Palya used our new CRDS system to measure the isotopic composition of the TOC & DIC (analyzed at RSMAS) during this study, as carbon isotopes may help to resolve different sources of carbon. This analytical approach is relatively new, and will be important for understanding the C-dynamics within the FCE.

Paleocological and paleoclimate research, collaboration with Utrech University (Gaiser)

Gaiser spent part of her sabbatical at Utrecht University, collaborating with Drs. Friederike Wagner, Gert-Jan Reichart and Stefan Dekker and their colleagues and graduate students on paleoecological research related to hurricanes and global change. The collaboration allowed us to complete several manuscripts for publication, begin several others and facilitated proposal planning and cross-site investigations. New collaborative manuscripts are focusing on reconstructing tropical storm events from sediment cores along the southwest Florida coast.

Woody Debris Spatial Patterns in Everglades Mangrove Forests after Hurricane Wilma (LSU group: Rivera & Castaneda)

Downed wood was estimated in December 2005 at two mangrove forests (Broad Creek – BC and Shark River – SRS-6) in the Florida Coastal Everglades (FCE) after the passage of Hurricane Wilma (October 2005). We used the line-intercept technique originally proposed by Van Wagner (1968) and Brown (1974) and later applied to mangrove forests (Allen et al. 2000) to evaluate the spatial variation in woody debris (WD). At each site, a transect was established perpendicular from the mangrove shoreline to the interior of the forest; transect length (~700-750 m) varied depending on soil elevation and mangrove cover. Woody debris was measured at different sampling points along each transect. In each sampling point, two 10-m-long transects were established as replicates at two random azimuths (120 and 210º) from the center of the sampling point. Coarse (> 7.5 cm in diameter) and fine (< 7.5 cm in diameter) WD intersecting the line along the 10 m transects was measured to 0.1 cm with a DBH measurement tape.

Volume for coarse and fine WD was calculated using the following formula (Van Wagner 1968; Allen et al. 2000):

$$v = \{[\pi^2 (\sum d_i^2)] / 8L\} * k$$

v = WD volume ($m^3\ ha^{-1}$)
d_i = diameter of an individual piece of WD (m)
L = sample line length (m) – in our case is the 10 m transect in each sampling point
k = per hectare conversion constant (10,000 $m^2\ ha^{-1}$)

Recent ecological shifts in South Florida estuaries (Wachnicka)
Wachnicka's recent research activities include analyses of the historic ecological regime shifts in the South Florida estuaries. Abrupt ecological and physical system shifts are very important in marine ecosystems because they affect many physical properties and ecosystem variables, and can involve all trophic levels of food web and the associated biochemical cycles. Therefore, it is extremely important to determine when and why such abrupt shifts in biotic and abiotic components occurred in the past and what the causes of these shifts were in order to understand the dynamics of the South Florida estuaries.

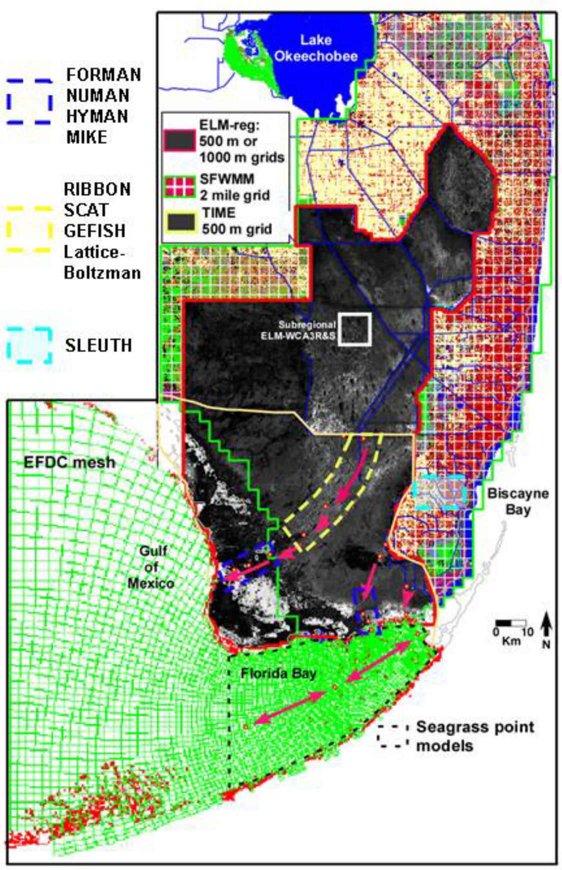
Isotope-dendrochronology (Rebenack, Cherubini & Anderson)
Research over the past year has centered on the analysis of five *Pinus elliottii* tree disks from northern Big Pine Key. A chronology for each tree disk was developed in collaboration with Dr. Paolo Cherubini during a visit to the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf, Switzerland. A transect from bark to pith has been defined for each disk and every earlywood-like and latewood-like ring along these transects is being separated by hand for isotopic analysis. Individual ring samples are ground and undergo a chemical extraction process that removes all wood components except for the α-cellulose fraction. Carbon and oxygen isotope analysis are being completed for each α-cellulose sample. Additional work includes the development of a corresponding Lower Florida Keys climatology using data supplied by the NCDC, ring-width measurements for each sample and a seasonal isotopic analysis of stem water from living *P. elliottii* trees near the disk collection site.

Paleo-hurricane reconstruction (Nodine and Gaiser)
The goal of our research is to extend the instrumented record of hurricane occurrence and the climate cycles that drive them using diatom community changes preserved in the sediment record. Ph.D. student Emily Nodine has been working with sediment cores from the southwest Florida coast and evaluating the diatom communities and their changes through time. Her research will explore the relationships between diatom community structure and the environmental effects of hurricane activity and test their application in sediment cores containing records of known hurricane events. She will also explore the rates of change in the communities to evaluate them as signals for climatic phase changes. Preliminary findings suggest that distinct changes have occurred in the diatom communities in these cores over time, and research is ongoing to identify patterns and their significance as paleoecological indicators.

8. Modeling and Synthesis

The modeling and synthesis cross-cutting theme enables FCE to synthesize research through integrated modeling efforts. A wealth of ongoing modeling projects required that FCE undertake an analysis of existing models to clarify uses, scales and applicability, determine empirical data needs and highlight a focus for future FCE modeling efforts. Other synthesis efforts include reviews of hydrological, paleoecological and soil accretion research, generating products described below.

Review manuscript preparation
Following up on the FCE Modeling/Synthesis coordination workshop in June 2009, the FCE modeling and synthesis group continues to perform the writing tasks for the review paper (working title), "Integrating ecohydrological models of the Florida Everglades: Advances and limitations in the context of the restoration." In addition to the detailed outline drafted during the June 2009 workshop, Jeff Onsted (Human Dimensions) has written sections addressing: a) the necessity of including a human aspect in ecological approaches; b) an overview of the SLEUTH model; and c) co-wrote the section dealing with the connection between water and socio-economic processes. Drs. Jeff Onsted, Laura Ogden, Amartya Saha, and Colin Saunders have also developed the Comprehensive Heuristic Model (an outcome of the 2010 ASM, described below) which will be integrated within the review manuscript as a means to provide the backdrop and context for the entirety of modeling and synthesis projects (Fig. 8.1).



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

Additional contributions by other members are expected to continue being compiled in the fall of 2011. A teleconference workshop is scheduled to coordinate the completion of the manuscript.

Landscape Ecosystem modeling

Carl Fitz has used the Everglades Landscape Model and Multi-Criteria Decision Analysis to explore the effect of simulated ecosystem performance, risk preferences and criteria weights on the ranking of three alternatives to restoring overland sheet flow in the Everglades, as described in their upcoming (in-press) manuscript Integrated Ecological Modeling and Decision Analysis within the Everglades Landscape.

Carl Fitz and Chris Madden continue to develop a linked ELM-SEACOM approach to understand impacts of freshwater landscape on estuarine processes, including a baseline case and a future with tripled inflows through S-332D. ELM is used to evaluate P accumulation along Everglades gradients, including the freshwater to coastal ecotone in Taylor Slough (our sites TS/Ph-1, -2, -3, -6 and -7), provide P outflow loads to Florida Bay, and evaluate seagrass/phytoplankton sensitivity to altered loads.

Vic Engel and colleagues have modified a spatially-explicit advection-reaction-diffusion model for explaining vegetation pattern formation in wetlands. They included a regional hydraulic gradient and effective anisotropy in hydraulic conductivity. Another model has been developed to develop a mechanistic framework to explain tree-grass coexistence in the Everglades wetland savanna by relating the dynamics of vegetation, nutrients and soil accretion/loss through ecogeomorphic feedbacks and interactions with hydrologic drivers.

Modeling primary production response to hydrology and water quality

Evelyn Gaiser and others from this group have been working with FCE data to develop statistical and mechanistic models of periphyton response to hydrologic and water quality changes in the Everglades. Once developed, these models will be coupled with models of nutrient transport, food web dynamics and carbon cycling. Because of spatial patterning in the form of these relationships, they began by developing a spatially-explicit periphyton-based hydrology and water quality models for the FCE domain where there exists the most concentrated sampling effort. The relationships between the primary drivers of phosphorus, hydrology and habitat structure and periphyton attributes were quantitatively evaluated to derive the best multivariate functions.

Effects of sea level rise on coastal forests of the Everglades

One of the central themes of the upcoming FCE III is the effects of sea level rise on the South Florida ecosystem. A multifaceted study has been carried out by Amartya Saha, René Price, Mike Ross and colleagues from University of Miami (Jiang Jiang, Leo Sternberg and Don DeAngelis), the Institute for Regional Conservation (Sonali Saha and Kristie Wendelberger) and the Everglades National Park (Jimi Sadle) with the overall objective to determine effects of sea level rise on the coastal forests of the Everglades. The first component examines trends in groundwater salinity along the coast and changes in vegetation composition of coastal forests including rare species along the Fl Keys and the Everglades over the past ten years. The second component reports on an ongoing greenhouse study that involves growing five coastal everglades species under different levels of salinity and looking at salinity effects on transpiration, growth, biomass allocation and survival. The third component, the MANBUTHAM model, has been developed by Jiang Jiang, Leo Sternberg and Don DeAngelis to look at how plant community dynamics in coastal forests of the Everglades (mangrove, buttonwood and coastal hammocks) change with increasing salinization of groundwater that accompanies sea level rise. This model assumes that mangroves are better adapted to high salinity areas than buttonwoods, while glycophytic hammock species are the least tolerant of salinity. At lower salinities, however, mangroves are out-competed by buttonwood and hammock species. All three vegetation types interact with the unsaturated soil (vadose zone) salinity by regulating their transpiration. Their respective transpiration and associated water uptake regimes have a feedback effect upon the vadose zone salinity, by driving different degrees of recharge of the vadose zone from the underlying saline water table to replenish the water absorbed by the plant. Thus, each vegetation type tends to promote local salinity conditions that favor their own establishment and maintenance. The model has been parameterized with transpiration data obtained from an ongoing shadehouse experiment (Sonali Saha and Kristie Wendelberger) examining the growth of various coastal plant species under different salinity levels.

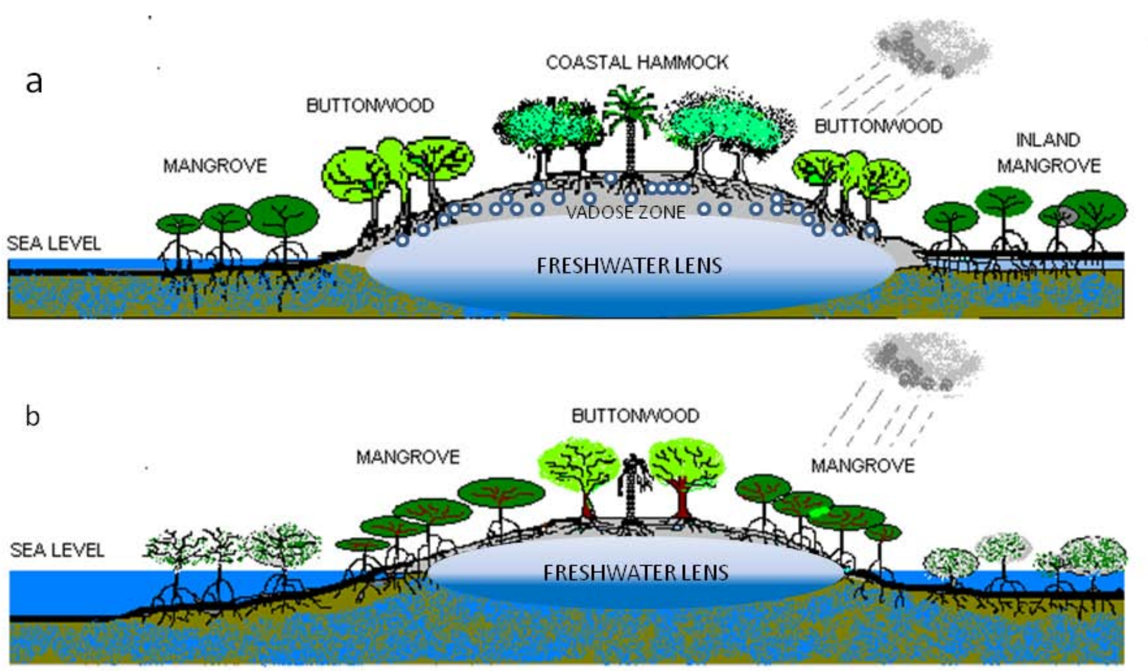


Figure 8.2: Sketch of a coastal hammock on an elevated rise flanked by buttonwood forests at intermediate elevations and mangrove forests at sea level. Also shown are the vadose zone (with water drops), freshwater lens (where shading indicates increasing brackishness towards the bottom of lens), and seawater. Bottom sketch (b) shows a rise in sea level that decreases the volume available to hold freshwater (shrinking of the freshwater lens), with consequent mortality of coastal hammocks and the migration of buttonwoods and mangroves along with the decrease in the freshwater lens. Elevation exaggerated in illustration to indicate water pools. From Saha et al 2011.

Modeling Mangrove Ecosystem Processes
Victor Rivera-Monroy and colleagues at LSU use the HYMAN model to evaluate water and salt budgets in three mangroves sites along Shark River. They also use the MIKEFLOOD platform to evaluate water, nitrogen, and phosphorus budgets along Taylor River. Both models are currently used to forecast potential changes in water budgets and biogeochemistry processes as result of the Everglades restoration project.

The flux tower group (Jordan Barr, Vic Engel and Jose D. Fuentes) are currently building and fine tuning a vegetation photosynthesis model (VPM) to estimate gross primary production (GPP) of all south Florida mangroves.

Consumer dynamics
Spatially explicit modeling by Don DeAngelis, Fred Jopp, and Joel Trexler focuses on small-bodied fishes that constitute an important assemblage in many wetlands. In wetlands that dry periodically except for small permanent waterbodies, these fishes are quick to respond to change and can undergo large fluctuations in numbers and biomasses. We have been working on a spatially explicit model of community dynamics that accounts for the movement of fishes across the landscape in response to water level fluctuation. In our model, populations of small fish expand into newly flooded areas during the wet season and contract during declining water levels in the dry season. If the marsh dries completely during these times (a drydown), the fish need refuge in permanent waterbodies.

The spatially explicit modeling was also used to investigate biomass dynamics of an aquatic food web in an Everglades marsh landscape including the following components: primary producer, detritus, invertebrates, fish consumers and nutrients. Long-term simulations over a period of 10 years were performed and the responses of trophic organizational levels to the seasonal changes in water level were observed.

Human Dimensions modeling
FCE collaborator Jeff Onsted has calibrated and run the SLEUTH urban growth and land use change model in the Redlands area of Miami-Dade County. Onsted experimented with calibration conditions in order to better understand the role of zoning in past land use change and discovered that goodness of fit metrics are greater when lands zoned for agriculture are integrated into the Excluded Layer. Onsted also ran future simulations of urban growth and land use change in the Redlands area. The solo paper, “Agricultural Retention in California: Modeling the Effectiveness of the Williamson Act as Public Policy” (Onsted forthcoming from *California Geographer*) assisted my efforts here at the FCE by honing my ability to use urban growth modeling to understand human decision making and public policy. Similar farmland protection policies exist in Florida and I am now well-equipped to examine them in an analogous fashion.

Onsted’s paper, "Using Cellular automata to forecast enrollment in differential assessment programs" (Onsted and Clarke forthcoming in *Environment and Planning B*) researched a novel methodology to not only forecast land use and land cover change but regulatory landscape change. This is critical to our research here at FCE because land cover and uses cannot be altered unless permitted by land use policy. These policies, therefore, create invisible landscapes of potentiality and these landscapes change with time. Coupling this approach with traditional land use change modeling will give outputs of future impermeable surfaces as well as land uses that can be associated with estimated inputs of fertilizers, pesticides, as well as water abstraction.

Another paper, "The inclusion of differentially assessed lands in urban growth model calibration: A comparison of approaches using SLEUTH" (Onsted and Clarke (Revise and Resubmit for *International Journal of GIS*)) comprehensively evaluated the effect that inclusion of differentially assessed farmland has on land use model calibration goodness of fit metrics. Despite the fact that many modelers ignore these lands, the results suggest that including these lands as excluded areas increases model accuracy. Onsted co-authored the paper, "Multi-Scale Dynamics of Residential Landscapes", (Roy Chowdhury et. al., forthcoming from *Cities and The Environment*). This examines how social dynamics help to constitute urban and suburban physical environments through the lens of residential yard management. "Urban Resilience and Social Vulnerability: Exploring Social and Ecological Theory using Hurricane Andrew as a Case Study", another co-authored paper being lead by Dr. Laura Ogden, will examine how socio-ecological systems react to pulse events, such as devastating hurricanes. An understanding of natural systems resilience to such events only tells part of the story. It is crucial to also understand how people respond, since they are major agents of change within the FCE. This paper seeks to address this and will be submitted this summer to *Frontiers in Ecology*. Onsted is also a Co-author on another paper led by Dr. Ogden which explores land use change and farmland loss in the Homestead area.

Onsted has attended the 2009, 2010, and 2011 FCE ASM, supporting Dr. Saunders in his role as group leader by providing him with relevant research findings. Onsted has also lead a poster at the LTER ASM, in Estes Park, CO in 2009, that examines the role that 5 acre minimum zoning has had on land use change in the Redlands area of Miami-Dade County (Fig 15). Onsted has given several lectures detailing agricultural land use change in Miami-dade County and one lecture, for the online graduate class, "From Yardstick to Gyroscope: Interdisciplinary Methods for the Long-Term Study of Social-Ecological Systems", where he explained the nature and methods of land use change modeling.

Hydrology synthesis

Understanding and restoring the Everglades, a hydrologically-controlled ecosystem, requires a reasonably accurate quantification of the inflows, storage and outflows of water.

As described in the Hydrology WG section of this report, Amartya Saha has developed an annual water budget of Shark Slough (the main drainage of ENP) for 2002-2008, employing a conservative mass balance approach with inflow, discharge and rainfall data along with models to estimate evapotranspiration and seepage. This project budget will lay the groundwork for improved integration among FCE modeling efforts. In addition, water residence times and phosphorus loads are being calculated based upon water flow velocity data and point phosphorus concentrations along the Shark River Slough.

Victor Rivera-Monroy and fellow FCE collaborators from Louisiana State University have developed a water budget for Taylor Slough, the other drainage in the ENP. Their estimates are based on long-term hydrologic data (1999-2007) and supplemented by hydrodynamic modeling using a MIKE FLOOD model to evaluate groundwater and overland water discharges

Paleoecological synthesis
A synthesis of existing FCE paleoecological investigations is under way to understand the long-term changes in hydrologic, water quality, and ecosystem responses to past climate change and water management across the FCE landscape and the greater Everglades. The product of this synthesis will be a special issue of the *Journal of Paleolimnology* and is described in the Climate Change/Disturbance section of this report.

Soil Accretion synthesis
Finally, a literature review of all published and newly emerging radiometric-based estimates of soil accretion over the greater Everglades (and including FCE sites) are being compiled by colleagues from SFWMD (Colin Saunders, Carlos Coronado, Dave Rudnick, and Fred Sklar), USGS (Debra Willard, Charles Holmes), and other FCE scientists. This study aims to quantify the primary abiotic and biotic determinants underlying regional and habitat-specific variation in soil accretion. Details are provided in the Organic Matter Dynamics sections of this report.

9. Information Management

Overview
The Florida Coastal Everglades (FCE) Information Management System (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 major focus of the FCE Information Management team (Linda Powell, Information Manager and Mike Rugge, FCE Project Manager) has been the planning phase for a FCE IMS physical hardware restructure and improving its network-wide standardization to facilitate increasing use of site data in synthesis projects.

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, is a member of the LTER Network Information System Advisory Committee (NISAC) and is the current chairperson of the LTER IM Unit Registry working group. She had also been an active member of the LTER IM Controlled Vocabulary working group this past year. Both Linda and Mike will be attending the annual LTER Information Management Committee meeting held in Santa Barbara, California in September of 2011.

IT Infrastructure

The FCE IMS team manages two Windows servers and three Linux servers with a total storage capacity of 2.9 Gigabytes and an additional 1.1 Gigabytes of storage between two desktop workstations. The servers housing the development and production versions of the FCE Oracle10g database are equipped with RAID5 technology (Redundant Array of Independent Disks). Connectivity within the FCE LTER Office is a gigabit switched Ethernet Network (Florida International University Computer Science Network). Linda Powell, who is located in Tallahassee, Florida, continues to remotely perform her information management duties via the FIU VPN. She also visits the FCE LTER Office at quarterly intervals and is in constant contact with the group via telephone, emails, and conference calls. Overlap between the IMS group's critical tasks allows collaboration on computer system administration issues and with the FCE web server and Oracle10g Database design issues, content and implementations.

The FCE information management system (IMS) model is in the process of moving from purchasing and maintaining its own physical servers to leasing five (5) virtual servers housed on Florida International University Division of Information Technology's (UTS) equipment. The FCE IMS team will continue to implement 2 levels of data protection locally: 1) nightly incremental backups to a backup server and weekly full backups to external hard drives with one set of drives (3 total) being stored offsite. This spring, we migrated the backup server from Windows 2003 to Linux, upgraded the RAID card, and increased storage from 1.2 TB to 2.2 TB. We also increased the storage in each external hard drive from 500GB to 1TB. We are in the process of adding another level of disaster recovery protection. The Oracle 10g, FCE Web and FCE FTP virtual servers housed with the FIU UTS department will be backed up to identical virtual servers residing at the Northwest Florida Regional Data Center (NWRDC) located at Innovation Park, Tallahassee, Florida. In the case of local tropical storms, hurricanes and hardware failures, the FCE website will be continually available throughout the disaster event via the virtual servers at NWRDC.

Website Development

The website serves as the primary portal for dissemination of information about the FCE LTER program, for distribution of datasets, to coordinate our Education and Outreach activities, and to aid FCE scientists and students in their research, so it is important the FCE information management team continue to improve existing web pages and expand the web site capabilities. The team has incorporated several LTER working group initiatives to improve standardization of data search and access across LTER sites through adoption of controlled vocabularies and common interface features. In addition to our 'Transformational Science' section on the web, plans are being made to add a 'Research Highlights' section that features some of the FCE exciting research projects.

The 'Education and Outreach' section of the FCE website (http://fcelter.fiu.edu/education_outreach/) is now managed directly by the Education and Outreach group and folks can now find the FCE LTER program on Facebook and Twitter.

Support for EML Metadata

The FCE IMS has fully adopted the LTER network metadata standard Ecological Metadata Language (EML) and one hundred percent of the FCE tabular data are accompanied by a Level 5 (Data Identification, Discovery, Evaluation, Access and Integration) EML (XML) metadata documents. FCE EML documents are harvested daily to the LTER network metacat XML database. The FCE Excel2EML metadata converter tool and template has been made available to the LTER network and broader ecological community via the LTER CVS repository and as download link on the FCE web site (http://fcelter.fiu.edu/research/information_management/tools/). The FCE IM team lends its expertise to site and network researchers when necessary by providing application support for the Excel2EML tool and assisting with metadata entry.

Work has been started on improving the quality and availability of LTER Data and EML Metadata. Existing FCE EML metadata is being modified to incorporate the LTER Controlled Vocabulary Key wording Best Practices. Improved tagging will facilitate FCE data set discovery via the LTER Metacat search.

FCE Website and Data Statistics

All of the FCE LTER core data and metadata files from individual research studies are stored in a hierarchical flat file directory system. FCE project information and minimal research data metadata are stored in an Oracle10g database that drives the FCE Web site. This hybrid system (flat file and database) gives FCE researchers, network scientists and the general public an option to download complete original data files submitted by individual FCE scientists in addition to downloading queried data from the Oracle10g database. Core data are made available to the public within two years of data collection and are accessible on-line in accordance with the FCE Data Management Policy.

Because we feel that it is extremely important that published online data be accessible at all times, the FCE IMS has implemented a versioning system where all previously published data are unchanged. Changes in data values or newly appended data will result in the creation of a 'new' version of the dataset as described under the 'Data Organization' section of the data management policy. Currently, the FCE archive contains 461 FCE datasets, of which a total of 431 are publically available online (Table 9.1).

	Archived FCE Datasets by Access Type
Access Type	**Count**
Public	431
FCE Only	3
Locked	17
Offline	10
All Access Types	***461***
	Public Access by Dataset Type
Public Dataset Type	**Online Data**
Climate	103
Physical	86
Primary Production	73
Nutrients & DOM	118
Soils & Sediments	26
Trophic Dynamics & Community Structure	25
All Dataset Types	***431***

Table 9.1: FCE Data Archives, by access type and dataset type.

Public downloads of FCE datasets from January 2001 to August 12, 2011 are listed in Table 9.2, broken down by dataset type and user affiliation. The University community continues to be the largest user group and the FCE nutrient data is most popular download.

Annual Dowloads by Type												
Dataset Type	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**All**
Climate	0	0	13	10	25	29	22	52	43	59	17	270
Nutrients	0	33	144	50	109	141	68	162	106	137	50	1000
Physical	0	15	64	17	84	69	46	160	76	30	29	590
Primary Production	0	25	76	14	69	115	48	56	50	47	46	546
Soils & Sediments	0	11	35	5	36	59	34	39	63	34	12	328
Trophy Dynamics & Community Structure	0	0	9	5	10	4	22	21	24	22	4	121
All Access Types	***0***	***84***	***341***	***101***	***333***	***417***	***240***	***490***	***362***	***329***	***158***	***2855***
Annual Downloads by Affiliation												
Affiliation	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**All**
Education (K-12) LTER	0	0	0	2	0	11	3	3	2	2	0	23
Education (K-12) Non-LTER	0	22	36	2	4	64	3	20	15	5	1	172
Government Research LTER	0	4	93	0	4	0	4	16	10	6	0	137
Government Research Non-LTER	0	0	6	3	8	25	21	159	7	17	42	288
Other LTER	0	0	1	1	13	5	0	0	0	2	0	22
Other Non-LTER	0	2	38	7	56	65	6	24	20	54	3	275
University Research LTER	0	47	128	57	158	206	81	157	196	108	50	1188
University Research Non-LTER	0	9	39	29	90	42	122	110	111	136	62	750
All Affiliations	***0***	***84***	***341***	***101***	***333***	***418***	***240***	***489***	***361***	***330***	***158***	***2855***

Table 9.2: Downloads of FCE data sets, Jan 2001 – Aug 12, 2011, by type and affiliation.

Web site activity was slightly less active in 2010 than in the previous year (based on web log analysis). The most popular web directories visited in 2010 were about us, research, data, education & outreach and publications, respectively (Table 9.3).

Number of Page Requests by Year				
Website Directory Name	***2007***	***2008***	***2009***	***2010***
About Us	100,063	293,776	277,153	249,729
Research	159,943	296,318	251,688	185,633
Education & Outreach	76,526	114,679	90,748	79,858
Data	32,711	86,623	68,510	84,273
Publications	76,199	88,311	60,378	60,761

Table 9.3: FCE Web site page requests compiled by year.

B. Findings

1. Primary Production

Phytoplankton communities
There were allelopathic effects of cyanobacteria in the periphyton community. Results showed that *S. gracile* and *K. contorta* growths were not impacted by the presence of toxic medium, while, *P. duplex* and *C. littorale* growths were altered by *M. aeruginosa* culture medium. *A. incerta* showed enhanced growth in the treated media over the control. Although *M. aeruginosa's* allelopathy only impacts 2/5 of the algae, the study pointed out that allelopathy could be a mechanism for *M. aeruginosa* to dominate hydrosystems during blooms. More similar investigations on other algal types (especially Bacillariophyceae) should be performed and the allelochemical should be isolated. This alleochemical could indeed be the cyanotoxin microcystin, but it also could be another toxin.

Despite the assumptions that algae can withstand such acute temperature variations and resume their normal metabolism once the temperature is within normal range, our results seem to contradict this assertion. It indeed seemed, although more investigations are deemed necessary, that warm-adapted periphyton was negatively impacted by the sudden overnight change of temperature (from 30ºC to 15, 10 and 5ºC) with a limited post thermal shock recovery. We are currently investigating this phenomenon in greater detail. These investigations are particularly important for the Everglades periphyton which, because it is found in shallow water, is prone to be exposed to fast temperature change during cold snaps. The cold snaps could therefore control the periphyton dynamics in the Everglades and thus the periphyton capability to sequester nutrients. Furthermore, from a more practical stand point, since chilling is performed on most algal samples for further investigations in the laboratory, finding that a cold thermal shock could have severe repercussions on the tropical algae could negate a fair amount of past studies.

Periphyton communities
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 (Fig. 1.1). 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 and decreased production with inceasing water depth, a trend reported extensively in this study and throughout the Everglades (Gaiser et al. 2011). Within the TS transect, periphyton production is highly variable, with highest rates occurring just after seasonal inundation of previously dry mat. 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. 2011; Hagerthey et al. 2011). 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. 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. 2009).

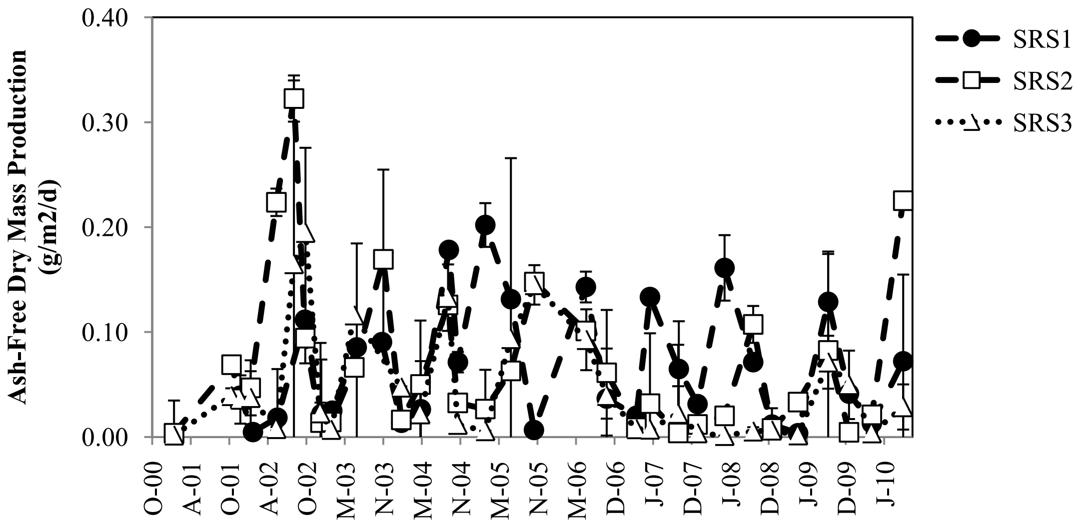


Figure 1.1: Variability in periphyton ash-free dry mass production on artificial slides at SRS 1-3.

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 2009). 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 (Fig. 1.2). 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., 2010, 2011).

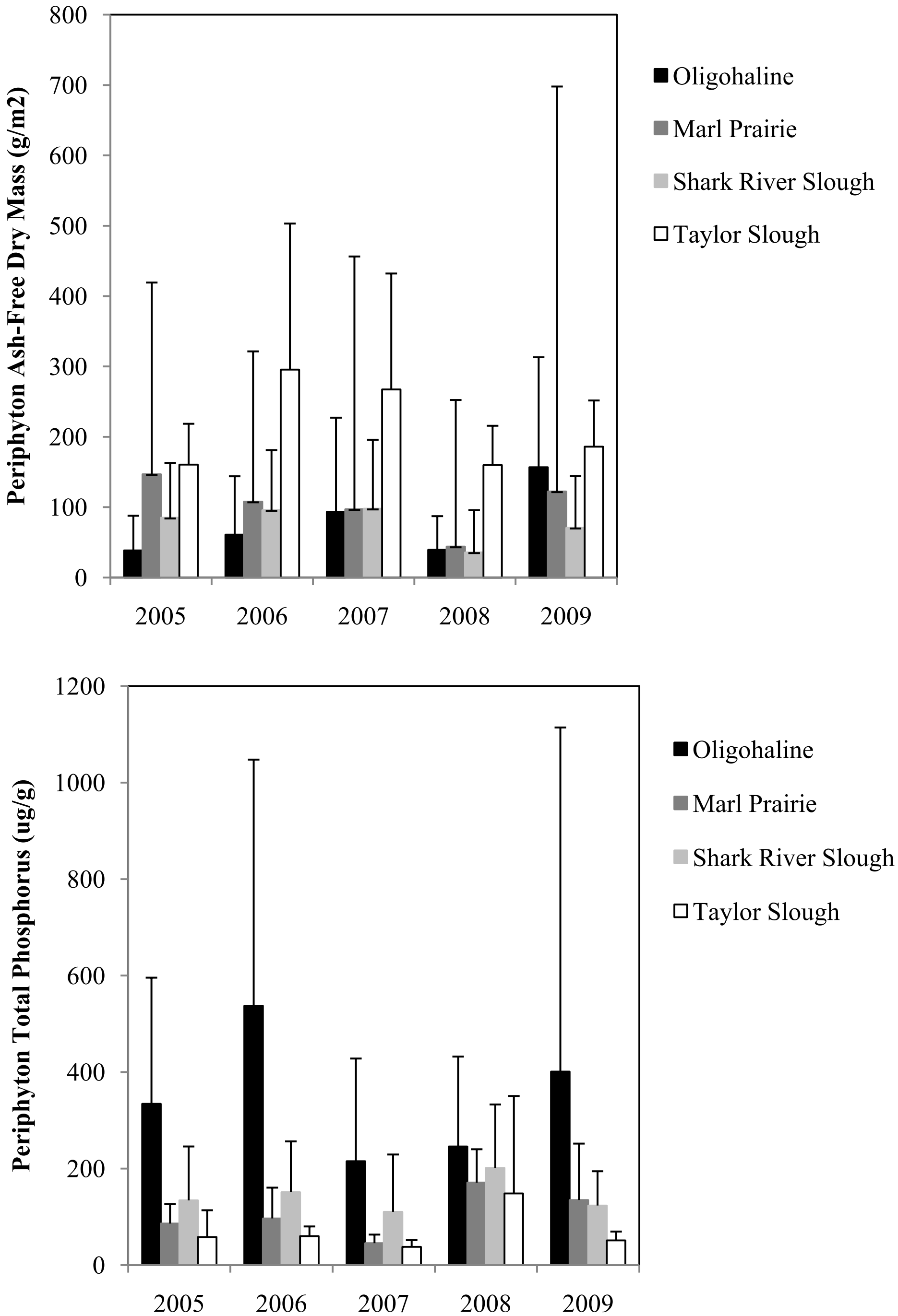


Figure 1.2: A spatial survey of over 50 sites in Everglades National Park was initiated in 2005. This ongoing annual survey provides a spatially-resolved understanding of periphyton dynamics to complement quarterly site sampling (Fig. 1.1). These data show how periphyton in the oligohaline zone is supplemented by a P-supply from the coast (supporting the FCE "upside-down estuary hypothesis"). It also shows how standing stocks are highest in the marl prairie and Taylor Slough where nutrients are most depleted, also supporting the FCE "productivity paradox" hypothesis (Gaiser et al. 2011).

Mangrove Ecosystems

Mean vegetation (i.e., leaf, wood, roots) C storage was four times higher in Shark River (74.1 ± 7.3 Mg C ha^{-1}) than in Taylor River (18.5 ± 2.3 Mg C ha^{-1}), with greater C allocation to belowground in scrub mangroves (73%) relative to riverine mangroves (20%; Fig. 1.3). Along Shark River, C storage decreased with distance inland from the mouth of the estuary, and followed the observed P fertility gradient (Fig. 1.3; Chen and Twilley 1999; Castañeda-Moya et al. 2010). Mean total (vegetation plus soil) C storage ranged from 236.4 ± 2.7 Mg C ha^{-1} (Taylor River) to 270.3 ± 15.1 Mg C ha^{-1} (Shark River) across the FCE landscape (Fig. 1.4). The vegetation C pool accounted for 8% (Taylor River) and 27% (Shark River) of the total storage; whereas the soil C pool represented on average the largest (92 and 73%) fraction of C storage in each region (Fig. 1.4). Mean total N storage was higher in Shark River (11.0 ± 0.6 Mg C ha^{-1}) compared to Taylor River (9.3 ± 1.5 Mg C ha^{-1}; Fig. 1.5a). Soil N pools represented the larger storage component ranging from 94% (Shark River) to 98% (Taylor River). Mean total P storage was twice as high in Shark River (0.6 ± 0.2 Mg C ha^{-1}) relative to Taylor River (0.3 ± 0.1 Mg C ha^{-1}), with 89 and 98% of the total storage allocated to mangrove soils in each region, respectively (Fig. 1.5b). There was a distinct trend in P storage along Shark River, with four times higher P storage in SRS-6 (1.01 ± 0.12 Mg C ha^{-1}) compared to the upstream site SRS-4 (0.25 ± 0.01 Mg C ha^{-1}; Fig. 1.5b). Our results show that riverine mangroves along Shark River store considerably more C and nutrients relative to scrub forests of Taylor River, which are P-limited and influenced by flooded hydroperiods. However, regardless of forest ecotype, a large proportion of mangrove carbon production and nutrients is stored in the soil. When comparing only C storage among vegetation components, the significantly higher C allocation to roots in mangroves of Taylor River relative to Shark River, suggests a physiological adaptation of these scrub forests to facilitate nutrient acquisition, but also minimize stress from regulators and hydroperiod in flooded soil conditions. Our findings underscore the relative contribution of structurally distinct neotropical forested wetlands in global carbon and nutrient budgets. Further studies will focus in comparing carbon and nutrient storage and production in FCE mangroves in response to hurricane disturbance.

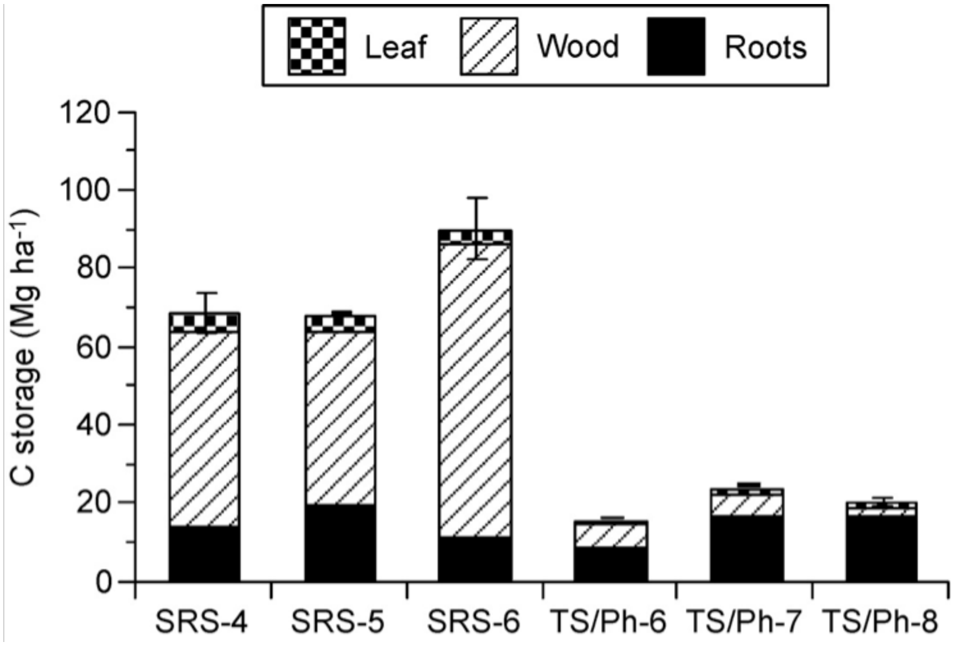


Figure 1.3: Carbon storage in above- and belowground vegetation components in mangrove forests of the Florida Coastal Everglades during the period 2001-2004.

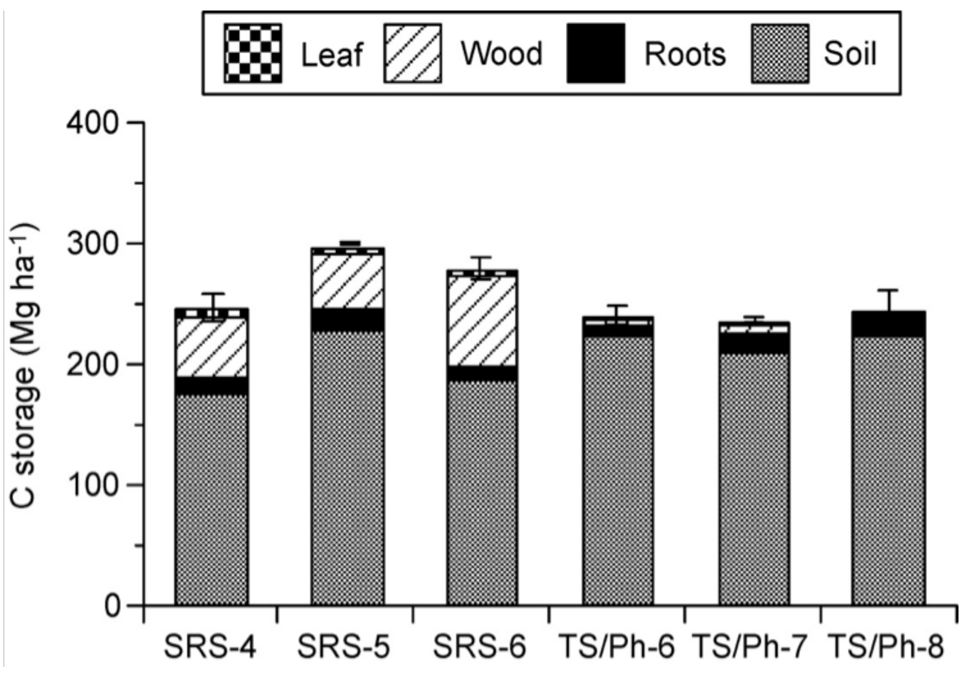


Figure 1.4: Carbon storage in vegetation (above- and belowground) and soil components in mangrove forests of the Florida Coastal Everglades during the period 2001-2004.

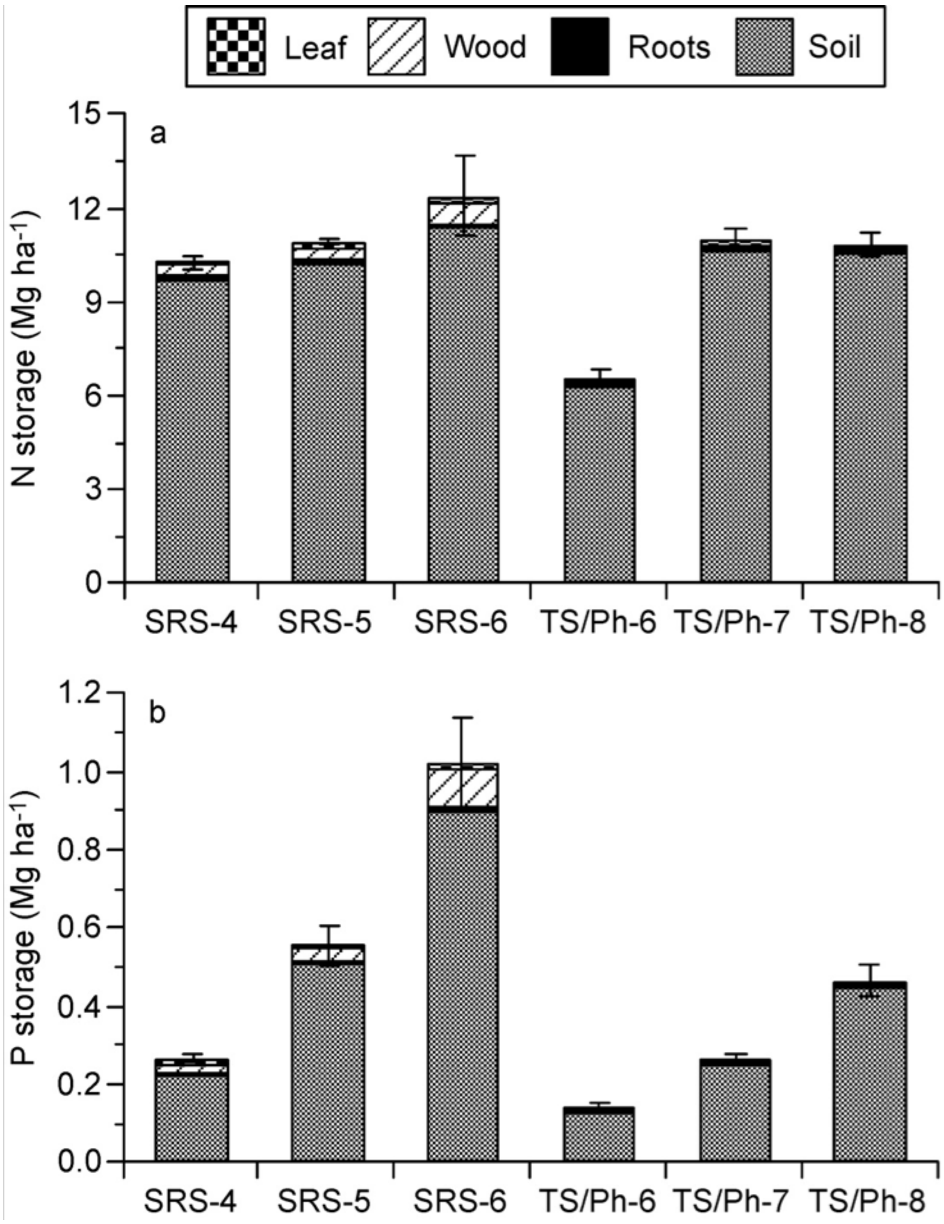


Figure 1.5: Nitrogen and phosphorus storage in vegetation (above- and belowground) and soil components in mangrove forests of the Florida Coastal Everglades during the period 2001-2004.

Seagrass ecosystems
Five of the six seagrass communities that were subjected to fertilization exhibited strong P limitation (Armitage et al 2011). Over the first 2 years, P enrichment increased *Thalassia testudinum* cover in the three most P-limited sites (Figure 1.6). After 3 years, *Halodule wrightii* began to colonize many of the P-addition plots, but the degree of colonization was variable among sites, possibly due to differences in the supply of viable propagules. *Thalassia* increased its allocation to aboveground tissue in response to P enrichment; *Halodule* increased in total biomass but did not appear to change its aboveground: belowground tissue allocation. Nutrient enrichment did not cause macroalgal or epiphytic overgrowth of the seagrass. Nitrogen retention in the study plots was variable but relatively low, whereas phosphorus retention was very high, often exceeding 100% of the P added as fertilizer over the course of our experiments. Phosphorus retentions exceeding 100% may have been facilitated by increases in Thalassia aboveground biomass, which promoted the settlement of suspended particulate matter containing phosphorus. Our study demonstrated that low intensity press disturbance events such as phosphorus enrichment can initiate a slow, ramped successional process that may alter community structure over many years.

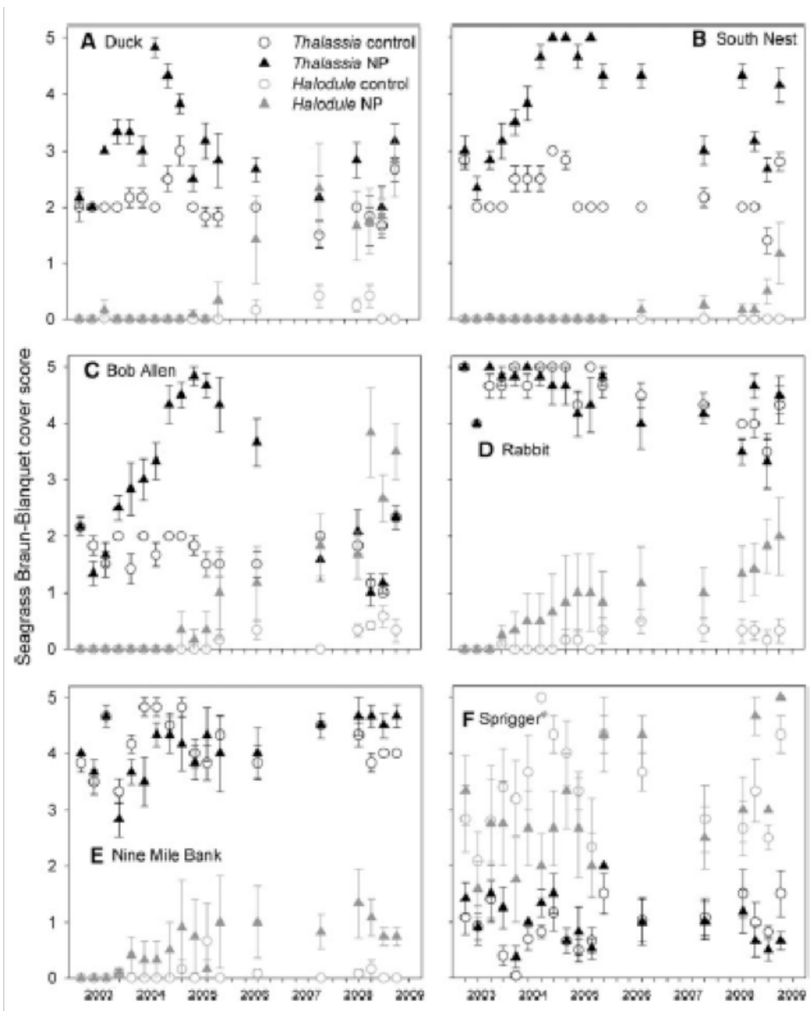


Figure 1.6: Changes in *Thalassia testudinum* and *Halodule wrightii* Braun–Blanquet percent cover score over time and in response to nutrient enrichment. There were no significant nitrogen effects and no nitrogen 9 phosphorus interactions; therefore, only control and nitrogen + phosphorus treatments are shown for clarity. Sites are listed in order from east to west. Bars represent standard error. / Note that grey symbols at Sprigger represent Syringodium filiforme; Halodule was absent at that site.

Our modeling of the response of water quality and seagrass community composition to changes in water management indicated salinity climates in the western sub-basins bordering the Gulf of Mexico were insensitive to even the largest (5-fold) modeled increases in freshwater inflow (Herbert et al 2011). However, the north, northeastern, and eastern sub-basins were highly sensitive to freshwater inflow and responded to comparatively small increases with decreased salinity and increased salinity variability. The discriminant function model predicted increased occurrences of *Halodule wrightii* communities and decreased occurrences of *Thalassia testudinum* communities in response to the more estuarine salinity climates (Figure 1.7). The shift in community composition represents a return to the historically observed state and suggests that restoration goals for Florida Bay can be achieved through restoration of freshwater inflow from the Everglades.

Our experimental techniques proved efficient at manipulating and maintaining pH and pCO_2 targets in experimental, in situ plots (Campbell and Fourqurean 2011). We were able to maintain conditions replicating forecasts for the year 2100. Enriched chambers displayed an average 0.46 unit reduction in pH as compared with ambient chambers over a 6-month period. Additionally, CO_2 and HCO_3^- concentrations were all significantly higher within the enriched chambers, and isotopic discrimination against ^{13}C by photosynthesizing seagrasses was enhanced in CO_2-enriched chambers (Figure 1.8).

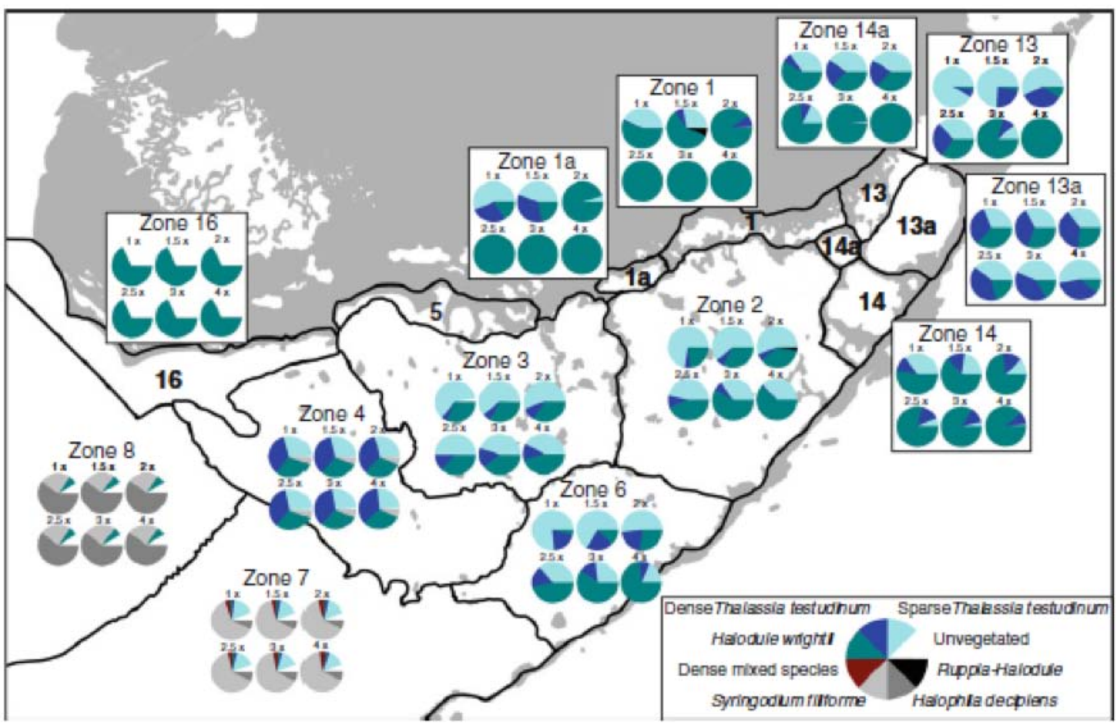


Figure 1.7: Discriminant function model predictions for the probability of occurrence of eight seagrass community types with salinity climates forecast by FATHOM for step increases in freshwater inflow. Salinity climates for baseline (1.0×), 1.5×, 2.0×, 2.5×, 3.0×, and 4.0× are represented.

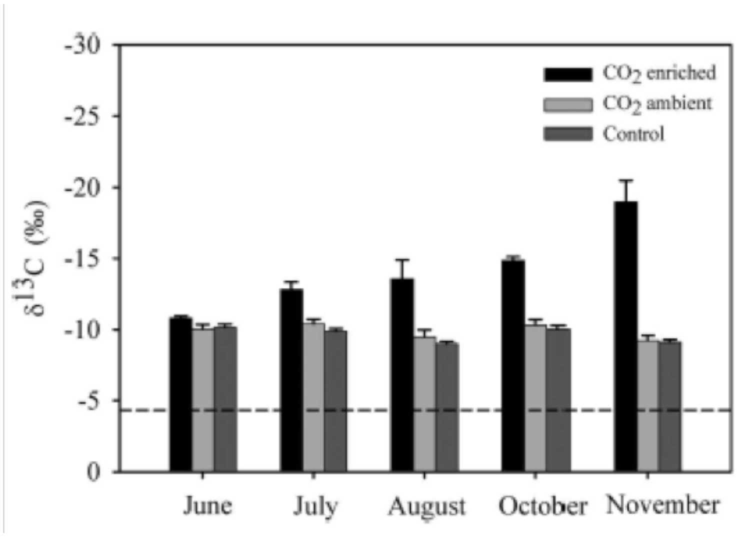


Figure 1.8: Stable carbon isotope values (means ± 1 SE) of aboveground leaf material of the seagrass *Thalassia testudinum* during the enrichment period. The June sampling date represents initial seagrass stable carbon isotope values prior to CO_2 enrichment. The dashed line represents the median isotopic signature of the source CO_2 gas used for enrichment.

Response of freshwater Everglades communities to water management activities

We are compiling a list of available historical datasets, along with a collection of pertinent literature, to inform our studies of the broad spatial scale response of macrophyte and periphyton communities to water management structures and activities.

In January, 2011, study areas along the periphery of the S-332 water control structures were visited to visually assess the current state of the areas bordering the retention ponds. Within this area, there are currently six transects along which periphyton, vegetation and associated environmental data have been collected over the last 8 years by the periphyton lab at FIU, as part of a study on phosphorus retention and sub-surface movement through the S-332 detention basins on the eastern boundary of ENP. Four of these transects (B1, B2, C and D) originate at the edge of water management structures (either retention ponds or spillways) and extend eastward into the ENP, while two other transects (E and F), considered reference transects, also extend eastward into the ENP, but do not originate at water management structures. The crude 8-year dataset was obtained and refined, and preliminary analyses have been conducted to examine changes in periphyton phosphorus concentrations along transects.

Average periphyton TP levels at the 0-point of transects at impacted and unimpacted sites were compared and the former had a significantly higher mean TP (608 µg P g^{-1} dry mass) than the latter (185 µg P g^{-1} dry mass) ($p = 0.018$). Preliminary results also show that at the four impacted sites (B1, B2, C and D), periphyton TP levels decline with distance from the edge of the retention ponds, whereas at reference sites (E and F), periphyton TP levels remain fairly consistent along the length of the transects (Figure 1.9 and 1.10).

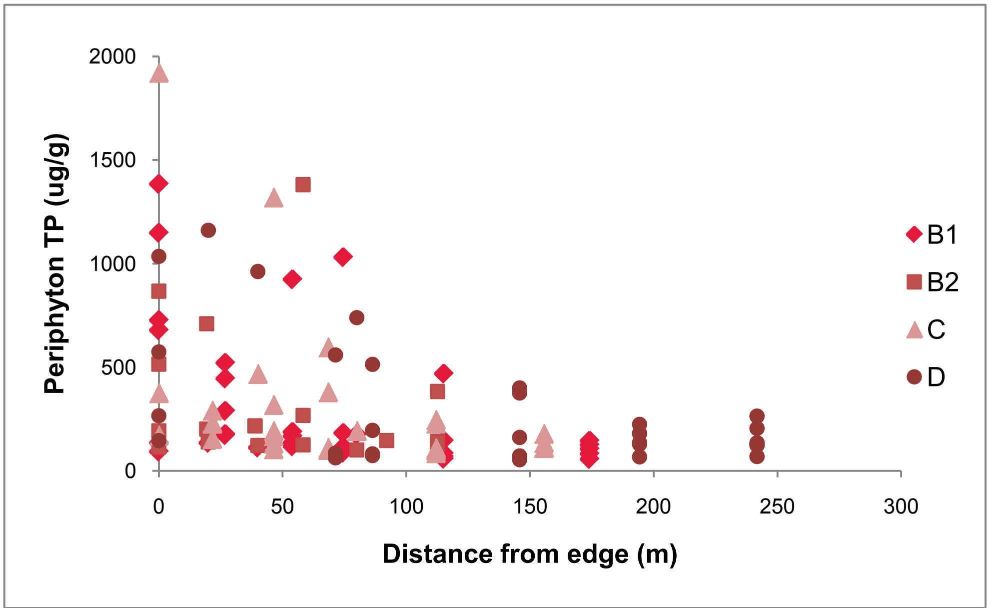


Figure 1.9: Change in periphyton phosphorus concentration with distance from retention pond edge at impacted sites B1, B2, C and D.

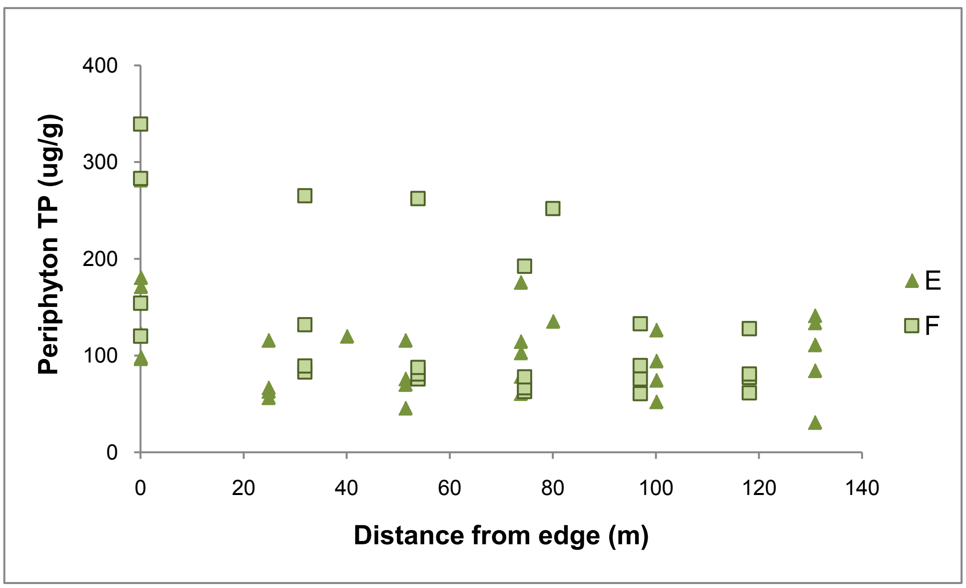


Figure 1.10: Change in periphyton phosphorus concentration with distance from retention pond edge at unimpacted sites E and F.

The marshes of the Taylor Slough basin are phosphorus limited, with periphyton TP levels not usually exceeding 200 µg P g^{-1} dry mass. Sites E and F are therefore representative of the typical marsh conditions, while sites B1, B2, C and D show obvious enrichment. These results suggest that (i) areas adjacent to water retention ponds and spillways are receiving higher levels of phosphorus compared to areas that are not adjacent to these types of structures and (ii) the impact decreases with distance from these structures.

Further analyses are being conducted to examine temporal changes in these patterns as well identify gradients in other related variables, such as biomass. Macrophytic vegetation and diatom community data are also available from these sites, and these are currently being compiled for analysis.

2. Organic Matter Dynamics

Highlights of new research findings from the past year are listed below:

1. High-resolution metabolism data show sustained net heterotrophy of Taylor River ponds. Heterotrophy is greatest in the dry season when pulses of nutrients are received from the groundwater. Allochthonous OM is expected to be fueling P-limited respiration rates in excess of autochthonous production of OM (Koch et al., 2011).

2. Seasonal and diurnal variation in POM transport and exchange processes have not yet been well characterized, but data from Taylor River suggest that floc transport during the dry season is significantly lower than the wet season (Koch, unpublished). Estuarine export of POM resuspended from fringing mangrove forest soils to the Shark and Taylor Rivers can reach Ponce de Leon Bay and Florida Bay. Biomarker-based studies of tidal cycling suggest that mangrove sediment resuspension and export are enhanced by incoming tide (He, Belicka and Jaffe unpublished), and such POM in the water column is exposed to high levels of light, resulting in photo-dissolution and transfer of carbon from POM to DOM, especially when litter and associated POM are aged (vs fresh; Pisani et al., 2011; Shank et al., 2011).

3. Effects of climatic disturbance (e.g., hurricanes) do not seem to have a bay-wide effect on DOM composition or dynamics, but localized effects, some lasting up to several months, occur primarily in areas influenced by large terrestrial runoff (Maie et al., 2011). While effects of DOM variations in quantity and quality after hurricane events have been suggested as causes for the appearance of plankton blooms, unequivocal cause and effect has not been proven.

4. Interestingly and unexpectedly, groundwater DOM in central-east Florida Bay, although at high salinity, exhibits terrestrial/allochthonous signals, consistent with GW transport from the Florida Keys through known S-to-N groundwater migration patterns (Chen et al., 2010).

5. A series of pilot experiments focused on understanding the effects of tidal inundation and salinity on peat stability were initiated. Evidence suggests that increased salinification and inundation brought about by sea-level rise may result in increased soil subsidence due to enhanced soil respiration. In the Everglades, the marine end-member is also a source of phosphorus, the element that limits primary production and possibly microbial processes. Initially, we are focusing on mangrove peats and considering CO_2 and porewater DOC fluxes as response variables. However, we will have the capacity to expand landward (i.e., into the oligohaline zone), include many more response variables, and to manipulate other variables such as P availability, temperature and light, etc. This work builds on past FCE work (see conceptual diagram below) and will have a direct connection with ongoing soil C flux measurements in the Shark River ecotone.

Photo showing layout of twelve, 250-gallon experimental tanks (foreground), salinity mixing and water distribution manifold (wood framed structure) and four, 2000-gallon head tanks (background). Not shown are saltwater pump with connection to Florida Bay, aeration system, and control box (funding SFWMD).

6. With regards to better understanding the carbon dynamics in the oligohaline ecotone of the Shark River, and being able to estimate carbon loss in the system, we initiated detailed studies to assess DOC and DIC dynamics along salinity gradients and throughout tidal cycles. Preliminary data based on DOC, DIC, optical properties, and stable C-isotope analyses (Cawley, Ya and Jaffé, and Jaffé & Anderson, unpublished) suggest that the DOC pool is quite variable in its reactivity and transport dynamics, where some freshwater DOC components travel through the system conservatively, while others are both generated by the mangrove forest environment or are consumed during transport. Both sources and associated compositional reactivity (bio- and photo-reactivity) are strongly dependent on tidal action. Much of the DIC in the oligohaline zone in the Shark River reflects a highly reworked mangrove-derived origin based on its isotopic composition.

7. The composition of DOM was found to be characterized by a ubiquitous 'black carbon' contribution, which was found to be present at ca. 10% of the DOC C-content, and up to 22% in some FCE samples. In the Everglades, this 'dissolved' black carbon (BC) abundance was directly correlated with DOC abundance, but not found to vary with respect to fire season. In addition, BC composition was found to be associated with wild-fire derived sources in the freshwater marshes as compared with an enhanced anthropogenic source for DOC in Florida Bay (Ding and Jaffe, unpublished). This anthropogenic source strength was enriched during the dry season.

8. We compared elemental ratios of nitrogen and phosphorus among different resource pools to examine nutrient coupling (and, presumably, OM processing) between wetlands and open water of Shark River Slough and Taylor Slough. From surface water for inorganic N:P, fringing wetland soils for total N:P, and wetland porewater for inorganic N:P, ratios ranged from over 500 to less than 40 and tended to decrease from freshwater through the oligohaline ecotone where P-limitation was less intense. Along the Taylor Slough gradient, however, average N:P ratios never exceeded 200 and were not significantly different for wetland soils and surface water, suggesting a strong coupling of factors influencing nutrient exchange and OM processing. Soil N:P ratios along the SRS transect were similar to TS, but surface water N:P was 3-4 times higher along the entire transect, suggesting weaker coupling of nutrient exchange and OM

processing between wetlands and open water. These patterns demonstrate that proposed freshwater flows for Everglades restoration should be added via diffuse sheet flows—not channelized flows—to enhance water-wetland interaction.

9. Mangrove leaf and root decomposition studies were initiated in May 2009 at three of the FCE mangrove sites (SRS-4, SRS-5, SRS-6; for methodological details contact V. Rivera-Monroy). Leaf degradation constant (Kd) values were significantly different among sites, although no interaction was observed between sites and decomposition rates for each species (Figure 2.1). Higher decomposition rates were observed in leaves of the mangrove species *A. germinans* followed by *L. racemosa* and *R. mangle*. As a result, half times (t50) of leaf decomposition were higher for *R. mangle* relative to other species across all sites (Figure 2.1). Overall, leaf decomposition rates were higher in mangrove sites downstream (SRS-5 and SRS-6) in the estuary relative to the upstream site SRS-4. C:N ratios of mangrove species consistently decreased over the incubation period, suggesting an increase in N concentration in leaves due to decomposition. Root decomposition rates also varied among sites and between depths (Figure 2.2). SRS-6 showed the highest root decomposition rates among sites. Overall, root Kd values were higher in the top (0-20 cm) section of mangrove soils compared to the bottom (20-40 cm) across all sites. Half root decomposition times were variable across sites ranging from 91 to 187 d^{-1}, with the highest values in SRS-5 at both depths (Figure 2.2). In general, mean leaf decomposition rates (0.0146 d^{-1}) across all sites and species were three times higher compared to root decomposition rates (0.0049 d^{-1}).

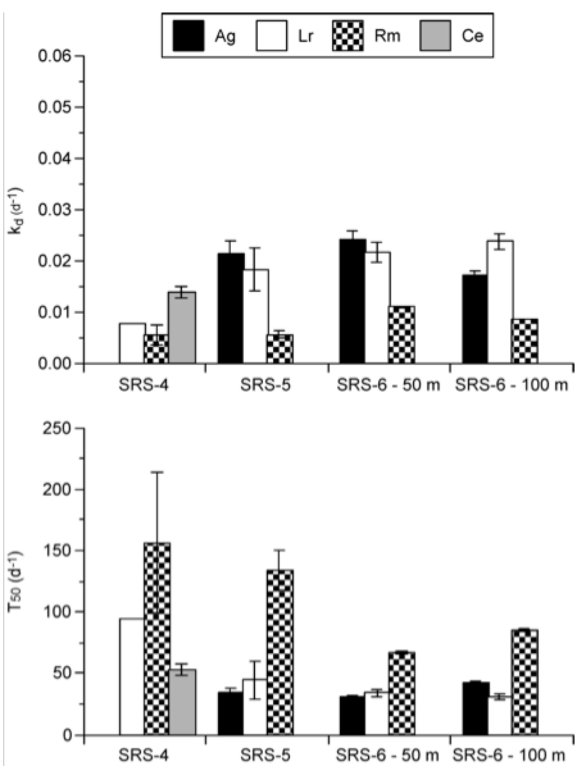


Figure 2.1: Decomposition rates (Kd^{-1}) and half decomposition times (t50) of mangrove leaves at study sites along Shark River estuary.

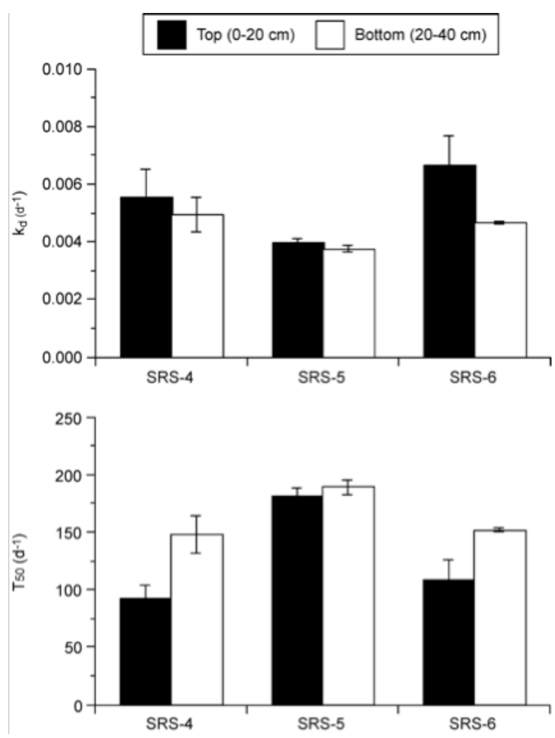


Figure 2.2: Decomposition rates (Kd^{-1}) and half decomposition times (t50) of mangrove roots at study sites along Shark River estuary.

Our results suggest the relative importance of initial substrate quality (i.e., leaf and root nutrient content) on decomposition rates as a function of P fertility along the Shark River estuary. In addition, our findings underscore the relative importance of hydroperiod in determining patterns of leaf and root decomposition along this estuarine gradient. Future research will be aimed to re-calibrate the NUMAN (nutrient biogeochemistry) model with actual mangrove leaf and root decomposition data from this study and root biomass and productivity data (Castañeda-Moya et al. in press) to simulate short- and long-term patterns in belowground allocation of FCE mangroves as part of the Everglades Restoration Project, and in response to current changes in sea level.

Research Summary

From an OM Working Group workshop held in March 2011, we developed a synthesis of OM dynamics (production, transport, transformation, accumulation) within the context of natural and anthropogenic drivers along the FCE-LTER transects representing hydrological and fertility gradients. Figure 2.3 diagrams the pools and pathways for exchange of OM within FW, estuarine ecotone, and marine environments in FCE. The figure inset summarizes the flows connecting environments and the drivers affecting the exchange of OM (timing, quality, quantity). Both POM (as floc) and DOM (derived from FW plant production) are delivered to the ecotone from upstream. Seagrass-derived litter, POM, and DOM are delivered to the ecotone

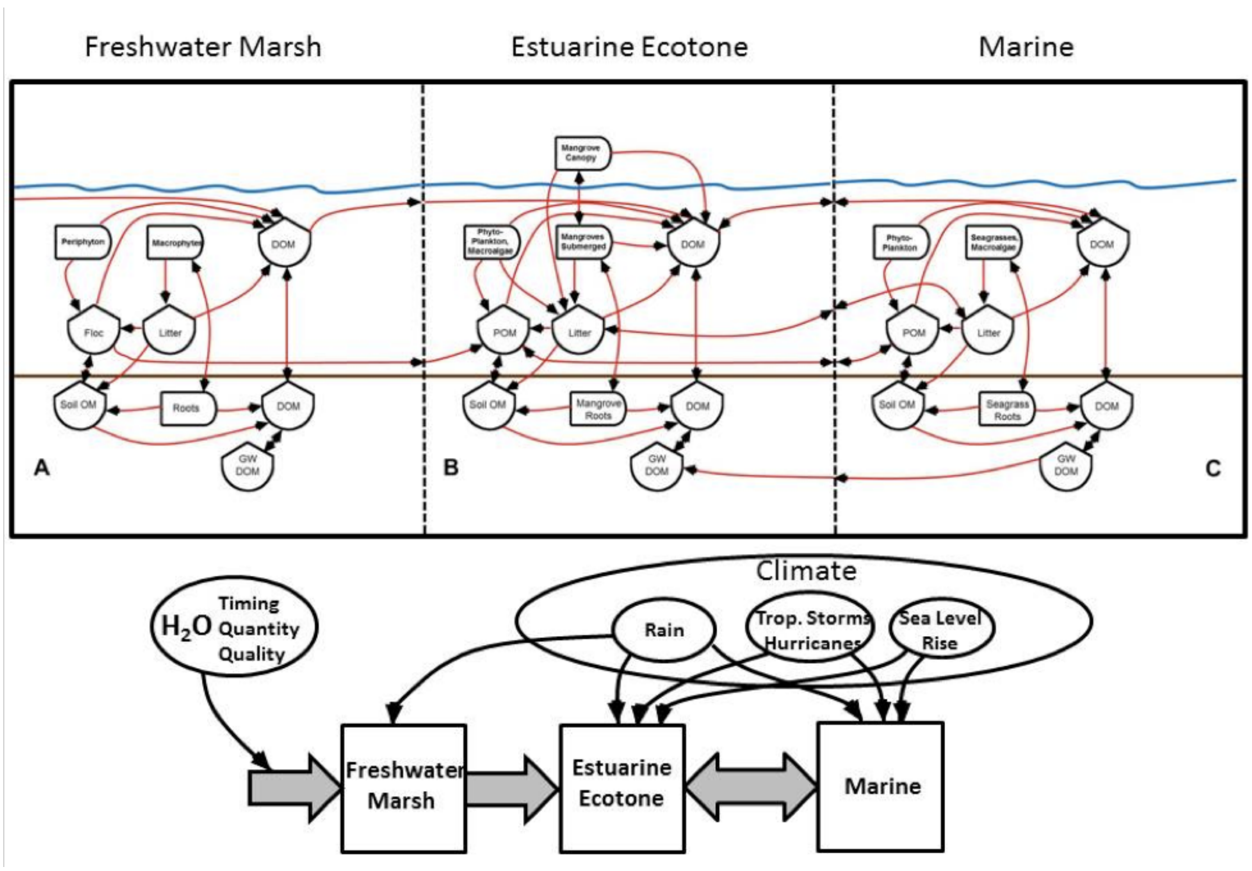


Figure 2.3: Conceptual model of OM compartments and fluxes, based on research conducted by FCE personnel. Lower diagram refers to drivers of ecosystem structure and exchange.

from downstream. Whether these allochthonous sources of OM help to fuel the estuarine productivity peak remains to be determined. Further, the grand experiment of additional FW inputs via water management has not yet occurred, but many OM pools and pathways are still to be investigated in the context of a dynamic south Florida hydroscape.

3. Biogeochemical Cycling

Water Quality

We are analyzing long-term trends in our water column nutrient data to determine causes for interannual variance and trends. We have observed long-term changes in TP and TN in both sloughs (Fig. 3.1). Patterns of TP availability appear to be driven by the storm surge associated with Hurricane Wilma in 2005. We hypothesize that the long-term spike in TP, particularly notable in the post-hurricane wet seasons, is being driven by losses of P from the marl soil layer deposited during the surge (Castenada-Moya et al., 2011).

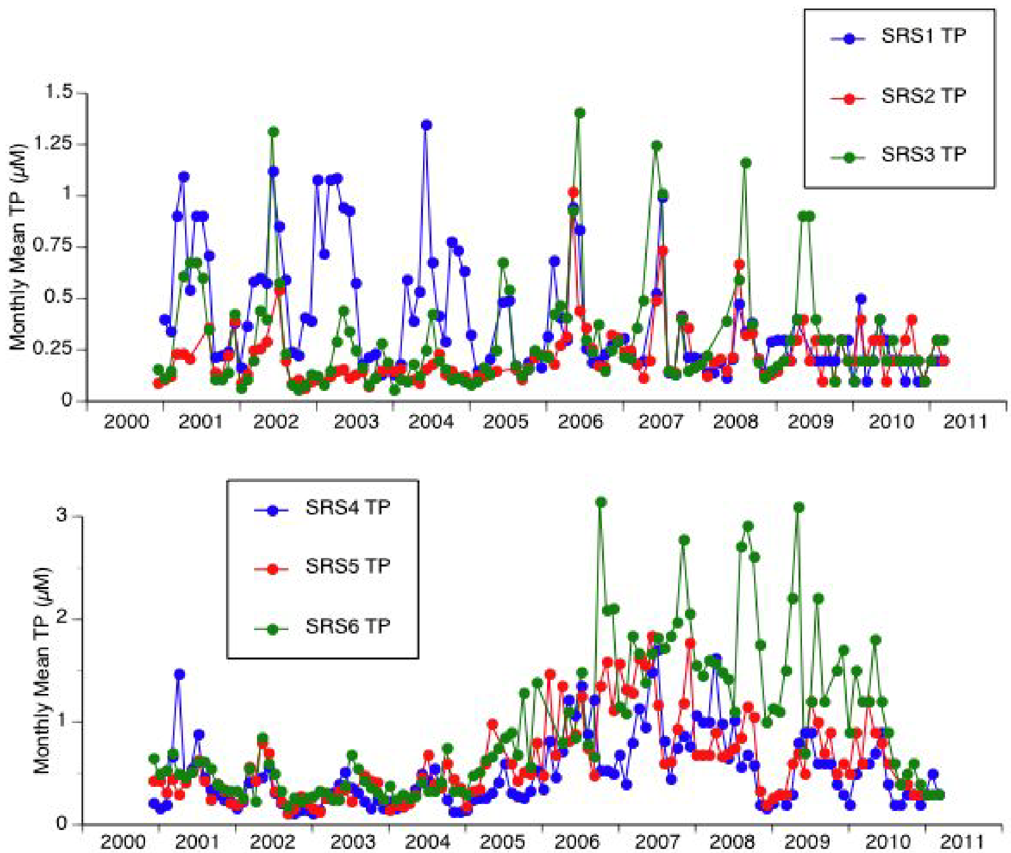


Figure 3.1: Long-term trends in total phosphorus (TP) from monthly water grab samples from 2000-2011, showing effects of P-release from storm deposits delivered from the Gulf of Mexico to SRS 4-6 by Hurricane Wilma in 2005.

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
Cross-site comparison of soil CO_2 efflux rates
As part of a FCE LTER supplement request, we received funds to initiate a new, cross-site project to investigate soil CO_2 fluxes in freshwater and saltwater coastal peatland forests of Shark River Slough (FCE LTER sites SRS 4, 5, and 6) and Bocas del Toro, Panama (3 sites). With this research, the goals are: 1) to describe local variability in soil CO_2 fluxes as related to P availability, salinity, and hydrologic gradients and 2) to investigate how climatic events associated with global climate change (i.e. precipitation, sea level rise) affect relationships between hydrology, P availability and soil CO_2 flux in two coastal peatland forests with similar gradients in soil phosphorus and aboveground productivity. These data are being used to initiate a collaborative, long term effort to investigate changes in soil CO_2 fluxes in Panama and FCE LTER sites.

SRS:
Intra-site varability in soil respiration fluxes – Over three years of measurements at these sites, SRS 5 has consistently lowest soil CO_2 efflux rates (Fig. 3.2; Troxler et al. in prep). Of the three sites, SRS 5 is characterized by a vegetation dominated by red mangrove (*Rhizophora mangle*) with little presence of pneumatophores, moderate salinity and soil P, lowest frequency of inundation (but longest duration tidal events) and highest soil C:N and soil organic matter content. SRS 4 experiences the lowest flooding duration and salinity, has the lowest TP content by volume and the highest tree density (<2.5cm DBH; Castaneda 2010).

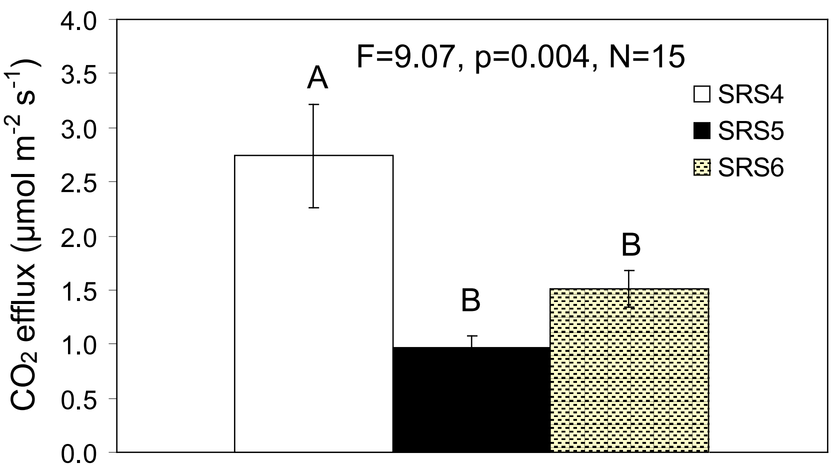


Figure 3.2: CO_2 efflux rates at SRS-4, SRS-5, and SRS-6 sites.

Inter-site variability in soil respiration fluxes – At SRS6, soil respiration flux measurements are partitioned by sub-canopy component [soil, course woody debris (CWD) and surface water], pneumatophore density, level of inundation, temperature and salinity. Soil CO2 flux was highest in CWD, increased with pneumatophore density, and increased with temperature and salinity. Over 40% of the variability in CO2 flux could be explained by soil salinity (Fig. 3.3). Some partitioning enabled these relationships; the datasets were normalized to inland soils excluding soil data with high PNPH density and soils that were inundated (Troxler et al. in prep).

A mesocosm experiment, beginning in summer 2011 will test the effects of flooding duration and salinity levels on soil respiration fluxes and DOM loss from soils collected at SRS4 and SRS6.

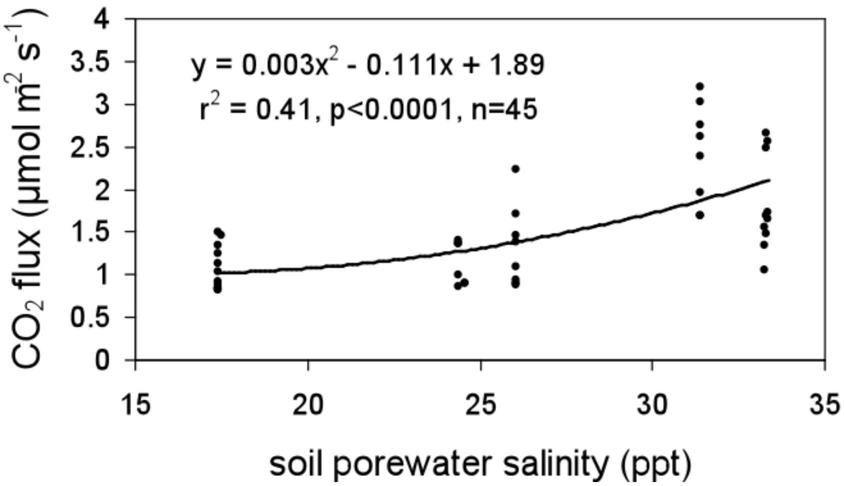


Figure 3.3: The relationship between CO_2 flux and soil porewater salinity at SRS-6.

Bocas del Toro, Panama:
While soil respiration work is in progress, the foundation for cross-site experimental work in this tropical peatland is developing well. With synthetic experimental work, there are strong prospects for disentangling salinity, nutrient and inundation effects in low-latitude peatland ecosystems. Strong spatial patterns in bacterial diversity, soil P, aboveground biomass and canopy diversity have been found in both Shark River peatlands (Castaneda 2010, Chen and Twilley 1999, Ikenaga et al. 2009) and the Bocas peatland despite large differences in salinity and inundation patterns (Troxler 2007, Troxler et al, in revision). For example, in the Bocas peatland, bacterial diversity is not only clustered as a function of soil TP, but increases significantly with canopy tissue P and N content, in non-linear and linear relationships, respectively (Fig. 3.4A&B). Experimental work will help to elucidate if these relationships indicate a shift from N to P-limitation, driving patterns of bacterial diversity from strong plant-soil feedback. Bacterial community composition and diversity patterns are very sensitive to variation in ecosystem structure, and will be coupled with other abiotic data to disentangle interacting effects of salinity, P availability and inundation regime in these peatlands.

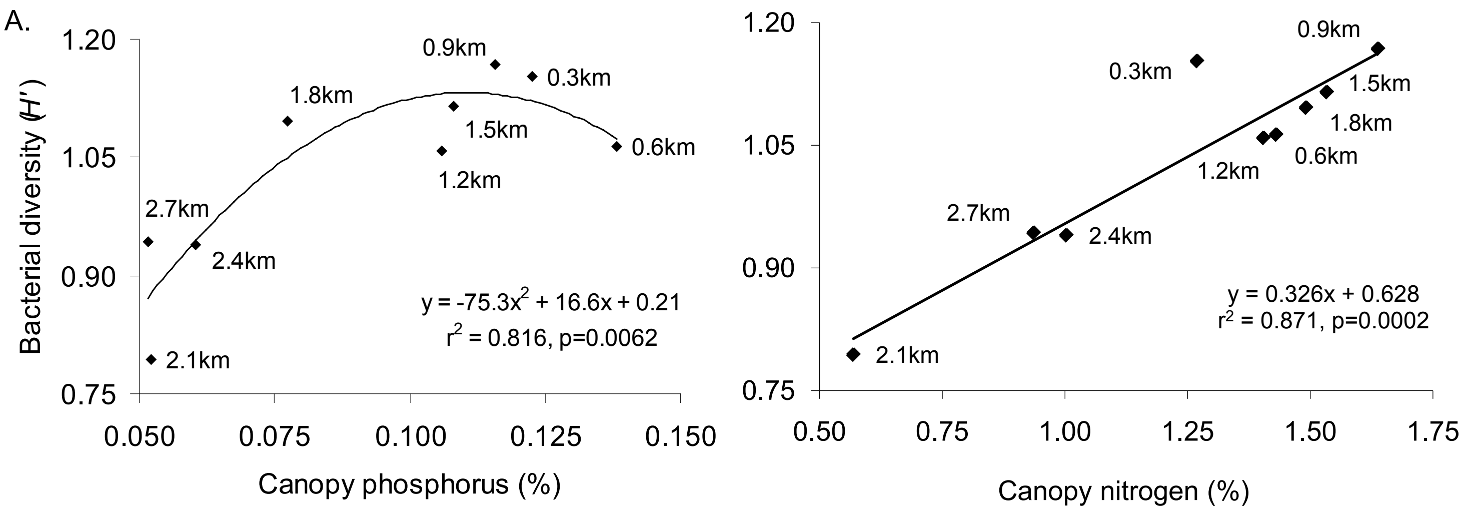


Figure 3.4: The relationship between bacterial diversity and canopy tissue phosphorus (A) and canopy tissue nitrogen (B) in the Bocas peatland.

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.

In each incubation, we measured 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 occurred at all sites indicating net heterotrophy in the peat-dominated soils and sediments. Consistent NO3 + NO2 uptake and NH4 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 PO4 uptake from the water column to the sediment. Enhanced PO4 uptake by sediments was found after the addition of 1 μM of PO4 in the water column. Intensified PO4 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 2009 showed that this trend ceased at all sites and reverted back to levels observed at the beginning of the study.

<u>Porewater biogeochemistry at mangrove sites</u>
There was a consistent seasonal pattern in porewater variables for all mangrove sites along Shark River and Taylor River for the period 2001-2010 (Figs. 3.5 to 3.8). Mean salinity was higher during the dry season (23.0 ± 2.2 g kg-1) compared to the wet season (11.6 ± 1.5 g kg-1) for all Shark River sites; whereas salinity along Taylor River sites remained fairly constant during both the dry (21.3 ± 1.1 g kg-1) and wet (20.9 ± 1.1 g kg-1) seasons throughout the years (Fig. 3.5). Along Shark River, salinity decreased with distance inland from the mouth of the estuary ranging from 26.4 ± 1.0 g kg-1 at SRS-6 to 5 ± 1.2 g kg-1 in SRS-4, suggesting the influence of the tidal regime along the estuary (Fig. 3.5). Sulfide concentrations showed an opposite trend compared to that of salinity, with higher values during the wet season and lower values in the dry season for all mangrove sites (Fig. 3.6). Along Shark River, sulfide concentrations ranged from 0.06 ± 0.02 mM (dry season) to 0.12 ± 0.03 mM (wet season), and from 1.1 ± 0.14 mM (dry season) to 1.43 ± 0.14 mM (wet season) along Taylor River. Overall, sulfide concentrations were higher for all Taylor River sites (1.3 ± 0.2 mM), with the highest values at TS/Ph-8 (1.72 ± 0.3 mM); sulfide concentrations for all Shark River sites were almost negligible (<0.1 mM) or below detection limit (<0.003 mM) for the period 2001-2010 (Fig. 3.5). Soil redox potential (Eh) did vary among sites ranging from -186 ± 9 to 297 ± 11 mv across all six sites and years. Soil Eh also was higher at 0 cm (145 ± 8 mv) and 10 cm (107 ± 10 mv) depths compared to 45 cm (-29 ± 11 mv). Overall, the Shark River sites (range: 96 ± 16 to 141 ± 9 mv) had higher soil Eh values compared to Taylor River sites (range: 1.3 ± 0.5 to 50.2 ± 19 mv). However, soil Eh values indicated slightly reducing conditions across all sites and depths (data not shown).

Porewater NO2- and NO3- concentrations were often <0.5 mM across all sites, seasons, and years. Thus, values for NO2-, NO3-, and NH4+ were pooled to determine dissolved inorganic nitrogen concentrations (DIN; Fig. 3.7). DIN concentrations were higher at all Taylor River sites

(19.4 ± 3.3 mM) compared to Shark River sites (5.7 ± 0.7 µM), with the highest concentrations at TS/Ph-6 (24.5 ± 7.3 µM) and the lowest at SRS-4 (4.6 ± 1.1 µM; Fig. 3.7). Overall, along Shark River DIN concentrations were lower during the dry season (5.1 ± 0.5 µM) and higher during the wet season (6.4 ± 0.8 µM), while along Taylor River DIN concentrations did not vary between the dry and wet seasons (19.4 ± 3.6 and 19.3 ± 3.0 µM, respectively). Soluble reactive phosphorus (SRP) concentrations varied among sites, especially along Shark River where concentrations increased from upstream to downstream in the estuary (Fig. 3.8). Overall, SRP concentrations ranged from 0.4 ± 0.1 µM (SRS-4) to 1.8 ±0.4 □M (SRS6) along Shark River, and from 0.93 ± 0.2 µM (TS/Ph-6) to 0.96 ± 0.2 µM (TS/Ph-7 & 8) along Taylor River (Fig. 3.8). SRP concentrations were higher during the wet season (1.3 ± 0.2 and 1.0 ± 0.1 µM) compared to the dry season (0.8 ± 0.2 and 0.84 ± 0.1 µM) for Shark River and Taylor River (Fig. 3.8). Results from this study suggest the significant effect of hydroperiod (frequency, duration, depth of flooding) on porewater chemistry along both estuaries. The strong tidal signature along Shark River reflects changes in salinity along the estuary and the lower accumulation of sulfides and DIN concentrations in soils, particularly ammonium. The higher DIN concentrations in Taylor River sites along with higher sulfide concentrations in soils are associated to the permanent flooding conditions and the lack of a tidal signature in these sites, promoting more anaerobic conditions in the soil.

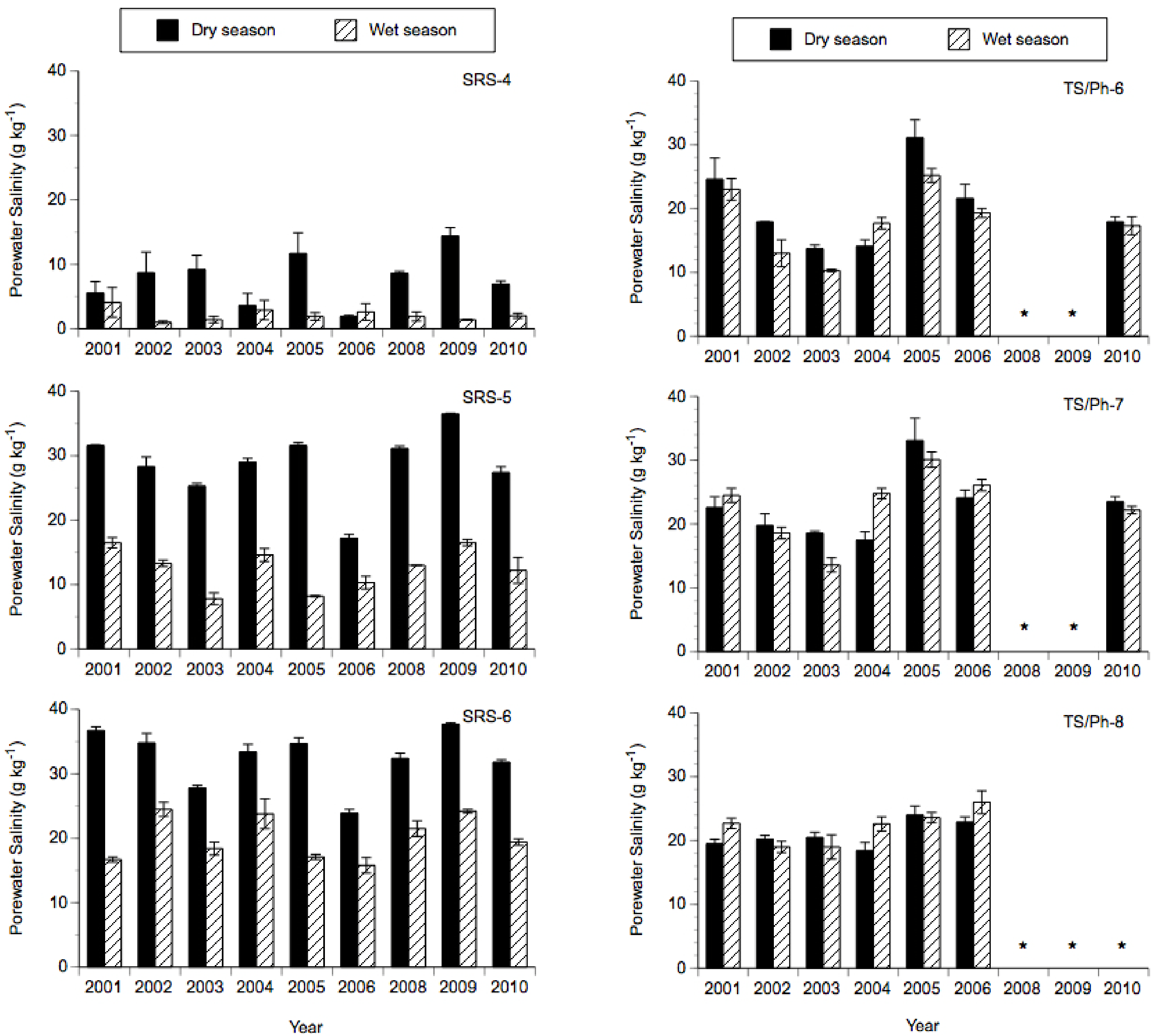


Fig. 3.5: Spatial and seasonal variation in salinity measured in mangrove sites of the Florida Coastal Everglades during the period 2001-2010. Asterisks indicate porewater sampling was not conducted.

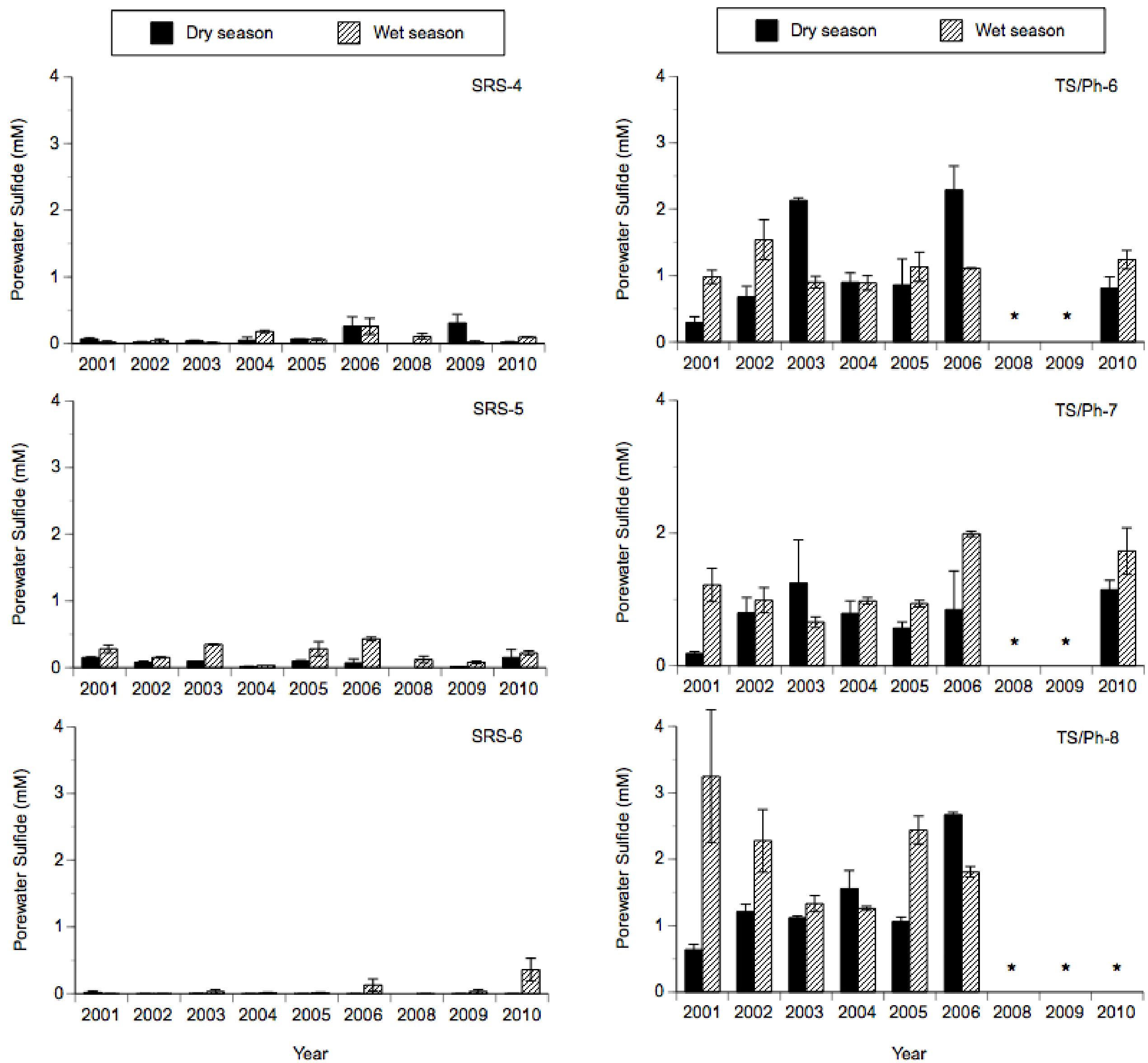


Figure 3.6: Spatial and seasonal variation in sulfide concentrations measured in mangrove sites of the Florida Coastal Everglades during the period 2001-2010. Asterisks indicate porewater sampling was not conducted.

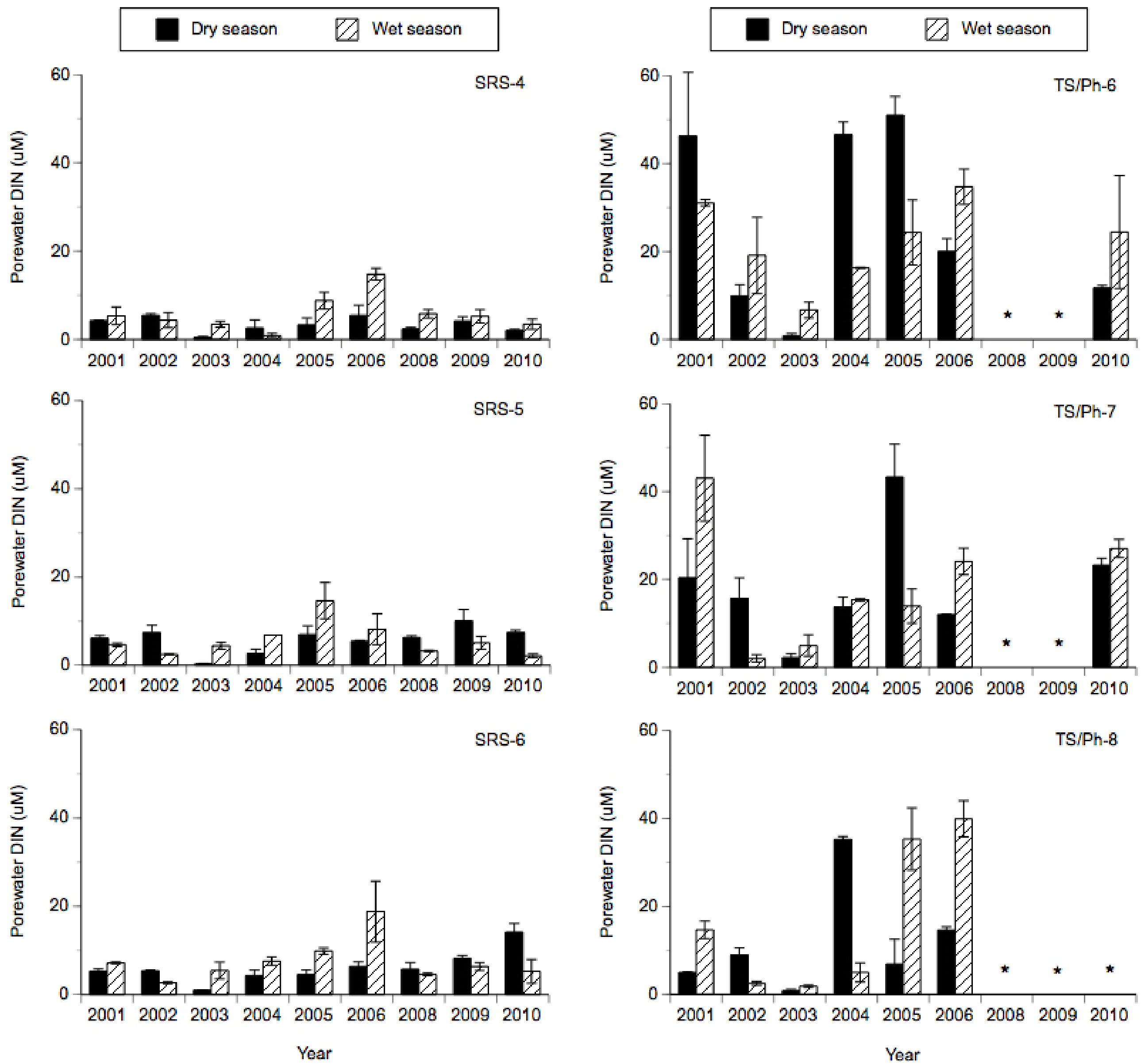


Figure 3.7: Spatial and seasonal variation in dissolved inorganic nitrogen (DIN) concentrations measured in mangrove sites of the Florida Coastal Everglades during the period 2001-2010. Asterisks indicate porewater sampling was not conducted.

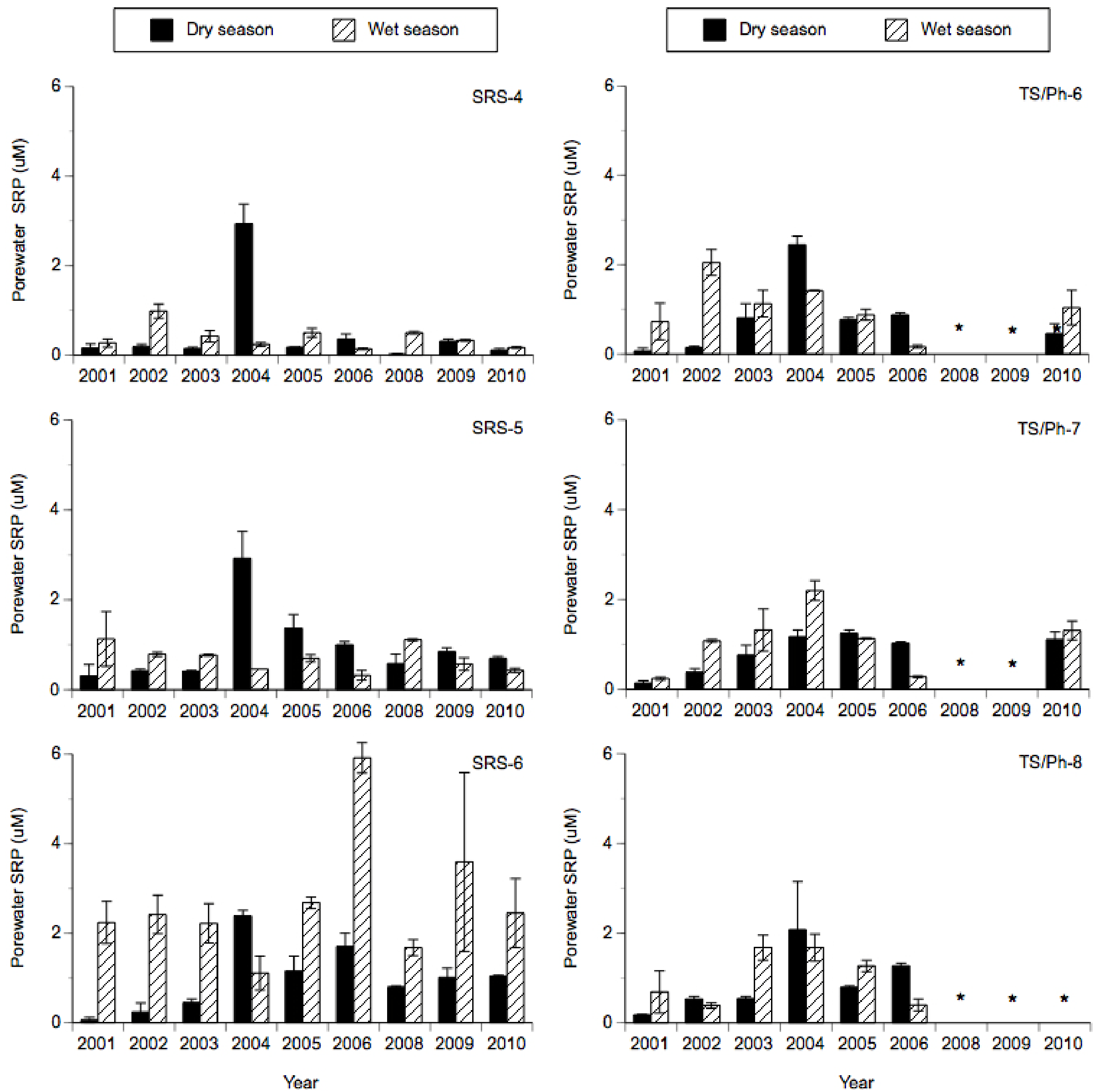


Figure 3.8: Spatial and seasonal variation in soluble reactive phosphorus (SRP) concentrations measured in mangrove sites of the Florida Coastal Everglades during the period 2001-2010. Asterisks indicate porewater sampling was not conducted.

Response of Everglades marsh communities to water management activities

Preliminary water quality data downstream of release locations along the Tamiami Canal suggest that canal stage exerts a strong influence on the spatial heterogeneity of habitats downstream of water releases, and initial anecdotal evidence suggests that periphyton productivity also reflects these trends. These trends are similar to those observed along the eastern boundary in the S-332 detention area at the head of Taylor Slough (see Primary Productivity section). Research conducted along these boundaries are showing that water quality and producer community characteristics are much more heterogenous, and indicative of enrichment, along the edge of the boundaries than at sites in the interior of the marsh.

4. Trophic Dynamics and Community Structure

Movements, foraging ecology, and habitat linkages of top predators

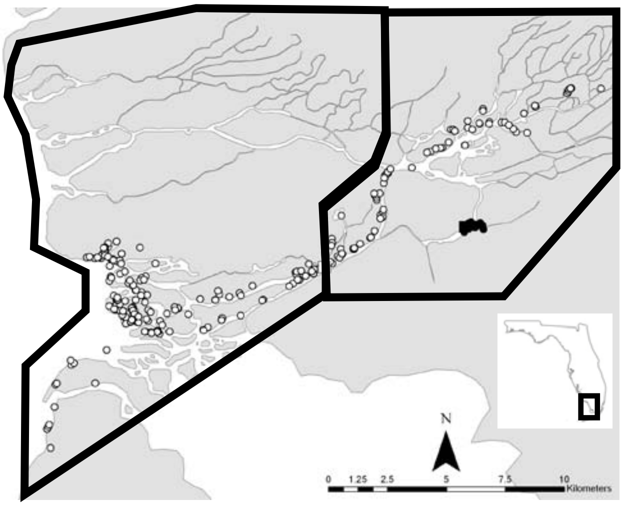


Figure 4.1: The Shark River Estuary is located in southwest Florida (inset, outlined in black box). Alligator 6825 (capture site = black square) and Alligator 6827 (capture site = white square) were tracked using GPS telemetry from October – February. Location fixes for Alligator 6825 are indicated by black circles and location fixes for Alligator 6827 are indicated by white circles. Black lines delineate zones of differing salinity regimes (from Rosenblatt and Heithaus, 2011).

This year, we were able to publish several papers summarizing results of recent studies of bull sharks and American alligators in the Shark River estuary (Matich et al. 2011, Rosenblatt and Heithaus 2011). We have found that both species may serve to couple marine food webs with those in the estuary and freshwater marshes. Alligators display seasonal movements from upstream and marsh habitats during the dry season into mangrove-lined channels and estuarine waters. Interesting, we found that during the wet season there is marked individual variation in movements (Figure 4.1). Acoustic telemetry revealed that some alligators make regular movements from mid-estuary waters downstream where they appear to feed in marine food webs. Indeed, the isotopic signatures of "commuting" alligators (see Figure 4.2) are the less C^{13}-depleted than alligators that remain in mid-estuary and upstream waters. GPS-tag deployments on two alligators provided a fortuitous glimpse into the extreme variation between movement tactics (Figure 4.1) in home range size and possibility of linking habitat dynamics. One alligator traveled hundreds of kilometers between the upper estuary and coastal waters over several months. The second traveled a total distance of less than 7k.

We recently completed an experiment to determine turnover rates of stable carbon and nitrogen values of blood plasma, whole blood, and skin of American alligators in a captive setting. Using a food-switching protocol we found that tissue turnover times were much longer than generally thought (months for blood plasma in alligators and > 1 year for skin tissue). These data will be instrumental in interpreting isotopic data collected from individuals in the FCE.

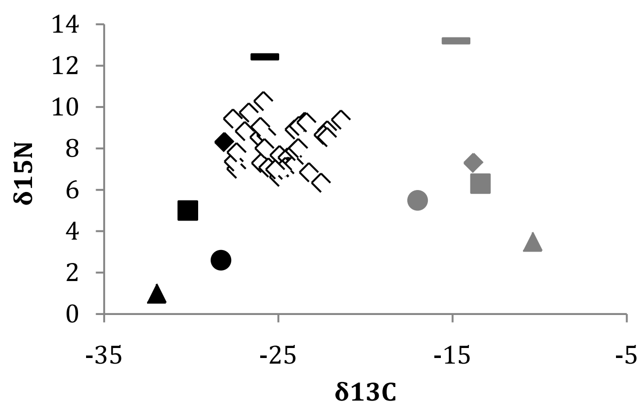


Figure 4.2: Trophic position of alligators (open diamonds) relative to organisms from marine (gray) and freshwater/estuarine (black) food webs. Commuting alligators have the least negative stable carbon values.

Bull sharks also appear to link marine and estuarine/freshwater food webs, but only a subset of individuals fill this role. Indeed, using differential turnover rates of tissues (i.e. blood plasma, muscle, fin clips), we found out that bull sharks have a high degree of individual specialization (Figure 4.3). Some of these specialists feed only in estuarine and freshwater food webs while others – despite being captured in the spatial domain of estuarine and freshwater food webs – showed long-term specialization on marine resources. Patterns of specialization in bull sharks contrast markedly with tiger sharks, another upper trophic level species, which show low degrees of specialization on particular resource pools (Figure 4.3). The presence of both alligators and bull sharks within the ecotone region, that appear to feed on marine resources, raises the possibility that these species are vectors for upstream transport of limiting nutrients.

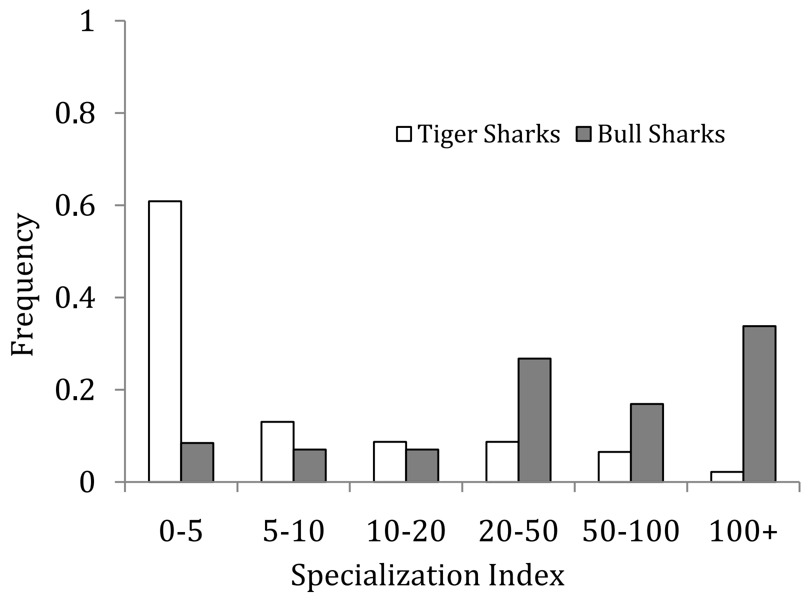


Figure 4.3: Specialization indices of bull sharks (Shark River Estuary) and tiger sharks (Shark Bay, Australia) using $\delta^{13}C$ isotope values from muscle (M), blood (B), and plasma (P) (bull sharks) and fin (F), blood (B), and plasma (P) (tiger sharks).

Trophic structure based on fatty acid and stable isotope markers

Fatty acid and stable isotopic markers suggest that a mixture of diatomaceous, flagellate, and bacterial organic substrates support lower trophic levels near SRS-5. Vascular plant inputs are also important, particularly for catfish, red drum, snapper, bass, and snook (Fig. 4.4). Vascular plant fatty acid inputs were well correlated to $\delta^{13}C$ (Fig. 1; R^2=0.655). The ingestion of vascular plant material may occur inadvertently as organisms feed on floc, as was shown for primary consumers in the freshwater marshes near Taylor Slough (Belicka et al., submitted to Limnology and Oceanography).

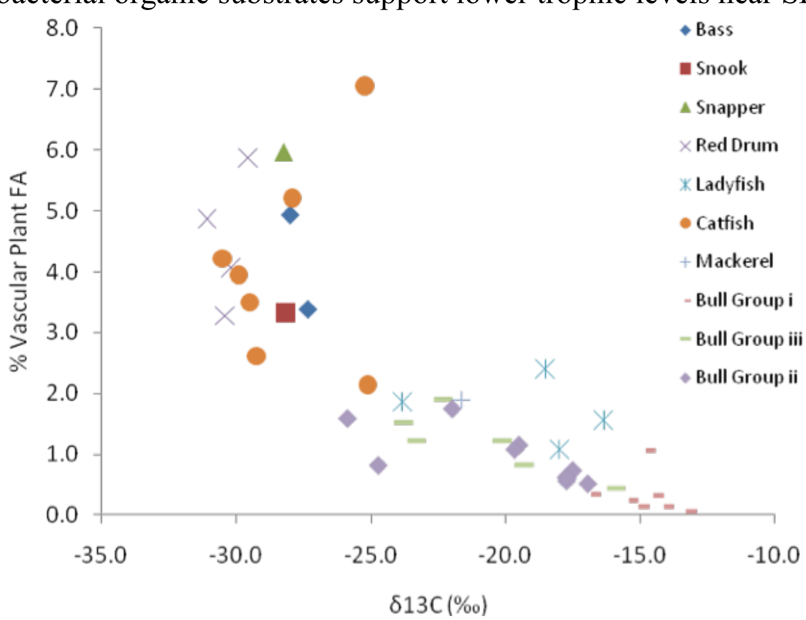
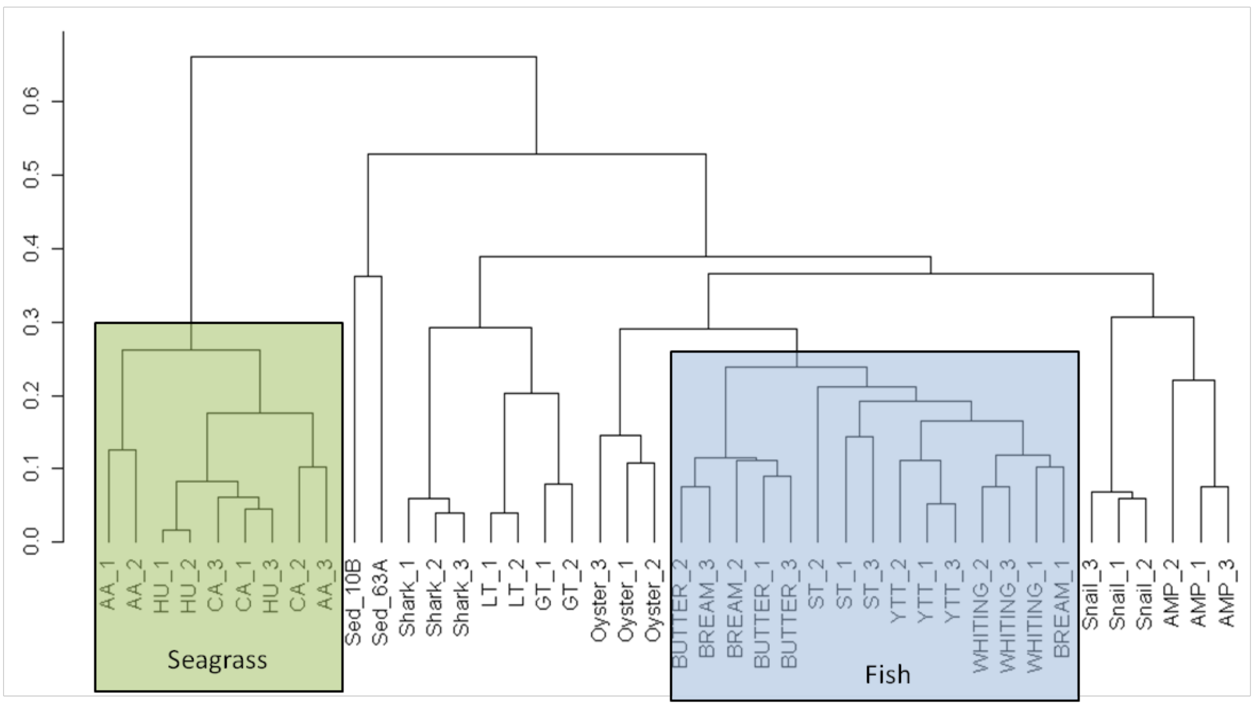


Figure 4.4: Relationship between d13C and % Vascular Plant fatty acids in consumer muscle tissues collected near SRS-6.

Of the large predators, the bull sharks marked "group i" in figure 4.4 contain the lowest concentrations of vascular plant fatty acids in their tissues, and had very enriched (marine-like) $\delta^{13}C$ signatures. Interestingly, these young sharks were all caught in the upper estuary near Tarpon Bay. This fatty acid data provides further evidence for the idea that young sharks are not feeding, but instead rely on maternal provisions, as was presented in Belicka et al., submitted to Marine Ecology Progress Series.

In the Shark Bay, Australia ecosystem, fatty acid analysis suggests that amphiphytes are a food source for snails in the region (Fig. 4.5). Oysters were also closely related to all investigated fish species, suggesting direct or indirect predation through a trophic intermediary. Interestingly, fatty acid composition did not link seagrass to any of the investigated consumers (Fig. 4.5). It is possible that the most diagnostic seagrass markers, including a C16:1-trans fatty acid that was only found in the seagrass samples, is either transformed to a more common fatty acid prior to assimilation, or is not assimilated. Measurements of stable carbon isotopic composition are currently underway to further investigate the importance of seagrass as a carbon substrate for consumers in this environment.



Key:

AA: Amphibolis antarctica (Seagrass)
CA: Cymodocea angustata (Seagrass)
GT: Green turtle?
(Tiger Shark?)
Butter: Butterfish
YTT: Yellow-tail Trumpeter

HU: Halodule uninervis (Seagrass)
LT: Loggerhead turtle?
Shark: GC = Galeocerdo cuvier?

ST: Striped Trumpeter
AMP: Amphiphytes

Figure 4.5: Average-Linkage Hierarchical Cluster Analysis based on Bray-Curtis Dissimilarity of Fatty Acid Relative Abundances in all samples collected from Shark Bay,Australia

Fish community structure and predator-prey interactions in SRS
Environmental heterogeneity affects ecological processes at multiple scales. Over space and time, species composition, food web structure, and pathways of energy flow not only reflect interactions among organisms, but also interactions between organisms & the abiotic landscape they experience. In the Everglades, periodic hydrological disturbance influences movement and habitat selection, as well as spatiotemporal abundance and distribution patterns, with implications for predator-prey interactions, trophic dynamics, and ecosystem function and services. We sampled fish assemblages in mangrove habitats along the SRS transect to examine the effect of hydrological conditions (e.g., marsh water levels and salinity) on fish community structure, and predator-prey interactions among freshwater, estuarine and marine fishes.

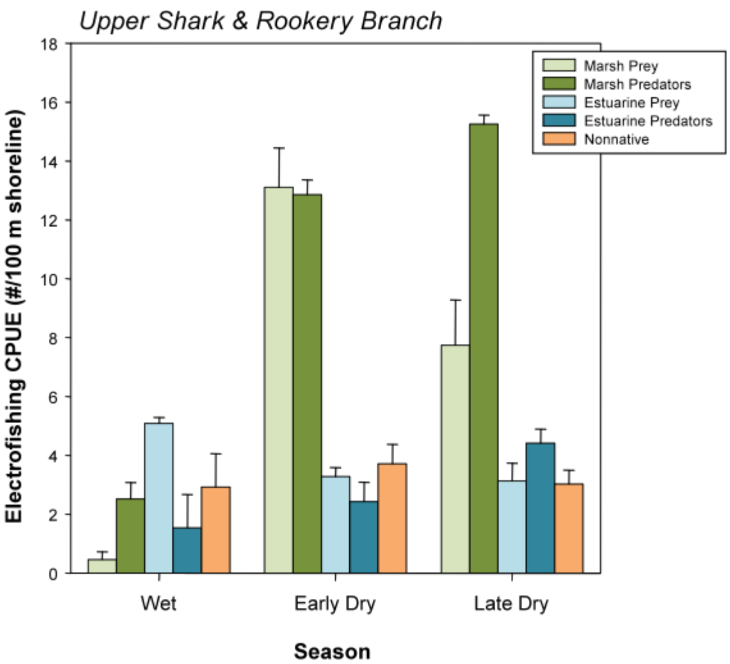


Figure 4.6: Seasonality in catch per unit effort (CPUE) across all 6 years shown by functional group: marsh fishes, estuarine/marine fishes, & nonnative taxa**.**

Our sampling shows that freshwater species are an important component of the fish community of ecotonal mangrove habitats, particularly in the dry season (Fig 4.6). Fish abundance in the headwaters of SRS varies markedly seasonally in response to hydrological conditions (Fig. 4.7). In the dry season, fish increase at the ecotone due to a pulse of freshwater taxa that enter the estuary as upstream marshes dry, and to the movement of estuarine consumers that move up the estuary to capitalize on high prey numbers. Freshwater prey represent an important resource subsidy for these estuarine consumers. The diet of snook, an important recreational fishery in South Florida, closely tracks the pulse of freshwater prey, particularly centrarchids, during the dry season.

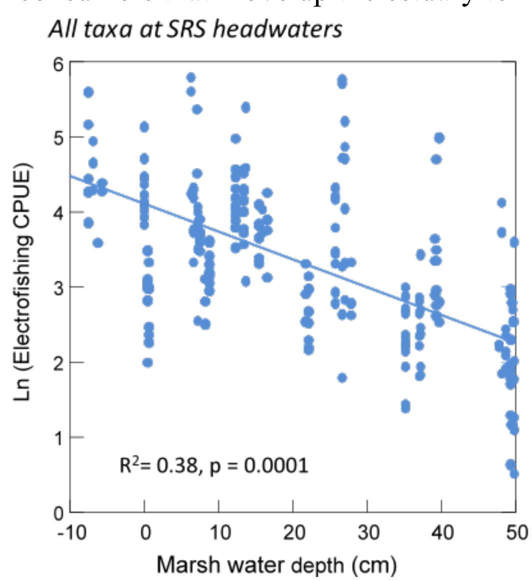


Figure 4.7: Relationship between fish abundance (all taxa) at the ecotone, and marsh water levels upstream in the SRS headwaters.

Overall, our repeated sampling indicates that marsh drying is a major driver of fish community structure at the ecotone. Marsh drying results in pulses of prey that are partitioned among freshwater and estuarine consumers. In addition to marsh water levels and prey abundance, fish dynamics at the ecotone are influenced by the abiotic landscape organisms encounter once they move to the ecotone. For example, numbers of freshwater consumers are negatively related to salinity levels, while estuarine consumer abundance is strongly influence by oxygen levels.

Food webs and fish movements in the freshwater Everglades

The past year has seen the culmination of several years of work on food webs of the oligohaline freshwater Everglades with documentation of strong microbial contributions to energy flow, comparable to or exceeding those of algal production (Belicka et al, in review). Also, we used path analytical modeling to document landscape-scale impacts of top-down effects, supporting results from experimental studies conducted at a relatively small number of local sites. The ability to scale-up these results is an important dimension of our research in this area (Sargeant et al. in press). We also documented a functional relationship between disturbance frequency and refuge use (a modal pattern best described our data on fish use of dry-season use of alligator ponds), as well as an effect of landscape position on refuge use (alligator ponds closer to canals were used by fewer fish than those further away, controlling for pond size; Parkos et al. in press). Other work has extended our understanding of how small fish move across the Everglades landscape in response to seasonal expansion and recession of water (McElroy et al. in press and Obaza et al. 2010). Finally, we have been developing a larger view for understanding the ecology of the Everglades are representative of a widely distributed habitat type, karstic wetlands of the Caribbean basin, that is interesting when considered in a larger context of wetlands because of its oligohaline trophic state and strong seasonal hydrology (Ruehl and Trexler 2011 and Gaiser et al. in press).

We have also been working on the role of life histories in predicting community assembly. Our published works this year were on expanding theory through the use of simulation modeling. We have documented that fish reproductive life histories focusing on female parental predict community assembly along gradients of disturbance frequency, resource level, and predation patterns (Trexler et al. 2011). Our simulation models also predicted that resource gradients were strong selective agents on fish life histories and mediated predation effects (Giacomini et al. in review). These simulation models have in common the emergence of suites of traits in assembled communities, similar to patterns that are well known in natural communities. What the new work adds is examination of multiple, simultaneously acting, selective gradients never before considered because of complexity caused limitations to analytical modeling. We believe that future researchers will no longer invoke individual drivers, such as r&K selection or bet hedging, to explain patterns in nature because these mechanisms are often acting in concert. Our future work will explore if these mechanisms can act additively, multiplicatively, or otherwise in real systems with multiple environmental gradients.

5. Hydrology

Our results indicate that in each slough, precipitation was the dominant water source while evapotranspiration was the dominant water loss (Zapata-Rios, 2009; Saha et al., 2010). Groundwater inputs were found to be a significant contribution to the surface water in both Taylor and Shark Sloughs (Fig. 5.6). In Taylor Slough, groundwater inputs were the second largest input, about 40% of the total inputs or equivalent to 60% of rainfall (Zapata-Rios, 2009; Michot et al., 2011), with upstream freshwater flows accounting for only 8% of the surface water. In Shark Slough, groundwater input was equivalent in magnitude to the upstream freshwater flows across Tamiami Trail, representing 19% of the total input (Saha et al., 2010). Groundwater inputs are important for the oligohaline ecotone region of the FCE as both fresh and brackish groundwater contains higher concentrations of phosphorus (Price et al., 2006), the limiting nutrient within our ecosystem.

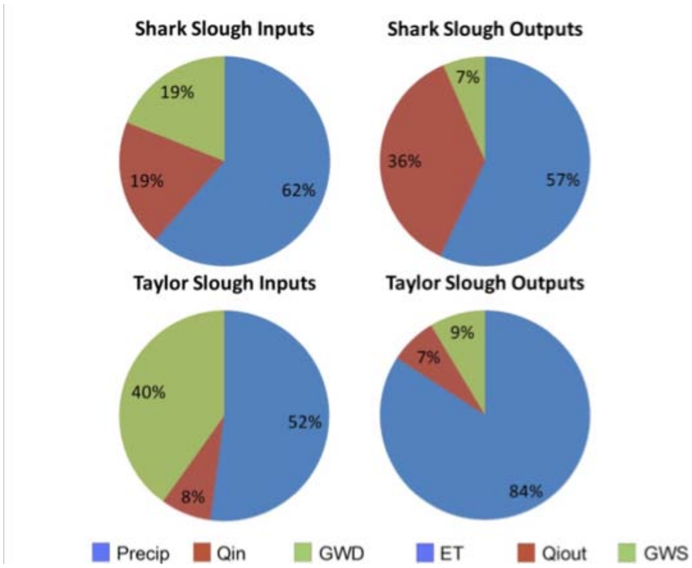


Figure 5.6: Pie charts of water budget components in Shark and Taylor Sloughs. Inputs include precipitation (blue), surface water inflow (red), and groundwater discharge (green). Outputs consist of evapotranspiration (blue), surface water outflow (red), and groundwater seepage (green). Values represent the average percentages of each component for Taylor Slough on a monthly basis between Jan. 2008 – July 2009, and on an annual basis in Shark Slough between 2002-2008.

Marine waters from Florida Bay and the Gulf of Mexico intrude into the coastal aquifer beneath the oligohaline ecotone, causing the groundwater to be brackish (Price et al., 2006). Our investigations have determined that brackish groundwater discharge (GWD) combined with long residence times and evaporation had a greater effect on water chemistry in Taylor Slough which seasonally became hypersaline (Zapata-Rios et al., 2009) as compared to Shark Slough which only became moderately hypersaline (Barr et al., 2009). The highest values of GWD occurred in May-July concurrent with the highest levels of evapotranspiration (Saha et al., 2010, Zapata, 2009), solar radiation (Price et al., 2007; Barr et al., 2009), phosphorus concentrations (Koch et al., 2011), and hypersaline conditions (Fig. 5.7). Ecosystem response was mixed under these conditions, with mangrove physiological functions limited (Barr et al., 2009), but gross primary production becoming elevated (Koch et al., 2011).

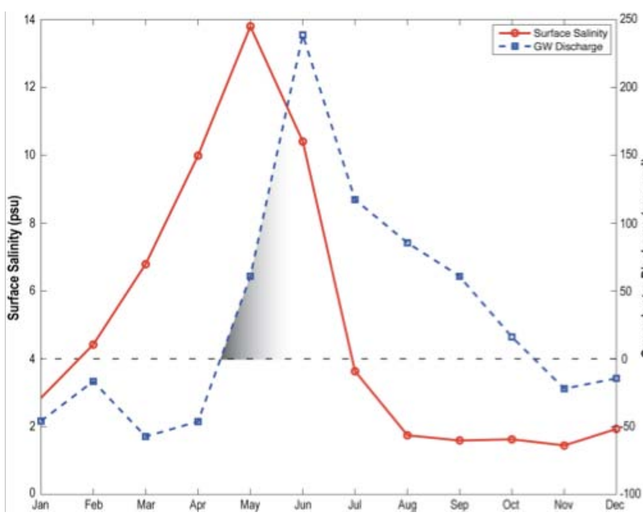


Figure 5.7: Monthly Groundwater discharge to SRS and monthly surface water salinity at SH2 (the oligohaline ecotone) averaged over 2003-2008 (Saha et al., 2010).

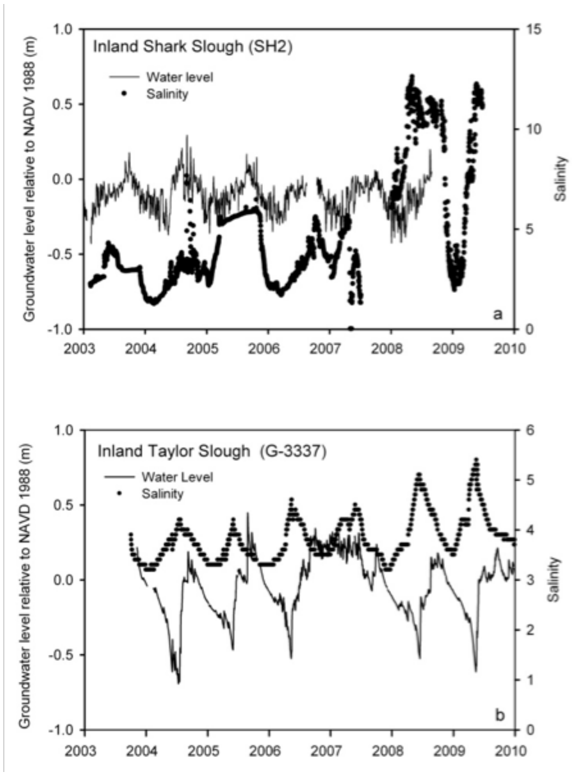


Figure 5.8: Groundwater salinity (black dots) and groundwater level (black line) in (a) Shark Slough and (b) Taylor Slough within the oligohaline ecotone. Source Saha et al., 2011b.

The position of the groundwater mixing zone varied seasonally but has been steadily increasing inland with sea level rise (Fig. 5.8; Saha et al., 2011b). Water levels along the coastline have been increasing since the 1960s at a rate of 2 mm/yr, equivalent to local sea level rise (Fig. 5.9), while water levels in the upper reaches of Shark Slough have increased at a higher rate (7mm/yr) due to increased releases of fresh surface water across Tamiami Trial (Fig. 5.10). Despite the increased releases of freshwater from the upstream Everglades, the resultant water becomes ponded in the upper reaches of Shark Slough due to the presence of sawgrass and floating peryphyton mats within the water column which restrict flow velocities (He et al., 2010). Our results suggest that managed surface water inflows to Shark Slough need to be increased in order to counteract the landward intrusion of seawater (Saha et al., 2011b).

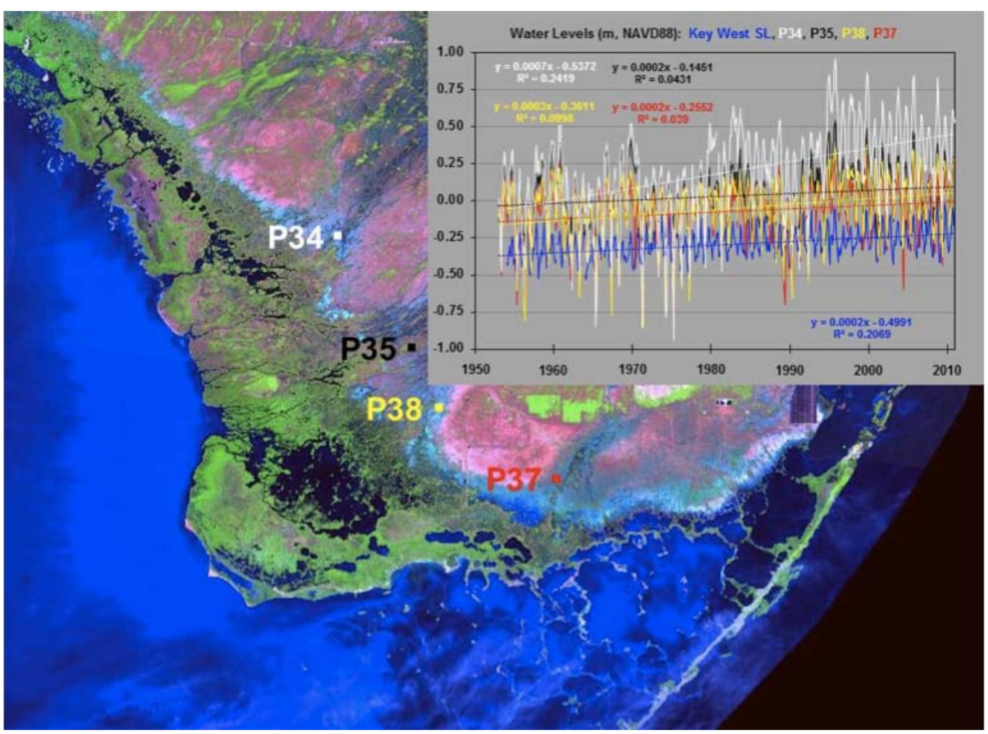


Figure 5.9: Long-Term water levels along coastal sites of ENP rose at a rate similar to sealevel rise at Key West (~2 mm/yr). Source Dr. Tom Smith III.

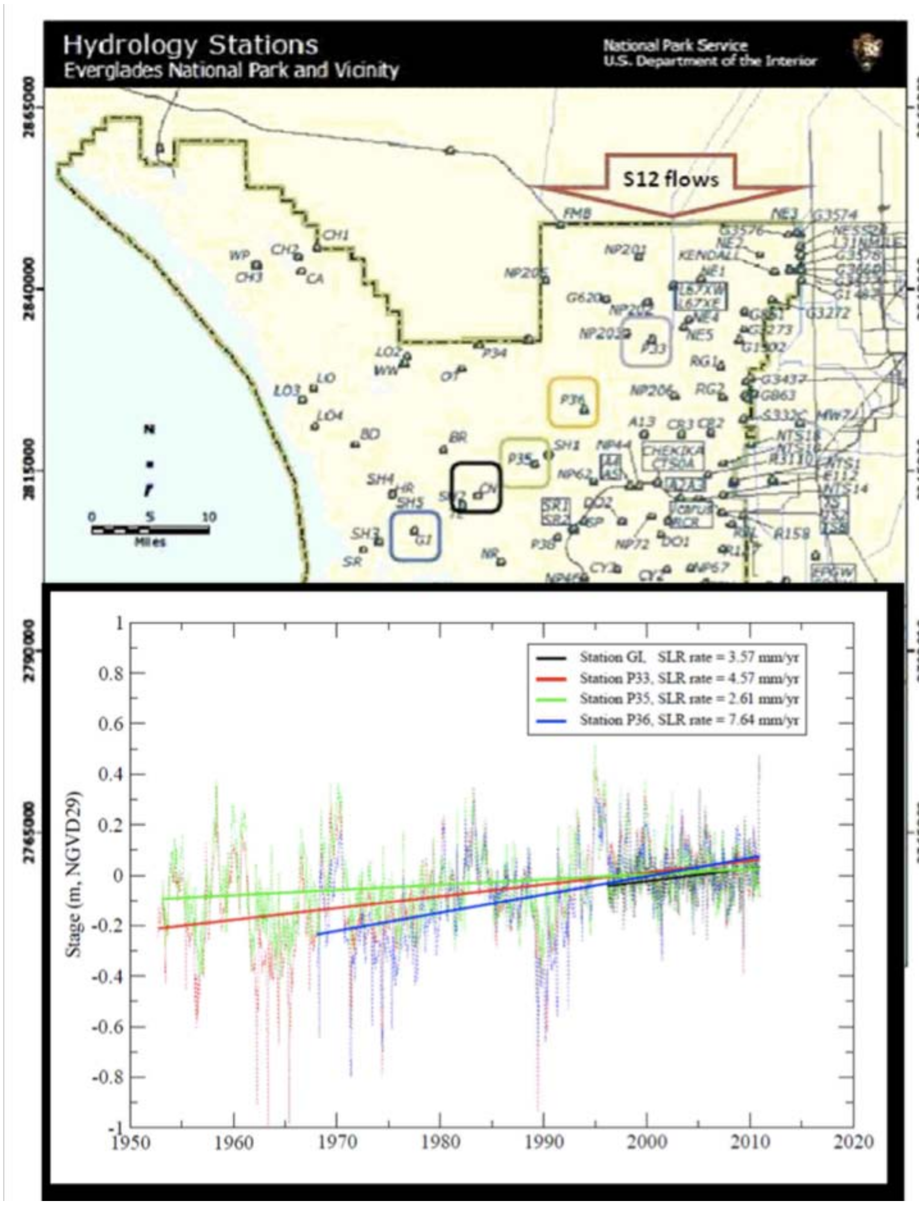


Figure 5.10: Rates of surface water level rise at upland sites were higher than the 2.25 mm/yr rise in sealevel as measured in Key West, Florida. Source: Vic Engel.

Estimated residence times in Taylor and Shark Sloughs are variable. Preliminary estimates of residence times in Taylor Slough indicate a bi-modal distribution with peaks at 7 and 180 days, corresponding with periods of high flow and low flow, respectively. In Shark Slough, residence times decreased in a downstream direction from >90 days to about 14 days between SRS-1 and SRS-4 (Fig. 5.11), due to increased surface water flow velocities in the slough (Saha et al., 2011). Within the mangrove ecotone region of Shark River Slough, where tides occur, residence times of 12 days or less were estimated (Wacksman and Chambers, 2005).

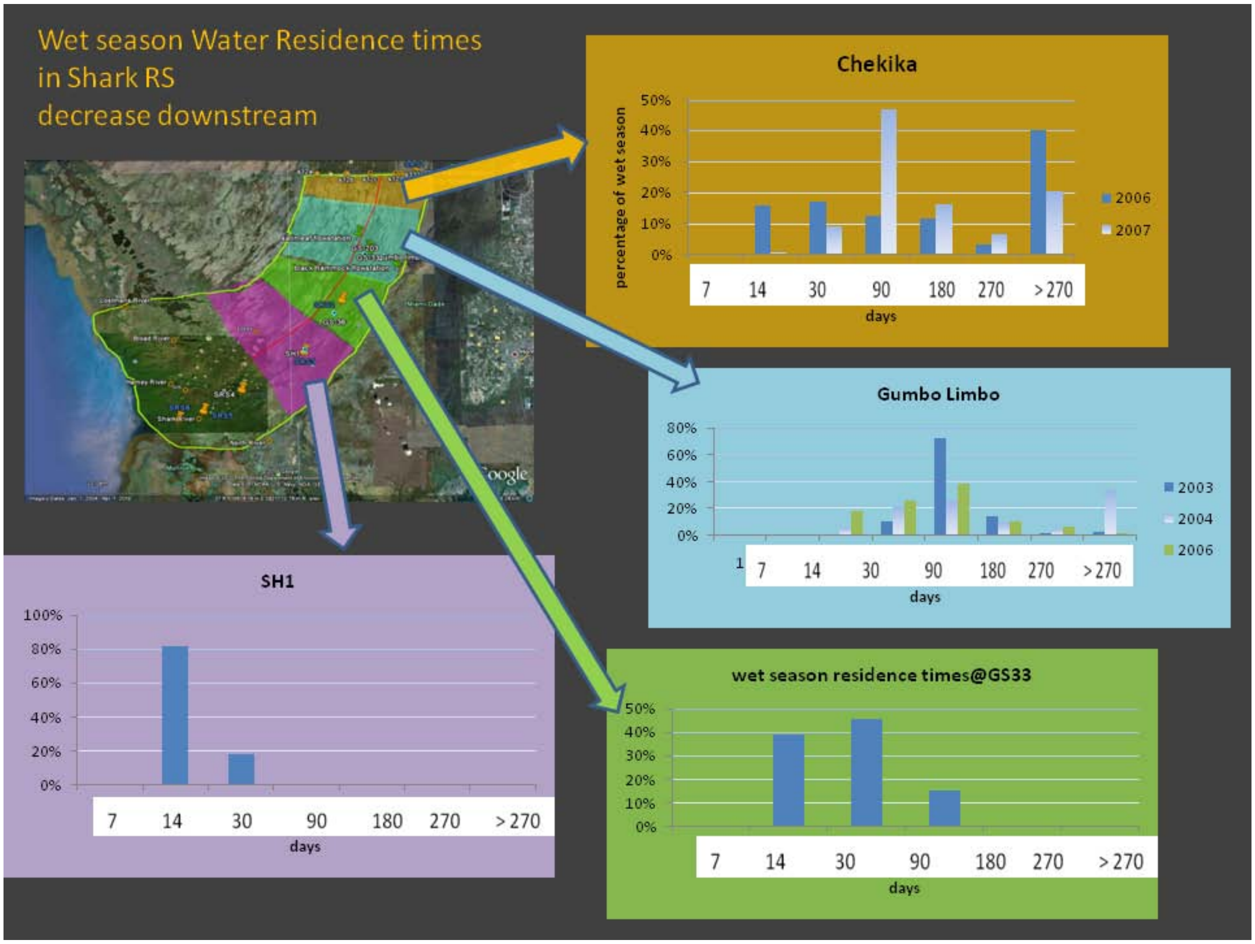


Figure 5.11: Wet season water residence time distribution in freshwater portion of Shark River Slough. The residence time distribution is expressed as the percentage of the wet season (June – Nov) having a residence time within a range of days (7, 14, etc) caused by variation in water flow velocities over the season. The residence time is seen to decrease downstream along the Slough, in response to faster flow velocities. (Saha et al., 2011).

6. Human Dimensions

Our results indicate the following key insights about parcel vegetation greenness and heterogeneity:

- About 45% of the land *area* (~3230 acres or 13.07 sq. km.) or 25% of land *parcels* (~4121 parcels) in Homestead were relatively very green (mean parcel NDVI values ranging from 0.5780 to 0.8556). In comparison, 23% of the land area (~6.53 sq. km.) or 31% of parcels were in the low NDVI category (0.1364-0.4727 range), the remaining area was of intermediate greenness. The high, intermediate and low greenness ranges are based on statistical breaks in the frequency distribution of pixel NDVI values.
- Parcel sizes are quite variable, and this is also related to vegetative cover. In the Homestead area, larger sized parcels are also greener. This is likely explained by the fact that many large parcels are under agricultural zoning and use, with the prevalence of tree

nurseries and agricultural crop covers. However, the larger parcels are also more internally variable in their NDVI values (Fig. 6.4).

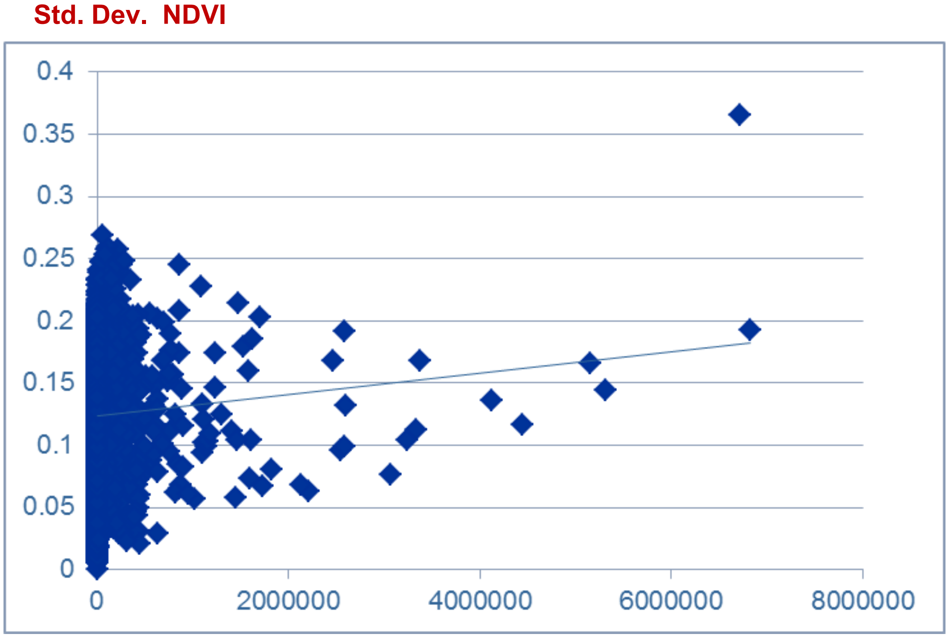


Figure 6.4: Within-parcel NDVI variability of pixels (Standard deviation) by parcel size.

- Parcel greenness varies by social structures that are formal (zoning) and informal (socio-demographic neighborhood "types"). Formal/zoning: Not surprisingly, agriculture and public lands had the largest parcel sizes on average, while residential parcels had the smallest average parcel sizes. Most (87%) of agriculturally zoned land *area* is very green (high parcel mean NDVI values). However, a majority (44%) of agricultural parcels (are not very green (low NDVI), and only 29% of agricultural parcels (with high greenness). This is consistent with the fact that many agricultural parcels are disproportionately large. In comparison, 45% of the land area and 25% of the parcels under single-family residential zoning were very green. Fig. 6.5 illustrates these trends. However, agricultural parcels are relatively more homogenous compared to single family residential parcels, which exhibit far greater internal heterogeneity (as suggested by the standard deviation of NDVI values).

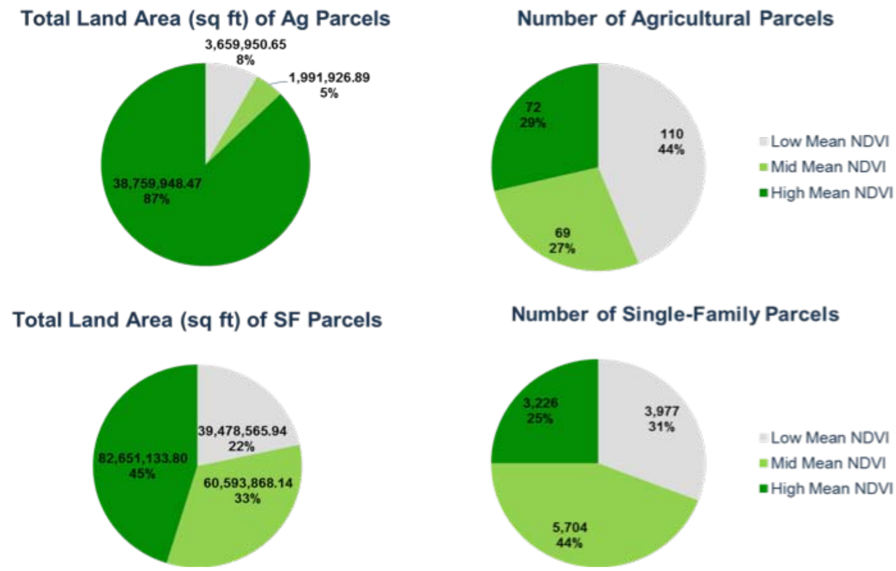


Figure 6.5: Comparison of greenness trends of agriculture vs. single family zoned land uses.

- *Parcel greenness displays significant and positive spatial autocorrelation*, with a Global Moran's I value of 0.4603. This indicates that parcels that are located closer together are also more likely to be alike in their greenness levels (parcel mean NDVI value) than parcels that are farther apart. While such findings are being further analyzed, and need to be expanded upon with ground-based social and ecological surveys, they appear to support some of the general assumptions of the (sub)urban "homogenization" of yards or residential neighborhoods.
- Moreover, the strength of spatial autocorrelation of parcel greenness varies in different socio-demographic groups/neighborhoods in Homestead. In other words, in some neighborhoods, neighboring parcels tend to be more similar to one another in their greenness levels, while in other neighborhoods, neighboring parcels are not necessarily as alike. We analyzed three examples of social groups/neighborhoods to illustrate, described in PRIZM nomenclature as "Gray Power", "Traditional Times" and "Back Country Folks" (PRIZM 2008). The "*Gray Power*" social-group/neighborhood (the relatively more "urban" and affluent group compared to the other two examined) displayed the strongest degree of spatial autocorrelation (~neighboring parcel similarity index), followed by the "*Traditional Times*" neighborhoods, with the "*Back Country Folks*" showing the lowest spatial autocorrelation. These two groups are much lower on the affluence and urbanicity scales as used by Claritas PRIZM. The last group notably has only 17% of their parcels in the high-NDVI category, maintaining most of their parcel areas in low or intermediate greenness levels.
- Preliminary cross-LTER site analyses indicate that empirical investigation of assumed "homogenization" of lands in urban residential neighborhoods is problematic, and needs to be disaggregated into two key components (Fig. 6.6 exemplifies residential yards in the four study sites). We therefore ask whether (1) distinct social groups produce distinct landscapes within each of these urban regions (Miami, Baltimore, the Boston area and

Phoenix), and (2) similar social groups residing in these distinct urban sites produce similar land covers and landscape structure across all those sites. Furthermore, we examine not only land cover, but also landscape structure (e.g., mean patch size of tree/vegetative covers, and patch shape complexity as measured by patch perimeter/area ratios).

Figure 6.6: Residential yards in four urban LTER study site locations.

- We explicitly compared 4-5 socio-demographic groups that span a range of relative urbanicity (urban to suburban and exurban) and relative affluence (high to low socio-economic status--SES). Contrary to much of the environmental justice literature that finds lower SES to be associated with lower environmental amenities (e.g., tree canopy cover), we find instead that less affluent neighborhoods reflect greater tree canopy cover in some cities (Boston, Miami, some Baltimore). Money & Brains (high affluence, urban PRIZM group) residents in Baltimore had the most distinct type of land cover behavior (maintaining large proportions of tree and grass cover in their residential neighborhoods) compared to 4 other distinct social groups (of lesser urbanicity and affluence) examined for the same city. However, those four other groups (Gray Power, Old Glories, Family Thrifts, and Young & Rustic) displayed some convergence of behavior despite their relative socio-demographic differences, each maintaining approximately equal proportions of their neighborhoods (census block-groups) in grass, tree and impervious surface covers. Money & Brains in both Baltimore and Boston maintained large proportions of tree and grass cover on their residential parcels, but this land cover behavior was also true of low-affluence, rural groups/neighborhoods in Miami, reflecting that we cannot easily generalize or affix land cover expectations to social groups. Tree patches were much larger and had the greatest patch complexity in the Boston area compared to the other sites, a possible artifact of geological history of its glacial till landscape, in interaction with social processes. This was not true for Phoenix, where grass and bare soil/water dominate in a highly affluent urban core neighborhood, and vegetation patches are simple shapes. Miami's less affluent and sub/ex-urban groups also had low patch complexity (simple shapes), despite significant proportions (63% of neighborhood area on average) in tree cover. Social groups in Miami had extremely different land cover behaviors, as exemplified in Fig. 6.7.

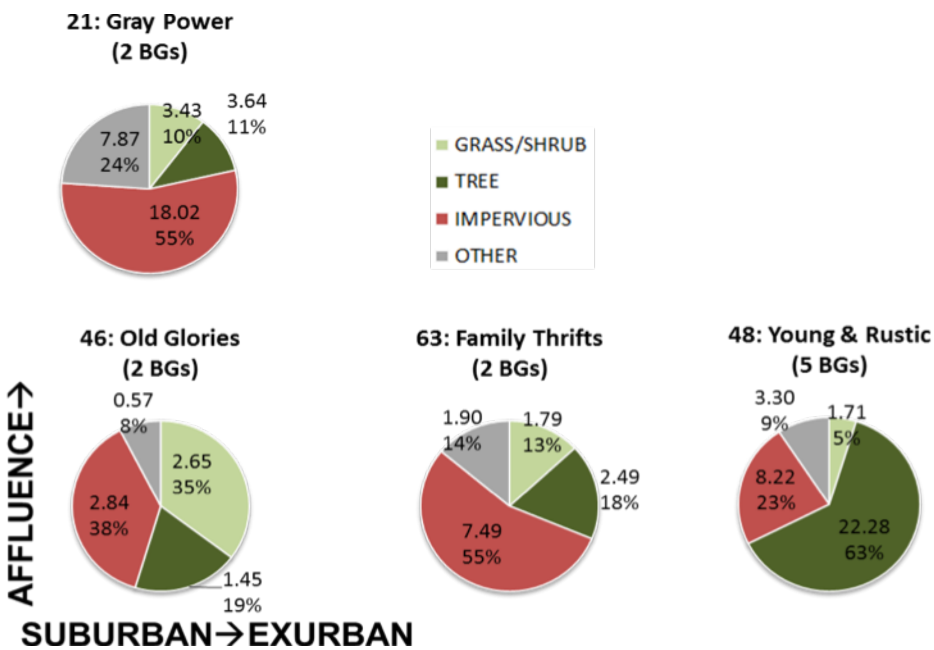


Figure 6.7: Land cover behaviors of four socio-demographic groups of varying affluence and urbanicity in southern Miami-Dade county. Charts depict absolute (hectares) and relative (%) neighborhood areas in each of four land covers: grass/shrub, tree, impervious and other (typically bare soil).

7. Climate and Disturbance

NSF WSC Workshop - Linking freshwater inputs to ecosystem function and services provided by a large mangrove estuary (Sukop, Jaffe, Rehage, Engle & Anderson)

Shark River supports one North America's largest mangrove forests, which is affect by tidal forcing and water flow (not to mention future sea-level). The mangrove ecotone provides many ecosystem services which include: 1) limited coastal protection from storms; 2) fisheries support, and 3) long-term carbon sequestration primarily through peat deposition. While there is abundant evidence from sediment cores shows there is significant peat accumulation (thus C sequestration in the very recent geologic past), the amount of C sequestration is difficult to quantify due to several issues and processes. There are significant challenges in measuring peat accumulation with radio isotope approaches. Additionally, the amount of CO_2 uptake of the ecosystem and DIC export via surface water need to be better assessed. These issues and processes are the focus of the present FCE scientific efforts at determining the carbon balance in the Shark river region.

The CERP goal of increase freshwater flow from ENP, may result in the reversal of the upstream migration of the mangrove forest, but sea-level rise and rate, will certainly have an effect too, if not completely overwhelm the system. Workshop participants noted the relative isolation Shark River system and the ongoing scientific investigation within the region make this area an ideal laboratory for developing more applicable economic valuation strategies for ecosystem services, which provides a direct linkage to hydrologic management of the system.

NSF WSC tracer study – Shark River isotopic composition of TOC (Engle, Ho, Jaffe, Palya & Anderson)

Initial results indicate that the TOC of the water samples from the November tracer study are composed of mangrove and/or other C3 derived terrestrial material and not seagrass (see Figure 7.1). Additionally the isotopic composition of DIC compared with salinity, indicate that near the mangrove zone mineralization of the OM (perhaps mangrove derived) is contributing to dissolved forms of carbon. Our next measurements will include DOC.

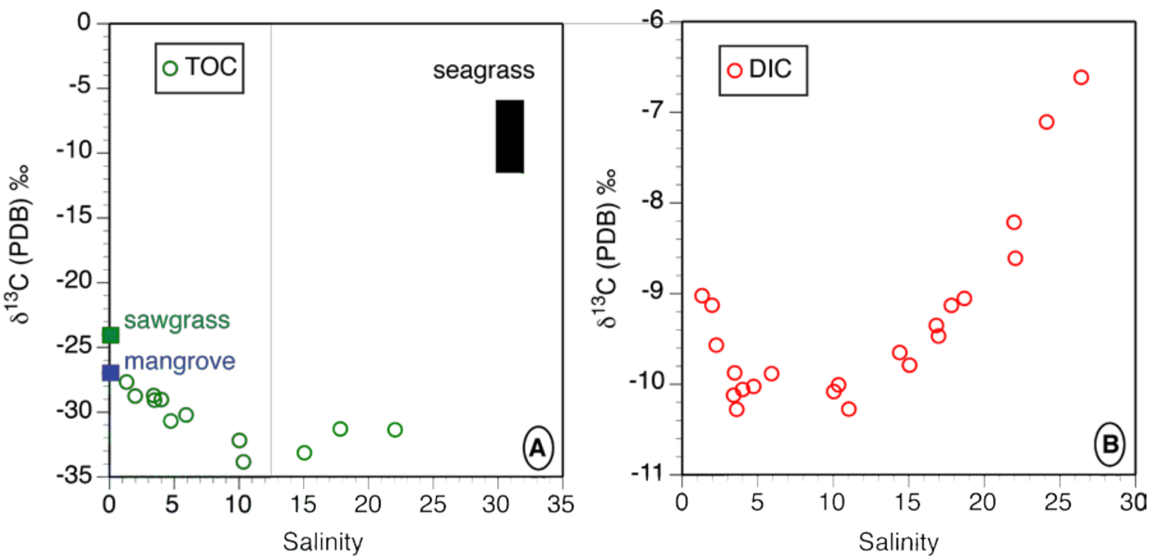


Figure 7.1: Two plots comparing the carbon isotopic composition of TOC and DIC with salinity for Shark River, water samples collected in November of 2010. A) Shows that the isotopic composition of TOC is much more depleted than the marine end member of seagrass, and is closer to that of mangrove derived OM. B) The relationship between the carbon isotopic composition of DIC and salinity is not linear, indicating that the addition of mineralized carbon to the system is occurring, and that the OM source is a C3 plant (e.g. mangrove).

Paleocological and paleoclimate research, collaboration with Utrech University (Gaiser)

During her sabbatical at Utrecht University, Gaiser worked with researchers there to complete manuscripts that will appear in a special issue of the *Journal of Paleolimnology* dedicated to the paleohistory of South Florida and two book chapters on paleoecological applications (Cooper et al. 2010, Gaiser and Rühland 2010). Contributions resulting from collaborative efforts on algal microfossil proxies include Quillen et al. (In Press) and Pearce et al. (In Press) that collectively show how the upper Everglades watershed reacts to thousands of years of Holocene climate and hydrologic variability. These compliment activities in the Everglades marsh, including the research of Sanchez et al. (In Press) that uses diatoms and plant fossils to understand how the marsh ecosystem responds to hydrologic variability driven by climate and management changes (Fig. 7.2), and extends into the coastal ecosystem where the research by Wachnicka et al. (In Press) shows how the same factors interact to influence the estuary and offshore environments.

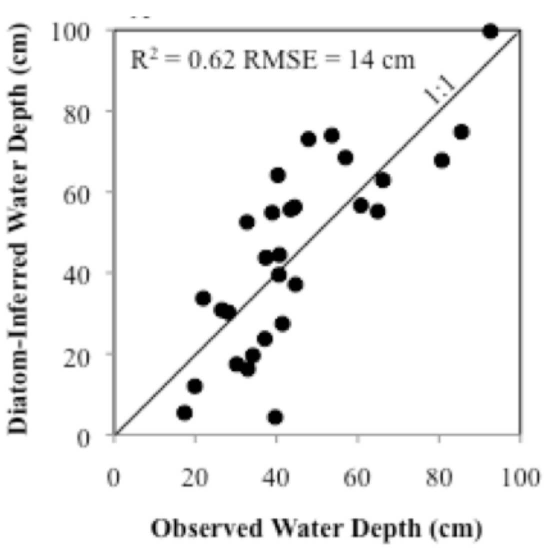


Figure 7.2: Relationship of measured water depth to that inferred from the preferences of diatom taxa. This model was employed by FCE high school student Christopher Sanchez to reconstruct past water depths from diatom remains in sediment cores (Sanchez et al. In Press).

Woody Debris Spatial Patterns in Everglades Mangrove Forests after Hurricane Wilma (LSU group: Rivera & Castaneda)

Woody debris (WD) distribution associated with Hurricane Wilma varied from mangrove shoreline to the interior part of the forest at both sites (Fig. 7.3a, b). Fine WD estimates were lower and showed a similar pattern along both transects, ranging from 10.6 ± 0.1 to 33.2 ± 10.1 m^3 ha^{-1} in BC, and from 4.1 ± 0.4 to 4.7 ± 1.4 m^3 ha^{-1} in SRS-6 (Fig. 7.3a, b). In contrast, coarse WD estimates were higher and variable along both transects, and ranged from 160.0 ± 11.3 to 303.4 ± 205.6 m^3 ha^{-1} in BC, and from 20.7 ± 0.1 to 310.5 ± 6.8 m^3 ha^{-1} in SRS-6 (Fig. 7.3a, b). Overall, there was a distinct trend in coarse WD along both mangrove transects. In BC, coarse WD gradually increased with distance inland from shoreline with a slightly decreased in the interior part of the mangrove forest; whereas in SRS-6 coarse WD was higher at the beginning and middle sections of the transect and drastically decreased at the end of the transect (Fig. 7.3a, b). Total (coarse and fine) WD ranged from 170.1 ± 62.3 m^3 ha^{-1} (SRS-6) to 259.1 ± 24.8 m^3 ha^{-1} (BC) across FCE mangroves, with coarse WD accounting for 86 and 91% of the total downed wood, respectively (Fig. 7.4). Our results also show that BC had 1.5 times higher WD volume compared to SRS-6, indicating a stronger effect of Hurricane Wilma in this site due to its closer proximity to the storm's eyewall as it passed through the FCE. This variation in total WD is in agreement with a previous study across FCE, suggesting higher volume of WD in mangrove sites

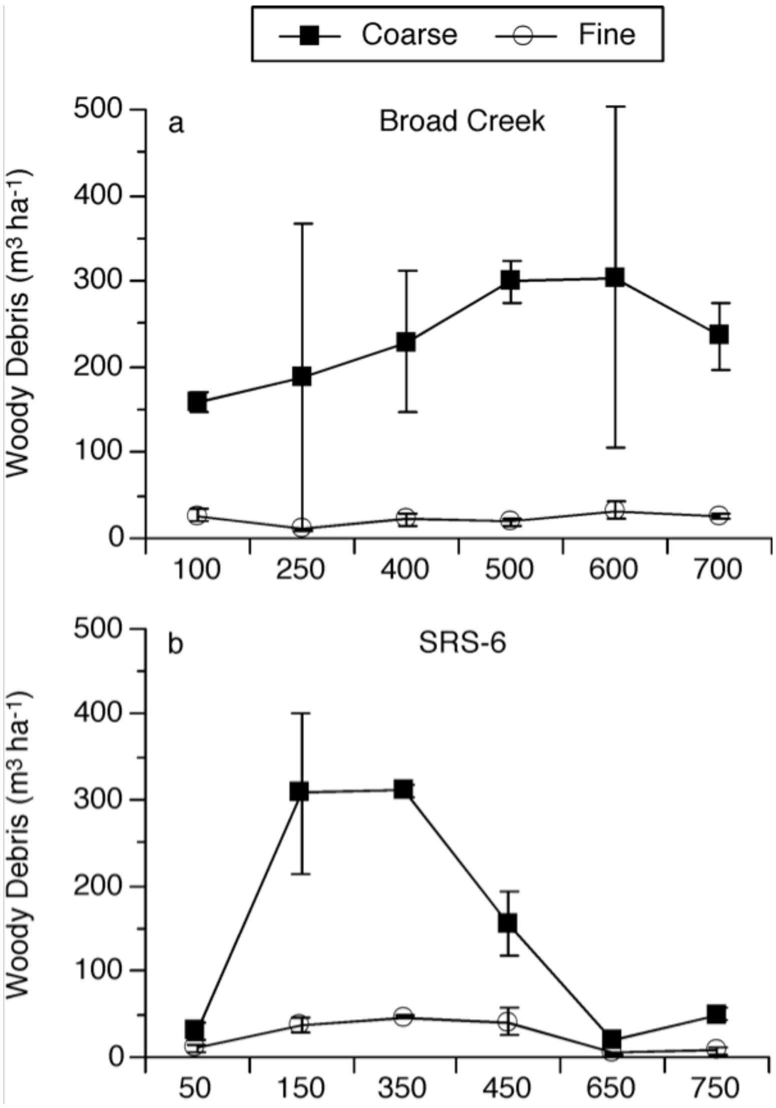


Figure 7.3: Spatial variation in mangrove wood debris along transects in the Florida Coastal Everglades after the passage of Hurricane Wilma (October 2005).

located in the storm's eyewall (ENP-Eye) and immediately to the right of the eyewall (ENP-Right; Fig. 7.5; Krauss et al. 2005). In fact, maximum sustained wind speeds for Wilma reached 45-50 $m\ s^{-1}$ at landfall in the BC and Shark River areas relative to weaker winds (30-35 $m\ s^{-1}$) in southeastern Everglades (i.e, Joe Bay area; Castañeda-Moya et al. 2010). This condition determined the higher magnitude of storm-surge-related sediment deposition and physical damage (i.e., defoliation, tree snapping, and uprooting,) to mangrove forests in western Everglades relative to the eastern region (Castañeda-Moya et al. 2010). In addition, our mangrove WD values were 2-4 times higher compared to estimates reported by Krauss et al. (2005). This result is logical since our study was conducted 1.5 months after the storm; while Krauss survey was performed 9-10 yr after Hurricane Andrew impacted the study area. Our findings underscore the relative importance of these pulsing events (i.e., hurricanes) in controlling the structure, productivity, and carbon biogeochemistry of neotropical mangroves, particularly in areas with high recurrence of hurricanes and tropical storms such as south Florida. Further, the high input of WD across FCE mangroves as a result of hurricane disturbance will have tremendous implications in understanding the potential contribution of this component to carbon and nutrient storage in neotropical mangroves.

Figure 7.4: Total woody debris in mangrove sites of the Florida Coastal Everglades after the passage of Hurricane Wilma.

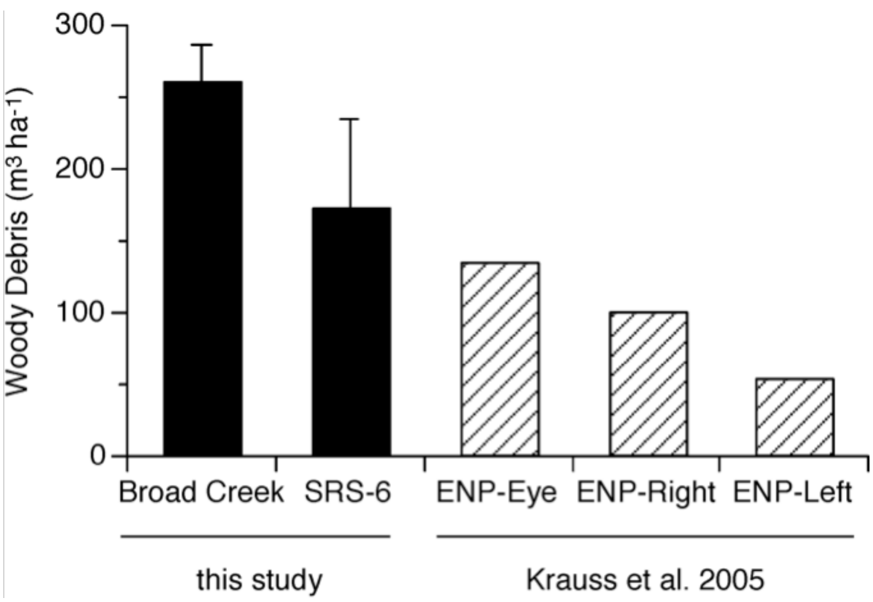


Figure 7.5: Total volume of woody debris in Everglades mangroves before (Krauss et al. 2005) and after (this study) Hurricane Wilma

Recent ecological shifts in South Florida estuaries (Wachnicka)

Wachnicka has compiled data on the historic changes in the abundance of diatoms, foraminifera, mollusks, ostracods and geochemical data from 3 locations in Florida Bay and 3 locations in Biscayne Bay, which have been the focus of paleoecological studies by the USGS and FIU over the last several years. A parametric method was used based on sequential t-test analyses of regime shifts to identify the periods of change in abundance in the above mentioned microorganisms in each sediment core and tested the significance of these changes. The next steps will involve the detection of periods of change in salinity, nutrients, air temperature, precipitation, ENSO, AMO, NAO and sea level, and comparison of the timing of the changes among the variables and among different coring locations.

Isotope-dendrochronology (Rebenack, Cherubini & Anderson)
Currently, only one tree disk, DBH1, has a completed carbon isotope chronology, and work has begun on DBH2. The data presented here have not yet been corrected to the atmospheric carbon signature over time, nor has a definite yearly chronology been assigned to each ring (some years show the growth of false rings or "ringlets" and these were sampled when possible in the hopes of capturing a stress-inducing event experienced by the tree). These preliminary results indicate that the trees are undergoing periods of stress that translate to increases in the $\delta^{13}C$ values (Fig 7.6). The large peak in the second ring of DBH2 most likely corresponds to the passage of Hurricane Wilma in 2005, which flooded the pine rockland and eventually led to the demise of the tree. Once the carbon isotope analysis is completed for each tree and the precipitation chronology for the Lower Florida Keys has been fully developed, a better understanding of the stressors affecting tree ring growth can be determined.

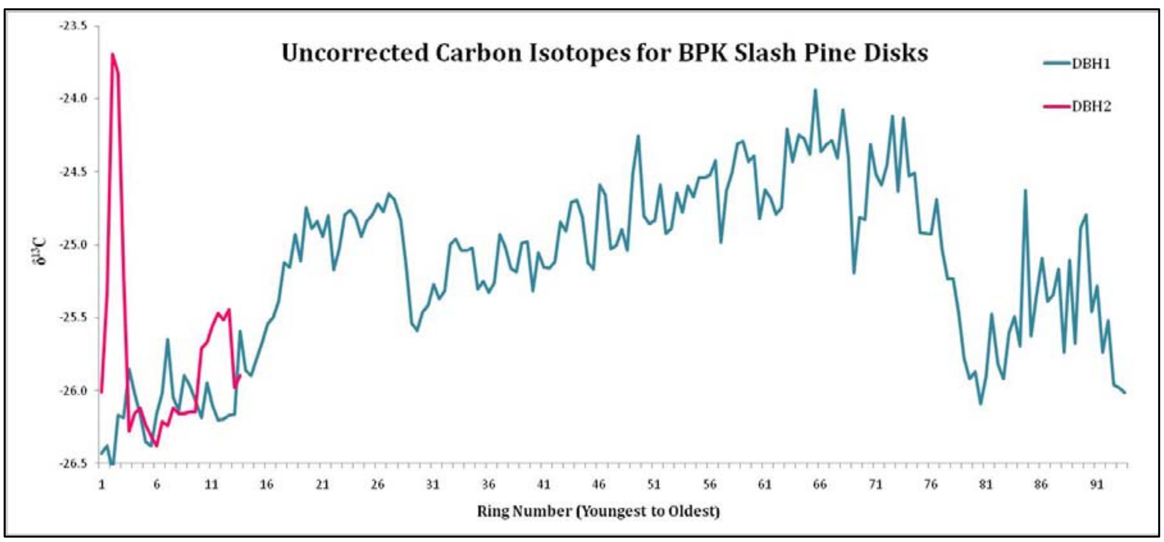


Figure 7.6: Carbon isotopic composition of tree rings from slash pine, Big Pine Key. Ring are plotted as ring number has not been defined as an exact year (this will be the next step).

8. Modeling and Synthesis

Landscape Ecosystem modeling
With higher inflow volumes (and more P mass), the HiFlo simulations of ELM displayed somewhat more P accumulation in the upstream region. In both runs, P accumulation decreased with distance downstream of inflow, but increased adjacent to FL Bay (areas downstream of site

TS/Ph-6) (Fig. 8.3). With increased P loads (HiFlo), SAV responded with generally lower biomass, largely due to phytoplankton shading (Fig. 8.4). Temporal variation in between-run loading differences led to non-linear SAV differences between runs.

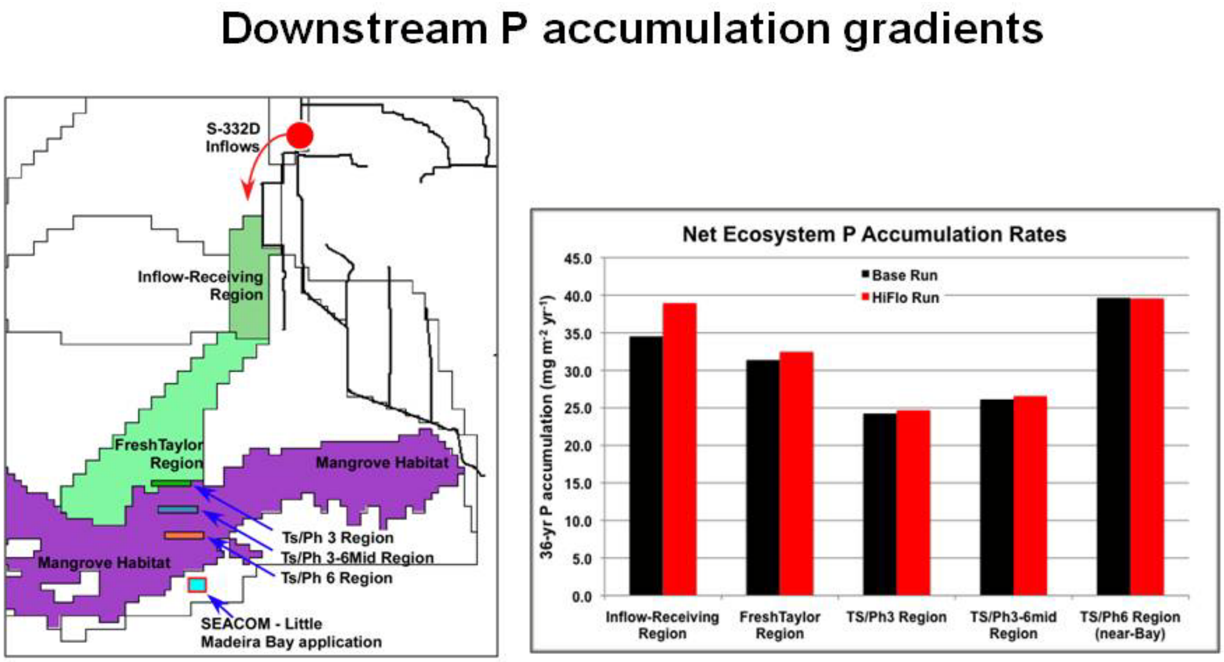


Figure 8.3: Left: Simulation study area for ELM-SEACOM sensitivity analyses. Right: Net ecosystem P accumulation rates simulated by ELM across the freshwater-to-coastal transect.

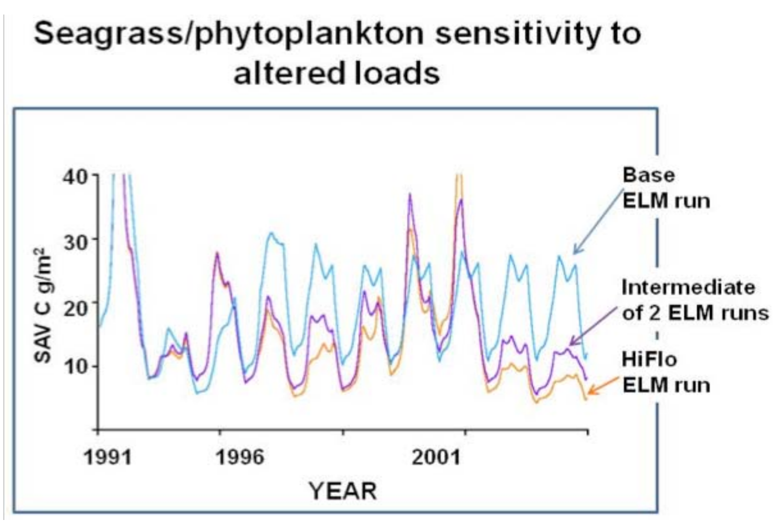


Figure 8.4: SEACOM output showing nonlinear responses of biomass to altered flow conditions simulated by ELM.

Vegetation patterns in wetlands
The effective anisotropic hydraulic conductivity that is included in the model implicitly represents the effect of ponding: a reduction in the long-range inhibition of vegetation growth in the direction perpendicular to the prevailing hydraulic gradient. Engel and colleagues demonstrate that by accounting for effective anisotropy in a simple modeling framework that encompasses only a scale dependent feedback between biomass and nutrient flow, we can reproduce the various vegetation patterns observed in wetland ecosystems: maze, and vegetation bands both perpendicular and parallel to prevailing flow directions. They examine the behavior of this model over a range of plant transpiration rates and regional hydraulic gradients. Results show that by accounting for the effective x-y anisotropy that results from biomass-water interaction (i.e., ponding) the mechanisms that drive ecosystem patterning can be better understood (Cheng et al 2011).

Tree-grass coexistence in Everglades wetlands
Engel et al. show via their process-oriented zero dimensional model that the stable coexistence of tree islands and marshes results as an effect of their both being (meta-) stable states of the system. However, tree islands are found to have only a limited resilience, in that changes in hydrologic conditions or vegetation cover may cause an abrupt shift to a stable marsh state (D'Odorico et al. 2011).

Modeling primary productivity response to hydrology and water quality
Gaiser *et al.* developed spatially-explicit periphyton-based hydrology and nutrient prediction models for Everglades National Park (Fig. 8.5). After removing the effect of unnatural phosphorus enrichment on periphyton attributes using previously published assessment methodology (Gaiser 2009), predictive models were developed for dry mass, organic content and periphyton edibility (an estimate of food quality based on diatom and green algal abundance). A 4-parameter partial regression model that includes periphyton total phosphorus concentration, water depth, hydroperiod and soil depth was found to best explain the variance in these variables. By mapping predicted patterns they were able to show how these equations can be used to understand periphyton abundance and composition under differing hydrological scenarios, which they will be developing further in FCE III. The output variables map directly onto existing models, including those predicting changes in consumer dynamics (Sargeant et al. 2011). By applying a stoplight reporting system for periphyton to these predictions, they can identify areas that are deviating from baseline. These are provided in a 2010 report to the Federal South Florida Ecosystem Restoration Task Force that reports progress on Everglades restoration to the U.S. Congress (SFERC 2010).

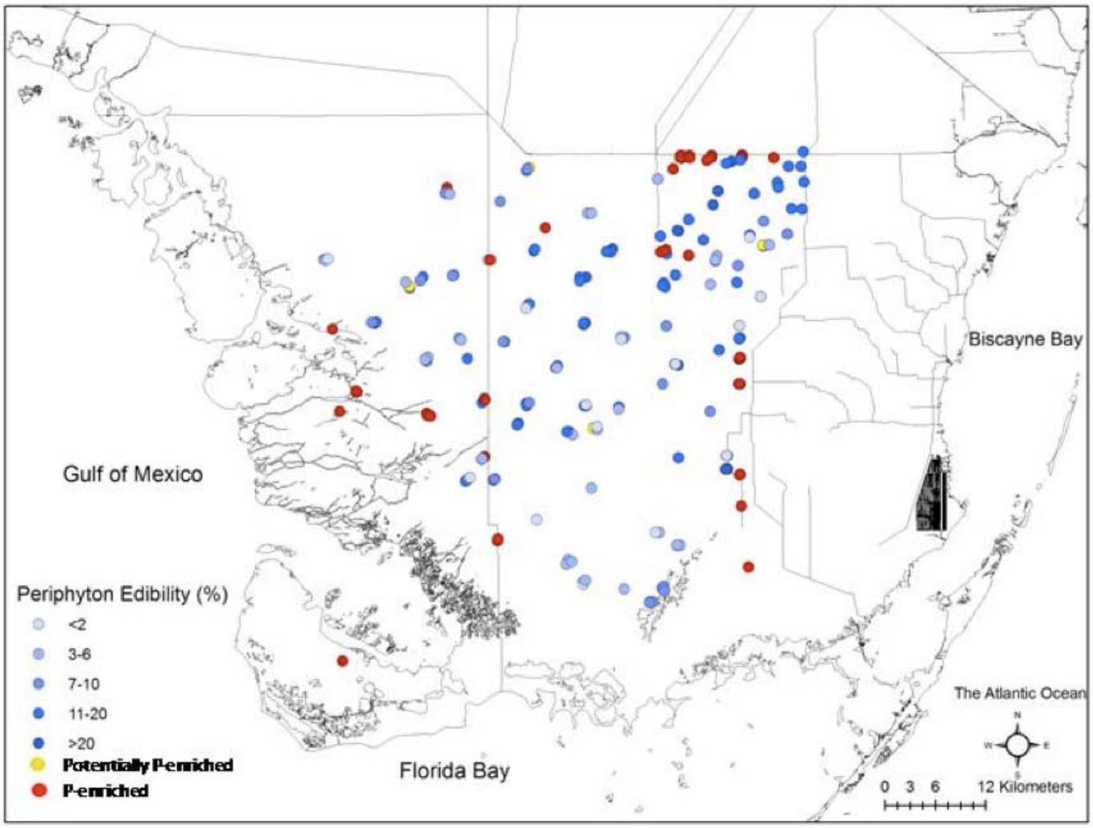


Figure 8.5: Map of periphyton edibility (relative biovolume of green algae and diatoms) predicted from a multiple regression of hydroperiod, water depth, total phosphorus and soil depth. Sites coded in red are identified as P-enriched and in yellow as potentially P-enriched as indicated by the stoplight approach. Sites in the mangrove ecotone are "naturally" P-enriched from coastal sources (the FCE "Upside-Down Estuary" hypothesis) while sites along the northern and eastern boundaries are enriched from canal sources of P. Models correctly predict greater edibility in the deeper water slough habitat of Shark River Slough and lower edibility in the short hydroperiod marshes of the Everglades marl prairie.

Sea Level Rise and Coastal Forests

The model MANBUTHAM simulates the expansion and fate of mangroves, buttonwood Forests and coastal hammocks under a salinity gradient, with each community availing of a feedback loop to maintain the respective optimal salinity conditions for their survival (Fig 8.6). It also indicates how increasing or decreasing salinity can lead to community range shifts (Fig 8.7).

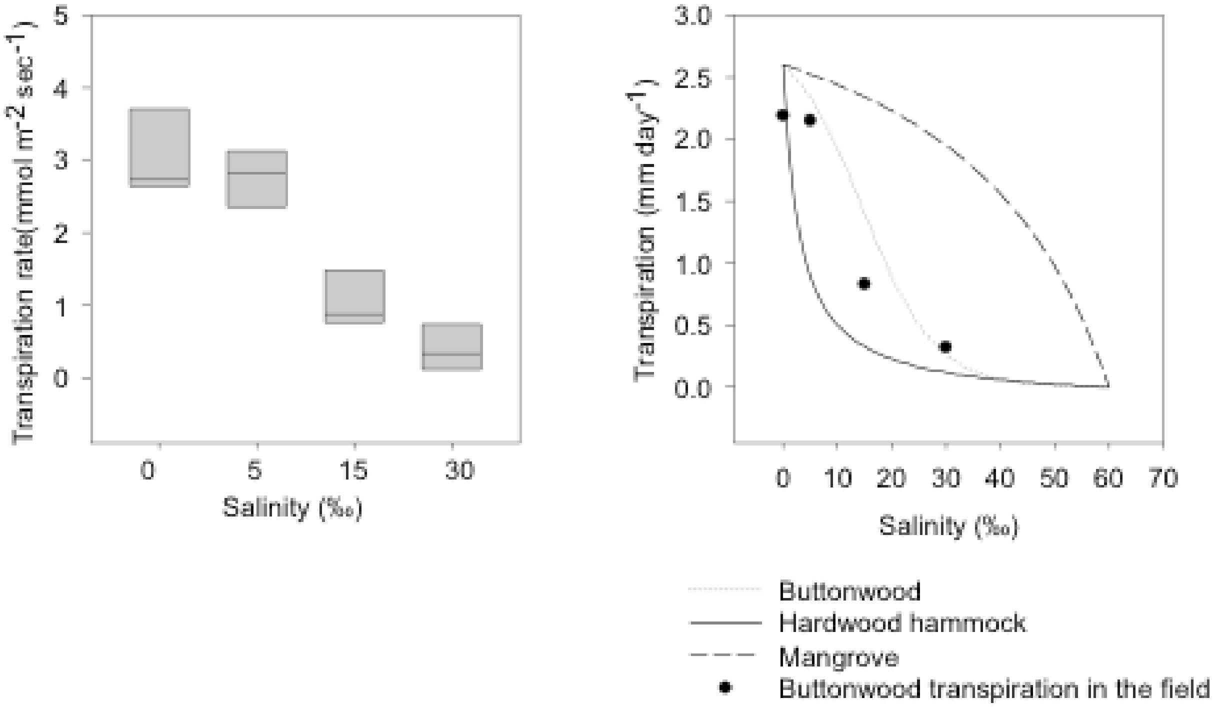


Figure 8.6: (a) Transpiration rate of buttonwoods grown at 4 different salinity treatments (A: 0 ‰ , B: 5 ‰ , C: 15 ‰ and D: 30 ‰). (b) model output of transpiration (mm/day) of mangrove, buttonwood, and hardwood hammock as a function of vadose pore water salinity while the circles denote model predictions using actual transpiration data.

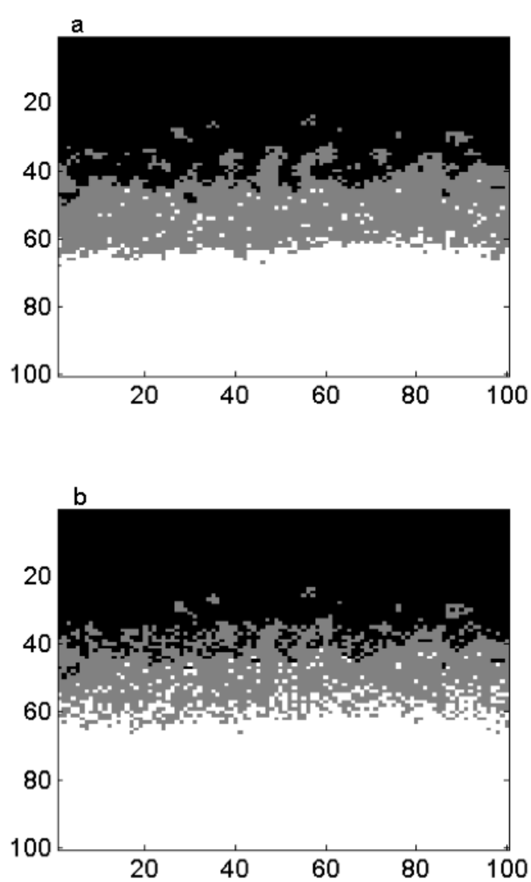
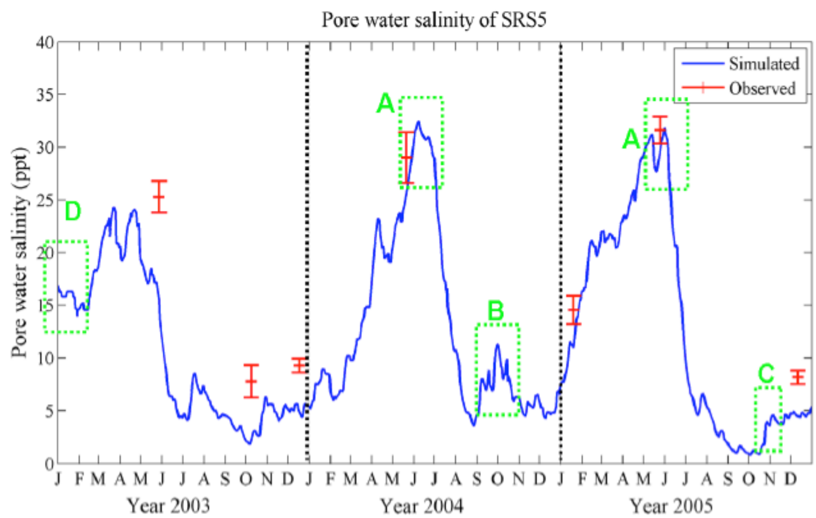


Figure 8.7: (a) Horizontal view 100 × 100 m2 grid cells showing distribution of mangrove (red), buttonwood (green) and hammock (blue) 33.3 years after stable pattern formed without sea level rise, and (b) subject to sea level rise 3 mm/ year. In these two graphs, upper x-axis depicts inland side while lower-x axis the seaward side.

Mangrove Ecosystem Process Models

Porewater salinity output from HYMAN followed observed seasonal values currently monitored along FCE LTER sites in Shark River (SRS4, SRS5, SRS6) (Fig. 8.8). Different scenarios are run to evaluate the critical role of precipitation, (especially at the beginning of the rainy season) in controlling porewater salinity maximum values. Results show that porewater salinity values at SRS4 (upstream station) is apparently controlled by groundwater flow than by overland flow. The HYMAN model showed robust forecasting in porewater salinity for sites SRS5 and SRS6.



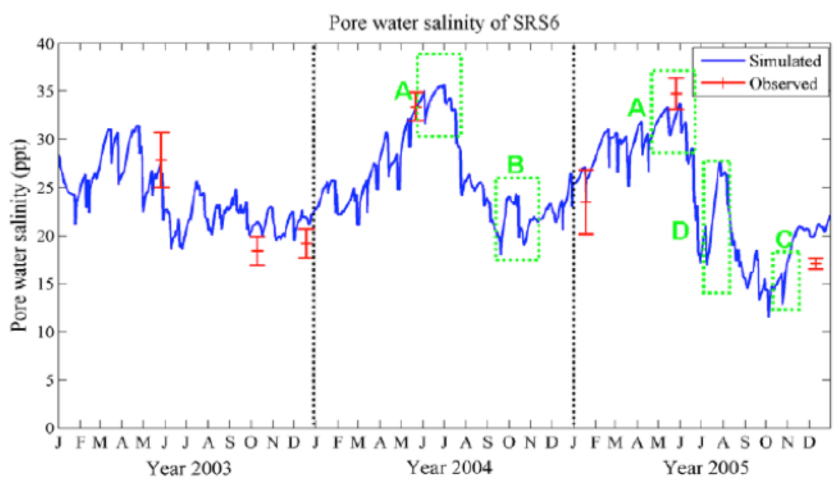


Figure 8.8: Simulated (HYMAN model) and observed pore water salinity in SRS5 (top panels) and SRS6 (bottom panels) in 2003, 2004 and 2005.

In the Taylor River ecotone, The MIKEFLOOD hydrodynamic model was calibrated against field measurements and showed satisfactory agreement (Fig. 8.9). A model efficiency (NSE Index) exceeding 0.70 was reached for all the simulation periods, with a 0.81 values obtained

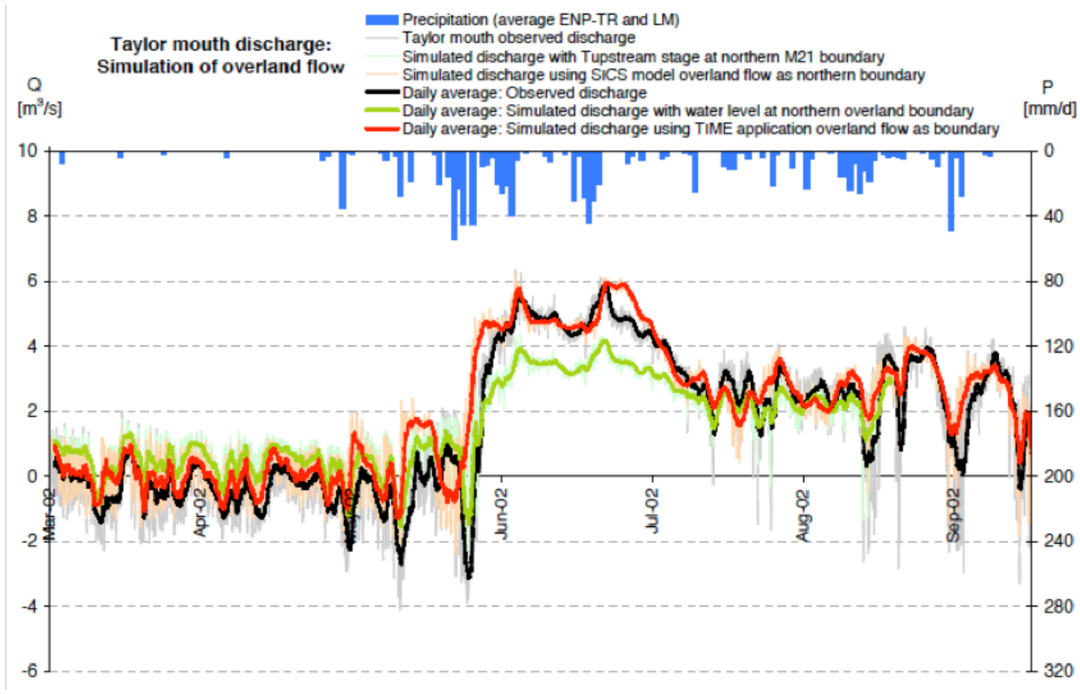


Figure 8.9: Overland flow simulation in the Taylor River area, March – September 2002

when simulating an overland inflow component. We were able to capture the overall salinity patterns and trends in the target model area. Three modeling periods were defined: 1) a dry period with minimum overland flow to calibrate the hydrodynamic parameters prevailing in the area (January to June 2001); 2) a dry season period with available groundwater data from December 2003 to June 2004 to determine the groundwater leakage factor – this period was then extended until May 2005 for salinity transport calibration; and 3) a period including overland flow simulation (March – October 2002), allowing to verify the hypothesis that the remaining budget closure term is directly linked to the overland flow (and the uncertainty associated with it). The largest term in the annual budget of this estuarine area is the outflow at Taylor mouth (17,265 mm y-1 in 2002), while the major inflow term is the overland surface flow outside of the channel. Precipitation and evapotranspiration are relatively unimportant budget terms in this part of the Taylor Slough, which is dominated by the accumulation of water retained by the Button-wood embankment. A comparison of our Taylor River water budget with a Taylor Slough water budget published in 2001 (encompassing the years 1996-1997) shows that the former includes a larger surface flow as compared to precipitation (P) and evapotranspiration (ET). Total N and total P budgets were calculated for the Taylor River region using annual and seasonal water budgets, as well as observed N and P concentrations near the northern boundary. Given the small size of the study area and large contribution of surface flow, the relative importance of atmospheric deposition is lower in the Taylor River region than in the entire Slough area as shown in previous studies. The relative magnitude of nutrient loads in both studies is dependent on the water flow volume and actual internal cycling processes such as burial and denitrification (Fig. 8.10). Current unpublished direct estimates of nitrification, denitrification, nitrogen fixation and burial rates in combination with estimated N and P budgets in this study indicate a large N and P deficit in the Taylor River model area. P burial rates for the modeling area ranged from 80 to 140 mg m-2 y-1, and were higher that the closure term ε estimated for the dry (64 mg m-2 y-1) and wet (-36 mg m-2 y-1) season in 2002; this result also indicates a large deficit of P as suggested by a) the low concentration of P in water and sediments in comparison to other sites in Southern Everglades, b) low mangrove vegetation stature (<5 m), and c) the regulatory control of soil (and porewater) P concentrations on nitrification rates in soils from up and downstream Taylor River.

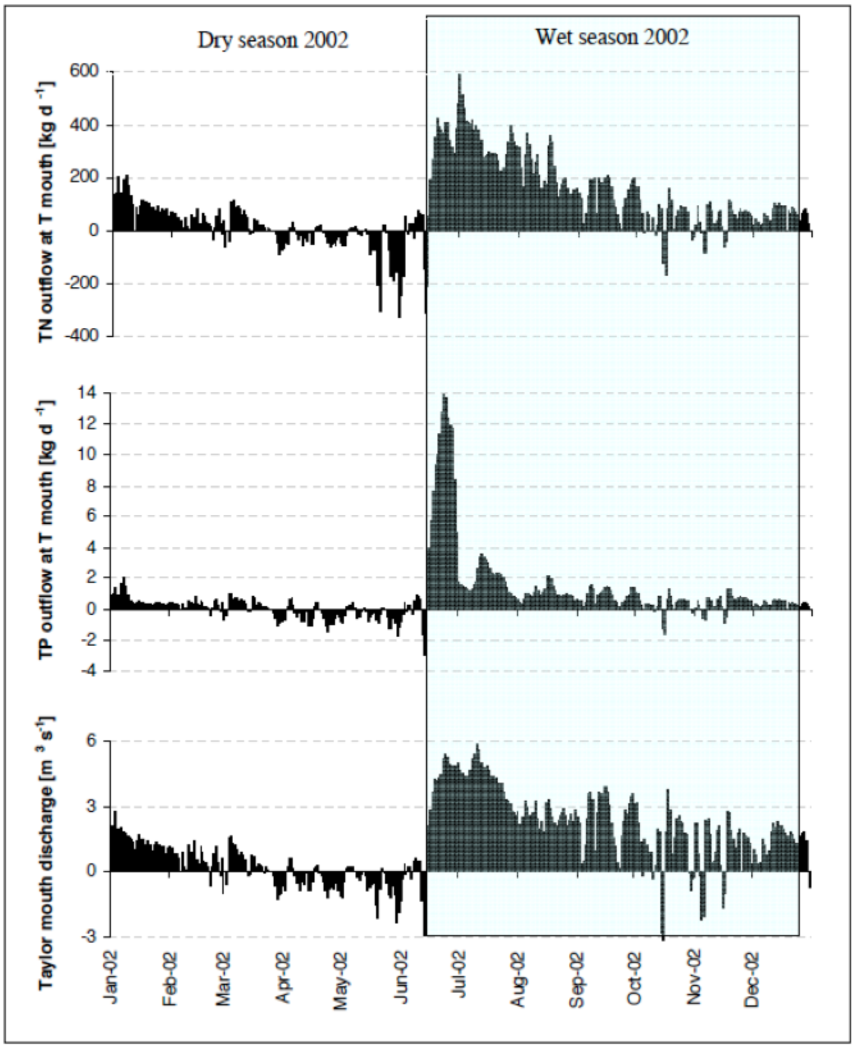


Figure 8.10: Taylor mouth daily water and nutrient outflow in 2002.

The seasonal hydrologic characteristics are very distinctive (average Taylor River wet vs. dry season outflow was 6 to 1 during 1999-2006) with a pronounced inter-annual variability of flow. The water budget shows a net dominance of through flow in the tidal mixing zone, while local precipitation and evapotranspiration play only a secondary role, at least in the wet season (Figure 8.11). During the dry season, the tidal flood reaches the upstream boundary of the study area during approximately 80 days per year on average. The groundwater field measurements indicate a mostly upwards-oriented leakage, which possibly equals the evapotranspiration term. The model results suggest a high importance of groundwater contribution to the water salinity in the

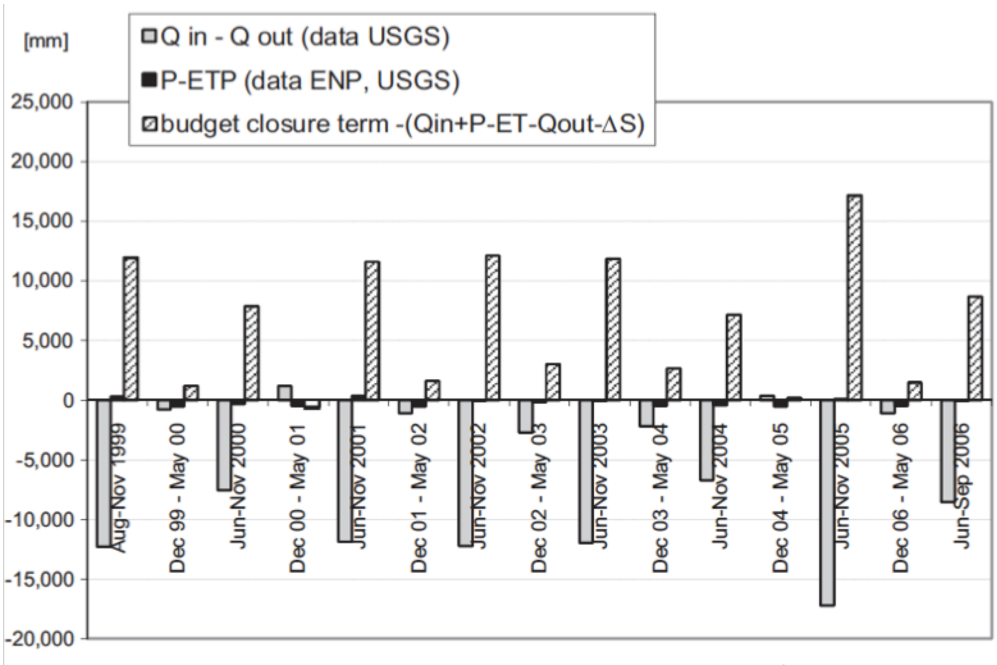


Figure 8.11: Taylor River seasonal water budget; dry season is from December to May and wet season from June-November (USGS, 1996-2008; U.S. Geological Survey, 2008).

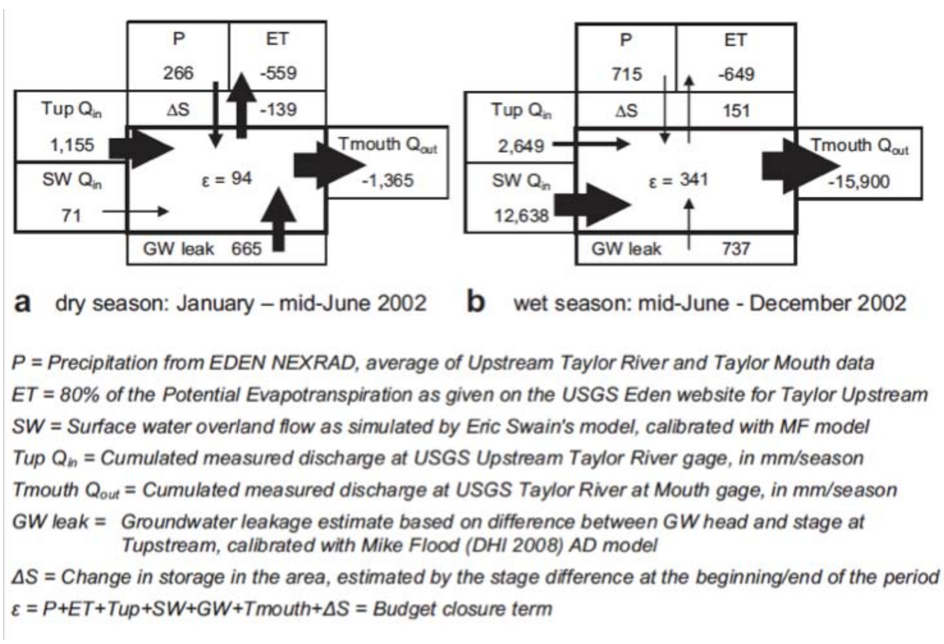


Figure 8.12: Taylor River cumulated water flow (mm/season). Direction of arrows indicates flow direction; positive and negative values indicate input and output, respectively. Arrow size is proportional to flow and weighted separately for each season.

Everglades Mangrove Ecotone Region (Figure 8.12). This region has a critical ecological role since it mediates freshwater and nutrient inputs and controls the water quality of Florida Bay. The EMER is not only vulnerable to changing hydrodynamics and nutrient loadings as a result of upstream freshwater management practices but also to sea level rise, as during the dry season its hydrology is dominated by tidal flow. The model performance is satisfactory during the dry season where surface flow in the area is confined to the Taylor River channel. The model also provided guidance on the importance of capturing the overland flow component, which enters the area as sheet flow during the rainy season. Overall, the modeling approach is suitable to reach better understanding of the water budget in the modeled area. However, more detailed field data is needed to ascertain model predictions by further calibrating overland flow parameters.

Flux Tower Group

Figure 8.13 shows the spatial variability in GPP across the mangrove ecotone, as well as the reduction in productivity resulting from the disturbance resulting from hurricane Wilma.

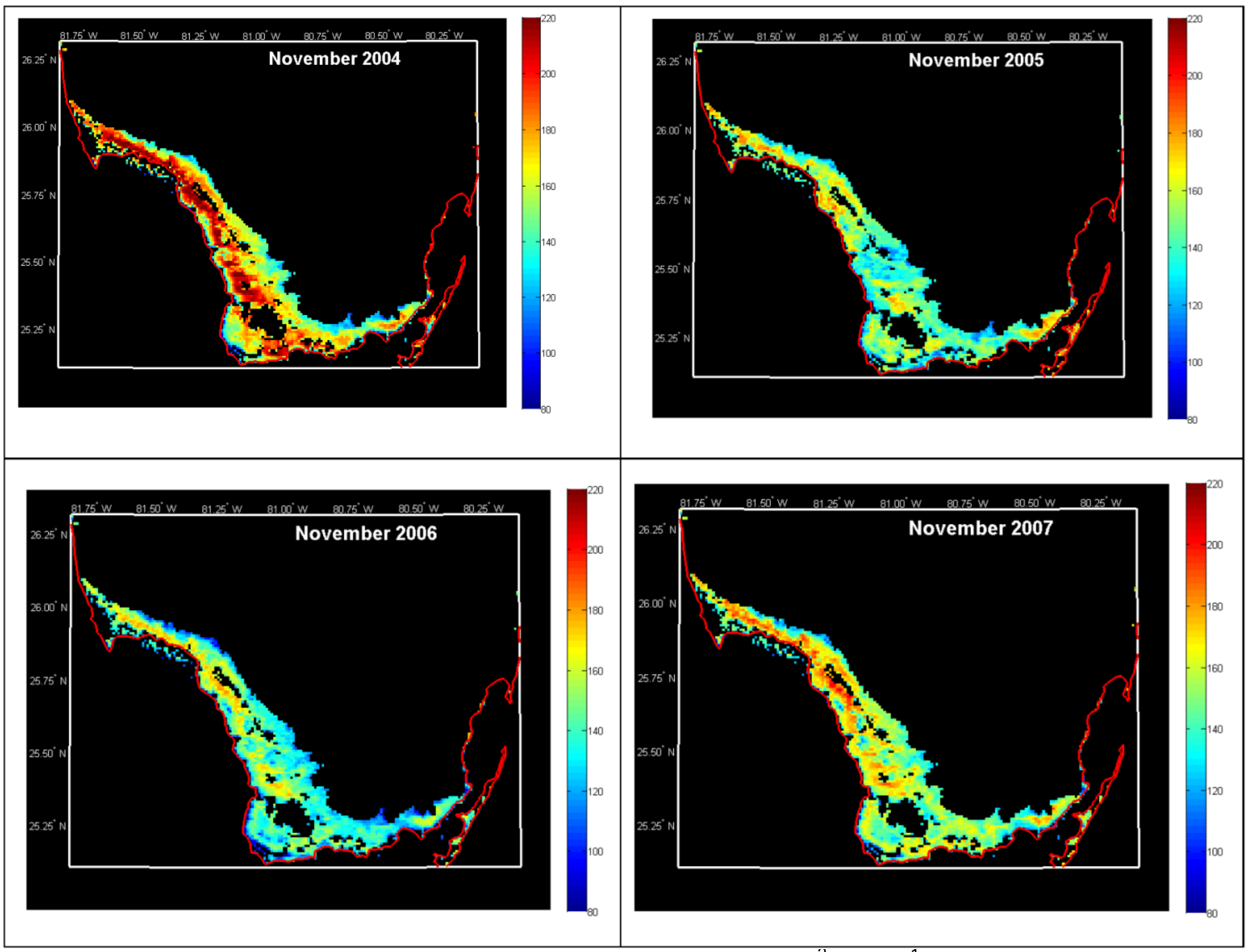


Figure 8.13. Model estimates of gross primary productivity (GPP, g C m^{-2} $month^{-1}$) during November for 2004 to 2007. Productivity was reduced in November 2005 as a result of defoliation and tree mortality following hurricane Wilma in October 2005.

Consumer dynamics
Spatially explicit modeling work has continued to examine the impacts of water level fluctuations on fish populations. This approach involved using a simple analytically tractable model in comparison with the GEFish1 model (Jopp et al., 2010) and led to three new and general conclusions about the impacts of water level fluctuations: (1) there is an optimal rate at which fish should expand into a newly flooding area to maximize population production; (2) there is also a fluctuation amplitude of water level that maximizes fish production, and (3) there is an upper limit on the number of fish that can reach a permanent waterbody during a drydown, no matter how large the marsh surface area is that drains into the waterbody. Because water levels can be manipulated in many wetlands, it is useful to have an understanding of the role of these fluctuations.

Additional simulation modeling of aquatic communities that include primary primary producers and higher trophic levels, De Angelis and colleagues show the effects of water level fluctuations on the ecosystem organizational responses as a whole. First, they found that temporally and spatially varying patterns of trophic cascades can be discerned in the simulations, but they were relatively weak compared to such cascades that are observed in some lake ecosystems. Second, the fish showed distinctive pulses at the edge of the drying front as water levels declined. The retreating fish added to the fish already in the present in the still-flooded cells, forming a pulse of fish retreating towards the persisting bodies of water. Pulselike behavior could also be observed following the flooding front during rising water level, but the pulses were much smaller. Third, biomass levels, averaged over the whole model, tended to increase moderately with the amplitude of water level fluctuations. However, the piscivore biomass always reached a peak at some fluctuation amplitude and then declined with further increase in amplitude.

Human Dimensions modeling
Results of the SLEUTH model to date indicate that goodness of fit metrics (related to land use change based on zoning) are greater (Fig. 8.14) when lands zoned for agriculture are integrated in an Excluded Layer which also accounts for government ownership and parklands, and flood zones. Land use layers used for 1994 and 2006 in the model are presented in Figure 8.15. The Excluded Layer and corresponding cumulative output of Monte Carlo iterations are presented in Figure 8.16. Simulations indicate the degree to which the forecasted land use is dependent on the initial conditions of spatial coverage of the Excluded Layer, with varying levels of resistivity to development (Figure 8.16).

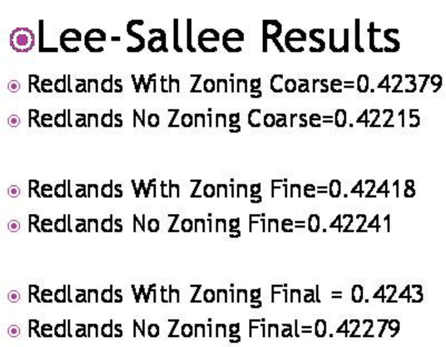


Figure 8.14: Results from SLEUTH experimentation demonstrating the improvement of metrics when integrating Ag zoned lands into the Excluded layer during calibration.

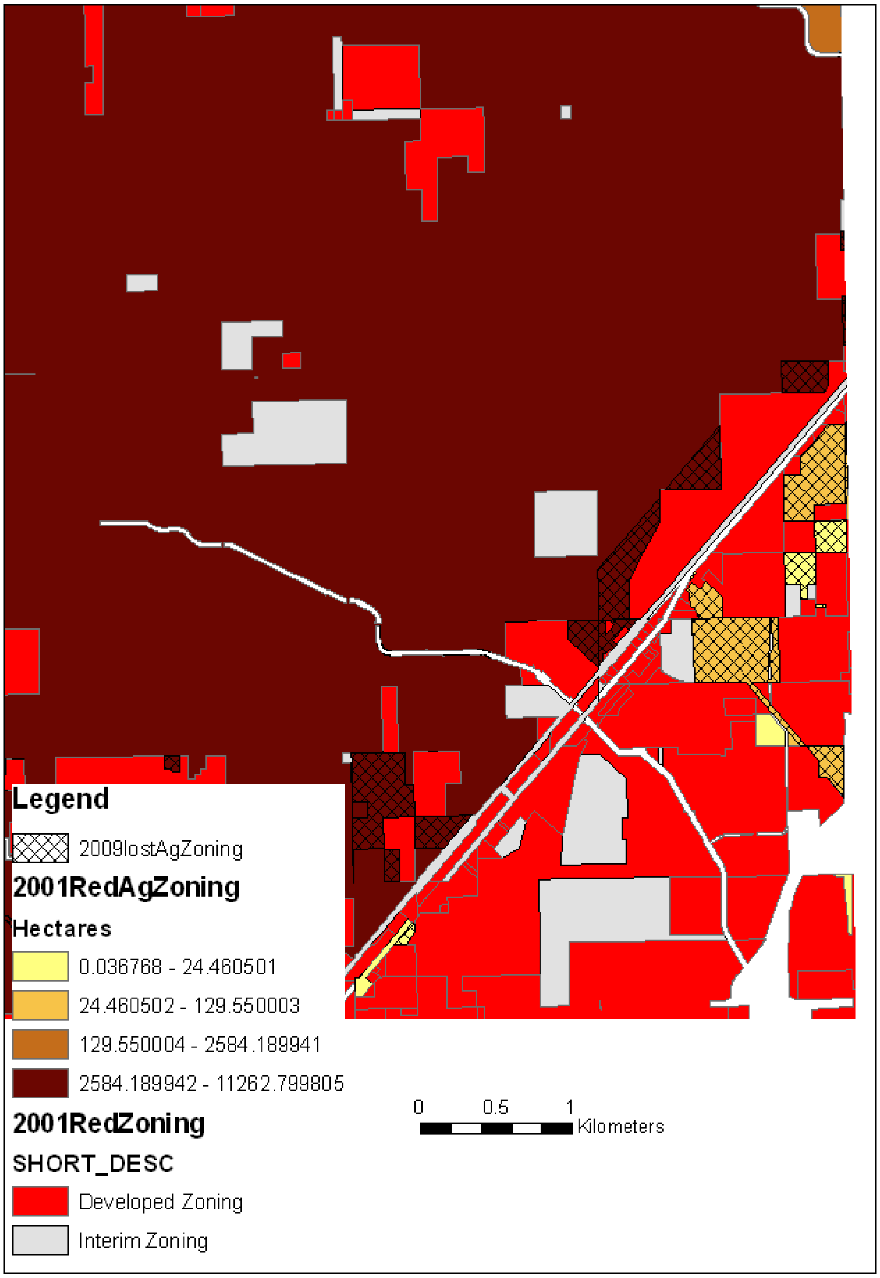


Figure 8.15: SE Corner of Redlands, 2001 lands zoned for agriculture that were rezoned for development by 2009, categorized by size of continuously zoned area.

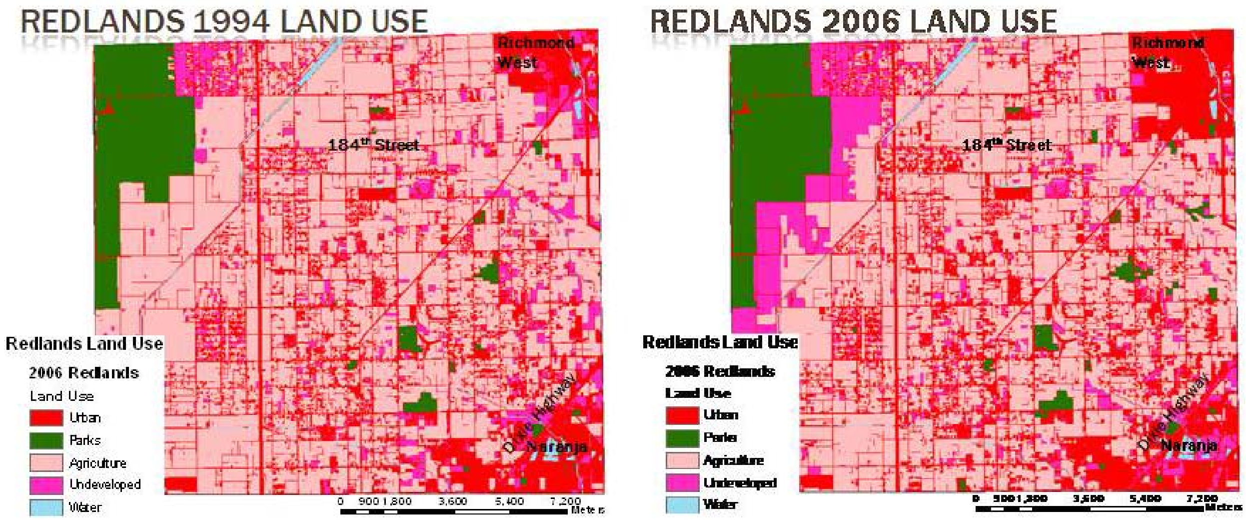


Figure 8.16: Land Use in the Redlands in 1994 and 2006

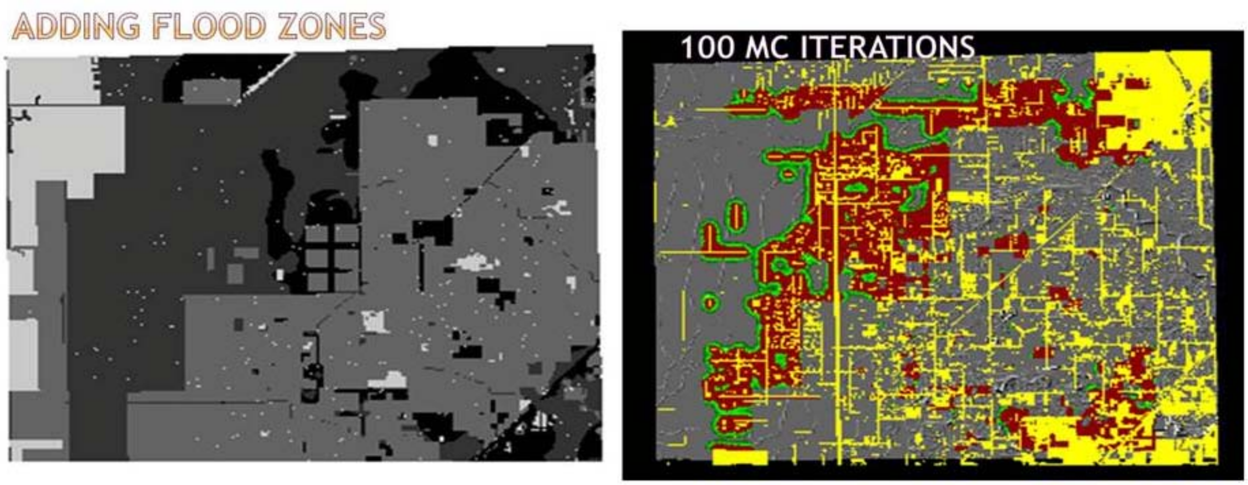


Figure 8.17: LEFT PANEL: Sophisticated Redlands Excluded Layer used in SLEUTH calibrated urban growth simulation for Redlands. Lighter colors offer more resistance to development while darker colors offer less. This excluded layer integrates government owned / parklands, land zoned for farmland, and flood zones. RIGHT PANEL: 100 runs of the SLEUTH model in the Redlands. Yellow cells were already developed in 2006, red cells were selected between 95 and 100 times out of 100 for development and the shades of green were selected between 50 and 95 times out of 100. Gray cells were selected between 0 and 50 times.

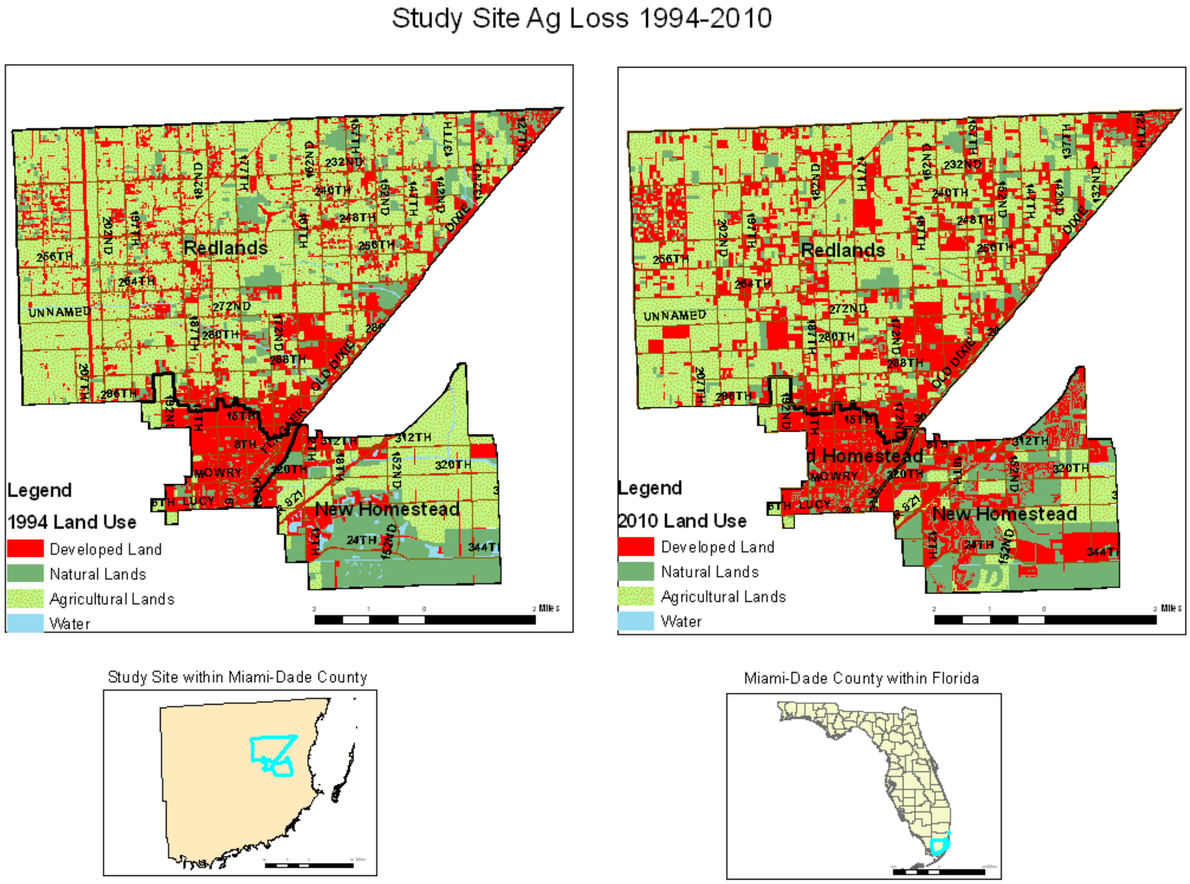


Figure 8.18: Land Use Change in the Homestead Area of Miami-Dade County (Ogden et. al. in preparation)

Hydrological syntheses

Water budget for Shark River Slough 2002-2008

A water budget has been completed for the Shark River Slough (SRS) over 2002-2008, that provides estimates of the major water balance parameters. This time period serves as a baseline for comparison of the effects of future restoration efforts that are expected to be finalized within the next decade. Inputs to the water budget include surface water inflows via hydraulic structures and precipitation, while outputs consist of evapotranspiration (ET), discharge to the Gulf of Mexico and seepage losses to an eastern bordering canal. Using a mass balance approach, daily change in volume of SRS (from stage changes) is equated to the difference between input and outputs, yielding a residual term that includes error in each of the components as well as net groundwater exchange. Results for 2002-2008 (Fig 8.19) predict significant net groundwater discharge to the SRS that peaks in May-July and is positively correlated with surface water salinity at the mangrove ecotone, lagging by one month. ET being a significant term in the water balance in SRS and one that is estimated here by six models, a sensitivity analysis is carried out to express the variation in the calculated groundwater discharge based on ET model used. Precipitation, the largest input over 2002-2008 to the SRS is offset by ET (the largest output – Fig 8.19 b), both terms being of similar annual magnitudes; thereby highlighting the importance of increasing surface water inflows into ENP for hydrating the freshwater marsh as well as for greater discharge into the downstream marine ecosystems .

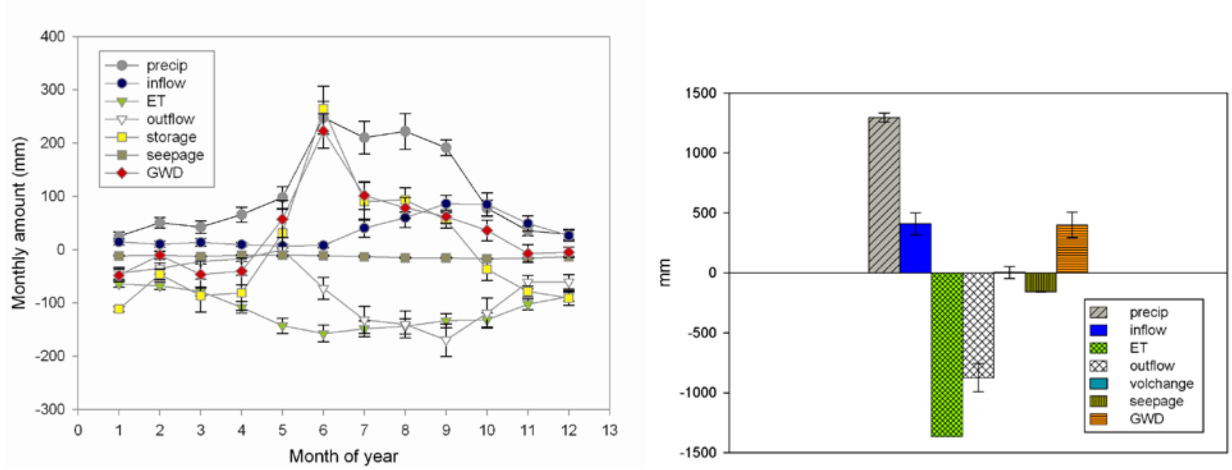


Figure 8.19: Left panel shows monthly water budget components while right panel shows annual water budget components. Results shown here are averages over 2002-2008. The combination Penman-Montieth model of evapotranspiration (Shuttleworth 1992) has been chosen amongst other models for the water budget shown here. This model has further been modified to account for seasonal water limitation (drying up, increasing salinity) that can decrease evapotranspiration in the dry season.

Water residence time and phosphorus loads have also been calculated for Shark River Slough and are described in the Hydrology section of this report.

C. Training and Development

FCE Education and Outreach 2010-11—Addressing the Strategic and Implementation Plan for Long-term Ecological Research Network (LTER): Research and Education 2011

The FCE LTER II Education and Outreach program specifically addresses the initiatives and goals for Education outlined in *The Decadal Plan for LTER—Integrative Science for Society and the Environment: A Plan for Research, Education, and Cyberinfrastructure in the US Long Term Ecological Research Network.*

Over the last year we have begun to revise our programs to include the goals and objectives for *Education, Communication, and Coordination with Other Networks* described in the *Strategic Implementation Plan* for the *Long Term Ecological Research Network (LTER): Research and Education, 2011 (SIP)*.

The *2011 SIP* includes the goals and initiatives of *The Decadal Plan* and identifies several new, Network-wide challenges. We are using the *2011 SIP* to structure our Education & Outreach programs and for guidance in their coordination. This report outlines the products and accomplishments of FCE Ed & Outreach during the summer of 2010 and throughout the 2010-2011 academic year (AY), and our progress integrating the *2011 SIP*.

Challenges to Education
FCE Education & Outreach is currently addressing all six of the *Challenges* for *Education* listed in *2011 SIP*. In this report, we describe our progress by dividing these challenges into two categories: site-level challenges and network-level challenges.

Site Level Challenges:

- *Limited engagement with under-represented groups at all levels*
- *Limited connection between sites and community colleges, independent schools, and citizen science programs*
- *Disparities in educational programs among sites due to different state standards, research emphases, and demographic settings*

FCE LTER's geographic location provides us with the unique opportunity to work with a large number of individuals from groups that are traditionally under represented in science. The majority of our "end users", within our K-20 constituency, are from Miami Dade County Public Schools (MDCPS) and Florida International University (FIU). The student demographics of MDCPS consists of >80% Hispanic and African American students and FIU is slightly more modest with >70% Hispanic and African American.

Research Experience for Teachers
The FCE Research Experience for Teachers (RET) program provides the foundation for our work with our K-12 constituents. This integral and essential component to our Education and Outreach efforts consists of two MDCPS secondary science teachers: Ms. Teresa Casal and Ms. Catherine Laroche.

Ms. Casal and Ms. Laroche are both veteran teachers with over 30 years of experience teaching a range of students middle school through the undergraduate level. Ms. Casal, is currently teaching Chemistry at Felix Varela Senior High School and in the Miami Dade [Community] College School of Education. Ms. Laroche works with Casal at Felix Varela teaching Earth Space Science and a variety of technology classes. Both teachers are working directly with FCE staff in developing activities for: students, pre-service teachers and providing professional development for veteran teachers in their school and schools across Miami Dade County.

In 2010-2011, Ms. Laroche used her research experience to introduce 60 of her Earth Space Science students to FCE research using FCE's *Intro to Google Earth*, *Intro to GIS* and *Buffer from the Storms*. Also a technology teacher, Laroche introduced FCE research to technology, art, and journalism students enrolled in a Web Design class at Felix Varela Senior High School. Some of those students have continued working with Ms. Laroche and are assisting her in revising our Ed & Outreach webpage. With the help of these students Laroche is working to increase the appeal of our website to broader range of our K-12 constituents and to translate the science for a more general audience. A selected group of technology students are assisting with HTML coding and Art students have designed new icons that will also be incorporated into the design.

Ms. Laroche is continuing to work with FCE staff on developing a high school lesson connecting the Florida Coastal Everglades with the history and culture of the local Miccosukee Tribe of

Indians. In 2009, Superintendent of Mt. Rushmore National Monument and Native American, Gerard Baker, agreed to assist Ms. Laroche in working with the Miccosukee to develop the lesson. Unfortunately, Mr. Baker retired from the National Park Service due to health reasons. Over the last year, Ms. Laroche has made some new contacts through the Army Corps of Engineers and expects to complete the lesson this fall.

Our second RET, Teresa Casal, used her 2010-11 funds to complete two podcast lessons from her research experiences along the salinity transition zone of the Everglades mangroves. The first podcast highlights her FCE research experiences with Dr. Victor Rivera-Monroy within the dwarf mangroves of Shark Slough and the second is an account of her shark tagging work with graduate student Philip Matich. Both podcasts and accompanying lessons will be posted to the revised Ed & Outreach webpage.

FCE LTER RETs play an important role in addressing *2011 SIP* challenges. While presenting their research experiences to their students, they are also playing important role models as women in science and improve our outreach to under-represented students. Furthermore, both teachers enable us to communicate with two of largest English Language Learner (ELL) groups in our community: Spanish and Haitian Creole-speaking students. Ms. Casal assists with Spanish-speaking students and Ms. Laroche assists with Creole-speaking students.

Felix Varela Senior High School's student demographics (80% Hispanic; 5% Black Non-Hispanic) reflect that of MDCPS. In addition, 47% of the students displaced by the 2010 earthquake that devastated Haiti migrated to Florida, a majority are now enrolled in MDCPS with the largest number attending Felix Varela. Our RETs are now fulfilling a secondary role: Casal as an example of a Hispanic woman in science and Laroche expanding our outreach to Haiti through the many students that have returned to their home with a knowledge of FCE LTER.

As National Board Certified Teachers, Casal and Laroche recognize the educational disparities that exist as a result of differences in state standards. Together they are working with FCE LTER Education & Outreach to address this challenge by including the National Science Standards in their lessons.

Our Education & Outreach Coordinator and Ms. Casal are working to foster a relationship with Miami Dade [Community] College. The Ed. & Outreach Coordinator, Nicholas Oehm, teaches at Miami Dade College and has presented FCE materials and educational activities, in the ecology section of his class, to 169 students enrolled in his General Education Biology class during AY 2010-2011. RET Teresa Casal is also a professor in the Miami Dade College School of Education and has presented FCE lessons to 23 pre-service teachers enrolled in two sections of *EME3410 Instructional Technology in Mathematics and Science*. In addition, Ms. Casal also continues to collaborate with Everglades National Park and Dr. Yvette Covert of Miami Dade College School of Education through the *Parks As Resources for Knowledge (PARK) Program* which has presented a hands-on Everglades fire ecology lesson to over 20 additional pre-service teachers.

Research Experience for Secondary Students and Research Assistantships for High School Students

FCE LTER continues with its long history of working with K-12 students in the classroom and our research laboratories. Since 2000, FCE has worked directly with over 65 high school students outside of the classroom in formal internships and workshops. Throughout the summer of 2010 and 2010-11 AY, our researchers hosted 12 high school students in our Research Experience for Secondary Students (RESSt) program. Two were returning RESSt interns from the previous year and one completed a Research Assistantship for High School Students (RAHSS) project.

Sohaib Ahmad and returning intern Shweta Kulkarni each used their RESSt internships to prepare projects for the *2011 South Florida Regional Science and Engineering Fair*. Shweta's project summarized her two years of work with Dr. Ligia Collado-Vides and first presented her results at the *2011 FCE All Scientists Meeting*. Shweta's second poster presentation received an "*Excellent*" rating at the science fair for her poster entitled "*Interpreting the effects of salinity and temperature on benthic communities along a salinity gradient*". Sohaib Ahmad also prepared a poster entitled "*Determining Interobserver Variability During Colonial Nesting Bird Census"* describing his work with Dr. Kevin Whelan. Unfortunately, Sohaib was not able to compete due to a scheduling conflict between the science fair and SAT testing.

Research Experience for Undergraduates

Over the last year, the FCE Research Experience for Undergraduates (REU) program has worked with 29 students, in 11 different research labs, and represents 7 different institutions. Through 2010 LTER Supplemental Funds, REU Francis Matthews worked in the Hydrogeology Lab mentored by Dr. Rene Price in analyzing surface water samples for major ion analysis. Francis presented his results in a poster entitled "*Major Ion Chemistry of Shark River Slough, Everglades National Park*" at the December *2010 American Geophysical Union* meeting in San Francisco and the January *2011 FCE LTER All Scientists Meeting*.

Graduate Student Activities and Productivity

The FCE Students Group includes over 40 graduate 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 2 MS theses and 5 Ph.D. dissertations from December 2010 to September 2011.

Theses and Dissertations

Bernard, Rebecca. 2010. Effects of light and nutrient supply on stable isotopic composition and fractionation in N-limited seagrass beds. Master's thesis, Florida International University.

Jimenez, Kristine L. 2010. A Comparison of CO2 Exchange Rates for Long- and Short-Hydroperiod Everglades Marshes. Master's thesis, University of Alabama.

Chen, Meilian. 2011. Characterization, Sources, and Transformations of Dissolved Organic Matter (DOM) in the Florida Coastal Everglades (FCE). Ph.D. dissertation, Florida International University.

Halun, Sitti Zayda B. 2011. The Effects of Fertilization and Simulated Grazing on the Community Structure of a Seagrass Bed in South Florida. Ph.D. dissertation, Florida International University.

Pisani, Oliva. 2011. Local Biomass Control on the Composition and Reactivity of Particulate Organic Matter in Aquatic Environments. Ph.D. dissertation, Florida International University.

Ruehl, Clifton B. 2010. The Interactive Effects of Predators, Resources, and Disturbance on Freshwater Snail Populations from the Everglades. Ph.D. dissertation, Florida International University.

Stringer, Christina Elaine. 2010. Hydrologic Controls on Salinity in Mangroves and Lagoons. Ph.D. dissertation, University of South Florida.

In Spring 2011, the FCE-LTER Student Group's Executive Board put together an exciting seminar series for graduate students about the FCE-LTER, called the "*Everglades Hour!*" It focused on explaining and exploring the FCE-LTER research program, and included discussions about FCE's guiding themes, key site documents and future research directions. The two central goals of the *Everglades Hour!* were: 1) to increase graduate student familiarity with the FCE-LTER's structure and overall research program and 2) to start a dialogue among graduate students about FCE III, the site's upcoming research renewal grant. Moreover, the *Everglades Hour!* included two Graduate Student Research Symposiums, which gave FCE graduate students an opportunity to present and receive feedback on their own research. *Everglades Hour!* seminars took place once a week over a six-week period in January and February 2011. In summary, the *Everglades Hour!* served as an important scientific and social event, building community among FCE graduate students.

Graduate students from Utrecht University (UU) (E. van Soeolen, E. Lammertsma, L. Bree) and Florida International University (FIU) (E. Nodine) are collaborating in the Gaiser laboratory to combine geophysical and biological proxies to interpret high-resolution changes from these sediment cores. To continue this effort, E. Lammertsma visited FIU in March 2011 to meet with E. Nodine to coordinate analytical and writing efforts. In addition, the environmental interpretation of these changes is dependent on linking the proxy organisms to biogeochemical parameters, so we have begun coordinated efforts toward this calibration. L. Bree visited FIU in March 2011 to conduct experiments in the Gaiser laboratory to determine the response of bloom-forming organisms to changes in nutrient availability. She and E. Nodine have coordinated sampling trips in the coring area to begin developing a descriptive diatom and chrysophyte training set. All of these efforts are contributing toward collaborative proposals from FIU and UU to determine rates of ecosystem change in response to the combined effects of tropical storms and sea-level rise.
Jordan Barr worked with a summer intern from Pennsylvania State University (Patrick Ritsko). P. Ritsko performed data analysis and worked as a field technician assisting with the mangrove flux tower.

Network Level Challenges

- *Network wide coordination and communication among site-based education programs*
- *Network-wide cyberinfrastructure support for education-related cooperation among sites and education partners, including support for student data collection and analysis*
- *Lack of metrics to assess/evaluate educational programs*

FCE LTER is an active participant in many Network-level committees aimed at addressing the coordination of Education & Outreach activities across the LTER Network. FCE is currently represented on eight committees and subcommittees including: Education; Communication; and ASM 2012 Planning Committees. FCE Ed & Outreach is also a member of the: E-newsletter; Education Website; Network Website; Science Journalism; and Transformational Science Publication/Future Scenarios Subcommittees.

The Assistant Education & Outreach Coordinator, Dr. Susan Dailey, is working on coordinating FCE communication with the Network and across sites. She is currently working closely with McOwiti Thomas at LNO as a member of the Network Newsletter Subcommittee. As our previous Education & Outreach Coordinator, Susan is a regular contributor to the printed version of the Network Newsletter and authored the lead article for the first, Network e-newsletter entitled "*LTER Network NEWS ENTERS new era*" and is busy preparing to contribute to the next edition. Although we decided to delay publishing FCE's first newsletter until the Fall 2011, the decision is allowing us to improve its appearance, content, coordination with the new Network e-Newsletter.

FCE Education & Outreach Coordinator, Nicholas Oehm, has been discussing the cyberinfrastructure and evaluation challenges for education in regular Education Committee teleconferences. In September 2011, he is scheduled to attend a coordination meeting for Education & Outreach Coordinators at VCR to share resources and work towards coordinating activities across the Network.

Other Education & Outreach Accomplishments

FCE researchers and staff are active in the community across south Florida and take advantage of travel opportunities to introduce LTER and FCE research across the US and abroad. Some examples include:

- FCE Data Manager, Linda Powell gave a talk on mangroves at Conley Elementary in Tallahassee, FL in December 2010.
- In January 2011, six FCE staff served as judges at the *South Florida Regional Science and Engineering Fair*.
- In February 2011, 45 students from Felix Varela Senior High School and 30 Students from the Gateway K-8 Environmental Magnet School installed 30 native bird boxes at the CEMEX habitat reclamation area.
- Dr. Rene Price presented a lecture summarizing FCE LTER research at the University of Western Australia on March 2, 2011
- Dr. Rudolf Jaffe has worked diligently on producing our FCE children's book *One Night in the Everglades*. The book was presented to an elementary class at Pinecrest Elementary School, a Miami-Dade County Public School and was well received. The students generated artwork that will be included on the back cover of the book. *One Night in the Everglades* has been finalized we are awaiting the final printing. We expect to receive the English and Spanish versions during

the fall. Rudolf Jaffe also attended the cross site meeting of education representatives to work with other sites that are interested in producing their own children's book.

- On March 31, 2011, Nicholas Oehm attended the NSF-sponsored "*Climate Change Education Partnership: Building Place-Based Climate Change Education through the Lens of National Parks and Wildlife Refuges"* workshop in Palmetto Bay, Miami. Invited by our Education & Outreach partners at Everglades National Park, the objective of the workshop was to create a strategic plan to implement informal climate change education programming in National Parks and Wildlife Refuges around the US.
- Houghton Mifflin Harcourt Publishing has produced three project-based videos describing the work of FCE's Heithaus Lab for use in four of their *Science Fusion Programs* (grades 4, 7, 8, and high school biology). These videos highlight Heithaus' FCE alligator, bull shark, and seagrass research.
- FCE and Heithaus graduate student, Adam Rosenblatt, presented his research at the International Game Fish Association Science Camp in Ft. Lauderdale, FL
- Adam Rosenblatt presented a talk to students under-represented in science at Miami Edison Senior High School for Communities in Schools of Miami, Inc.
- Dr. Mike Heithaus worked with Kansas City Schools in presenting his research to 50 elementary school teachers in 2 professional development workshops. Dr. Heithaus also used the opportunity to give a third presentation to the general public.
- Dr. Joe Boyer's lab continued to work with Marine Lab, a non-profit educational organization in Key Largo. Their main purpose is to educate junior and high school students about the south Florida marine environment. Jeff Absten and I made a presentation to their staff concerning operation and maintenance of field meters and data analysis. We hope to use their volunteer data in our future analyses.
- Dr. Randy Chambers included a unit of Everglades Restoration Research in two undergraduate courses (ENSP201: Watershed Dynamics and BIOL427: Wetland Ecosystems) taught this year at the College of William & Mary.
- Laura Ogden and Jim Heffernan, co-taught Urban Ecology graduate seminar, an interdisciplinary course.
- In March 2011, Rebecca Garvoille taught a three-week community education class at the Delray Beach, Florida public library's Continuing Education Symposium entitled "Reimagining Nature: The Everglades as a Peopled Landscape" about the human history of the Everglades.
- FCE graduate students receiving Everglades Foundation fellowships were featured in a video at http://www.evergladesfoundation.org/videos/
- Former FCE researcher and middle school science and social studies teacher at the Key Largo School, Lisa Giles, traveled to Shark Bay Australia with Dr. Mike Heithaus to study seagrass and consumer ecology. Lisa is using this research experience as a comparison in her Everglades ecology lessons.

Challenges to Communication

FCE LTER is addressing the four 2011 SIP challenges to communication through our partnerships, collaborators and our Education & Outreach programs. These challenges include:

- *How to make research findings tangible and visible to diverse constituents*
- *Establishing effective dialogue with end users*
- *Understanding regional and audience diversity and developing strategies and messages to address [them more] effectively*

- *Uneven distribution of communication knowledge, technologies, and costs within the LTER Network*

FCE LTER research findings are tangible and made visible to our diverse constituents through our collaborative relationship and our Education & Outreach Programs. FCE is a diverse research group that currently consists of 32 collaborating institutions. One third of our collaborators are researchers imbedded within our constituencies including: state (1) and federal agencies (5); Non-Governmental Organizations (3); and a private consulting firm. Through these collaborative partnerships, these imbedded FCE researchers insure that FCE results are included in the reports that are used in policy-making decisions.

Through the coordination of our Research Experience (RE) programs, our RET, REU, and RAHSS fellows are working directly with FCE scientists to make our research findings tangible and visible to diverse educational groups and establishing a consistent dialogue with our end users. Our Ed & Outreach Coordinator and RETs are our primary points of contact for: Miami Dade [Community] College School of Education and Department of Biology, Health, and Wellness; Miami Dade County Public Schools and Monroe County Public Schools.

In an effort to broaden the diversity of our audience we turned to social networking sites for communicating with both internal and external groups. FCE researchers and educators contribute regularly to FCE's Facebook to provide announcements of research findings and publications. We currently have 91 Facebook friends and 47 followers on Twitter and continue to work towards increasing our audience.

FCE is also publishing an E-newsletter that will be distributed to email list of agencies, partners, educators, students, and posted to our webpage. This FCE newsletter is intended for a wide and diverse audience and will include information about FCE research, education, the researchers and educators and provides updates on network level collaborations, educational curriculum development, and opportunities.

We are currently working through the Communication and Education Committees to explore best communication practices across sites and are working to improve the range of our audience through new communication tools and technology.

Challenges to Coordination with Other Networks

- *Engaging groups and networks that have diverse objectives and are at different developmental stages*
- *Ensuring good communication among networks to foster interactions.*
- *Maintaining participation of other networks and observatories in a network of networks without overtaxing LTER's existing human and financial resources.*
- *Reaching consensus on how best to ensure complementary research toward predicting environmental change.*
- *Determining strategies for designing interoperable data management systems across networks with divergent goals and priorities.*

FCE Education & Outreach is actively coordinating our programs with a diverse group of other networks that are in various developmental stages including: ESA SEEDS (15 years); Miami ULTRA-Ex (2 years); and Everglades Educational Consortium (forming).

In May 2011, the *Strategies for Ecology Education, Diversity and Sustainability (SEEDS)* program of The Ecological Society of America's (ESA) visited FCE. The SEEDS program was established in 1996 to improve the participation of under-represented groups in the field of ecology. Since 2001, *SEEDS* has led field trips for undergraduates to visit ecological research programs. The 2011 trip to FCE was the 19th such trip and was hosted by Dr. Laura Ogden. During their five day visit, *SEEDS* students representing 16 colleges and universities from the US and Puerto Rico heard presentations from our graduate students and were led on field trips through Everglades National Park, the Big Cypress Seminole Reservation, the Loxahatchee National Wildlife Refuge. Students participated in a career panel of FCE researchers at Florida International University. A student report of the trip can be viewed online at http://www.esa.org/seeds/programs/fieldtrips/past.php.

In June 2011, FCE LTER, Miami ULTRA-Ex, and Miami Dade County Public Schools Division of Advanced Academics presented a professional development workshop for six Advanced Placement Human Geography teachers on the human dimensions of urbanization in south Florida. Nicholas Oehm, FCE Ed & Outreach Coordinator, and Gail Hollander, Miami ULTRA-Ex PI organized this three day long workshop at TERRA Environmental Institute that included: an introduction to the AP Human Geography curriculum by former FCE Coastlines RET, Mr. Gary Holbrook; guest lecture entitled *Regional Perspectives: A Brief History of Everglades, its Restoration and the Relationship with Miami Dade County*, by FCE's Rosana Rivero; a field based lesson entitled *The Value of Trees in Urban Environments*, developed/conducted by FCE RET Catherine Laroche; and an afternoon in the FIU GIS-RS Center.

FCE Ed & Outreach is currently collaborating with the Everglades Foundation to improve communication and foster interaction by establishing the Everglades Educational Coalition. This purpose of this group will be to collaborate with other local groups involved in Everglades education to create a central repository of information and materials. Our hope is to improve communication, coordinate efforts, consolidate resources, and form new relationships with networks and observatories within and beyond south Florida.

The collaboration between FCE and the Miami ULTRA-Ex is one example of how we are working with other networks on complementary research toward predicting environmental change. FCE and Miami ULTRA-Ex have a large number of collaborators in common which will improve the ability to design interoperable data management systems across networks with divergent goals and priorities.

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 105 presentations from September 2010 - September 2011.

The inclusion of community leaders and agency scientists is an intrinsic component 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.

Several FCE scientists are collaborators or advisors to the SFWMD Comprehensive Ecosystem Restoration Program Monitoring and Assessment Program (CERP MAP) Team. Data collected by these investigators help expand the spatial coverage and landscape ecology investigated by FCE, and FCE data are used to inform long-term trajectories of change elsewhere in the ecosystem. Investigators contribute integrated results to the annual Everglades System Status Report to the U.S. Congress and present their findings at frequent meetings of the CERP MAP team. In addition, FCE collaborators are training representatives of State and Federal agencies in the use and application of the Everglades Landscape Model through the Interagency Modeling Center at SFWMD. While FCE scientists frequently participate in formal collaborations and informal science workshops geared toward improving integration of science and water management, new FCE collaborations with climate scientists from a number of agencies are improving integration of the science of climate change with water management policies.

Details of additional outreach by FCE scientists to restoration policymakers are listed in Section IVB ("Contributions to Other Disciplines") of this report.

The FCE LTER Program also reaches out to the public through our web site. Although our web statistics show a slight decrease in web activity in 2010, the numbers do show that we have been reaching a steadily growing number of new web clients since the inception of the web site in 2001, 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 243 datasets from August 2010 thru August 12, 2011.

The FCE information manager, Linda Powell, gave a talk about the Florida Coastal Everglades LTER Program and Information Management to all the fourth grade students at Conley Elementary in Tallahassee, Florida in December 2010.

Tiffany Troxler is a member of the US LTER international committee along with FCE members Chris Madden and Rinku Chowdhury. In her participation as a committee member, she is co-PI on a recently funded planning grant entitled "US-Mexico Workshop: Catalyzing International Collaborations to Develop a Platform for Ecohydrological Research".

Rivero, Rosanna. Presentation at the AP Human Geo-ULTRA Workshop - Advanced Placement Summer Institute for Miami Dade Advanced Placement (AP) Teachers. “A tale at two scaled: regional perspective on Everglades, its restoration and the city of Miami and Dade County”, Miami, June 2011

Rivero, Rosanna G., Ivan Blanco-Rubio, G. Melody Naja, and Rene Price. Presentation at ULTRA Water Workshop, led by Rene Price. “GIS analysis of changes in chloride concentrations in Biscayne aquifer wells”. August 18, 2011.

South Florida Ecosystem Restoration Task Force 2010. System-wide Ecological Indicators for Everglades Restoration. 2010 Report. http://www.sfrestore.org/documents/Final_System-wide_Ecological_Indicators.pdf

E. Project Outcomes

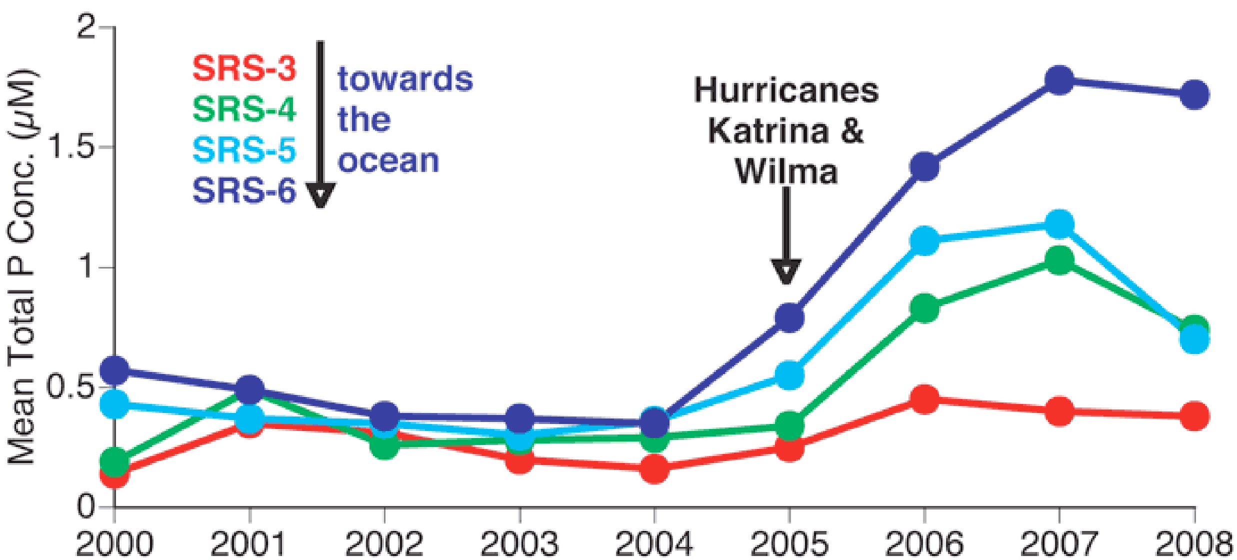
During year 5, we evaluated the history of FCE research to illustrate a few of our “key findings” that change the way we think about coastal ecosystems. These transformational findings were presented to the LTER network community and are highlighted on our website. These findings are the type that have and will influence textbook material, and are highlighted in a book chapter by Gaiser et al. (2011) in “Wetland Habitats of North America: Ecology and Conservation Concerns” (Batzer and Baldwin, 2011). We present them here as products of our synthesis activities during FCE Year 5.

1. Unique Nutrient Sources

FCE scientists discovered that, unlike in most coastal areas, the natural source of phosphorus (the nutrient that limits ecosystem productivity) for coastal Caribbean estuaries is seawater, not inland environments. This important finding has ramifications for both restoration and conservation and is informing decision making in coastal areas.

FCE research has shown that the Everglades operates differently from other coastal ecosystems in that its estuaries that are "upside-down," with seawater supplying limiting nutrients landward, rather than the other way around. Collaborative research with Caribbean scientists, particularly those associated with Mexican LTER programs (MexLTER), has shown similar upside-down features in similar tropical low nutrient wetlands of the Yucatan peninsula and northern Belize. Because this finding has ramifications for coastal restoration and conservation, FCE scientists are continuing collaborations with Mexican colleagues to establish coordinated science and education programs to improve adaptive decision-making in coastal ecosystems of south Florida, the Yucatan, and throughout the Caribbean.

These two FCE research sites show the unexpected 'wedge of productivity' of mangrove forests in the Everglades. Marine sources of phosphorus enable mangrove forest canopy to reach 20m or more, as is seen in the image on the right, compared to the mangroves on the left that are growing several miles inland.
Credit: Robert Twilley (image on the left) and Stephen Davis (image on the right)



FCE scientists monitor total phosphorus concentrations in the water column in the mangrove ecotone. Their data suggest that sediment depositions after hurricanes, such as illustrated in the graph above, provide another source of marine phosphorous to the mangroves. Rather than a long-term increase in

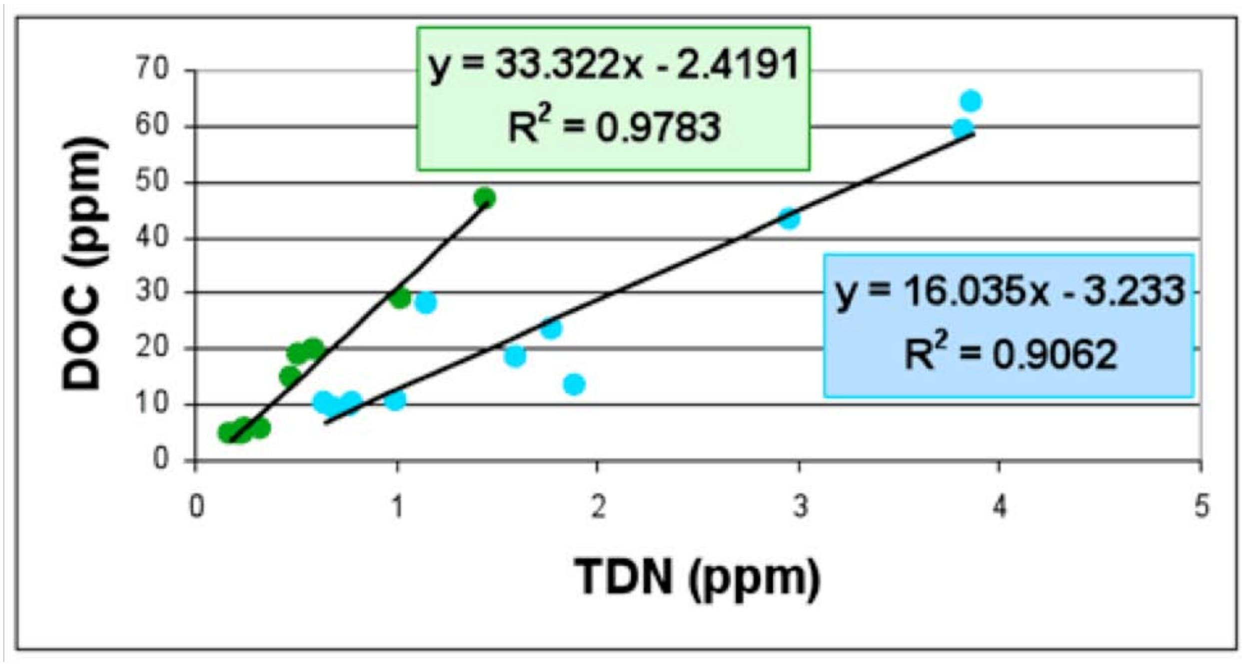
estuarine phosphorous concentrations, these changes show how storm surge delivers this nutrient to wetlands and fuels productivity there.
Source: Daniel Childers

2. Food Webs
FCE scientists discovered that decomposing plant material, rather than the plants themselves, supports the freshwater food web. When exported to coastal waters, this material also supports substantial marine plant and animal life.

Determining the sources, fate, and transport of dead organic matter is an important aspect of understanding the linkages between freshwater and marine environments in estuaries such as the Everglades. Comparative work among aquatic sites in the LTER network has shown that the dissolved form of organic matter is abundant in the Everglades but less biologically available compared to other estuaries. However, particulate organic matter, found as a detrital layer above the soil surface, is formed in unusual quantities in the freshwater Everglades and moves slowly as bedload into estuaries. FCE researchers have shown that this material, rather than the living or dissolved form, forms the base of the Everglades food web. Large mobile consumers, such as bull sharks and alligators, may play a role in transporting nutrients upstream from the Gulf of Mexico. Although they reside primarily in low-salinity areas particular individual alligators and bull sharks will commute to the coastal oceans to feed before returning back upstream. Alligators in particular may link the marshes, estuaries, and coastal ecosystems through their movements and feeding patterns.

Michael Heithaus, FCE Co-PI, prepares to place a GPS tag on an alligator. Using these, and much smaller acoustic transmitters, FCE researchers have been able to show that some alligators commute from marine waters where they feed to the ecotone, possibly moving important nutrients upstream.
Credit: Photo by Jeff Rauch

In addition, when detrital material meets the estuary, metabolic rates are high, suggesting its importance to nutrient regeneration and biogeochemical cycling. The particulate matter was found to be highly reactive upon exposure to sunlight, resulting in the release not only of high levels of dissolved carbon, but also nutrients. These processes have implications for Everglades' restoration, as expected increases in freshwater inflows should increase detrital transport to estuaries, increasing nutrient availability via diverse re-mineralization processes.



Exposure of flocculent material to sunlight causes the generation of significant amounts of dissolved organic carbon and nitrogen. This process can potentially influence nutrient dynamics in this oligotrophic environment.
Source: Oliva Pisani; PhD Dissertation work.

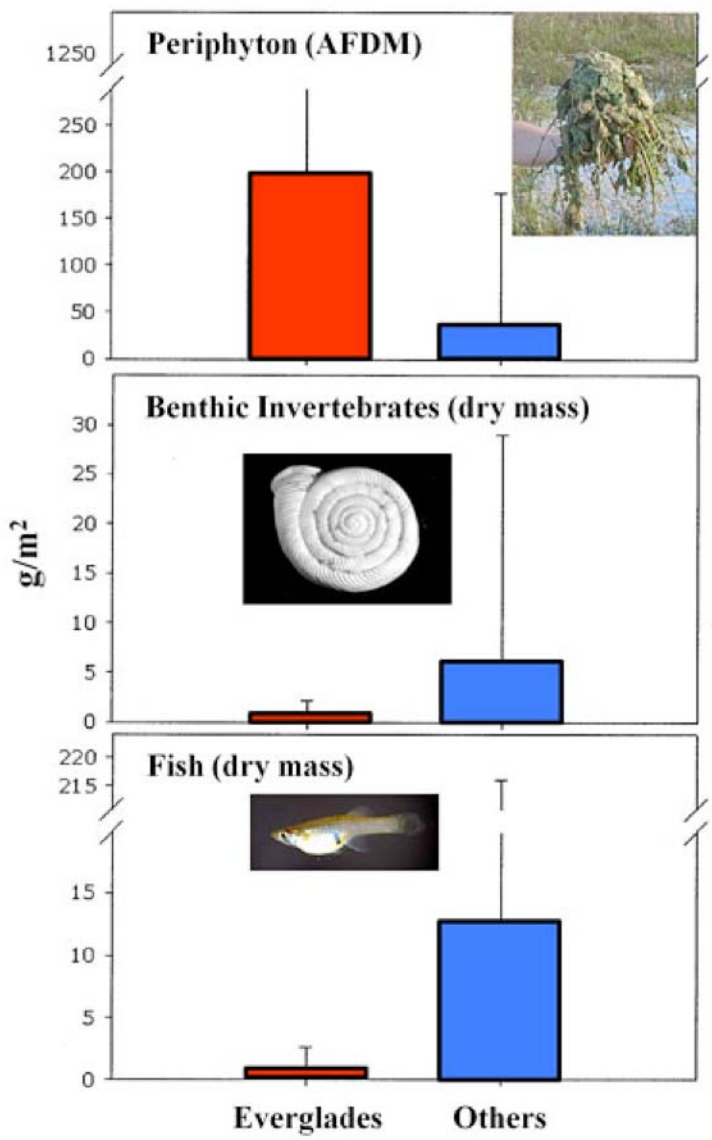
3. Productivity Paradox

FCE scientists revealed how human-induced nutrient enrichment in the Everglades and Caribbean wetlands affect the "productivity paradox" in which an extraordinarily high level of algal growth supports far fewer aquatic animal consumers than expected. Understanding this dynamic is critical to the restoration of the Everglades ecosystem.

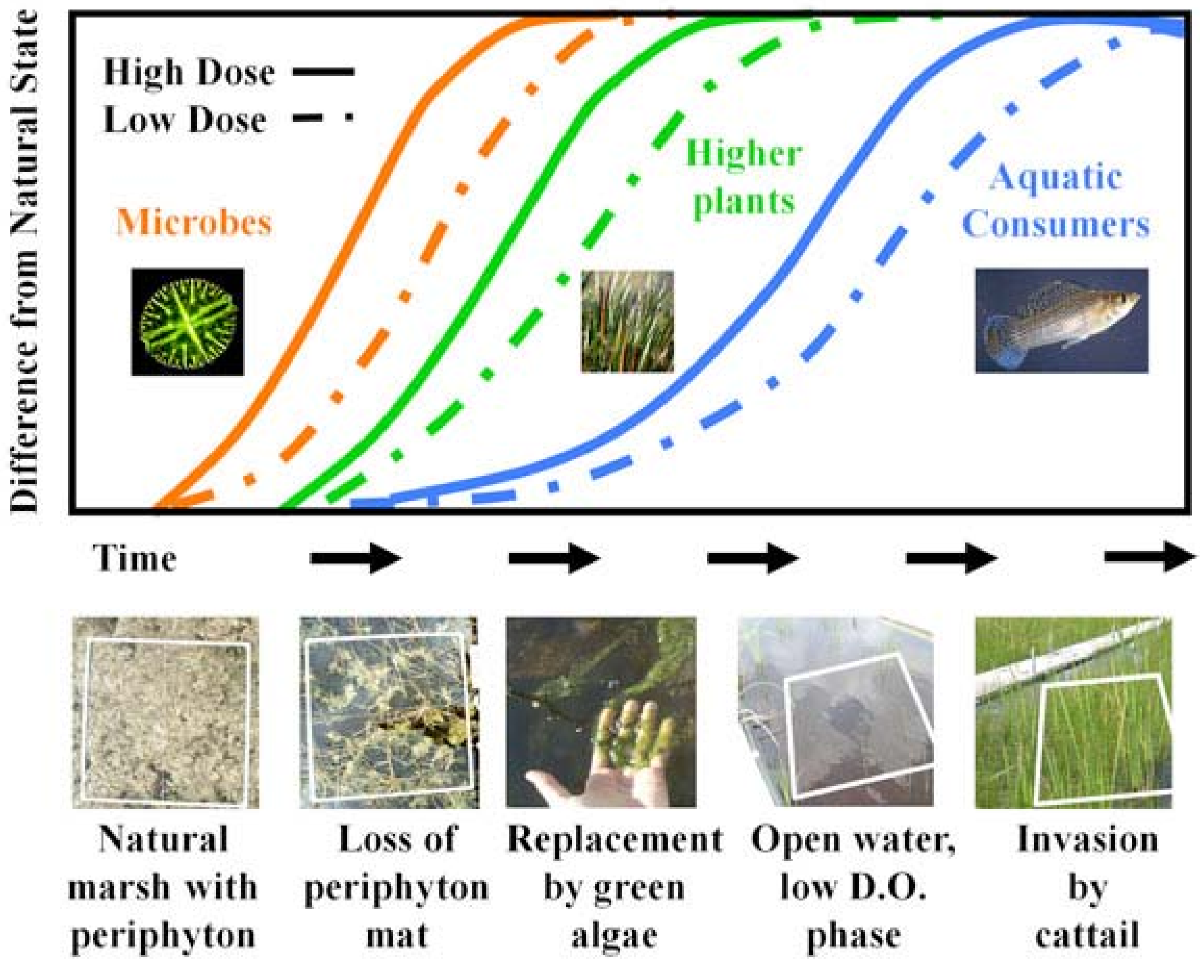
FCE researchers have found that productivity in the Everglades, and other limestone-based Carbbean wetlands, is dominated by extraordinarily productive algal mats, despite extreme nutrient limitation. This phenomenon has been called a "productivity paradox" (Gaiser et al. 2011). This production would be expected to support a large biomass of aquatic primary consumers but does not (Turner et al. 1999). Instead, algal mats are highly inedible and aquatic consumers rely on less energetically efficient detrital pathways (Sargeant et al. 2010). Top predators (i.e., wading birds, large fish, alligators) are supported by the seasonal concentration of these prey animals during the dry season. Long-term research at FCE has been necessary to determine how interannual variation in wet and dry-season hydrology and water quality influence algal mat production, grazer abundance and predator efficiency. Through international collaborative research in other Caribbean wetlands, we have been able to show that this phenomenon is not just distinctive of the Everglades, but of limestone-based Caribbean wetlands in general.

Long-term observational data have been coupled with long-term manipulations of the limiting nutrient, phosphorus, to determine its influence on the productivity paradox and trophic cascades. Our research indicates that anthropogenic nutrient enrichment erases the unusual pyramid of biomass by temporarily increasing algal edibility, thereby increasing production of aquatic consumers. However, phosphorus enrichment ultimately leads to a loss of algal mats, which reduces the structural refuge for aquatic animals, increasing their vulnerability to predation. This shift in algal and consumer biomass and structure is initiated at all phosphorus levels above background levels, and leads to an altered ecosystem state at rates dependent on the nutrient loading rate.

This research is of critical importance to hydrologic restoration of the Everglades and for protection of Caribbean wetlands, as it describes how hydrology controls food web structure directly and through interactions with the loading of the limiting nutrient.



This graphic compares the biomass structure of the Everglades aquatic food web to other aquatic ecosystems, showing how the large mass of primary production in the Everglades (primarily periphyton) does not translate to a large mass of benthic invertebrates and fish, as would be expected from studies in other aquatic ecosystems.
Source: Gaiser, E., J. Trexler and P. Wetzel. In Press. The Everglades. In Batzer, D. and A. Baldwin (eds). Wetland habitats of North America: Ecology and Conservation Concerns. Berkeley: University of California Press.



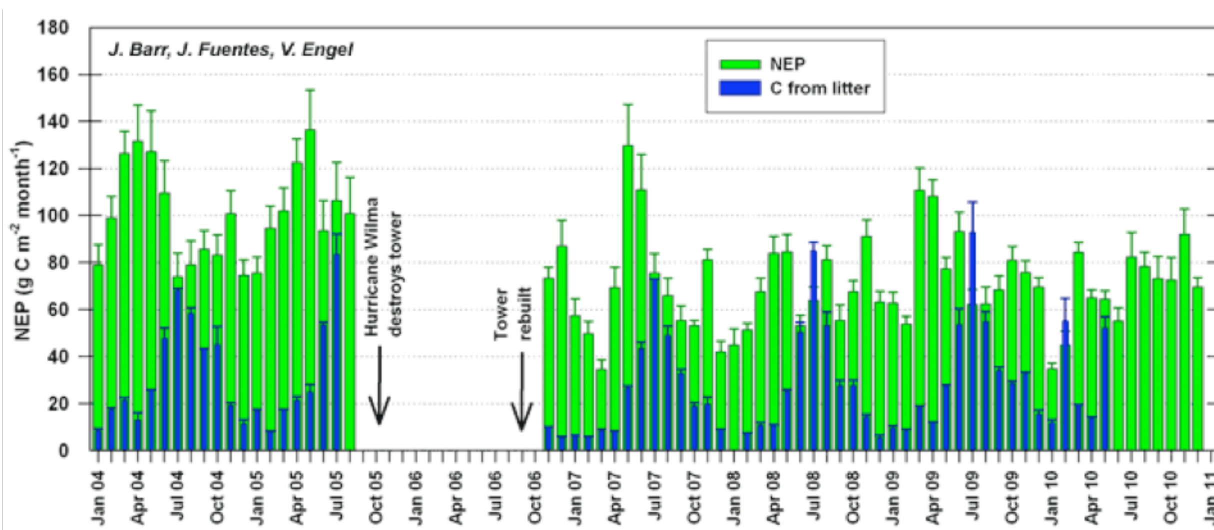
This graphic shows the effects of long-term phosphorus enrichment in Everglades wetlands. FCE scientists have shown that exposure to phosphorus at any level above background initiates a cascade of changes, from a loss of natural periphyton communities, to replacement by more palatable non-mat forming algae, then to an open-water state that eventually leads to the spread of invasive cattails.
Credit: Gaiser, E., J. Trexler and P. Wetzel. In Press. The Everglades. In Batzer, D. and A. Baldwin (eds). Wetland habitats of North America: Ecology and Conservation Concerns. Berkeley: University of California Press.

4. Productivity Gradients in Mangroves

FCE researchers have found significant spatial differences in mangrove productivity; from riverine mangrove forests with productivity rates similar to tropical rain forests to low structure scrub mangroves that grow in nutrient-poor environments. Mangrove forests growth and survival are greatly influenced by the impacts and legacies of hurricanes, sea-level rise, and human impacts along coastal areas.

Mangrove forests in the Florida Everglades form an ecotone, which is a critical link between freshwater marshes and the marine environments of Florida Bay and the Gulf of Mexico. These forested wetlands provide shoreline protection against storms, "nurseries" for shrimp, fish, and crabs, as well as habitat for several endangered and threatened species such as the American crocodile. FCE researchers have made important contributions to our understanding of mangrove forest structure and productivity trends. FCE researchers installed - and still operate - the first eddy covariance tower in a riverine tall mangrove forest in 2003 to measure the net ecosystem exchange of carbon dioxide between the mangrove forest and the atmosphere. Mangroves remove relatively large amounts (about 1000 g of carbon per m^2 per year) of carbon dioxide from the atmosphere compared to other forest types, such as tropical rainforests. Temporal and spatial mangrove forest productivity and structure differences are largely controlled by large-scale disturbances, such as tropical cyclones, which can defoliate and kill mangrove trees. Recovery rates vary with the magnitude of disturbance, but can be accelerated by delivery of nutrients in water and soils from associated storm surge. FCE also has a network of sediment elevation tables (SETs) that measure accretion and relative elevation rates in coastal wetlands. Results from these devices are used in predictive modeling efforts to project magnitudes and consequences of sea-level rise. Further, FCE is collaborating with the Luquillo and the Mexican LTER programs to establish a Caribbean Hurricane Research Network (CHURN) to facilitate cross-site, collaborative research on the ecological and socio-economic factors influencing hurricane impacts on the greater Caribbean coastal regions.

FCE researchers evaluate mangrove mortality at the mouth of the Shark River estuary after the passage of Hurricane Wilma in October of 2005.
Photo taken by Victor Rivera, May 2009.

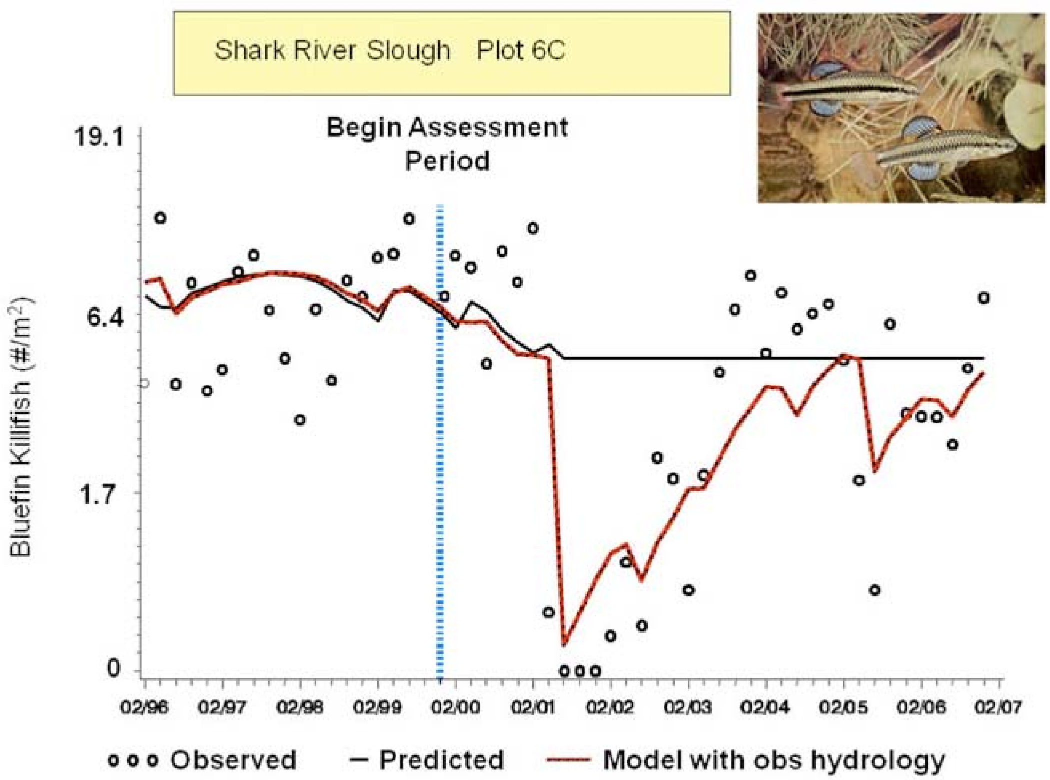


Seasonal patterns in net ecosystem carbon exchange (NEE) for the mangrove forest located in the western Everglades. The NEE values were determined from flux tower measurements. The carbon content in leaf litter production is also shown. Despite their harsh habitat, mangroves remove from the atmosphere substantial amounts of carbon, with net assimilation exceeding 1000 grams of carbon per m^2 per year. We now know the environmental and physiological controls on mangrove ecosystems.

5. Communication to Policymakers

Collaborating with agency scientists, FCE scientists developed an effective communication tool for directly informing the U.S. Congress and other decision makers about the science of Everglades restoration.

The Everglades is imbedded in a human-dominated landscape that is constantly changing in response to local and global environmental manipulations. Working with an inter-governmental task force, FCE has helped create a reporting system linking the causes and consequences of these dynamics and communicating the results in a transparent format accessible to a wide audience. This reporting system has been used in bi-annual reports to the U.S. Congress by the South Florida Ecosystem Restoration Task Force (http://www.sfrestore.org/) to assess progress in ecosystem restoration. The "stoplight" reporting system allows us to communicate our science to other scientists and policy makers through a multi-layered reporting tool that extracts management signals from long-term datasets. The reporting system includes 11 indicator types that address diverse spatial and ecological dimensions of the Everglades restoration initiative. Three of the indicators, periphyton-epiphyton, fish and macroinvertebrates, and Florida algal blooms, are closely linked to FCE core research topics and long-term data gathering. FCE scientists collaborated with the Federal Task Force on Everglades Restoration, National Park Service, US Army Corps of Engineers, US Fish and Wildlife Service, and other universities to develop this communication tool.



Time series data are compared to targets derived from a model linking rainfall and baseline conditions identified as approximating historical hydrological conditions. In the example presented here, the density of an indicator species was much lower than the target in 2001 through 2003. *Credit: Trexler, J. C., and C. W. Goss. 2009. Aquatic fauna as indicators for Everglades restoration: Applying dynamic targets in assessments. Ecological Indicators 9S:S108-S119.*

Performance Measure	'00	'01	'02	'03	'04	'05	'06	'07	Cur-rent Status	Current Status	2-Year Prospectus
Shark River Slough											
Eastern mosquitofish	G	G	Y	R	R	Y	Y	R	Y	Fewer than expected.	Two-year prospects are for no change, but Tamiami bridge project should im-prove this PM in future.
Flagfish	G	G	G	Y	G	G	G	G	G	At expected levels based on rainfall and target-period hydrology.	Two-year prospects are for no change, but Tamiami bridge project should im-prove this PM in future.
Bluefin killifish	G	Y	Y	R	Y	Y	Y	Y	Y	Fewer than expected.	Two-year prospects are for no change, but Tamiami bridge project should im-prove this PM in future.
Total fish	G	G	R	R	R	R	R	R	Y	Fewer than expected.	Two-year prospects are for no change, but Tamiami bridge project should im-prove this PM in future.
Everglades crayfish	G	Y	G	Y	R	Y	Y	Y	G	At expected levels based on rainfall and target-period hydrology.	Two-year prospects are for no change, but Tamiami bridge project should im-prove this PM in future.
Non-native fishes	Y	Y	Y	Y	Y	Y	Y	Y	Y	Present at all monitoring sites. None more than 2% of all fish collected; num-bers highest at mangrove boundary.	Two-year prospects are for possible increase or no change, but Tamiami bridge project may negatively af-fect this PM.
Taylor Slough											
Eastern mosquitofish	G	G	G	Y	Y	Y	Y	G	G	At expected levels based on rainfall and target-period hydrology.	New projects at S-332 and C-111 should lock in good performance of past year.
Flagfish								G	G	At expected levels based on rainfall and target-period hydrology.	New projects at S-332 and C-111 should lock in good performance of past year.
Bluefin killifish	G	Y	R	R	R	R	R	G	Y	Near, but below, expected levels based on rainfall and target-period hydrology.	New projects at S-332 and C-111 should lock in good performance of past year.
Total fish	G	G	Y	Y	R	R	R	G	G	At expected levels based on rainfall and target-period hydrology.	New projects at S-332 and C-111 should lock in good performance of past year.
Everglades crayfish	G	G	G	Y	R	Y	Y	G	Y	Above expected levels based on rainfall and target-period hydrology.	New projects at S-332 and C-111 should lock in good performance of past year.
Non-native fishes	Y	Y	Y	Y	Y	Y	Y	R	Y	Present at all monitoring sites. None more than 2% of all fish collected; num-bers highest at mangrove boundary.	New projects increasing connectivity to canals may negatively affect this PM.

An example report card with stoplights indicating compliance with targets (green), deviation from targets that require ongoing attention (yellow), and deviation from targets indicating a failure to meet management goals (red). This example is for 6 aquatic consumer performance measures from two regions of the Everglades. Trends can be seen by comparison across years; a statement about current status and projected condition is included for each. These performance measures were selected based on life history patterns linking hydrological management and production of food for wading birds, which are a major concern for management.
Source: Trexler, J. C., and C. W. Goss. 2009. Aquatic fauna as indicators for Everglades restoration: Applying dynamic targets in assessments. Ecological Indicators 9S:S108-S119.

III. PUBLICATIONS AND OTHER SPECIFIC PRODUCTS

A. Publications

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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 105 such presentations during the fifth 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 461 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.

The FCE IM team lends its expertise to site and network researchers when necessary by providing application support for its Excel2EML tool, available to the community via the FCE website (http://fcelter.fiu.edu/research/information_management/tools/).

Recordings

Sprinkler: New Music by Colby Leider. In press. DVD+CD two-disc set. Homestead, Florida: everglade records, Inc. EVG11-05.

Leider, C., 2011. [in]: Sounds of Biscayne Bay. (Erik DeLuca, composer). DVD+CD two-disc set. Producer and mastering engineer. Homestead, Florida: everglade records. EVG10-03.

C. Internet Dissemination

The url of the main FCE LTER Program website is http://fcelter.fiu.edu. Detailed discussion of FCE's data management and website management is available in Section IIA9("Information management") of this report.

IV. CONTRIBUTIONS

A. Contributions within Discipline

During her 2010-11 sabbatical at Utrecht University in the Netherlands, Gaiser collaborated with Drs. Friederike Wagner, Gert-Jan Reichart and Stefan Dekker and their colleagues and graduate students on paleoecological research related to hurricanes and global change. The collaboration allowed us to complete several manuscripts for publication in the FCE special issue of *Journal of Paleolimnology*, begin several others and facilitated proposal planning and cross-site investigations. All of these efforts are contributing toward collaborative proposals from FIU and UU to determine rates of ecosystem change in response to the combined effects of tropical storms and sea-level rise, pertinent to the development of the FCE III proposal. She also hosted several Utrecht University students in her laboratory in spring 2011 to further enable these cross-site paleoecological activities.

Gaiser is also facilitating collaborations with the Finnish LTER network by hosting Dr. Saku Anttila on his sabbatical at FIU during Fall 2010 and by working with Dr. Martin Forsius (Lead PI, Finnish LTER) during her sabbatical there in 2011. Dr. Antilla collaborated with FCE collaborators Boyer and Briceno to map patterns of algal production across Florida Bay using satellite imagery and Dr. Forsius is pioneering ways of integrating social and ecological sciences in long-term aquatic research.

Several FCE scientists participate in large-scale high-density monitoring programs in the Everglades compliment FCE-LTER research. This includes the RECOVER program of the Comprehensive Everglades Restoration Monitoring and Assessment Program funded through the South Florida Water Management District, which collects and analyzes periphyton, vegetation and consumer data from 125 sites throughout South Florida every year in conjunction with abiotic and other biotic data. Gaiser and Trexler are collecting periphyton, consumers and plants from >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 continued to collaborate with Linda Amaral-Zettler at International Census of Marine Microbiology, (ICoMM) (icomm.mbl.edu), Marine Biological Laboratory. They 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). The strategy is based on 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. This project involves the aquatic component at 4 sites in FCE during wet and dry season.

Roy Chowdhury, Rinku. 2010- Chair, Human Dimensions of Global Change (HDGC) Specialty Group, Association of American Geographers.

Ogden, Laura A., Executive Board, Anthropology and Environment Section, American Anthropological Association.

Tiffany Troxler is a PI on the following research contracts funded that directly support Everglades restoration activities:
2011 Hydrogeochemical patterns at temporal and spatial scales of a “pristine” island and a degraded tree island located in WCA-3A: Restoring ecological function of degraded tree islands, South Florida Water Management District, $39,600
2010 Surface-groundwater interactions in Everglades tree islands, U.S. Army Engineer Research - Monitoring for potential water quality impacts along Eastern Everglades National Park, National Park Service, $120,000
2010 Ecological monitoring of southern Everglades wetlands, mangrove transition zone and “white zone” interactions with Florida Bay, South Water Management District, $340,000 (3 year contract)
2010 Spatial pattern in nutrient fluxes on two tree islands in WCA-3A: toward restoration of degraded tree islands, South Florida Water Management District, $89,950

B. Contributions to Other Disciplines

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 2010 and continues to report their findings to the U.S. congress annually.

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.

Gaiser is a steering committee member of 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.

Joe Boyer attended the NOAA MARES Integrated Conceptual Ecosystem Model for SW Florida Coast Meeting at Ft. Meyers, FL on Aug. 19-20, 2010.

Catherine Laroche served on the LTER Communication Network Website Subcommittee.

Nick Oehm served on the following committees:

- LTER Network Education Committee
- LTER Network 2012 ASM Planning Committee
- LTER Network Communication Committee
- Communication E-newsletter Subcommittee
- Communication Network Website Subcommittee
- Communication Transformational Science Publication/Future Scenarios Subcommittee

Susan Dailey served on the following committees:

- LTER Communication E-newsletter Subcommittee
- LTER Communication Network Website Subcommittee

C. Contributions to Human Resource Development

Pre-Service and Professional Service Teacher Education

Key to working with pre-college students is providing the appropriate training for pre-service teachers and professional development to professional service teachers. FCE is working to improve learning progressions that lead towards environmental science literacy by working with pre-service teachers through our partnerships with teacher education programs and by providing RETs to professional service classroom teachers.

Professional Service Teachers

Our RET program provides a unique opportunity for teachers to work directly with FCE researchers in developing hands on activities for use in the classroom and providing professional development to other pre- and professional service teachers.

In 2010-2011, Teresa Casal and Catherine Laroche continued working with FCE as RETs and remain an integral part of our Education and Outreach Program. This year's RET consisted of three components: field experience, curriculum development, and presentation of their products.

Undergraduate Students

Over the last year, the FCE Research Experience for Undergraduates (REU) program has worked with 29 students, in 11 different research labs, and represents 7 different institutions. For example, eight undergraduate students in Mike Heithaus' lab at FIU gained experience in field sampling techniques working with alligators, bull sharks, snook, and gar.

Mentoring High School Students
Kevin Whelan, Nicholas Oehm, and Teresa Casal mentored Sohaib Ahmad in conducting and presenting a project at the 2011 South Florida Regional Science and Engineering Fair.

Ligia Collado-Vides, Nicholas Oehm, and Teresa Casal mentored Shweta Kulkarni in conducting and presenting a project at the 2011 South Florida Regional Science and Engineering Fair.

D. Contributions to Resources for Research and Education

FCE Children's Book
Dr. Rudolf Jaffe has worked diligently on producing our FCE children's book One Night in the Everglades. The book was presented to an elementary class at Pinecrest Elementary School, a Miami-Dade County Public School and was well received. The students generated artwork that will be included on the back cover of the book. One Night in the Everglades has been finalized we are awaiting the final printing. We expect to receive the English and Spanish versions during the fall. Rudolf Jaffe also attended the cross site meeting of education representatives to work with other sites that are interested in producing their own children's book.

Educational Videos
Houghton Mifflin Harcourt Publishing has produced three project-based videos describing the work of FCE's Heithaus Lab for use in four of their Science Fusion Programs (grades 4, 7, 8, and high school biology). These videos highlight Heithaus' FCE alligator, bull shark, and seagrass research.

Website
The FCE LTER website (http://fcelter.fiu.edu/) 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 243 datasets from September 2010 through August 12, 2011.

E. Contributions Beyond Science and Engineering

Nicholas Oehm is working with the Everglades Foundation to create an Everglades Educational Coalition to facilitate networking among Everglades Educators and create a central repository of educational materials

Now that the Everglades Digital Library (EDL) has been stable leadership, Nicholas Oehm is in discussions with the EDL about the possibility of combining FCE's "Ask a Scientist" feature with EDL's "Ask an Everglades Librarian"

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