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## FCE II Year Two Annual Report for NSF Award DBI-0620409 (2008)

Evelyn E. Gaiser

*Florida International University, gaisere@fiu.edu*

Michael R. Heithaus

*Department of Biological Sciences and Marine Sciences Program, Florida International University, heithaus@fiu.edu*

Rudolf Jaffe´

*Southeast Environmental Research Center, Department of Chemistry and Biochemistry, Florida International University, jaffer@fiu.edu*

Laura Ogden

*Florida International University, ogdenl@fiu.edu*

René M. Price

*Florida International University, pricer@fiu.edu*

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

FLORIDA COASTAL EVERGLADES LTER  
Florida International University

Submitted September 2008

Principal Investigators

Evelyn Gaiser  
Mike Heithaus  
Rudolf Jaffé  
Laura Ogden  
René Price

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# I. PARTICIPANTS

## ***A. Participant Individuals***

### **Principal Investigators:**

Evelyn Gaiser

### **Co Principal Investigators:**

Mike Heithaus, Rudolf Jaffé, Laura Ogden, René Price

### **Senior personnel:**

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

### **Post-docs:**

Tom Frankovich, Robinson Fulweiler, Jessica Schedlbauer, Tiffany Troxler, Jeff Wozniak, Youhei Yamashita

### **Graduate students:**

Jose Bazante, Robin Bennett, Edward Castaneda, Meilian Chen, Josh Cloutier, Kendra Dowell, Katherine Dunlop, Rebecca Garvoille, Patrick Gibson, Daniel Gomez, Noemi Gonzalez-Ramirez, Erin Hanan, Elizabeth Harrison, Kelly Henry, Kristine Jimenez, Greg Koch, Josette La Hee, Laurel Larsen, Kung-Jen Liu, Lauren McCarthy, Ron Mossman, Jay Munyon, Danielle Ogurcak, Amy Omae, Oliva Pisani, Amanda Quillen, Adam Rosenblatt, Clifton Ruehl, Michelle Sanchez, Jeremy Stalker, Christina Stringer, Pamela Sullivan, Travis Thyberg, Matthew Toro, Cheng-Feng Tsai, Ania Wachnicka, Xavier Zapata

### **Research Experience for Undergraduates:**

Katya Cabeza, Jose Javier, Daniel Sarmiento

### **Undergraduate students:**

Yilmael Diaz, Roger Lopez, Greg Losada, Tatiana Marquez, Carrie Rebenack, Rachel Tennant, Mary White, James Wilson

**Pre-college teachers:**

Nicolas Oehm, Teresa Casal, Carlos Escobar, Catherine Laroche

**High school students:**

Brian Aguilar, Nia Brisbane, Sara Claro, Magaly Dacosta, Jorge Delase, Sebastian Diaz, Rebecca Fonseca, Ben Giraldo, Oscar Marti, Christopher Sanchez, Michael Fins, Christine Khan, Naureen Fashihi, Geovanna Kamel, Timothy Vega-Hidalgo, Giselle Castrillon, Sommer Carabuccia

**Technicians, programmers:**

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

***B. Partner Organizations***

- College of William & Mary: Collaborative Research; Personnel Exchanges
- Ecology and Environment, Inc.: Collaborative Research; Personnel Exchanges
- Everglades National Park: Collaborative Research; Personnel Exchanges
- Florida Gulf Coast University: Collaborative Research; Personnel Exchanges
- Harbor Branch Oceanographic Institute: Collaborative Research
- 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
- Rutgers University New Brunswick: Collaborative Research
- South Florida Water Management District: Financial Support; In-kind Support; Collaborative Research
- Texas A&M University Main Campus: Collaborative Research; Personnel Exchanges  
Collaborations with Stephen Davis.
- Texas A&M University at Galveston: Collaborative Research; Personnel Exchanges
- U.S. Department of the Interior: In-kind Support; Facilities; Collaborative Research
- Department of Interior U.S. Geological Survey: In-kind Support; Collaborative Research
- University of Alabama: Collaborative Research; Personnel Exchanges
- University of Colorado: Collaborative Research; Personnel Exchanges

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

### ***C. Other collaborators***

We have maintained important collaborative partnerships with 5 federal agencies (Everglades National Park, USGS, NOAA, EPA, and NASA-JPL) during the first year of the FCE II LTER Program. We also partner with 1 state agency (South Florida Water Management District), 1 NGO (National Audubon Society), and 15 other universities (Louisiana State University, College of William & Mary, and Texas A&M University through subcontracts).

Some examples of specific collaborations include:

- FCE Education and Outreach has maintained its relationships with Miami Dade County Public Schools (MDCPS) and Miami Dade College (MDC). Both MDCPS and MDC students receive frequent lectures and a variety of curriculum materials from our Education and Outreach Coordinator and frequently serve as the testing grounds for many of our products.
- FCE Education and Outreach collaborated with Science Approach (SA) LLC of Tucson, Arizona, Alison Whitmer (Georgetown University, SBC, MCR), SBC, MCR, and BES as participants in Coastlines GIS Institute.
- The CEMEX FEC Aggregate Quarry has partnered with FCE in an effort to restore an area adjacent to their oldest, inactive quarry. In May 2007 CEMEX and FCE recruited local high school students to plant native plants and saplings in a hardwood hammock, pineland, tree island, and wetland habitat.
- Everglades Digital Library
- The FCE Human Dimensions group is collaborating with Miami-Dade County's Department of Planning and Zoning to develop a methodology to incorporate historic zoning data into a GIS platform.
- The FCE Human Dimensions group is collaborating with the PIE, CAP and BES LTER sites to develop common approaches to studying the role of zoning in land use/land cover change.
- The FCE Human Dimensions group is collaborating with USGS and Everglades National Park to develop and refine the Everglades Portfolio Model. USGS, is cooperating with Everglades National Park, the University of Pennsylvania, Florida International

University, and Florida Atlantic University, to develop the Ecosystem Portfolio Model (EPM). The EPM is a Geographic Information System-based multi-criteria decision support tool that evaluates land use plans in terms of ecologic values, land market prices, and community quality-of-life metrics in Miami-Dade (as a pilot area).

- Joe Boyer collaborated 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. This 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 started this fall on the aquatic component at 4 sites in FCE during wet and dry season.
- Joe Boyer collaborated with Ryan Penton at Michigan State University to sample marine sediments in Florida Bay for metagenomic profile using massively-parallel, 454-based tag sequencing strategy. Preliminary analysis suggests that FL10 is drastically different from 9 and 11. Looking at the database, it seems like FL10 has much lower DOC and is a more refractory site. The proportion of observed OTUs and Chao1 ratios indicate that FL9,10, and 11 are all relatively phylum poor in contrast with the richest communities observed at barrow canyon (Alaskan maritime), Juan de Fuca (Pacific) and Cascadia basin (Pacific).

## **II. ACTIVITIES AND FINDINGS**

### ***A. Research and Education Activities***

The second phase of Florida Coastal Everglades (FCE) research (FCE II) focuses on understanding how dissolved organic matter (DOM) from upstream oligotrophic marshes interacts with a marine source of phosphorus, the limiting nutrient, to control estuarine productivity in the estuarine ecotone. We also now incorporate a socio-ecological theme 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 5 working groups (Primary Production, Organic Matter Dynamics, Biogeochemical Cycling, Trophic Dynamics and Community Structure, Hydrology) and 3 cross-cutting themes (Human Dimensions, Climate and Disturbance, Modelling and Synthesis). We include summaries of the second year of research by FCE II working groups, cross-cutting theme groups, education, and information management activities below.

## 1. Primary Production

### *Phytoplankton*

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

### *Periphyton*

As it is a major contributor to NPP in this ecosystem, we measure periphyton biomass, productivity composition at FCE LTER sites. Long-term trends at FCE sites are interpreted in relation to those gathered from joint large-scale landscape surveys in the Everglades and Florida Bay and field and laboratory experiments. These data are being combined into models that predict changes in periphyton biomass, composition and nutrient content from hydrologic, water chemistry and other abiotic and biotic variables. Effects of variability in periphyton abundance, composition and quality on consumer standing stocks and composition continue to be examined using these surveys and linked experimental work in collaboration with Joel Trexler and the Trophic Dynamics group. We are also pursuing an understanding of mechanistic linkages between periphyton attributes to variability in hydrology, light, nutrients and vegetation through field and lab experiments, conducted mainly by FCE graduate students. In particular, manipulations of periphyton in laboratory chemostats have revealed mechanistic triggers for the pervasive inverse relationship of periphyton production to nutrient availability. Species-based models that predict salinity, nutrient availability and habitat structure are being used to environmentally calibrate sediment cores from the ecotone and Florida Bay so that modern fluctuations apparent in FCE data can be placed in a long-term context. Through a joint DOE-NCCR project, we have been manipulating periphyton and plant production to determine controls on CO<sub>2</sub> sequestration or evasion in peat and marl-forming environments, and these findings will be interpreted with respect to atmospheric eddy covariance data obtained from our two marsh flux towers. Our 2006 ILTER supplement supported comparisons of periphyton and consumer standing stocks and composition between FCE and karstic wetlands of the Yucatan peninsula and Belize. Visits supported by NSF in 2006-07 were supplemented by FIU-SERC foundation support in 2007-08, so we now have two years of wet and dry season data from these sites.

### *Sawgrass*

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

### *Seagrass ecosystems*

We continue to assess primary production of the seagrass ecosystems in the FCE-LTER domain every 2 months. On these trips, we have been measuring seagrass leaf productivity using standard hole punch methods and periphyton productivity as described above since 2000. This year, we initiated measurements of below-ground production of seagrasses, as well as macroalgal production.



### *Mangrove Ecosystems*

We continue monitoring mangrove litter dynamics in three mangrove sites (SRS4, SRS5, SRS6) along the freshwater-estuarine fertility gradient of Shark River and one mangrove site (TsPh8) at Taylor River. We did not continue the study at TsPh8 after December 2006. Litterfall was collected in 0.25 m<sup>2</sup> wooden baskets supported approximately 1.5 m aboveground, and the bottom of each basket was constructed of fiberglass screening (1 mm mesh). Litterfall has been collected monthly since January 2001. In each mangrove site ten litter baskets were randomly placed in two 20 by 20 m permanent plots (5 baskets per plot). Plant material within each basket is dried for 72 h at 60 °C. Material is separated into leaves, fruits, flowers, stipules, wood, and miscellaneous and weighed to within 0.1 g. Litter fall rates of each component is expressed in g m<sup>2</sup> day<sup>-1</sup>.

In addition to our routine measurements of primary productivity at the mangrove-dominated LTER sites, this year we initiated a carbonate sediment amendment experiment to understand the effects that sediment deposition associated with hurricanes has on mangrove primary production. Hurricanes Irene (1999) and Wilma (2005) deposited a significant layer of carbonate (bay-derived) sediment in the mangrove ecotone of our TS/Ph transect. Since this area is not well-flushed with daily tides, these deposits persist for extended periods and may affect long-term patterns in mangrove productivity. In Year 1 of FCE II, collaborators from TAMU, LSU, and FIU initiated a small-scale sediment amendment experiment to better understand how carbonate sediment deposition--a potential source of inorganic P--controls dwarf *R. mangle* productivity and biomass allocation. Specifically, we selected 6 tree clusters at the TS/Ph-6 ecotone site. Of those, half received sediment addition at the base of the tree. Sediment thickness was maintained at 3-4 cm--an average thickness measured from multiple cores taken near TS/Ph 8 (Figure 2). The remaining trees will serve as un-amended controls. We also began tracking track seedling growth in response to sediment deposition—through fertilization of seedlings— relative to control (un-amended) seedlings.

## **2. Organic Matter Dynamics**

### *Dissolved organic matter (DOM) studies*

The restoration of the Everglades may have a significant effect on DOM dynamics (and DOM-associated N and P), and thus, might affect plankton dynamics in Florida Bay. However, the existing data on DOM dynamics are still insufficient to clearly predict potential consequences based on restoration activities, and more research is needed, particularly on DOM sources and its bio- and photo-reactivity to be able to generate scientifically based, sound predictions of environmental effects of increased DOM loadings under a scenario of increased water delivery. We need to specifically address the questions of DOM source variations on spatial and temporal scales within the Greater Everglades, quantify specific source strengths, determine the bio- and photo-reactivity of DOM across the ecosystem, identify monitoring tools that will generate reliable data on DOM source and reactivity to be used in on-going modeling efforts, and ultimately assess the bioavailability of DOM of varying quality (and associated nutrients) by different marine planktonic organisms. More detailed information on DOM dynamics will allow, in conjunction with hydrological information and water delivery expectations for the restoration project, to estimate potential negative effects of DOM on plankton blooms and associated detrimental environmental conditions in the FCE. Thus, our long term goals within the FCE-

LTER DOM studies are to assess DOM dynamics on both spatial and temporal scales in the greater Everglades and to associate DOM composition to reactivity. These studies are primarily based on the application of optical parameters to characterize and determine environmental dynamics of DOM in the FCE and are discussed below in the ‘findings’ section. We have continued the monthly surveys of DOM optical properties (UV-Vis and fluorescence) with particular emphasis on Excitation Emission Matrices (EEM) in combination with parallel factor analysis (PARAFAC). Thus we have now completed a four year survey, and are processing the data. This activity is expected to continue throughout the LTER-2 period, generating an eight year long continuous database on DOM dynamics.

To better define DOM end-member components as defined by EEM-PARAFAC, we have analyzed biomass leachates from the main aquatic vegetation in the Everglades (sawgrass, spikerush, mangroves, periphyton and seagrass), soil leachates and surface waters and have determined their reactivity to solar and microbial exposure. Thus far we have been able to clearly distinguish between surface and ground water DOM, and are trying to determine the possible differences between oxic and anoxic groundwater DOM components. Compositional and reactivity differences between different biomass and soil leachates are also being determined.

Fluorescence properties of components with different molecular weight ranges were determined (both by size exclusion chromatography and by optical means) in order to better characterize the DOM across the Everglades. Preliminary results show larger molecular weights for soil derived DOM compared to biomass derived sources and both high and low molecular weight DON components, probably reflecting the presence of both proteins and peptides in the DOM pool.

Based on the successful application of EEM-PARAFAC in the FCE-LTER we applied our Everglades PARAFAC Model to the assessment of trace metals interaction with DOM as a means to assess metal transport and dynamics in the system. We studied the fluorescence quenching of DOM from several LTER sites with known differences in DOM composition and determined their reactivity with metals of concern for this ecosystem, such as Mercury ( $\text{Hg}^{2+}$ ) and Copper ( $\text{Cu}^{2+}$ ). The results describe a novel methodology to better assess the trace metal interactivity with specific DOM components (vs. bulk components).

Lastly, we have also conducted a series of collaborative, inter-LTER DOM characterization studies in order to assess DOM quality variations on larger spatial (climatic) scales. We are close to complete the analyses of six ultrafiltered DOM samples from the ARC, BNZ, NWT, KNZ, CWT and LUQ LTER sites using an extensive suite of advanced analytical techniques, in an attempt to characterize DOM composition for headwater streams across different North American biomes. One of these sites (CWT) was selected for a temporal variation study (monthly for one year) including sampling stations from watersheds subjected to different forest management strategies. Another site (BNZ) was selected for a collaborative project on DOM bioavailability. Preliminary findings on these projects are presented below.

#### *Particulate (POC) and soil organic matter*

We are continuing to work on better understanding of sources and fate of flocculent (floc) OM and particulate OM (POC), and on the preservation/degradation mechanisms of OM in soils from the Everglades. During FCE-1 we had concluded several such studies on POC dynamics in

Florida Bay and the Shark River as well as an assessment of sources and fate of OM in soils from Everglades freshwater marshes (SRS1 to 3 and TSPH2) and from Florida Bay. These studies have been published or are presently in preparation for publication. While we continue to wrap up similar studies on mangrove soils from the estuarine areas (SRS4-6 and TSPH6-7), we have also expanded our work on OM source characterization of ‘floc’. A seasonal study of floc and periphyton composition using biomarkers (lipid fingerprints) and pigments (chemotaxonomy) is presently underway and includes floc depth, in-situ density and respiration determinations. We will present results on these studies in next year’s FCE-LTER report.

Bacterial carbon sources in the estuarine regions of the FCE-LTER were assessed by studying spatial patterns of pelagic, seagrass epibiontic, and sediment surface bacteria carbon cycling in Florida Bay, a subtropical estuary with a recent history of seagrass loss and phytoplankton blooms. This study was conducted using a stable isotope approach. Bulk  $\delta^{13}\text{C}$  values were used to determine carbon sources in the estuary and compound-specific fatty acid  $\delta^{13}\text{C}$  values were used to determine the source of carbon to heterotrophic bacteria.

#### *Soil nutrients and organic matter*

We continue our long-term collection and analysis of soil samples along Everglades and Florida Bay transects to document responses to both short- and long-term drivers of hydrologic change. To date we have seen changes in soil structure and nutrient availability related to an acute storm event (Hurricane Wilma in 2005) that redistributed sediments along the lower portion of the Shark River Slough transect. The impacts of hydrologic changes driven by long-term press events (e.g., drought, freshwater diversion or addition, sea-level change), however, can only be determined through long-term analysis of changes in soil nutrients and organic matter. Our ongoing, eight-year data set is being used to identify long-term changes in soil nutrients and organic matter that are related to these hydrologic changes.

#### *Soil CO<sub>2</sub> fluxes at FCE LTER sites and Bocas del Toro, Panama*

As part of a LTER FCE supplement request, we received funds to initiate a new, cross-site project to investigate soil CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> fluxes in Panama and FCE LTER sites.

To date, we have recruited project collaborators of the FCE LTER and biologists from the Institute for Regional Conservation to develop baseline datasets on ecosystem structure, hydrology and bacterial and plant communities that typify the variability in wetland types within the Panama coastal peatland. Our products include one manuscript in preparation, and invited seminar presented in Bocas del Toro, Panama as part of the Smithsonian Tropical Research Institute’s Seminar series, oral presentation made at the Estuarine Research Federation meeting in Providence, RI entitled “Bacterial diversity, enzyme activities, and soil CO<sub>2</sub> flux along a soil P

gradient in a coastal peatland, Panama” and an anticipated NSF proposal submission for January 2009. Our greatest accomplishment resulting from LTER supplement support is a third place award in the Environmental Section of the Florida State Science Fair to our high school student that participated in and presented this work.

### **3. Biogeochemical Cycling**

#### *Baseline Water Quality*

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

#### *Microbial Dynamics*

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

#### *Microbial Metagenomics of Floc*

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

#### *Biogeochemical Cycling*

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

Sediment core flux studies - Beginning in January 2007, we initiated a set of experiments to quantify the vertical exchanges of nutrients (N and P) and DOC between the benthos and water column at various sites along Taylor River. During this first set of pilot incubations, we collected sediment/soil cores from two inland (TS/Ph 7 and Pond 1) and two bay sites (Little Madeira Bay east and west of Taylor River mouth). The surrounding of TS/Ph 7 is vegetated with dwarf mangrove. Both Little Madeira Bay sites were covered with seagrass (*Thalassia*

*testudinum*). These samplings have been repeated through the May 2008 sampling. Beginning in May 2007, we also began amending the water column (in a separate set of incubations) with 1  $\mu\text{M}$  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.  $\text{NO}_3+\text{NO}_2$ ,  $\text{NH}_4$ , SRP, and DOC samples were analyzed according to the methods described above.

#### **4. Trophic Dynamics and Community Structure**

We continued to sample fishes and macroinvertebrates between SRS3 and 4 to assess spatiotemporal dynamics in relation to hydrological conditions, which was started in 2004. Sampling was conducted via electrofishing and trapping at 10 locations in the wet, early dry, and dry seasons. We also started a new sampling effort targeting palaemonid shrimp along the entire Shark River Estuary from SRS 3 to downstream of SRS 6 to examine community composition and species replacement in relation to varying salinity regimes along the estuary. For this project, sampling thus far has been conducted in the dry season, and will be repeated in the wet season (September 2008). We obtained additional palaemonid shrimp samples for stable isotope analyses to assess the trophic placement of the different species.

We continued gathering fish and macroinvertebrate density estimates at SRS 2 and 3 and TS 2 and 3 to contribute to the growing FCE-LTER database on consumer density. Samples were collected in February, April, July, October, and December, similar to all past years of the project. We submitted updated versions of all of our data to the data manager; data on all field samples through July 2007 have been submitted and data files from October and December, 2007, and February and April 2008 are in the QA/QC process at this time. After working with Jennifer Rehage and Bill Loftus to evaluate sampling methods to quantify littoral-zone fish standing crops in the Shark River transect, we have decided to focus on use of a Dual frequency IDentification SONar (DIDSON) instrument to produce near-video quality streaming images of fishes (Moursund et al. 2003) in the channel of the Shark and Taylor River. Thanks to generous support by the Dean of FIU's College of Arts and Sciences, we took delivery of a DIDSON device on August and are in the process of evaluating its capabilities for use at our SRS and TS deep-water sites.

We initiated telemetry studies of four species in the Shark River Slough. Over the course of the year, we have placed 42 VR2 monitoring systems throughout the Shark River Slough (from all exits to the Gulf of Mexico upstream almost to SRS3) to create acoustic "gates" that allow us to determine when individual tagged animals are within range of a gate, their direction of travel, and their residence time within gates and areas between gates. We have completed range testing

of the monitors, which is approximately 800m, and developed a computer program to automate some of the data processing. To date, we have tagged 23 American alligators, eight bull sharks, seven snook and seven gar which represent two primarily freshwater taxa and two primarily marine taxa.

We completed our longline-based study of the factors influencing the distribution of juvenile bull sharks in the Shark River (Heithaus et al. in review) and completed the bulk of our work on trophic position of bull sharks. We also continued to collect samples for stable isotopic studies throughout the Shark River Slough have begun to analyze isotopic signatures of alligators, snook, and gar.

## **5. Hydrology**

The mangrove hydrology model, HYMAN, was used to quantify how changes in hydrology at the landscape level influenced the water and salt budgets in three mangrove forests along the Shark River estuary, Everglades. The monitored hydrological data of years 2003 to 2005 from the FCE-LTER program and National Park Service database were compiled as inputs to the HYMAN Model and compared to the observed pore water salinity in situ. Site-specific parameters were also calibrated for each study site (SRS4, 5, and 6).

Several projects started last year continued into this year. Two of these projects were conducted with funding from state and federal partners, the SFWMD and the USGS. The objectives of these projects were to provide estimates of nutrient concentrations in the groundwater beneath Florida Bay and the mangrove ecotone region of Shark Slough. Field work was conducted in September 2007 and March 2008 in Florida Bay and in September through December 2007 in Shark Slough. The Florida Bay sampling was conducted in conjunction with streaming resistivity surveys and flow-through <sup>222</sup>Rn concentrations conducted along transects across northeastern Florida Bay by the USGS.

Interactions between ecology, hydrology and nutrient studies continued on 3 tree islands and in the mangrove ecotone of Shark Slough. Transpiration measurements were measured on 36 trees on 3 tree islands in Shark Slough. In addition, half-hourly measurements of latent energy fluxes were measured at the eddy covariance tower at SRS6.

An REU student continued her work on digesting rock core samples following a series of sequential extractions for determinations of loosely adsorbed, carbonate bound, organic bound and total phosphorus. Rock core samples from depths of zero to 60 meters were collected. Cores exposed to fresh and brackish groundwater conditions analyzed to determine if there was an influence of groundwater chemistry on the amount of phosphorus in the rock.

A new project initiated this year was aimed at estimating the major water budget parameters in Taylor River. Groundwater wells were installed at TS/PH6. Those wells along with pre-existing wells at TS/PH3, TS/PH6b and TS/PH7b were sampled for major cations, anions, stable isotopes of oxygen and nutrients. In addition, a weather tower was installed at TS/PH-7b to provide estimates of rainfall and evapotranspiration. This project is being conducted by an M.S. student (Xavier Zapata) at FIU.

In addition to activities conducted at the FCE LTER, hydrology working group members initiated comparative studies at several of the Mexican ILTERs using NSF LTER supplemental funds to support cross-site collaborations. In March 2008, Drs. Rene Price (FIU) and Victor Rivera-Monroy (LSU) along with Ph.D. student Jeremy Stalker (FIU) collected surface water samples at Celestun Estuary, Yucatan, Mexico in conjunction with Jorge Herrera of CINVESTAV. The objective of that project was to use geochemical tracers to quantify groundwater inputs to the Celestun Estuary. Samples were analyzed for stable isotopes of oxygen and hydrogen, trace metals and dissolved and total concentrations of nutrients. An additional sampling is planned for October 2008, the wet season in the Yucatan. In July 2008, Dr. Mark Rains (USF) and undergraduate and graduate students from USF joined Francisco de Asís Silva Bátiz and Enrique Godínez Domínguez of the Universidad de Guadalajara to collect surface-water and groundwater samples from throughout and around the mangrove and lagoon in Barra de Navidad a RAMSAR site and part of the Ecosistemas Arrecifales del Pacifico program of the Mexican ILTER. Samples are being analyzed for dissolved constituents and stable isotopes. These data will be combined with previously-collected data and used to better constrain mass-balance mixing models that quantify the proportional contributions of freshwater and seawater to brackish water in mangroves and lagoons on the central Pacific coast of Mexico. A broader impact of this collaborative effort was to strengthened the relationship between Rains of USF and de Asís Silva Bátiz and Godínez Domínguez of the Universidad de Guadalajara, which had recently been formalized through the drafting and signing of a cooperative agreement to promote collaborative research, cross-training, and faculty and student exchanges.

## **6. Human Dimensions**

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

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

- Collaborating with Miami-Dade County's Department of Planning and Zoning to develop a methodology to incorporate historic zoning data into a GIS platform

- Acquiring and cleaning up zoning data for southern Dade-County. The period we are analyzing is from 1992 through 2008. We have spent the past year closely collaborating with the county to identify various discrepancies and errors in the data, and then incorporate this data into GIS. All zoning data is being geo-referenced to the parcel.
- Incorporating other data into our GIS parcel-level analyses. These include parcel boundaries (and changing boundaries), assessment and sale amounts over time, comprehensive plan classification, land use zoning, and census-derived socioeconomic data.
- Collaborating with the PIE, CAP and BES LTER sites to develop common approaches to studying the role of zoning in land use/land cover change. In this regard, we are acquiring high-resolution remotely-sensed QuickBird imagery to help us quantify green vegetation and classify prevailing land use/covers (including lawns) and derive indices of landscape structure for the study site. FCE HD members are working with other LTER sites to employ common approaches to analyze this data (using ECognition).
- Collaborating with USGS and Everglades National Park to develop and refine the Everglades Portfolio Model. USGS, is cooperating with Everglades National Park, the University of Pennsylvania, Florida International University, and Florida Atlantic University, to develop the Ecosystem Portfolio Model (EPM). The EPM is a Geographic Information System-based multi-criteria decision support tool that evaluates land use plans in terms of ecologic values, land market prices, and community quality-of-life metrics in Miami-Dade (as a pilot area).

Our second (and related) project examines the role of hurricanes in landuse/cover change in southern Miami-Dade County. For this project, we are examining how Hurricane Andrew, in 1992, acted as a “pulse” event that reconfigured the landscape in heterogeneous ways. This heterogeneity, we hypothesize, stems from ongoing press processes that produces uneven resilience to pulse events among different communities. For this project, we are building upon the conceptual model developed for the LTER Decadal Research Plan. Activities associated with this second project include:

- Collaboration and writing with FCE ecological scientists to develop a theoretical framework that incorporates the regime change and resilience literature (from ecology) and the disaster, vulnerability, and environmental justice literatures (from the social sciences). We held a week-long workshop in May 2008 to investigate the commonalities of these literatures.
- Incorporation of census and land use change data into GIS for three separate communities within the study site (Homestead, Florida City, and South Miami Heights).
- Analyzing the response differences within these communities to Hurricane Andrew. Variables we are analyzing include changes in demographics (ethnicity/race, income, home ownership variables), land use, and community character and quality of life issues.



- Analyzing differences within these communities that contributed to their resilience (or lack of) to Hurricane Andrew. These variables include type and degree of homeowner insurance (strongly correlated to ethnicity), home ownership variables, income and community governance.

Analyzing the role of hurricane evaluation processes as a variable (including differential communication of threat information and differential constraints on communities' ability to respond in ways that sustain themselves) in the restructuring of the landscape. Hurricane threat communication and consequent survival behavior provides an opportunity to study information feedback involved in human-nature interaction. Two NSF-funded projects with Hugh Gladwin, FCE HD collaborator, as one of the PIs will begin in January 2009 to study hurricane forecast communication processes, evacuation behavior, and agent-based modeling of collective response.

## 7. Climate and Disturbance

The Climate and Disturbance Working Group is operating in its second year in the FCE organizational structure. During the 2008 ASM, we presented our immediate research goals for the next year. Presented below are the main activities for the working group ranging from paleo studies to research within the modern FCE system.

### *Studies of long-term climate effects on freshwater marshes in SRS*

Cores from marsh transects (slough – ridge) in Shark Slough are being analyzed for macrofossils and radiometric dating to determine long-term changes in accretion and vegetation in relation to past climate changes. Research includes examining millennial changes (last 5KYBP to present) in the context of major paleo-climate proxies related to rainfall patterns (ITCZ, NAO, etc.) and a focus on the past 200 years in the context of multiple proxies that include paleo-climate (NAO, ITCZ, etc.), climate records (mainly rainfall), and known water management events (e.g., Tamiami Trail construction).

### *Studies of stable isotopic indices of waterlogging stress*

We are obtaining mesocosm- and field-based measurements of species-specific changes in  $\delta^{13}\text{C}$  signatures as a proxy for waterlogging stress. A second objective of this study is to apply these relationships in conjunction with soil macrofossil studies to infer past waterlogging stress from the isotopic signatures of dated plant macrofossils (mainly seeds). Our studies have been conducted through a collaboration with Drs. Susan Newman and Shi Li Miao (South Florida Water Management District), the Lead PIs of mesocosm studies examining different hydrologic regimes on the growth of several marsh, slough and tree island species.

### *Response of carbon dioxide, water, and energy exchange of peat and marl wetlands*

Two eddy covariance towers measuring  $\text{CO}_2$ , water, and energy fluxes have been added to the FCE LTER site. The goal of this research is to determine the  $\text{CO}_2$  balance of Everglades marshes while also evaluating the relative magnitudes of biotic and abiotic  $\text{CO}_2$  exchange processes in response to hydroperiod. One tower located at Ts/Ph 1b, a short-hydroperiod marsh, has been operational since 12/07 and the second tower at SRS 2, a long-hydroperiod marsh, has been operational since 6/08. Monthly chamber measurements are made at each site

as an additional check on ecosystem CO<sub>2</sub> exchange rates and to quantify the role of periphyton in driving these rates.

#### *Mangrove forest disturbance*

We are still analyzing data to determine mangrove canopy recovery in several forest locations impacted by hurricane Wilma (October 2005); these locations include Shark, Broad, and Harney Rivers. On December 2004 permanent transects of variable length were established (300-700 m) in these study sites. Sampling points were selected at variable distances along each transect, with locations pre-determined to sample canopy variation evident using previous acquired LIDAR data from the area. At each point hemispherical photography was used to determine leaf area index (LAI) changes. Sampling dates include December 2005, and February 2008, two months and twenty-eight months after hurricane impact, respectively. This information will be used to estimate the relationship between LAI and leaf productivity as forest canopy recovers from defoliation. We plan to use this relationship to calibrate individual base-models currently being used to evaluate mangrove community dynamics (e.g species composition and density).

#### *Pine rock land response to Hurricane Katrina*

In order to better predict how future sea-level rise will affect coastal forest, we have been studying the effects of Hurricane Wilma's storm surge on Big Pine Key. A LIDAR study funded by DOE NICCR being contacted is presently underway (Zhang and Ross) and this summer we recovered 20 tree discs from slash pine that were killed in the event. In September, we will travel to the WSL in Switzerland to measure the tree-rings from these samples with Paolo Cherbuni.

## **8. Modeling and Synthesis**

#### *Overview*

Modeling and synthesis activities address a range of physical and biological dynamics spanning many temporal scales (hourly to millennial), spatial scales (meters to whole-Everglades) and processes or variables of interest (vegetation, biogeochemistry, peat development, etc.). Because these activities integrate within other working group activities, they are unavoidably described to some degree elsewhere in this report. To avoid repeating information, this overview attempts to emphasize only the modeling and synthesis aspects (e.g., numerical or statistical modeling) components rather than the underlying empirical studies to which they are linked.

#### *Everglades Landscape Model (ELM)*

A new fine-scale (500 m grid resolution) application of the Everglades Landscape Model (ELM) has been developed for the regional domain ranging from the northern freshwater Everglades to the border of Florida Bay and Gulf of Mexico, for multi-decadal simulation scenarios. The calibrated/validated application is available to support other research and modeling activities investigating the spatio-temporal ecological dynamics in and around the freshwater-estuarine ecotone. Output variables include water depths and flows, water column and soil phosphorus, water column chloride, soil accretion, and periphyton and macrophyte distributions.

#### *Mangrove Hydrology (HYMAN)*

Hydrologic processes (e.g., inundation frequency) and salinity are important regulators controlling the growth and productivity of mangrove forests in South Florida. To quantify how changes in landscape-level hydrology will influence pore water salinity, the hydrology model-

HYMAN- was applied to three sites with distinct tidal forcings along the Shark River (SRS4, SRS-5, SRS-6) estuary in the Everglades National Park. HYMAN model uses mass balance equation to determine daily water and salt budgets as the combined effects of inputs from precipitation and tide, and losses through evapotranspiration, seepage, and runoff. Statistical analysis of the surface water depths in each forest was conducted using data from 2003-2005 to develop relations as a function of channel water elevations. Other model inputs (evapotranspiration and seepage) were estimated from field data. Due to the varying hydrologic forcings in each site, this study tested the applicability of HYMAN to more general coastal wetlands settings.

#### *Dynamic P Budgets (Ribbon model)*

We have completed a dual approach of constructing empirical P budgets and a semi-mechanistic dynamic model (that follows from empirical budgets) to understand the key processing controlling P cycling along the freshwater transect of FCE LTER sites in Shark Slough. The dynamic model (coded in STELLA modeling software) simulates P standing stocks ( $\text{g P m}^{-2}$ ) and net P fluxes for the major ecosystem components (i.e., water, algal, plant, consumer, and detrital pools) for three conceptual landscape “ribbons” encompassing sites SRS-1, -2 and -3. These models were calibrated with site-specific FCE data (and data from related studies) for sawgrass-dominated (shallow water) and spikerush-dominated (deeper water) plant communities. We determined model sensitivity of P dynamics (e.g., long-term P accumulation and net P flux through the system) to slight changes in individual model parameters (e.g., turnover rates of P in periphyton), initial conditions (e.g., initial standing stocks of periphyton), and environmental conditions (e.g., annual average water depths).

#### *Shark Slough Spatially explicit Carbon Accumulation and Transport (Shark SCAT)*

We are continuing to develop a simulation model of vegetation change and soil accretion in historic Shark Slough (from WCA-3B through the freshwater transect of the FCE LTER). The 3-D model (10-m spatial resolution) is a spatially explicit extension of previous 1-D models that aim to understand long-term dynamics of soil accretion and plant community and productivity and the feedbacks that govern these dynamics under changing climate or water management effects (Rybczyk et al., 1998; Saunders, 2003; Nungesser, 2003). The model is further refined for the Everglades ridge-and-slough landscape in that it also includes transport of water-borne mineral and organic matter among habitats as mediated by water flow, a process believed to underlie spatial patterning and microtopography of the historic ridge-and-slough system. Process-level data from FCE LTER sampling (e.g., plant productivity, SOM decomposition, nutrient cycling, water velocity-vegetation relationships) and data from ongoing paleo-ecological studies associated with freshwater FCE LTER research sites are being used to calibrate and test the model.

#### *Aquatic consumer models*

Three types of modeling activities are underway for aquatic consumers: community simulation models; ecological forecasting models; and path analytical models. Each project takes advantage of the FCE LTER transects. Don DeAngelis and colleagues are developing spatially referenced food web models that simulate a 5-trophic level community in a dynamic landscape. This model focuses on a trophic level of omnivorous consumers representing five life histories with different dispersal biology and drought survival strategies. These are based on life histories found in Everglades aquatic consumers. This model currently generates spatially referenced community composition created by sorting of a regional species pool that is consistent with patterns observed in nature. Our goal for this model is to generate hypotheses to be tested with field data, and to conduct simulated sampling studies to evaluate the ability of realistic sampling effort to

reveal underlying patterns, in this case, that we place in the data. Charles Goss is developing forecasting models for use in evaluating management of the Everglades. This work served two purposes, first to generate results of immediate use by environmental managers, but also to improve the sophistication of statistical analyses of our time series data. Finally, Brooke Sargeant is using a path analytical model to examine potential interactions of hydrological disturbance and resource variation on food-web dynamics in the Everglades. Path analytical and structural equation models are natural approaches to test hypotheses about cascading effects of environmental factors in food webs. However, these methods are not often applied because of the amount of data and because of the analytical sophistication required to use them.

#### *Florida Bay Seagrass Community Model Development*

A sector-based, coupled seagrass-phytoplankton model has been developed during 2007-8 and is being parameterized based on field experiments, bioassays and monitoring data. The model has been calibrated for several bay regions with seagrass, phytoplankton and nutrient cycling data, light and residence time and other physical parameters specific to each sector.

The SAV (submersed aquatic vegetation) portion of the model currently models *Thalassia* and *Halodule* interactively and has been updated to include the growth dynamics and recruitment of *Ruppia*, a low salinity species expected to expand with additional freshwater inputs to northern Florida Bay. The *Ruppia* module is being parameterized with data from field and laboratory experiments on seed germination rates and salinity tolerance. Data show that salinity is a major control on the ability of *Ruppia* seeds to germinate in Florida Bay (Figure 2). Although adult plants tolerate high salinity well, seeds rarely germinate above 30 PSU salinity (Koch 2008), potentially explaining the restricted distribution of *Ruppia* in the bay. The seagrass model is being refined to include this recruitment mechanism so that it can be used to project the ecosystem responses restoration planning. It is anticipated that the *Ruppia* and phytoplankton modules will be fully integrated into the primary ecological model and calibrated by late 2008.

## **9. Information Management**

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. With last year's primary focus being the FCE web site (<http://fcelter.fiu.edu>) redesign, this year's focus has been on FCE web site enhancement. The web site 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 that the FCE information management team continue to improve existing web pages and expand the web site capabilities. The second phase of FCE research (FCE II) entered its second year and several new FCEII working and cross-cutting theme groups have started to work with the FCE information management team on ideas about how to present their research and data on the FCE web site. Two groups in particular, Modeling & Synthesis and Human Dimensions, have plans for dynamic web interfaces that may allow the web user to enter their own set of parameters into one of the FCE models and see the real-time model results or possibly allow users to see and listen to human interest interviews about living in the South Florida area from the early developmental stages of the area to the present day.

Work continues on a web-based query interface tool linked to FCE physical and chemical research results stored in the FCE Oracle10g database. The tool is expected to facilitate data discovery and data access for FCE and LTER network scientists. Over 4 million physical and chemical data values from outside agencies, such as Everglades National Park, South Florida Water Management District and the USGS, have also been added to the FCE Oracle10g database to enhance data discovery and access of important ‘support’ data from outside agencies.

The FCE Information Management (IM) team continues to provide total support of the site and network science by: 1) collecting and archiving both FCE and historical Everglades data, 2) providing comprehensive metadata for data interpretation and analysis, 3) designing and implementing tools that facilitate data management, data discovery and data access and 4) contributing to LTER network informatics activities.

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

The FCE information manager, Linda Powell, continues to serve as an IM representative on the LTER Network Information Systems Advisory Committee (NISAC). She will be attending the annual LTER Information Management Committee meeting held in Albuquerque, New Mexico in September 2008.

## **10. Education and Outreach**

In 2007, the primary objective for FCE LTER Education and Outreach was to address the strategic initiatives and goals of *The Decadal Plan for LTER*. Our plan for addressing the *Decadal Plan* was to expand the scope of our existing programs to include other LTER sites, promote our work to an international community, establish community partnerships, and to continue to support educational programs that promote scientific literacy.

There are several approaches that we took towards accomplishing these goals:

### Education:

- Collaborate with SBC, MCR, and BES as participants in *Coastlines GIS Institute*
- Use our existing programs to integrate each of these initiatives.

### Outreach:

- Forge a relationship with the international mining and aggregate producer CEMEX
- Initiate and strengthen relationships with other Universities and Departments at Florida International University (FIU).
- Promote scientific literacy on both a local and international level.

### *Coastlines*

The most prominent accomplishment for FCE Education & Outreach is our partnership with Science Approach (SA), LLC of Tucson, Arizona and Alison Whitmer (SBC & MCR).

Through an NSF *Information Technologies for Students and Teachers (iTEST)* grant (award # 0737706) we worked with SA to provide teachers with professional development and instruction that would help them to incorporate GIS as part of their science and technology curriculum. The resulting *Coastlines Summer Institute* will take place over three consecutive summers, at alternating LTER sites. The first summer institute was held at FCE and provided professional development for 50 teachers. In all, 28 local teachers and 6 taken from a national search completed the program. The program included 24 high school and 10 middle school teachers, and each participant received 24 hours of online training; 80 hours of face-to-face professional development; and 16 hours of implementation support.

In a series of eight, online training sessions, teacher participants received: background on LTER and an introduction to its core areas of research; instruction specifically tailored to FCE research; and an introduction to MyWorld GIS software. In addition, each teacher received a 10-seat license for the MyWorld GIS software and tech support for its installation and use.

During the two week summer institute in Miami, SA staff provided 40 hours of professional development in the use of MyWorld software and guided participants on two field trips to Everglades National Park where they were given the opportunity to collect data for GIS analysis. On the second field trip, teachers worked directly with students and tested the GIS activities that they developed the previous week. In 2009, *Coastlines II* will be hosted by BES and Georgetown University where a limited number of *Coastlines I* participants will be given the opportunity to continue to develop and adapt their projects at *Coastlines II* and again in 2010 at *Coastlines III* hosted by MCR & SBC.

### *Research Experience for Secondary Students (RESSt)*

Through *Coastlines* we also provided research experience internships to both secondary and middle school students. In all, 26 high school and 5 middle school students participated in *Coastlines* and received an intensive, 40 hours, of face to face instruction in: Everglades field data collection; GPS and GIS instruction; data analysis. Those students also met with two of our researchers who discussed how they use GIS in their LTER research.

In addition to the *Coastlines RESSt* internships, we have continued to provide ongoing support for traditional *RESSt* internships and placed fourteen students with LTER researchers in 2007. Five of those students were second year interns and four were recruited directly from the *Coastlines RESSt* program.

The RESSt program has continued the success from previous years and two interns competed in the 54<sup>th</sup> *South Florida Regional Science and Engineering Fair*. Second year intern Ben Giraldo received *Superior* in the *Environmental* division and first year intern, Michael Fins, received *Superior* in the *Zoology* division. Both students advanced to the 54<sup>th</sup> *State Science and Engineering Fair of Florida*, where Ben Giraldo received *Third Place* in the *Environmental*

division. In addition, both Ben and Michael presented posters at our annual ASM meeting, and also await the results for the posters they submitted to the American Statistical Association.

#### *Research Experience for Middle Schools (REMS)*

In March 2007, Nia Brisbane, former *RESSt* intern, initiated our *Research Experience for Middle School Students (REMS)* by visiting a local middle school. Nia used her award-winning science fair project to develop an interactive presentation entitled “*Mission: Everglades Restoration*” based on the *Mission: Impossible* theme. During the presentation Nia was role-playing a special agent investigating the effects of Everglades restoration, presented her results, and led a hands-on lab activity sorting, and collecting data from sawgrass seeds with over 150 students.

As an extension to *REMS*, five seats were reserved in the *Coastlines Institute* for middle school students. Later this year *RESSt* and *REMS* interns will lead an activity and will introduce other middle school students to GIS technology.

#### *Research Experience for Teachers (RET) and International LTER*

Our RET program provided an opportunity for two teachers to develop hands on activities for use in the classroom. The first RET completed his project during the summer of 2006 and his accomplishments are described in our previous annual report. Our second RET, Teresa Casal, continued working on her project throughout the school year. Working closely with our Data Manager, Teresa developed a series of investigative modules that directs students through the development and execution of a science fair project. The modules also incorporate the downloading, use, and analysis of FCE datasets.

Teresa presented the initial draft and limited release at the *2007 Annual Meeting of the Miami Dade County Science Teachers Association*. Later, in May 2007, Teresa presented her work to Miami Dade County Public School (MDCPS) district personnel and has been working to incorporate the modules in two newly developed courses: *Integrated Science* and a *Scientific Research* class. In a meeting with Colleen Del Terzo, Administrative Director for Science Education, they discussed how these modules could improve participation and quality of projects at the district science fair.

The full release of the project is expected shortly. Teresa is currently adapting the modules to incorporate changes made in the new FCE webpage. She will also add material on field research that was gathered on her first field adventure to the Everglades’ Taylor and Shark River Sloughs with FCE and Mex LTER scientist Victor Monroy.

#### *Research Experience for Undergraduates (REU)*

During the summer of 2008 Katya Cabeza worked as an REU with Evelyn Gaiser, Bill Anderson and Colin Saunders. Her work uses a traditional approach to isolating phytoliths through different types of acid digestions of live tissues in sawgrass and many other species (wet prairie, slough and some tree species). Katya is also working on phytolith analysis of one core sample and will compare it with macrofossil and biomarker profiles found within the core and plans to finish before the fall.

Our second REU was Jose Javier, an undergraduate student in the Department of Earth Sciences. Jose's project examined the effects of wildfires on the magnetic properties of soils from the Cape Sable seaside sparrow habitat in the southern Everglades. In his experiment, he identified major magnetic minerals within the soils and results indicate a weak correlation between burn frequency and the concentration iron oxyhydroxide minerals.

Although Jose continues to work on the project, initial results indicate a major decrease to complete removal of iron oxyhydroxides within shallow and surface samples whereas concentrations tend to increase with depth. It appears that iron oxyhydroxides are nearly replaced by magnetite, which indicates a reduced phase, within the surface/shallow samples. Since phosphorous is strongly absorbed onto iron oxyhydroxides, these results may have important implications for the role of fires in the phosphorous cycle. Jose and his mentors plan to present their result at the American Geophysical Union meeting and to begin preparing a manuscript for publication.

The third REU, Daniel Sarmiento, assisted Jose Fuentes with: field work evaluating the physiological response of mangroves to storm events; maintenance and calibration of flux tower instruments, and several leaf-level cuvette experiments. In the first experiment, he examined the influence of nutrient concentration on carboxylation and transpiration, in red mangrove leaves found along the salinity gradient of the Taylor River. The results will be included in a manuscript currently in preparation by Kendra Dowell. In a second experiment, Daniel participated in the design and execution of a series of soil respiration studies. This study was conducted at the tower site and will supplement the SRS 6 dataset. The results of this experiment will improve our understanding of the relationship between soil respiration and its contribution to the carbon budget of the mangrove ecosystem. Daniel is also analyzing the flux tower data and will use the data to generate figures that describe post-hurricane responses of the mangrove forest. Preliminary results indicate a significant decrease in carbon assimilation rates and a minimal recovery time following storm events.

In other work, Daniel discovered that increasing soil respiration rates have a significant influence over the decreasing carbon fluxes observe in the initial respiration studies. These results will improve our understanding of the influence of atmospheric stability regimes on carbon fluxes throughout the canopy. He continues to observe the temporal effects of energy partitioning by the forest.

## ***B. Findings***

### **1. Primary Production**

#### *Phytoplankton*

PAM fluorescence data was used to describe the relative abundance and community composition of the phytoplankton communities of the FCE domain. The Shark Slough transect had a plankton community with greater brown algae biomass component than cyanobacteria or green algae. Phytoplankton biomass decreases from freshwater to the estuary (chlorophyll a). Not all phytoplankton contributed equally to primary productivity; greater productivity was found in



cyanobacteria fraction (measured by electron transport rate). There was also some evidence that PP increases from marsh to estuary.

There were some similarities along the Taylor Slough transect, where there also was greater brown algae biomass component than cyanobacteria or green algae. In contrast to the Shark Slough transect, we found a plankton biomass peak at the ecotone between the estuary and the freshwater everglades (corresponding to site TS3). However, there was no significant spatial pattern along the transect in primary productivity.

We have identified a long-term pattern in phytoplankton community biomass and productivity in the domain of the FCE-LTER. Primary productivity has declined overall beginning fall of 2005, even though biomass has increased during the same period at most sites. Our interpretation of this is that the extremely active 2005 hurricane season had a remarkable stimulatory effect on primary productivity in the plankton community.

### *Periphyton*

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<sup>-2</sup> in wet biovolume, 210 g m<sup>-2</sup> in dry mass and 60 g m<sup>-2</sup> 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<sup>-2</sup> yr<sup>-1</sup> vs. 1400 g m<sup>-2</sup> yr<sup>-1</sup>, respectively). Within the SRS transect, the highest rates of periphyton production occurred during the wet season of each year, with values being highest in the central slough (SRS 2, 3) and lowest at the SRS 1a and b, close to the Tamiami Canal. Movement of this site in 2005 and 2006 to areas further from the S-12 water delivery structures dampened this trend. There was a general negative relationship between periphyton production and phosphorus availability, a trend reported extensively in this study and throughout the Everglades (Gaiser et al., 2006). Within the TS transect, periphyton production is highly variable, with highest rates occurring just after seasonal inundation of previously dry mat (Iwaniec et al., 2006). The relationship of periphyton production to P availability along this transect is positive, but the gradient was within the natural range of variation exhibited in the Everglades rather than reflecting excess P income that instigates the disintegration of the mat matrix (Gaiser et al., 2005). Epiphyte accumulation rates in Florida Bay were lower than those for the marsh. Rates are significantly higher at TS/Ph-11 than TS/Ph-9 and 10 at all times of the year and these epiphytes contain a higher concentration of phosphorus than those at the two upstream sites. Compositional differences in the epiphytic diatom flora were also pronounced among the three Florida Bay sites and were related to gradients in salinity and phosphorus availability (Frankovich et al., 2006).

Collaborative mapping efforts to determine landscape scale distribution of periphyton in the Everglades are showing similar trends in production, relative to water quality, salinity and hydrologic gradients in the system. These relationships have been modeled and are being used to indicate ecosystem status, using an assessment approach that accounts for climate-driven inter- and intra-annual variability and builds upon those used for other sensitive organisms in this system (Gaiser et al., 2008). One exciting result of these large-scale mapping surveys has been the appearance of elevated periphyton phosphorus values throughout the ecotone, lending support to FCE hypotheses that coastal sources of phosphorus impact not just the estuaries but

the adjacent marshes, as well, and enabling us to evaluate the seasonality of this response in a rapidly responding community. The cascading influence of periphyton productivity and composition on consumer dynamics were examined in a path analysis using data from these surveys (Seargent et al., Submitted) and manipulative experiments (Ruehl et al., Submitted).

FCE graduate student David Iwaniec successfully defended a master's thesis in June 2008 that examined, through the use of laboratory chemostats, the triggers of periphyton mat disintegration (Iwaniec 2008). Very low levels of phosphorus initiated changes in system respiration which triggered disintegration at rates that were slower when nitrogen was present in sufficient quantities. FCE graduate student Jay Munyon received funding from the Everglades Foundation in 2008 to continue these experiments to determine changes in the microbial community that result in these functional and structural shifts.

FCE graduate student Ania Wachnicka has completed two complex predictive models that link diatom distribution in the Everglades to water quality (TN, TP, TOC), salinity and habitat structure in the southern estuaries, lakes and Florida Bay. All of the models produce estimates with very low error, cross-validated with survey data from adjacent Biscayne Coastal Wetlands and Bay. She is applying these models to predict past variability from 6 chronologically-calibrated sediment cores from Florida and Biscayne Bays to place variability detected in FCE data in a long-term context. Predictions are being incorporated into larger modeling efforts to estimate the freshwater flows that would be necessary to restore coastal habitat to pre-drainage conditions, critical to the "Grand Experiment" driving FCE II research.

FCE graduate student Josette La Hée has completed two years of wet and dry season sampling in karstic wetlands of Belize and the Yucatan peninsula, in conjunction with the 2006 ILTER supplement. She received additional support from the FIU Latin-American Caribbean Foundation in 2007 to extend this work to similar wetlands in Jamaica. Collectively these wetlands have been shown to support similar standing stocks of periphyton to the Everglades (mean biovolume and mass across sites was 3200 ml m<sup>-2</sup>; 80 g AFDM m<sup>-2</sup>) and the same negative relationship between mass and phosphorus availability (R<sup>2</sup>=0.45). Taxa thought to be endemic to the Everglades are common in these wetlands, enabling cross-site extensions of species-based modeling work described above.

### *Sawgrass*

Along the Shark River Slough transect, *Cladium* produces about 400-700 g dw m<sup>-2</sup> y<sup>-1</sup> and peaks in the downstream marsh site (SRS3) adjacent to the mangrove ecotone. Notably, we found an inverse relationship between *Cladium* productivity and several hydrologic variables, including hydroperiod, mean annual water depth, and depth-days (a hybrid variable that combines the two). We also found that other plant species—primarily *Eleocharis*—increase their density as sawgrass ANPP declines (Childers et al. 2006). Along the Taylor Slough/Panhandle transect, *Cladium* production is lower than in the SRS transect (250-400 g dw m<sup>-2</sup> y<sup>-1</sup>), but although plants are smaller, culm density is higher than for plants in the SRS transect. The stations are similar in composition to the upstream portions of SRS, being dominated by *Cladium* and periphyton, but because they dry more frequently and for a longer duration, they are dominated marl rather than peat soils. Differences in *Cladium* structure and productivity are perhaps due to this difference in soil type and hydrology. *Cladium* production has been consistently and significantly higher at the

ecotone sites (TS/Ph-3 and 6) than upstream sites (TS-Ph 1, 2), although 8 years of data show a trend of decreasing productivity, perhaps due to a transition from relatively wet to relatively dry years during this time.

### *Seagrass ecosystems*

Biomass, net primary productivity (NPP), foliar elemental content, and demography of *Thalassia testudinum* was monitored in populations from five sites across Florida Bay beginning in January 2001. Sites were selected to represent the gradient in phosphorus (P) availability and salinity variability across the bay. Aboveground biomass and NPP of *T. testudinum* were determined 5 - 6 times annually. Ramet demography, belowground biomass, and belowground NPP were assessed from a single destructive harvest at each site and ramet cohorts were estimated from leaf scars, scaled by site-specific annual leaf production rates. Biomass, relative growth rate (RGR), and overall NPP were strongly increased by P availability. Additionally, there was a positive relationship between P availability and the ratio of photosynthetic to non-photosynthetic biomass suggesting that *T. testudinum* invests in aboveground biomass relative to the variability of P. Population turnover rates increased with P availability, evident in positive correlations of recruitment and mortality rates with P availability. Departures from seasonally modeled estimates of RGR were found to be influenced by salinity, which depressed RGR when below 20 psu. Freshwater management in the headwaters of Florida Bay will alter salinity and nutrient climates. It is becoming clear that such changes will affect *T. testudinum*, with likely feedbacks on ecosystem structure, function, and habitat quality. The spatial pattern in seagrass primary productivity and P availability suggest enhanced P availability and primary productivity at the seagrass bed-mangrove interface that overrides the general decrease in P availability from west to east in Florida Bay. We are now hypothesizing that groundwater discharge is responsible for the increased productivity of seagrasses near the mangrove shoreline.

FCE graduate student Sergio Ruiz-Halpern found that microbial metabolism of organic matter (OM) in seagrass beds can create sulfidic conditions detrimental to seagrass growth and that iron (Fe) has ameliorating effects through titration of the sulfides and the precipitation of iron-sulfide minerals into the sediment. The availability of Fe and OM was manipulated in a 2x2 factorial experiment arranged in a Latin square, with 4 replicates per treatment. The treatments included the addition of Fe, the addition of OM, the addition of both Fe and OM as well as no addition. The experiment was conducted in an oligotrophic, iron-deficient seagrass bed. Fe had an 84.5% retention efficiency in the sediments with the concentration of Fe increasing in the seagrass leaves over the course of the experiment. Porewater chemistry was significantly altered with a dramatic decrease in sulfide levels in Fe addition plots while sulfide levels increased in the OM addition treatments. Phosphorus increased in seagrass leaves collected in the Fe addition plots. Decreased sulfide stress was evidenced by heavier  $^{34}\text{S}$  in leaves and rhizomes from plots to which Fe was added. The OM addition negatively affected seagrass growth but increased P availability; the reduced sulfide stress in Fe added plots resulted in elevated productivity. Fe availability may be an important determinant of the impact that OM has on seagrass vitality in carbonate sediments vegetated with seagrasses.

### *Litter Dynamics*

There was a consistent seasonal pattern of litterfall production from 2006 to 2007 in all mangrove sites compared to previous years. Higher rates were observed during the wet season

(June-November) compared to the dry season (Figure 1). However, litterfall rates were lower in all sites compared to previous years as a result of Hurricane Wilma in October 2005. Litterfall rates ranged from  $0.39 \pm 0.04 \text{ g m}^{-2} \text{ day}^{-1}$  (TsPh8, 2006) to  $1.29 \text{ g m}^{-2} \text{ day}^{-1}$  (SRS4, 2007) during the dry seasons of 2006-2007, whereas rates varied from  $0.94 \pm 0.11 \text{ g m}^{-2} \text{ day}^{-1}$  (TsPh8) to  $4.56 \pm 1.0 \text{ g m}^{-2} \text{ day}^{-1}$  (TsPh8) during the wet season of 2006-2007. Overall, we observed an increase in seasonal rates of litterfall from 2006 to 2007 in all sites. Leaf fall comprised most of the total litterfall in all sites ranging from 89.6% (SRS4) to 95.1% (SRS5). Wood fall contribution to total litterfall ranged from 3.5% (TsPh8) to 8.2% (SRS4), while reproductive parts had the smallest contribution varying from 0.5% (SRS5) to 5.7% (TsPh8).

Mean annual rates were significantly lower in all sites when compared to previous years. Litterfall rates ranged from  $253 \pm 8.5 \text{ g m}^{-2} \text{ yr}^{-1}$  (TsPh8, 2006) to  $428 \pm 43 \text{ g m}^{-2} \text{ yr}^{-1}$  (SRS4) during 2006-2007 with greater rates during 2006. The productivity gradient observed along Shark River during previous years was not observed during these two years as a result of canopy defoliation during Hurricane Wilma in October 2005. The forest was completely defoliated in SRS5 and SRS6, while in SRS4 the damage was considerable less severe and the canopy was not defoliated. Therefore, we are observing greater seasonal and annual rates in SRS4 compared to SRS5 and SRS6 during 2006. Overall, rates along Shark River are two to three times lower during 2006-2007 when compared to previous years. This progress report only includes litterfall rates estimated up to July 2007 in all sites. Thus, we expected an increase in annual rates for all sites from 2006 to 2007 once all samples are processed.

#### *Carbonate sediment amendment experiment*

After nearly 1.5 years, we have seen little response of the dwarf mangrove tree clusters to sediment amendment. However, we have seen a significant increase in height in amended seedlings relative to un-amended seedlings (T-test;  $p = 0.004$ ). We will continue to track aboveground responses in seedlings and mature tree clusters over the next few years. Results of this pilot study will be used to design and implement a large-scale sediment amendment study that will track patterns of biomass allocation both above and belowground.

## **2. Organic Matter Dynamics**

### *Sources, spatial and seasonal variability and photo- and bio-reactivity of DOM in the FCE-LTER*

Dissolved organic matter (DOM) sources and transformations in wetlands and estuaries are complex and often difficult to assess using traditional geochemical approaches. It has become clear that quantitative measurements (DOC) alone do not properly allow assessing sources and environmental dynamics of DOM in aquatic ecosystems. In this study we applied various measurements, including TOC, 3D fluorescence (EEM) coupled with Parallel Factor Analysis (PARAFAC), to determine spatial and seasonal variations of DOM in freshwater marsh, fringe mangrove, and estuarine seagrass-dominated environments of the greater Everglades. DOM in surface and groundwater, dominant vegetation leachates and soil leachates were characterized using EEM-PARAFAC and potential degradation processes were assessed through bio- and photo-degradation studies. Fluorescence based EEM-PARAFAC analyses revealed seasonal DOM source differences such as increased microbial sources in some estuarine areas and Florida Bay during the wet season. Compositional differences between waters from the peat based Shark

River Slough and the marl-based Taylor Slough were also observed. Clear differences between surface and ground water were also observed both for surface and groundwater from the Everglades and from Florida Bay. The components controlling these differences (based on PCA) were humic- and protein-like components, where the former were more abundant in the groundwater compared to surface waters, particularly for the Everglades samples, and one unidentified component which seems to be a reduced hydroquinone-like component (tentative identification) which was more dominant in the groundwater samples. Photo- and bio-degradation of plant leachates readily demonstrated that biomass leachates will degrade effectively through a combination of both photo- and bio-degradation processes into a DOM pool featuring a composition similar to those in natural surface water of the FCE. This was particularly evident for seagrass leachates, which seemed to be most reactive, compared to those from other local biomass sources. This is an on-going study and efforts are made to further identify end members for the FCE-LTER PARAFAC model.

*Assessment of molecular weight distribution of dissolved organic matter in the greater Everglades*

The molecular weight of DOM is an important parameter which can provide information on the sources and diagenetic state of natural organic matter. As such, it has often been assumed that terrestrial-soil derived DOM features a larger molecular weight (MW) range compared to DOM derived from biomass or microbial/marine sources. While the MW distribution of DOM can be determined using size exclusion chromatography (HPLC-SEC; see Maie et al., 2007, *Water Research* 41: 563-570 and Tzortziou et al., 2008, *Limnology & Oceanography* 53: 148-159) a recent report by Mopper and co-workers (Helms et al., 2008, *Limnology & Oceanography* 53:955-969) has reported correlations between MW and some UV-Vis optical properties ( $S_R$  value) of DOM. We have used both approaches for the MW characterization of DOM in the FCE-LTER and the greater Everglades region. Our results from a grid of over 100 surface water samples ranging from the Northern Everglades to Everglades National Park in the South clearly showed that based on  $S_R$  values, the average molecular weight of DOM decreased along the general North to South transect. This is actually an expected trend as high P levels in the Northern Everglades result in higher rates of soil oxidation and consequential high terrestrial-soil derived DOM compared to the Southern Everglades where DOM from biomass leaching has a higher contribution to the overall OM pool. The correlation between the  $S_R$  and the Fluorescence Index values seem to confirm this assumption. The determination of the  $S_R$  values was since incorporated into our monthly surveys of DOM from all active FCE-LTER stations. In addition to the  $S_R$  study, we have physically fractionated (HPLC-SEC) surface water DOM samples from SRS2, TSPH2 and the C111 canal, and determined the fluorescence characteristics of the different molecular weight fractions. Preliminary data after EEM-PARAFAC characterization, suggest that both humic and protein-like DOM components have a characteristic range of MW distributions. As such, the DON components make up both the largest and the smallest MW cuts, likely representing intact proteins and smaller peptides respectively. In contrast, the humic-like components seem separated into the higher MW humic and lower MW fulvic components. This investigation is presently on-going.

*Assessing trace metals interactions with DOM from different locations in the FCE using fluorescence quenching and EEM-PARAFAC*

Natural dissolved organic matter (DOM) is composed of a variety of organic compounds which can interact with metals in aquatic environments. The interactions between DOM and two metals of environmental concern (Cu(II) and Hg(II)) was studied using fluorescence quenching titrations combined with excitation-emission matrix (EEM) spectra and parallel factor analysis (PARAFAC). This allowed characterizing the specific interactions between eight fluorescent components in DOM and two metals. Triplicate titration experiments used to test the accuracy of the method showed good reproducibility when assessing the interactions between humic-like components with Cu(II). Our data shows clear differences in metal-DOM interaction for samples of different DOM composition and between two different metals. The results demonstrate that the combination of fluorescence quenching titrations with EEM-PARAFAC was appropriate for the accurate determination of binding properties of humic-like components with trace metals. The enhancement in fluorescence intensity after its initial decrease for the protein-like components with addition of Cu(II) was observed at mangrove dominated sites, suggesting the release of protein-like components from the DOM matrix due to increased Cu(II) complexation to the former. The application of EEM-PARAFAC in fluorescence quenching studies is a useful tool to evaluate inter-molecular DOM and DOM/trace metals interactions.

*Dissolved organic matter bioavailability and composition in streams draining catchments with discontinuous permafrost (BNZ-LTER site collaboration)*

We examined the impact of permafrost on dissolved organic matter (DOM) concentration and quality in Caribou Poker Creeks Research Watershed (CPCRW), a watershed underlain with discontinuous permafrost, in interior Alaska. We analyzed long term data from watersheds underlain with varying degrees of permafrost, sampled springs and thermokarsts to capture the range of DOM concentration and quality throughout the watershed, used fluorescence spectroscopy to examine DOM composition, and measured the bioavailability of dissolved organic carbon (DOC) using in-lab mesocosms. Permafrost driven patterns in hydrology and vegetation played a significant role in determining DOM patterns in streams and across years, with the stream draining the high permafrost watershed having higher DOC and dissolved organic nitrogen (DON) concentrations, higher DOC:DON and greater specific ultraviolet absorbance (SUVA) than the streams draining the low and medium permafrost watersheds. Streams, springs and thermokarsts exhibited a wide range of DOC and DON concentrations (1.5 – 37.5 mgC/L and 0.14 – 1.26 mgN/L, respectively), DOC:DON (7.1 – 42.8) and SUVA (1.5 – 4.7 L mgC<sup>-1</sup> m<sup>-1</sup>). All sites had a high proportion of humic components, a low proportion of protein components, and a low fluorescence index value (1.3 – 1.4), consistent with terrestrially derived DOM. Principal component analysis revealed three distinct groups in our fluorescence data, which were likely determined by reduction-oxidation potential and DOM source. The bioavailability of DOC in stream, spring and thermokarst samples ranged from 2 – 35 % after forty days of incubation. DOC loss was highly correlated with the proportion of tyrosine and tryptophan in the fluorescing DOM ( $r = 0.99$ ). Our results indicate that the degradation of permafrost in CPCRW will result in a decrease in DOC and DON concentrations, a decline in DOC:DON of DOM, and a reduction in SUVA, possibly accompanied by an increase in DOC bioavailability if the contribution of water from deeper flow-paths to streams increases. If thermokarsts become more prevalent as permafrost degrades, the contribution of highly recalcitrant thermokarst DOM to streams will likely increase.

*Assessing seasonal patterns and the influence of forest management on DOM quality (CWT-LTER site collaboration)*

Dissolved organic matter (DOM) in terrestrial environments plays important roles in the global biogeochemical cycles by fueling heterotrophic microbial communities, serving as a means of nutrient and trace metal transport, controlling light availability for primary producers, and serving as a pH buffer among others. Thus, both the quantity and quality of DOM are important drivers in stream ecology. However, still little is known about changes in DOM composition on spatial and temporal scales in many biomes, and about how DOM quality might affect the photo- and bio-reactivity of DOM. This study was performed at the Coweeta Hydrologic Laboratory, a US Forest Service Experimental Forest (and CWT-LTER site) is located in the southern Appalachian Mountains of western North Carolina and is primarily considered an Eastern Deciduous biome. Since its establishment in 1934 various forest management strategies have been implemented on a watershed scale. Little is known about the potential effects of forest management on stream DOM quality. Since July of 2007 scientists from the CWT-LTER have collected surface water samples monthly and have shipped these to the FCE-LTER for DOM quality determinations (optical properties) with the objective of evaluating the seasonal changes in and effects of past forest management on DOM quality and quantity in Coweeta streams. Our preliminary data suggest that: (1) Differences in temporal changes in humic-like components among watersheds are likely the result of greater leaf litter inputs during the fall in native deciduous watersheds (WS 2 and 7) compared to the pine dominated watershed (WS 1). On the other hand, the difference in periods of maximum concentration between humic-like and tyrosine-like components, suggests that tyrosine-like components have different sources than humic-like components and might be derived from microbial productivity in the streams and/or the riparian zone. (2) The similarity/difference in temporal changes between DOC and humic-like components among watersheds indicates the different dynamics of DOM in the forest system, i.e., through watershed to stream, between native deciduous watersheds (WS 2 and 7) compared to the pine dominated watershed (WS 1). (3) The higher levels of humic-like components in the undisturbed watershed (WS 2) compared to the clear-cut watershed WS (WS 7), suggests differences in levels of accumulated soil organic matter between managed (clear-cut, 1977) and undisturbed forests. In addition, PCA result suggests that undisturbed watersheds are enriched in terrestrial humic-like component while managed watersheds are enriched in microbial humic-like components.

*Molecular characterization of DOM from headwater streams from different North American biomes (Inter-LTER collaboration)*

During the summer of 2006 a series of large (40 Liter) surface water samples were collected at six LTER sites (ARC, BNZ, NWT, KNZ, CWT, LUQ) and the DOM isolated using ultrafiltration (>1000 dalton). These UDOM samples have since been characterized by <sup>13</sup>C-Nuclear Magnetic Resonance (<sup>13</sup>C-NMR), ultrahigh resolution mass spectrometry (FT-ICR/MS), X-ray Photoelectron Spectroscopy (XPS), EEM-PARAFAC, <sup>13</sup>C and <sup>15</sup>N stable isotope analyses, C/N ratios, Black Carbon content and Amino Acid distribution. Preliminary data analyses suggest that while there are many similarities in the overall molecular characteristics of these UDOM samples, clear differentiation between DOM from different biomes is possible using a highly interdisciplinary analytical approach. For example, the low degree of aromaticity (as determined by <sup>13</sup>C-NMR and ICR/MS) in combination with a slightly more enriched stable

carbon isotope value for the KNZ sample, suggests that C4 grasses are an important contributor to the UDOM at this site. Similarly, the highest Black Carbon content was observed for the ARC and BNZ sites, suggesting a higher degree of contribution from biomass burning to the DOM pool at these sites. This project is presently on-going.

#### *Bacterial carbon sources in estuarine areas of the FCE-LTER*

Spatial patterns of pelagic, seagrass epibiontic, and sediment surface bacteria carbon cycling in Florida Bay, a subtropical estuary with a recent history of seagrass loss and phytoplankton blooms, were assessed by a stable isotope approach. Bulk  $\delta^{13}\text{C}$  values were used to determine carbon sources in the estuary and compound-specific fatty acid  $\delta^{13}\text{C}$  values were used to determine the source of carbon to heterotrophic bacteria. Seagrass (*Thalassia testudinum*) green leaf with epiphytes removed  $\delta^{13}\text{C}$  values ranged from -9.9‰ to -6.9‰ and were significantly enriched in  $^{13}\text{C}$  over pelagic particulate organic matter, epibiontic, and sediment surface  $\delta^{13}\text{C}$  values, which were similar in their  $\delta^{13}\text{C}$  range (-16.7‰ to -9.6‰). Bacterial fatty acid  $\delta^{13}\text{C}$  values ranged from -25.5‰ to -8.2‰. Bacterial  $\delta^{13}\text{C}$  values were significantly depleted in  $^{13}\text{C}$  over *T. testudinum*  $\delta^{13}\text{C}$  values. Bacterial  $\delta^{13}\text{C}$  values may have resulted from 1:1 mixing between mangrove and seagrass-derived organic matter, but this high bacterial reliance on mangrove inputs seems unlikely for the estuary as a whole. Seagrass epiphytes and/or benthic algae/cyanobacteria were the likely carbon sources to pelagic, seagrass epibiontic, and sediment surface bacteria communities in Florida Bay. One sampling station, located in the south-central bay, deviated from this generality, and bacteria  $\delta^{13}\text{C}$  of epibiontic and sediment surface communities indicated that *T. testudinum* was the primary carbon source to heterotrophic bacteria at this station. Presented data support previous stable isotope studies of aquatic consumers in Florida Bay, indicating that epiphytic/benthic algal and/or cyanobacterial production with mixing from seagrass-derived organic matter sustained the estuarine food web.

#### *Variation in soil nutrients and organic matter related to storm events*

Since Hurricane Wilma in 2005, the redistribution of sediments on the estuarine portion of the Shark River Slough transect has been “assimilated” and soil organic matter and nutrients have returned to their pre-storm levels. Longer-term changes in nutrients and organic matter, however, may accrue with changes in differential seedling recruitment and plant success driven by storms—a landscape-level feature we observed in 2007 and again in 2008.

#### *Variation in wetland response to iron amendments*

In 2002 we began a long-term experiment testing the addition of reactive iron to sediments in the freshwater Everglades, for comparison with seagrass ecosystems where iron additions stimulated plant growth. Sawgrass in iron-addition plots in the Everglades, however, is significantly smaller than sawgrass from control plots, and the pool of plant-bound phosphorus has decreased significantly. Concomitant with the decrease in plant phosphorus has been an increase in soil phosphorus not specifically associated with iron-phosphorus sorption. Sawgrass in iron-enriched plots exhibit no obvious signs of iron toxicity other than reduced growth. In the coming year we will assess plant condition in control and iron addition plots using a portable field photosynthesis meter that measures the density of light absorbance in leaves and converts those measures to a proxy for chlorophyll concentration. Once we develop the technique, we plan to use it to assess plant condition both in sawgrass at TS/Ph 1 and in red mangrove along both TS/Ph and SRS transects.



### 3. Biogeochemical Cycling

#### *Microbial Dynamics*

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

#### *Biogeochemical Cycling*

##### Upstream/downstream sampling of mangrove ecotone

We see considerable differences in water quality and constituent concentrations between TS/Ph 6 & TS/Ph 7 and across samplings, indicating strong spatial and seasonal controls on water quality and materials exchange in this region. During August 2006 and 2007 samplings, SRP was low and averaged  $0.07 \mu\text{M}$  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 2006) or the ratios of inorganic:total nutrients change from one end to the other (e.g., P in May 2007). 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

Significant DO removal occurred from the water column to sediment at all sites indicating net heterotrophy in peat-dominated soils (TS/Ph 7), marl sediment (Pond 1) and carbonate sediment (LMB sites). Strong  $\text{NO}_3 + \text{NO}_2$  uptake and  $\text{NH}_4$  release from soil at both sites suggested denitrification via microbial activity in addition to ammonification of organic material contributing to release of reduced inorganic nitrogen. DOC consumption supported this. In ambient conditions, we observed weak, but significant  $\text{PO}_4$  uptake at both sites between water column and sediment. In the bay sites, the less vegetated eastern bay site (LMB East) and vegetated western bay site (LMB West), we saw similar uptake of  $\text{PO}_4$  and release of  $\text{NH}_4$ , but fluxes of  $\text{NO}_3 + \text{NO}_2$  were inconsistent. Significant  $\text{PO}_4$  uptake by sediments was found after the addition of  $1 \mu\text{M}$  of  $\text{PO}_4$  in the water column. Intensified  $\text{PO}_4$  removal from water column may be due to the stronger gradient between the water column and sediment or may have contributed to microbial demand for this limiting element. In support of this, fluxes of  $\text{NO}_3 + \text{NO}_2$  and DOC shifted direction or exhibited a greatly altered magnitude of flux coincident with added P, indicating a P effect on microbial respiration and mineralization.

### 4. Trophic Dynamics and Community Structure

We have just begun our analyses of alligator movements in the Shark River estuary but have found interesting results. Our preliminary results show that alligators may remain in localized areas for weeks at a time, but make long-distance moves between the mouth of the river to the

marsh-mangrove ecotone and likely into the marsh as salinities increase during the dry season. Additionally, some individuals followed a stereotyped pattern in their movements during the wet season. Over a three day period, they commuted from upstream areas (~18km from the mouth of the river) to the Gulf of Mexico and back and then repeated the movement several days later. Such movements may represent foraging in higher salinity waters with more abundant prey and resting in lower salinity waters. If this is the case, it is possible that individuals that make these moves could play a role in upstream transport of marine phosphorus.

Movements of bull sharks also show considerable individual variation. Although sample sizes are low it appears that some individuals make short-term use of the estuary (i.e. resident for 7-14 days) while others have remained in the estuary for eight months and have not yet left. These resident sharks move widely from downstream areas to the ecotone region. Movements of gar and snook are less dramatic, and tagged individuals have remained largely in the vicinity of initial tagging.

We discovered that the presence of sharks and the number of sharks captured on a longline were most heavily influenced by distance upstream and dissolved oxygen content of the water. There was a peak in shark abundance in the areas north of Tarpon Bay with a significant concentration of neonates near SRS4. Shark catches were much higher with high DO levels, but surprisingly showed little variation with salinity.

Our studies of trophic structure in the estuary have continued over the past year. We found considerable inter-individual variation in the carbon isotopic signatures of bull shark muscle. Some individuals specialize in feeding in marine-based food webs and others in freshwater/estuary-based food webs, and others exhibit intermediate signature. All three signature types are found throughout the system from SRS6 to at least 26km upstream. The finding of sharks with long-term isotopic signatures suggestive of feeding in marine systems indicates that sharks might be a vector of upstream nutrient transport. We are currently working on several manuscripts on bull shark trophic position.

#### *Spatiotemporal dynamics of the fish and macroinvertebrate community in SRS ecotonal creeks*

We examined seasonal, yearly and spatial dynamics in the fish community of ecotonal mangrove creeks along the SRS transect, particularly between SRS 3 and 4. Our four years of sampling reveals a highly dynamic community composed of marsh fishes, resident estuarine species, and transient marine taxa (i.e., 37 species collected to date via electrofishing).

Catch per unit effort (CPUE) varies markedly yearly and seasonally. Catches peak in the drier months, reflecting a pulse of freshwater taxa into creeks as marshes upstream dry seasonally. The timing of this pulse is closely tied to the pattern of water recession in upstream marshes, and may have important ramifications for wading bird foraging and nesting success. Catches generally peaked in the transition period (Feb-Mar) in dry years; whereas in 2006, the wettest of the sampled years, catches peaked later in Apr-May. In these dry years, high CPUE samples in the transition period are typically followed by lower catches, suggesting that some of that fish biomass that moves into creeks in response to early marsh dry-down may be lost to piscine predators, instead of remaining on the marsh

surface where it may be available to wading bird predators. This is of critical importance to Everglades restoration since a major performance measure for restoration is wading bird nesting success, particularly in the historical coastal mainland rookeries in the vicinity of SRS sites.

Catches of Palaemonid shrimp in minnow traps the 2008 dry season were highest at the upstream most and lowest salinity site (RB10), which is located nearby SRS3 and experiences the greatest freshwater marsh influence. Catches at this site were dominated by riverine grass shrimp *P. paludosus*, whereas downstream catches were dominated by Florida grass shrimp *Palaemon floridanus*. Mid-estuary, multiple species co-occurred. The spatial distribution of shrimp assemblages is expected to shift in response to seasonal variation in salinity and to the lower salinity regimes expected to occur with restoration. The implications of shrimp species replacement or distributional shifts for the ecology of the estuary are presently unknown and require further work.

## 5. Hydrology

The results of the HYMAN model reasonably matched the observed trends in pore water salinity the three riverine mangrove sites (SRS4, 5 & 6) and was consistent with distance along the estuary to its mouth. Precipitation, especially at the beginning of the rainy season, determined the seasonal timing of the pore water salinity peak. In addition, it was hypothesized that the most inland site, SRS4, was more sensitive to groundwater inputs or upstream overland flow than the other two sites. This project resulted in the culmination of an M.S. thesis (Cheng-Feng, 2008).

The extent of seawater intrusion into the groundwater beneath Shark Slough was found to be dynamic, varying on a seasonal basis. Groundwater nutrient concentrations of nitrogen, phosphorus and carbon were found to be higher in groundwater beneath Florida Bay and Shark Slough as compared to the overlying surface water. The relationship between groundwater concentrations of phosphorus and salinity differed between the two regions. A positive relationship was observed between groundwater phosphorus concentration and salinity beneath Shark Slough, while a negative relationship was observed between phosphorus and salinity beneath Florida Bay. In Shark Slough, phosphorus concentrations (total and soluble) in all of the waters (surface, porewater, and groundwater) seemed to be a function of mixing of three end-members waters: 1) fresh surface water; 2) Gulf of Mexico surface water; and 3) high salinity groundwater.

Nutrient concentrations of phosphorus in groundwater beneath Shark Slough are most likely dominated by water-rock interactions such as carbonate mineral dissolution and ion exchange. In Florida Bay, however, phosphorus and nitrogen species in groundwater are most likely associated with redox reactions, most likely related to the decomposition of organic matter. There were no strong correlations between TN and TOC with salinity in the groundwaters beneath either Florida Bay or Shark Slough.

The results of a six year study to evaluate the importance of water flow in maintaining the ridge and slough landscape of the Florida Everglades was recently summarized at the GEER 2008 meeting by Leonard et al. (2008) and Gabriele et al. (2008). The results of that study determined

that water velocity was less than 3 cm/s with higher values (0.03 to 1.89 cm/s) observed during the wet season associated with higher discharges from the upstream gates (S12C, S12D, and S333). Lag times between the peaks in gate discharge and water velocity measured at the downstream sites of Chekika (CH) and Gumbo Limbo (GL) were 5 days and 17 days, respectively. Stage gradient (water surface slope) in the slough ranged from 0 to 10 cm/km with an average between 0.5 and 5 cm/km. A simple relationship between stage gradient and water velocity could not be established. Water velocity was determined to be affected by the presence of vegetation (particularly by *Utricularia* spp. and periphyton and not so by emergent stems) and increased as much as three times when the submerged vegetation was removed. During the dry season flow velocity in the slough were lower (0.05 to 1 cm/s) and flows were typically higher in the sloughs than on the ridges. In addition, this study determined that particulate accumulations rates and floc layer thickness were greatest at the terminal end of a dead-end slough.

The results of the rock core digestions resulted in total phosphorus concentrations ranging from 30 to 100 µg of P/g of rock from the ground surface to 10 m depth. Below 10 m, the P concentrations in the rock core increased to values exceeding 800 µg of P/g of rock. The increase in P with depth in the rock core is attributed to the proximity to the underlying Tamiami Sands unit that contains phosphorite deposits. A relationship between the P content in rock core collected from fresh groundwater areas versus brackish groundwater areas is still being investigated.

The results of the SF<sub>6</sub> tracer tests conducted in the ridge and slough regions of the Everglades resulted in average surface water flow rates of 0.25 cm/s in regions where the ridge and slough topography was well preserved. The surface water flow direction was dominantly in the same longitudinal direction of the slough. In regions where the ridge and slough topography was degraded, the surface water flow direction was across the original longitudinal direction of the ridge and slough topography and instead flowed in the direction of a nearby canal. Surface water flow rates in the degraded ridge and slough region was higher at 0.4 cm/s.

## 6. Human Dimensions

Much of our work this year has focused on refining our research approach (as outlined in the “activities” section of this report). We have completed the following products for year-one:

- Refined data layers for the larger study site. This data enables us to locate properties with lawns in relation to other properties in the south Miami-Dade county area. Land use classification of properties (from the County Tax Assessor data—1992-94 pre/post Hurricane Andrew and current 2007) allows analysis of both changes in land use between agricultural and residential (mapping growth/sprawl, among other variables) and GIS positioning of properties in relation to other data layers we are adding. These layers include 2000 census blocks and block groups, the coverage of the 2006 American Community Survey (Census) sample over the area, canal/hydrological features locations, and LIDAR elevation coverage for identifying potential sites of lawn chemical runoff and sinks.

- Identified an archival data set previously unknown to scholars. Working with Miami-Dade County, we have identified the first land surveys of the county, conducted by the federal Works Projects Administration (WPA) during the 1930s. The WPA was a federal program under the New Deal. This archive includes hand-written surveys for each property in Miami-Dade County and describes land use, property characteristics, soil information, and demographic information for home and landowners. We are currently scanning this archive so that it can be geo-referenced into our GIS parcel layers. We anticipate this archive will provide a critical baseline for our understandings of land use change and an important contribution to our overall understandings of the region's history and growth.
- Preliminary findings for our research into the role of hurricanes, as pulse events, into land use/cover change in our study site suggest the following:
  - The pulse of Hurricane Andrew exacerbated ongoing press events for each community under study (cities of Homestead, Florida City, and the unincorporated community of South Miami Heights). These ongoing press events include differential rates of growth and market presses on real estate, existing income inequalities correlated with ethnicity and race, and structural inequalities that contribute to community vulnerability to pulse events.
  - More specifically, communities and neighborhoods with higher percentages of African-American residents were less resilient to Hurricane Andrew, as a pulse event. African-American households were characterized as being underinsured for the disaster, less likely to be homeowners, and were less able to rebuild after the pulse event.
  - The greatest changes occurred in neighborhoods with the highest degree of vulnerability to press events. These post-Andrew changes include shifts in demographics and community character (housing type, for instance).
  - We have found that the impact of pulse events upon the human landscape is heterogeneous and correlated to differential press processes. Land use/cover change, therefore, results from the interplay of press and pulse processes. Land use/land cover change, therefore, emerges as a result of complex natural and social processes, creating a landscape that is mutually constituted by these processes.

## 7. Climate and Disturbance

### *20<sup>th</sup> Century and millennial-scale changes*

Soil cores analyzed to date show substantial vegetation change in historic Shark Slough over the past century or more. In general, they show increasing *Cladium* and the reduction or disappearance of water lily sloughs, starting mostly in the early 20<sup>th</sup> Century and possibly reflecting drainage due to water use by humans and the completion of the Tamiami Trail by 1940. Some of the cores also indicate a return to wetter conditions, including increased water lily abundance, in the 1990s, consistent with higher rainfall and water stages observed in the 1990s relative to previous decades. We have found a general pattern of major changes in accretion

over the past 5 KYBP show an initial fast rate of peat accretion (from ~4.5 KYBP to ~3.5 KYBP) followed by a slow phase that has lasted until the last few centuries. This change is most pronounced in the NE-SRS region (technically within the SRS-2 “oligotrophic” landscape) in which the slow accretion phase corresponds with the switch from a peat-substrate to marl-substrate and also corresponds with a switch from ridge-slough vegetation (water lily and sawgrass macrofossils) to one dominated by Charophytes (oospores) and Cyperaceae (seeds, species not yet determined).

#### *Water level, water logging and ecohydrologic changes*

Our findings show that waterlogging alters leaf  $\delta^{13}\text{C}$  in Pond Apple, Red Bay, Gumbo Limbo and sawgrass and that species differ in their baseline  $\delta^{13}\text{C}$  signatures and isotopic relationships to waterlogging.  $\delta^{13}\text{C}$  signatures of tree species become more negative with increased waterlogging, but the opposite is true for sawgrass. A soil profile of seed  $\delta^{13}\text{C}$  signatures (from a core taken in SRS-3) showed correlations between seed  $\delta^{13}\text{C}$  signatures and seed production rates (i.e., accumulation in soil), showing more negative values (less stress) with higher seed concentrations. This is consistent with mesocosm findings that more negative  $\delta^{13}\text{C}$  signatures indicate less physiological stress and greater sawgrass productivity. As such this approach provides a useful proxy for reconstructing physiological changes in key species over the past hundred years (based on soil dates) and in the context of past water management activities. Our most recent calibration work on emergent macrophytes in wetland settings, sawgrass (*Cladium jamaicense*), yielded a positive correlation with  $\delta^{13}\text{C}$  values and increasing water level, which is similar to the response of wetland trees such as cypress to changing amounts of precipitation (Anderson et al, 2005). It is possible to use this approach to reconstruct the relative changes in water level during shallow phases, during transition from more open lacustrine settings to wetland depositional environments

#### *Eddy tower findings*

Preliminary eddy covariance data from the short-hydroperiod site (TS/Ph 1b) indicate light-saturated  $\text{CO}_2$  uptake rates of  $1.43 \mu\text{mol m}^{-2} \text{s}^{-1}$  in the dry season (January) and  $2.63 \mu\text{mol m}^{-2} \text{s}^{-1}$  in the wet season (July). Preliminary data from chamber measurements at this site indicate that both dry and wet season  $\text{CO}_2$  uptake is dominated by macrophytes, rather than periphyton. In terms of ecosystem respiration, mean efflux values from eddy covariance data are  $0.65 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$  in the dry season (January) and  $0.99 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$  in the wet season (July). Chamber measurements indicate that periphyton are a minor component of these respiratory fluxes.

#### *Mangrove disturbance*

Sampling sites showed different degrees of impact as reflected by extreme defoliation in most sites. Leaf area index estimated in 2005 varied from 0.0-0.3. There is a distinct level of recovery depending on relative locations to original Wilma wind fields. The area most impacted was Harney River showing total defoliation in several locations. Defoliation was strongly influenced by individual gaps created before Hurricane Wilma, which created numerous canopy gaps, and the number of gaps per square kilometer increased from about 400~500 to 4000 after this large scale disturbance.

#### *Slash pines and Hurricane Wilma*

In August, we confirmed that non-dominant slash pine trees did survive Wilma's storm surge on Big Pine. Once the LIDAR map is complete we will evaluate elevation's role in these isolated patches of survivors, where all dominant trees were killed by the effects of the storm.

## **8. Modeling and Synthesis**

### *Mangrove Hydrology (HYMAN)*

Based on the sensitivity test, the best-fit parameters were determined for each site and most of the simulated results fell within a reasonable range of salinity values compared to field data. Simulations for each site indicate the relative importance of hydroperiod and groundwater sources, particularly in SRS-4. Discrepancies in observed vs simulated values for this site suggest the relative importance of inter-annual variation in precipitation and the contribution of groundwater stage at the mangrove ecotone boundary where SRS-4 is located. Future work is planned to include this component either as a fitting parameter or a mechanistic interaction with other state variables.

Based on the sensitivity test of the HYMAN model, the best-fit parameters were determined for each site and most of the simulated results fell within a reasonable range of salinity values compared to field data. Simulations for each site indicate the relative importance of hydroperiod and groundwater sources, particularly in SRS-4. Discrepancies in observed vs simulated values for this site suggest the relative importance of inter-annual variation in precipitation and the contribution of groundwater stage at the mangrove ecotone boundary where SRS-4 is located. Future work is planned to include this component either as a fitting parameter or a mechanistic interaction with other state variables.

### *Dynamic P Budgets (Ribbon model)*

In the first phase of the Ribbon modeling study, one of the key findings was that nutrient transport (as flocc-P and waterborne-P) across communities boundaries was primary in controlling P cycling at the landscape-level and in substantially improving simulated water TP and flocc-P stocks of the central oligotrophic portion (FCE LTER site SRS-2) of Shark Slough. A break-out session during ASM 2008 by the modeling/synthesis working group highlighted the need for this model to be extended in two ways: (1) to include connectivity via downstream flow of nutrients; and (2) to extend a budget and/or modeling approach to the remaining conceptual landscape "ribbons" in the ecotone and mangrove regions of Shark and Taylor Slough. The latter step should help address the FCE II hypotheses concerning estuarine ecotone responses to changes in freshwater flow.

### *Shark Slough Spatially explicit Carbon Accumulation and Transport (Shark SCAT)*

Preliminary runs of the Shark SCAT model show that sawgrass and slough microtopographic differences may arise based solely on differential production and litter decomposition of the two communities and can be reduced with drainage scenarios that allow for increased oxidation of higher elevation peats. Additionally, using driving variables from water gage data, rainfall records and an assumed drainage scenario (assuming Tamiami Trail construction in 1930 reduced water depths by 30 cm), the model was able to replicate downcore profiles and concentrations of fossil seeds showing greater water lily abundance in pre-drainage layers, followed by a recent invasion by sawgrass.

### *Florida Bay Seagrass*

The preliminary model is fully functional and has been used in depicting the eastern bay phytoplankton bloom, useful in research planning purposes and restoration strategy assessment. The model demonstrates that a single injection of phosphorus, similar to that which was observed in 2005, can be sufficient to sustain phytoplankton blooms for months-to-years from internal recycling. The model is currently being updated with our most recent data on nutrient uptake kinetics by bay sector that will enable prediction of phytoplankton species composition based on optimum nitrogen substrate availability.

## **C. Training and Development**

### **Education, Outreach, and Diversity Activities**

Through *Coastlines* we also provided research experience internships to both secondary and middle school students. In all, 26 high school and 5 middle school students participated in *Coastlines* and received an intensive, 40 hours, of face to face instruction in: Everglades field data collection; GPS and GIS instruction; data analysis. Those students also met with two of our researchers who discussed how they use GIS in their LTER research.

In addition to the *Coastlines RESSt* internships, we have continued to provide ongoing support for traditional *RESSt* internships and placed fourteen students with LTER researchers in 2007. Five of those students were second year interns and four were recruited directly from the *Coastlines RESSt* program.

The *RESSt* program has continued the success from previous years and two interns competed in the 54<sup>th</sup> *South Florida Regional Science and Engineering Fair*. Second year intern Ben Giraldo received *Superior* in the *Environmental* division and first year intern, Michael Fins, received *Superior* in the *Zoology* division. Both students advanced to the 54<sup>th</sup> *State Science and Engineering Fair of Florida*, where Ben Giraldo received *Third Place* in the *Environmental* division. In addition, both Ben and Michael presented posters at our annual ASM meeting, and also await the results for the posters they submitted to the American Statistical Association.

### **Graduate Student Activities and Productivity**

The FCE Affiliated Students Group includes over 40 graduate, undergraduate, and high school students who are members. The group meets once a month for meetings. They receive funding from the FIU Graduate Student Organization and host seminars and social activities with other graduate student organizations. FCE students earned 2 MS theses and 1 Ph.D. dissertation from December 2007 to October 2008.

#### *Theses and Dissertations*

Iwaniec, David M. 2008. Regulation and Organization of Periphyton from the Florida Everglades, U.S.A.. Master's thesis, Florida International University.



Tsai, Cheng-Feng. 2008. Application of the HYMAN Model to evaluate the water and salt budgets in three mangrove sites along Shark River, Everglades. Master's thesis, Louisiana State University.

Williams, Clayton. 2008. Relative significance of pelagic, benthic, and allochthonous organic matter to microbial carbon cycling in a phosphorus-depleted subtropical estuary (Florida Bay). Ph.D. dissertation, Florida International University.

#### **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 71 presentations from December 2007 - September 2008.

##### *Partnerships*

FCE Outreach has established several partnerships over the last year. In addition to Science Approach, we have been active in a restoration project with the CEMEX Corporation. CEMEX is one of the largest mining conglomerates in the world with nearly 1000 quarries located in over 50 countries, on five continents, and is North America's largest cement producer.

The CEMEX FEC Aggregate Quarry has partnered with FCE in an effort to restore an area adjacent to their oldest, inactive quarry. In May 2007 CEMEX and FCE recruited local high school students to plant native plants and saplings in a hardwood hammock, pineland, tree island, and wetland habitat. Over a four-day period, nearly 30 high school students worked in small groups mentoring 75 middle and elementary school students throughout the habitat restoration planting. In all, 7500 plants and trees were planted in the 0.63 acre restoration area. Later this year, CEMEX will install a classroom building and boardwalk that will allow students to monitor the restoration area. In the future, CEMEX also plans to install a boardwalk and dock at the adjacent quarry/lake that will allow students to monitor water quality.

##### *Building Minority & International Programs*

In effort to support our mission to educate the international community we have begun working with the *Department of Diversity and Minority Programs* within the *Center for Diversity in Engineering and Computing (CDEC)* at *Florida International University*. The CDEC is also a member of *Engaging Latino Communities for Education* and is supported by the W.K. Kellogg Foundation. Together with CDEC and ENLACE-Miami, FCE has submitted proposals to the *Miami Children's Trust* and *Motorola, Corp.* for funds to provide additional financial support for supplies, competition and travel fees, and stipends for our *RESSt* interns.

Our second Minority & International effort focuses on Asia. During the summer of 2008, our Education and Outreach Coordinator traveled to Taiwan. During his visit to the island, he spent time exploring the island for accessible sites that could serve as a comparison to FCE sites. In

his next step, he plans to contact the Taiwan Ecological Research Network (TERN) and search for English-speaking schools in Taiwan that are willing to participate as an FCE partner schools.

### *Community Education*

In March 2008, Nick Oehm presented *The role of mangroves in the Everglades estuarine ecotone* to 34 visitors at Dagny Johnson Key Largo Hammock Botanical State Park. Visitors were from across the United States and North America.

FCE continues to have a presence at Miami Dade College where Nick Oehm, Education and Outreach Coordinator, presented information about FCE and the Everglades to 235 of his biology students. In addition, Nick, Teresa, and our new RET gave FCE presentations to an additional 386 students at Felix Varela Senior High School.

In October 2007, 50 Miami Dade County Public High School students participated in a live, interactive broadcast with FCE's Patrick Gibson from the Aquarius underwater habitat. Students were given the opportunity to ask Patrick questions about his research and interact with a diver with a helmet camera that was positioned outside of the underwater research station.

### *Scientific Literacy*

In our efforts to promote scientific literacy beyond the classroom, we have focused our efforts on producing short LTER videos, the internet, and translating FCE materials for an international community.

In 2007, we completed the first of our FCE data education movies entitled "*FCE FILES*". The initial debut and release of *Part I: Aboveground Net Primary Production (ANPP) of Sawgrass* took place at our *All Scientist's Meeting* in March 2008. Since then the film has been evaluated by both teachers and students in Miami Dade County Public Schools and Newton County, GA. In response to teacher evaluations, we are adapting the activity so that students can complete it outside of the classroom. The revised assignment will ask students to view the video and write a short essay that will be incorporated into a class discussion. The film will also be edited into shorter segments for downloading from the internet in place of DVD distribution.

In 2007 we began working with the *Everglades Digital Library (EDL)*. Together we are working to develop a searchable database and combine *EDL's Ask an Everglades Librarian* with FCE's *Ask a Scientist* into a single, joint *Ask an Everglades Expert*.

In June 2008, FCE released the *En Español* feature of our webpage and *Foreverglades* classroom presentation and script. Both the website and presentation were translated by English teacher and native Spanish speaker Carlos Escobar. The translation presented him with several difficulties with the translation of vernacular terms. Carlos made a great effort in consulting resources from the University of Spain to insure an accurate translation.

The FCE information manager, Linda Powell, attended attend the State of Florida Ocean's Council Metadata Workshop in January 2008 as a 'metadata expert' and was able to contribute to the development of a metadata standard document to be used by multiple State of Florida agencies.

The FCE LTER Program reaches out to the public is through our web site and web statistics have shown that we have been reaching a steadily growing number of new web clients, suggesting a strong positive trajectory for our web-based public outreach. Visitors to the data section of our website downloaded 447 datasets from October 2007 through August 2008.

All FCE scientists and students are, to some degree, also involved with Everglades restoration. FCE researchers have been involved with RECOVER (Everglades Restoration planning) with scientists and managers at the South Florida Water Management District. We shared results of our findings with Everglades National Park rangers and interpreters.

### **III. PUBLICATIONS AND OTHER SPECIFIC PRODUCTS**

#### ***A. Publications***

##### **Books**

Hollander, G. 2008. Raising Cane in the Glades: The Global Sugar Trade and the Transformation of Florida. The University of Chicago Press, Chicago.

##### **Book chapters**

Dittmar, T., B. Koch, R. Jaffe. (In Press). Tools for studying biogeochemical connectivity among tropical coastal ecosystems . In Nagelkerken, Ivan (ed.) Ecological Interactions Among Tropical Coastal Ecosystems. Springer

##### **Journal articles**

Bouillon, S., A.V. Borges, E. Castaneda, K. Diele, T. Dittmar, N.C. Duke, E. Kristensen, S.Y. Lee, C. Marchand, J.J. Middelburg, V.H. Rivera-Monroy, R.R. Twilley, T.J. Smith. 2008. Mangrove production and carbon sinks: A revision of global budget estimates. *Global Biogeochemical Cycles*, 22: GB2013.

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- Lindquist, E.S., K.W. Krauss, P.T. Green, D.J. O'Dowd, P.M. Sherman, & T.J. Smith III. 2008. The role of land crabs: key factors in tropical coastal forest recruitment. *Biological Reviews – In Press*.
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- Maie, N., O. Pisani, R. Jaffe. 2008. Mangrove tannins in aquatic ecosystems: their fate and possible role in dissolved organic nitrogen cycling. *Limnology & Oceanography* , 53(1): 160-171.
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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 71 such presentations during the second 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 343 FCE and historical Everglades datasets. Datasets include climate, consumer, primary production, water quality, soils, and microbial data as well as other types of data. An Oracle10g relational database has been designed to accommodate the diverse spatial and temporal heterogeneous core data and accompanying metadata submitted by the FCE researchers. Datasets are available for public download from the data section of the Florida Coastal Everglades LTER website at <http://fcelter.fiu.edu/data>.

## ***C. Internet Dissemination***

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

## **IV. CONTRIBUTIONS**

### ***A. Contributions within Discipline***

Joe Boyer collaborated with Linda Amaral-Zettler at International Census of Marine Microbiology, (ICoMM) ([icomm.mbl.edu](http://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. This 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 started this fall on the aquatic component at 4 sites in FCE during wet and dry season.

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

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

Dr. Rene Price chaired a special session at the AGU Spring 2008 Meeting in Ft. Lauderdale on Recent Advances in Hydrology of Karst Aquifers. She also attended the 20<sup>th</sup> Salt Water Intrusion Meeting in Naples, FL (June 2008) in which she gave the following presentation and assisted in organizing a field trip into the coastal mangroves of the Everglades and Big Cypress.

Several FCE scientists participate in large-scale high-density monitoring programs in the Everglades compliment FCE-LTER research. This includes the REMAP program of the Environmental Protection Agency, which collects and analyzes periphyton, vegetation and consumer data from 125 sites throughout South Florida every 3 years in conjunction with abiotic and other biotic data. Similar mapping occurs through support through the Comprehensive Everglades Restoration Monitoring and Assessment Program funded through the South Florida Water Management District. Evelyn Gaiser and Joel Trexler are collecting periphyton, consumers and plants from >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.

## ***B. Contributions to Other Disciplines***

Joe Boyer attended the following meetings and workshops:

- Southeast Florida Coral Reef Initiative Technical Assessment Committee. Ft. Lauderdale May 1-2, 2008.
- Florida Bay Biogeochemistry Workshop. Miami – June 3-4, 2008.
- Gulf of Mexico Alliance Meeting. St. Petersburg, FL – June 5-6, 2008.
- Florida Bay Cyanobacterial Bloom Meeting. Homestead, FL – July 7, 2008.
- FKNMS Steering Committee Meeting. Marathon, FL – July 24, 2008.

J.S. Rehage and W.F. Loftus attended several meetings of the CERP MAP Greater Everglades Module and of the CERP RECOVER Assessment Team throughout 2007. They also gave a presentation before the Assessment Team on their findings to date.



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

Laura Ogden participated in the US-China International Workshop on Long-Term Ecological Research in Urban Environments (U.S. Delegation, NSF LTER Program, Research Center for Eco-environmental Sciences, Chinese National Academy of Sciences, Beijing, June 19–27, 2008).

Hugh Gladwin has served on the Miami-Dade Climate Change Advisory Task Force from 2006- to the present. He has served on the Steering Committee, Local Mitigation Strategy, Office of Emergency Management and Homeland Security in Miami-Dade County, Florida from 1997 to the present.

Drs. Evelyn Gaiser, Rene Price, Michael Ross and Len Scinto prepared a technical review and response to the Army Corp of Engineers plan for the Tamiami Trail Bridge Construction report.

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

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

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

Evelyn Gaiser is a collaborator on an NSF Research Coordination Network grant for the Global Lakes Ecological Observatory Network. This is a grassroots network of limnologists, engineers and information specialists who aim to equip lakes and wetlands with high-resolution sensors and real-time global conveyance to evaluate large-scale patterns in ecological change in aquatic ecosystems. Participation in GLEON will facilitate future high-resolution sensor data collection and communication within the FCE LTER and a site at the head of the FCE watershed at Archbold Biological Station. Evelyn Gaiser helped organize and host the GLEON 6 meeting at Archbold Biological Station in February 2008 that had 112 participants. She and FCE students Jay Munyon and Greg Koch attended and presented at the meeting. Greg Koch will be implementing GLEON buoys in ponds of the FCE ecotone as part of his dissertation work, and is

participating in a collaborative GLEOM effort to describe methods for calculating NEP in lakes. The following presentations have been based on this work:

Gaiser, E. E., N. Deyrup, R. Bachmann, L. Battoe and H. Swain. 2008. Effects of changes in precipitation on transparency and thermal structure in subtropical, monomictic Lake Annie, Florida. Annual Meeting of the American Society of Limnology and Oceanography. St. John's, Newfoundland.

Gaiser, E. E. and H. Swain. 2008. Deployment of continuous monitoring sensors on Lake Annie, FL. Global Lake Ecological Observatory Network meeting. Archbold Biological Station, FL.

Jim Fourqurean, Evelyn Gaiser, Laura Ogden, Hugh Gladwin and Rene Price participated on the LTER Science Coordination Committee at the annual meetings.

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

### ***C. Contributions to Education and Human Resources***

Ten undergraduate students at FIU gained experience in field sampling techniques working with alligators, bull sharks, snook, and gar. Two high school students gained research experience in the field and lab associated with our working group. We gave two talks to Marine Camps at the International Game Fishing Hall of Fame (Ft. Lauderdale, FL).

J.S. Rehage developed and taught a new undergraduate Everglades Ecology and Conservation taught in the Winter 2008 term at NSU. The course had a large field component, which allowed students to experience different areas of Everglades ecosystem first-hand.

Laura Ogden, Ted Gragson, and Morgan Grove. "From Yardsticks to Gyroscopes: Interdisciplinary Methods for Socio-ecological Research," Spring semester 2008. This course was video-assisted using a live interactive video-feed. Eight students participated in this course from 18 different universities and three countries. All materials from the course (readings, video presentations, power point slides) are archived and available through the course website.

The FCE SLTER program is working with Miami Dade County Public Schools to 1) improve the quality of projects and number of participants competing in the local science fair and 2) develop a county-wide research class curriculum.

Drs. Rene Price and Jim Fourqurean were science fair judges for Frank C. Martin K-8 International Center.

Colin Saunders co-supervised (with Evelyn Gaiser and Bill Anderson) REU student Katya Cabeza (FIU undergraduate student) on developing methodology for phytolith analyses of ridge-and-slough vegetation and soil cores.

Colin Saunders supervised interns Nicolle Gale and Erika Wunderlich (Florida Atlantic University undergraduate) on paleoecology research with the South Florida Water Management District, Everglades Division. Summer 2008.

Colin Saunders supervised Chris Sanchez, high school intern (Felix Varela High School), on paleo-research at FIU (worked with REU student Katya Cabeza).

#### ***D. Contributions to Resources for Science and Technology***

Jim Fourqurean gave a guest lecture on “GIS applications in Marine Science” to 30 students and teachers as part of the CoastLines program. CoastLines is a three-year Comprehensive Project for Students and Teachers funded by the Information Technologies for Students and Teachers program at the National Science Foundation. It introduces fundamental concepts about information technologies (IT) to grade 7-12 schools. June 15, 2008

##### **Website**

The FCE LTER website provides a variety of information, including data, educational activities, maps, project information, site information, publications, presentations, and photos. Visitors to the data section of our website downloaded 447 datasets from October 2007 through August 2008.

#### ***E. Contributions Beyond Science and Engineering***

Jim Fourqurean served as a Judge, for the annual Science Summit science fair, F.C. Martin K-8 school, May 5/2/08-5/5/08

##### *Popular Article:*

Gaiser, E. 2008. Honoring Darwin by building partnerships for socio-ecological reform. *Word & World* 28: In Press.

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