Florida International University
FIU Digital Commons

FCE Annual Reports and Proposals

FCE LTER

8-2007

Final Report for NSF Award #9910514 (2000-2006)

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

Dan Childers
Biology Department, Florida International University, childers@fiu.edu

Joseph N. Boyer
Southeast Environmental Research Center, Florida International University, boyerj@fiu.edu

James W. Fourqurean
Florida International University, fourqure@fiu.edu

Joel C. Trexler
Department of Biology, Florida International University, trexlerj@fiu.edu

FINAL REPORT FOR NSF AWARD # 9910514

FLORIDA COASTAL EVERGLADES LTER

Florida International University

2000 – 2006

Submitted August 2007

Principal Investigators

Rudolf Jaffé

Daniel Childers

Joseph Boyer

James Fourqurean

Joel Trexler

CONTENTS

I. Participants 3
A. Participant Individuals 3
B. Partner Organizations 4
C. Other Collaborators 5

II . Activities and Findings 6
A. Research and Education Activities 6
1. Primary Production 6
2. Soils and Sediments 10
3. Nutrients and DOM 15
4. Trophic Dynamics and Community Structure 20
5. Ecological Modeling 21
6. Abiotic Factors 22
7. Information Management 22
8. Education and Outreach 23
B. Findings 28
C. Training and Development 43
D. Outreach Activities 44

III. Publications and Products 45
A. Publications 45
B. Other Specific Products 55
C. Internet Dissemination

IV. Contributions 56
A. Contributions within Discipline 56
B. Contributions to Other Disciplines 60
C. Contributions to Education and Human Resources 63
D. Contributions to Resources for Science and Technology 64
E. Contributions Beyond Science and Engineering 64

V. References 65

I. PARTICIPANTS

A. Participant Individuals

Principal Investigators:
Rudolf Jaffé; Dan Childers

Co Principal Investigators:
Joseph Boyer; Rudolf Jaffé; James Fourqurean; Joel Trexler

Senior personnel:
William Anderson; Thomas Armentano; Mahadev Bhat; Henry Briceno; Randolph Chambers; Alice Clarke; Laurel Collins; Timothy Collins; Carlos Coronado-Molina; Stephen Davis; Frank Dazzo; Paolo D'Odorico; Robert Doren; Kelsey Downum; Daniel Dustin; Vic Engel; Sergio Fagherazzi; Jack Fell; Carl Fitz; Jose Fuentes; Evelyn Gaiser; Jennifer Gebelein; Hugh Gladwin; Anne Hartley; Mike Heithaus; Gail Hollander; Krish Jayachandaran; Frank Jochem; Lynn Leonard; Julie Lockwood; William Loftus; Jerome Lorenz; Christopher Madden; Carole McIvor; Jack Meeder; Sherry Mitchell-Bruker; Greg Noe; Laura Ogden; Thomas Philippi; Rene Price; Mark Rains; Jennifer Rehage; Jennifer Richards; Victor Rivera-Monroy; Michael Robblee; Michael Ross; Rinku Roy Chowdhury; David Rudnick; Leonard Scinto; Marc Simard; Fred Sklar; Ned Smith; Helena Solo-Gabrielle; Leonel Sternberg; Miyoshi Toshikazu; Robert Twilley; George Wolff; Joseph Zieman

Post-docs:
Anna Armitage; Susan Dailey; Sharon Ewe; Nagamitsu Maie; Renato Neto; Brad Peterson; Jay Sah; Colin Saunders; Norm Scully; Serge Thomas; Tiffany Troxler-Gann; Youhei Yamashita

Graduate students:
Dane Barr; Jordan Barr; Jose Bazante; Robin Bennett; Dorothy Byron; Pablo Cardona-Olarte; Edward Castenada; Meilian Chen; Josh Cloutier; Virginia Cornett; Kevin Cunniff; Kim de Mutsert; Bryan Delius; Bryan Dewsbury; Kendra Dowell; Samantha Evans; Meredith Ferdie; Tom Frankovich; Min Gao; Patrick Gibson; Noemi Gonzalez; Charles Goss; Andy Gottlieb; David Green; Erin Hanan; Alison Holinka; David Iwaniec; Gary Jacobi; Vera Jones; Greg Juszli; Greg Koch; Ken Krauss; Michael Laas; Josette LaHee; Shawn Liston; Regina Lynch; Ernesto Mancera-Pineda; Ralph Mead; Elizabeth Mickler; Danielle Mir-Gonzales; Ron Mossman; Jay Munyon; Amy Omae; Kathy Parish; Nicole Poret; Amanda Quillen; David Reed; Matthew Rogers; Melissa Romigh; Craig Rose; Gustavo Rubio; Sergio Ruiz; Michelle Sanchez; Jenise Snyder; Kathryn Stanaway; Chris Stevenson; Adele Tallman; Travis Thyberg; Matthew Toro; Raul Urgelles; Theo Vlaar; Ania Wachnicka; Kevin Whelan; Wendy Wildson; Clayton Williams; Jade Williams; Adam Wood; Kathy Worley; Jeffrey Wozniak; Yunping Xu; Chengyong Yang

Research Experience for Undergraduates:
Rene Aguilera; Jennifer Arce; Jody Chong; Jennifer Foss; Jenny Jun; Kathleen Kelley; Christa Lopez; Kametra Matthews; Tiffany McKelvey; Daniel Muth; Robert Muxo; Jill Schrlau; Angie Zafiris

Undergraduate students:
Carla Baez; Ashley Bubp; Michelle Calvo; Roger Lopez; Greg Losada; Kristin Pederson; Alberto Pisani; Oliva Pisani; Carrie Rebenack; Michael Right; Mary Shockley; Jeremy Wacksman; Annika Wagenhoff; Mary White

Pre-college teachers:
Jennifer Alvord; Kathy Kermes; Nicolas Oehm

High school students:
Brian Aguilar; Nia Brisbane; Sara Claro; Magaly Dacosta; Jorge Delase; Sebastian Diaz; Rebecca Fonseca; Juan Gallo; Ben Giraldo; Lauren Lesser; Oscar Marti; Natalie Navarro

Technician, programmers: Daniel Bond; Alex Croft; Andy Davis; Amanda Dean; Joel Detty; Lisa Giles; Tim Grahl; Imrul Hack; Bernice Hwang; David Jones; Steve Kelly; Mark Kershaw; Amanda McDonald; Jennifer O'Reilly; Alaina Owens; Linda Powell; Amy Renshaw; Sarah Ridgway; Damon Rondeau; Mike Rugge; Pablo Ruiz; Timothy Russell; Brooke Shamblin; Christine Taylor; Franco Tobias; Raphael Travieso; Josh Walters

B. PARTNER ORGANIZATIONS

- U.S. Department of the Interior: In-kind Support; Facilities; Collaborative Research
- South Florida Water Management District: Financial Support; In-kind Support; Collaborative Research
- Department of Interior U.S. Geological Survey: In-kind Support; Collaborative Research
- Environmental Protection Agency: Collaborative Research
- NOAA: Financial Support
- National Aububon Society: Collaborative Research; Personnel Exchanges
- University of Virginia Main Campus: Collaborative Research; Personnel Exchanges
- Fairchild Tropical Garden: Collaborative Research
- UNC-Wilmington: Collaborative Research; Personnel Exchanges
- University of Miami Rosenstiel School of Marine&Atmospheric Sci: Collaborative Research; Personnel Exchanges
  Jack Fell through a separately funded NSF grant.
- Texas A&M University Main Campus: Collaborative Research; Personnel Exchanges
  Collaborations with Stephen Davis.
- Harbor Branch Oceanographic Institute: Collaborative Research
- Rutgers University New Brunswick: Collaborative Research
- Louisiana State University & Agricultural and Mechanical College: Collaborative Research; Personnel Exchanges
- University of South Florida: Collaborative Research; Personnel Exchanges
- NASA: Collaborative Research
- Florida State University: Collaborative Research
- University of Liverpool: Collaborative Research
- College of William & Mary: Collaborative Research; Personnel Exchanges

- University of Miami: Collaborative Research; Personnel Exchanges
- Miami 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
- Nova Southeastern University: Collaborative Research
- University of Florida: Collaborative Research
- University of North Carolina at Chapel Hill: 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 6 years of the FCE LTER Program. We also partner with 1 state agency (South Florida Water Management District), 1 NGO (National Audubon Society), and 14 other universities (Louisiana State University and College of William & Mary through subcontracts).

Examples of specific collaborations include:

- Rudolf Jaffé collaborated with (1) Dr. G. Wolff; The University of Liverpool, UK; (2) Dr. Miyoshi Toshikazu, Macromolecular Technology Research Center, Japan; (3) Dr. H. Knicker, Technical University Munich, Germany; (4) Dr. B.R.T. Simoneit, Oregon State University; (5) Dr. D. McKnight, University of Colorado; (6) Dr. J. Jones, University of Alaska; (7) Dr. B. Kloeppel, University of Georgia; (8) Dr. R. Benner, University of South Carolina; (9) Dr. W. Dodds, Kansas State University; (10) Dr. J. Ortiz, University of Puerto Rico; (11) S. Ziegler,University of Arkansas; (12) Dr. P. Hatcher, Old Dominion University.

- Jim Fourqurean spent six months on sabbatical at Institut Mediterrani d'Estudis Avancat, Spain, discussing LTER related ideas with scientists and graduate students from Spain.

- Colin Saunders collaborated with a number of researchers (Dr. Deborah Willard, USGS, Reston, VA; Dr. Christopher Craft, Indiana University; Dr. Jason Lynch, North Central College; Dr. Brian Beckage, University of Vermont; Drs. Susan Newman and Shili Miao at the South Florida Water Management District) to use paleoecological data such as plant pollen, seeds, biomarkers, charcoal abundance and stable isotopes of carbon to understand and model historic changes in vegetation and environment within the Everglades National Park.

- Sharon Ewe collaborated with Dr. Maria Sobrado (Universiti of Simon Bolivar; Smithsonian funded)on the 'Understanding linkages between aboveground plant water-use and belowground water uptake patterns' study and Dr. William Overholt (University of Florida)on the 'Salinity tolerance of Brazilian pepper from different habitats of South Florida' project.

- Since 2004, we have collaborated with the SFWMD (Coastal Ecosystems Division; Carlos Coronado-Molina). The district is interested in the nutrient cycling and modeling results obtained by the FCE-LTER program in the mangrove transition zone. These results will contribute to develop 'performance measures' for mangrove forests and to evaluate water management scenarios proposed by the Comprehensive Everglades Restoration Plan for the Taylor and Shark River sloughs.

- Greg Noe communicated research methods and findings to SFWMD and their contractors to improve monitoring of STAs.

- We continue to communicate with the education groups at Everglades National Park to share educational developments and opportunities. We have become active in the Everglades Education Committee, an open organization of educators in South Florida that meet to discuss avenues to improve South Florida Environmental education and awareness.

II. ACTIVITIES AND FINDINGS

A. RESEARCH AND EDUCATION ACTIVITIES

The first phase of Florida Coastal Everglades (FCE) research (FCE I) focused 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 established 17 research sites located along freshwater to marine transects in the Shark River Slough (SRS), and the Taylor Slough/Panhandle (TS/Ph) regions of Everglades National Park. Our research was organized into 7 working groups: Primary Production, Soils and Sediments, Nutrients and DOM, Trophic Dynamics and Community Structure, Ecological Modeling, Abiotic Factors, and Education and Outreach. We've included summaries of FCE I working group activities and information management activities below.

1. Primary Production

The goal of the primary production group is to measure the production of the dominant primary producers at the FCE sites to determine the interaction of hydrology and nutrients in controlling productivity along the coastal gradient represented by our two transects. We expected that peaks would occur where communities are released from N or P limitation by the confluence of fresh and marine water. In order to address this hypothesis, a major challenge was to convert productivity estimates for each major producer to common units, and combine them to estimate system annual net primary production (ANPP) for each site. We accomplished this with our first 6 years of data and presented the findings in Ewe et al. (2006). We found an increase in *Cladium* and mangrove productivity in the oligohaline regions of Shark River Slough and two production peaks in the Taylor River Slough, one in the oligohaline zone and one at the terminal site close to the Gulf of Mexico. These productivity patterns conformed generally to our interpretation of water quality trends (Childers et al., 2006a), with the unexpected oligohaline peak in the TS transect likely being driven by a supply of nutrients from the groundwater (Childers et al., 2006b). This hypothesis is going to be further explored in FCE II, where we will focus on how the relative supply of nutrients from the surface and groundwater interact to control biomass allocation and production in the ecotone.

We provide a brief synopsis here of results and activity, organized to follow the flow of water from the upstream freshwater marsh to the downstream marine end member for each transect.

Beginning with the Shark Slough transect, primary producer biomass in the marsh is dominated by sawgrass (*Cladium*) and periphyton. Annual production of *Cladium* is calculated from above and below-ground biomass and mortality measures and periphyton by accumulation on artificial substrates and O_2 change in light-dark bottle BOD incubations. *Cladium* produces about 400-700 g dw m^{-2} y^{-1} while periphyton produces 20-30 g C m^{-2} y^{-1}; on average periphyton accounts for about 15% of above-ground production in the marsh (Ewe et al., 2006). Biomass of both producers changed significantly from the site near the canal input (SRS-1) to the downstream marsh site (SRS-3). 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). We quantified belowground biomass of and productivity by *Cladium* at our 2 estuarine ecotone sites (SRS-3 and 4), and found higher biomass but lower productivity at the SRS-4 site, which has direct, tidal connectivity to the marine source of P (Juszli, 2006). Decomposition of the 3 dominant herbaceous species at these 2 sites (*Cladium*, *Eleocharis*, and *Juncus*) showed some interesting inter-species differences. *Cladium* decomposed more quickly at the SRS-4 site, where P was more available, while *Eleocharis* decomposition was more rapid at the SRS-3 site, where N was more available. Additionally, *Cladium* litter tended to immobilize P while *Eleocharis* litter showed net remineralization during the decomposition process (Rubio & Childers, 2006).

The ratio of epiphytic to floating periphyton also decreased from the canal site to the two interior sites, possibly denoting a nutrient-induced loss of the calcareous floating mat, observed frequently in the Everglades. Net productivity per unit biomass of the periphyton was also consistently low at SRS-1 compared to the two downstream sites (8, 29, 33 g C m^{-2} y^{-1}, respectively) perhaps due to shading by the dense sawgrass culms at this site. A significant negative relationship between production and phosphorus content of the mats was detected. Periphyton production was highest in the wet season and lowest in the dry season, while no significant interannual trends were detected.

Further downstream, productivity at SRS-4, 5 and 6 is dominated by mangroves. Annual litterfall rates were determined using monthly collections of litter fall material in litter baskets. SRS6 had the highest mean rate (3.12 ± 0.26 g m^2 d^{-1}), followed by SRS4 (2.76 ± 0.31 g m^2 d^{-1}), SRS5 (2.30 ± 0.21 g m^2 d^{-1}), showing a productivity peak at the marine end of the transect. Leaf fall comprised most of the total litterfall in all sites ranging from 69% (SRS4) to 83% (SRS5). Wood fall contribution to total litterfall ranged from 9% (SRS5) to 13% (SRS6), while reproductive parts had the smallest contribution varying from 5% (SRS5) to 9% (SRS6). There was a consistent seasonal pattern of litterfall production in all sites. Higher rates were observed during the wet season (June-November) compared to the dry season (December-May). For SRS6, the mean daily rate during the dry season was 1.73 ± 0.14 g m^2 d^{-1}, while wet season rates were 4.53 ± 0.33. There was significant interannual variation at SRS4, with higher rates during 2005 compared to 2001-2004. These higher rates (up to 15.4 g m^2 d^{-1}; annual mean of 16.28 ± 0.58 Mg ha^{-1} yr^{-1}) observed during the rainy season of 2005 reflected the effect of two major hurricane events, Katrina (August 29, 2005) and Wilma (October 29, 2005) that strongly impacted the study sites in the Florida Coastal Everglades.

Water level data recorded in the interior part of these mangrove forests during the passage of hurricane Wilma indicated the strong effect of these pulsing events in the mangrove forests. Water level values in SRS5 and SRS6 were above 1 m, while in SRS4 water levels were not as high (up to 50 cm). Thus, most of the litterfall was washed out of the forest in the downstream sites. The extremely high annual rates of litterfall observed during 2005 in SRS4 compared to the downstream sites (SRS5 and SRS6) of Shark River is likely the result of the strong wind effect and the lack of the storm surge effect in the upstream site of the Shark River estuary.

Overall, the estimated values for the Shark River sites and TS/Ph8 are within the range of values reported for other mangrove sites in the Neotropics. However, the hurricane effect episodically altered the productivity gradient, which has been well documented along the Shark River estuary (Chen and Twilley 1999). After hurricane Wilma the observed productivity gradient was as follows SRS6 > SRS4 > SRS5. These results corroborate the significant effect of pulsing events such as hurricanes in the structure and function of mangrove forests. We are currently analyzing nutrient concentrations (carbon, nitrogen and phosphorous) in the plan material to determine litterfall nutrient fluxes into soils at each site.

Phytoplankton, measured monthly by pulse amplitude modulated (PAM) fluorometry has shown that biomass (dominated by diatoms, rather than cyanobacteria and green algae) decreases from the freshwater system to the estuary, while photosynthetic rates (highest for cyanobacteria) increase from the marsh to the estuary along the SRS transect.

The Taylor Slough/Panhandle transect is bifurcated at the upstream end, containing freshwater marsh sites in both the Taylor Slough and C-111 wetlands. 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. Perhaps due to this difference in soil type, *Cladium* plants are smaller and production is lower (200-500 g dw m^{-2}) in the upstream TS/Ph marsh sites relative to the SRS marsh, while culm densities are significantly higher. In addition to quantifying ANPP of *Cladium*, we also quantified belowground biomass and productivity, and decomposition rates at the two southern Everglades ecotone sites (TS/Ph-3 and 6). We found no significant difference in *Cladium* belowground biomass at these two sites, and belowground productivity values that were high and similar to those measured at the SRS-3 upper ecotone site—a result that reflects the fact that the southern Everglades ecotone does not receive marine P (Juszli, 2006). We also found that *Cladium* litter tended to immobilize P while *Eleocharis* litter showed net remineralization during the decomposition process (Rubio & Childers, 2006).

In contrast to the SRS transect, periphyton in the TS/Ph transect is dominated by thick, highly agglutinated, sediment-associated mats, rather than floating or epiphytic aggregations. These mats are more productive than the SRS mats, contributing an average of 55% of total primary production at the research sites (Iwaniec et al., 2006). Site TS-Ph 4 was particularly productive, at times exceeding 10,000 g C m^{-2} yr^{-1}. Spatial trends in production were positively related to total phosphorus availability. Temporal trends in production were related to water flow, with production being highest immediately following pulses of water delivery.

In contrast to mangrove communities at the marsh-marine ecotone of Shark River slough, the mangrove-dominated sites in Taylor Slough have significantly shorter trees and had lower rates of litterfall (1.03 ± 0.1 g m^2 d^{-1} at TsPh-8) and root production. Wood fall contributed only 9% to total litterfall. The current estimates of fine root productivity in the Taylor region reflect significant phosphorus limitation, in contrast to the marine site along the SRS transect (SRS-6) that were very highly productive, supporting the hypothesis marine P is being sequestered by Florida Bay.Seasonal changes were similar to those on the SRS transect, with dry season values at TS/Ph8 averaging 0.84 ± 0.17 g m^2 d^{-1} (TS/Ph8) and wet season rates averaging 1.32 ± 0.1 g m^2 d^{-1} (TS/Ph8). The 2005 hurricanes also affected the TS/Ph8 site where wind and storm surge partially destroyed litter baskets.

Like the SRS transect, phytoplankton production in panhandle sites show a decrease in biomass (dominated by diatoms) from freshwater to estuary sites while primary production by cyanobacteria increases in that direction. Taylor Slough biomass is also dominated by diatoms, with a peak at TSPh3; primary production is divided equally across guilds with no observable trends in PP along the transect

Seagrass composition and production continue to be measured quarterly in Florida Bay (TS/Ph-7-11) using in-situ visual cover and abundance assessments and leaf marking. Data from these efforts can be found at www.fiu.edu/~seagrass. LTER data are being coupled to larger seagrass monitoring activities and to a large-scale nutrient manipulation study.

One student used PAM fluorometry to assess seagrass productivity and response to salinity stress along the TS/Ph transect (Byron 2006). She coupled field measurements of seagrass fluorescence-salinity relationships with direct measurements of the response of fluorescence to salinity manipulation in mesocosms. Her results showed that the main seagrass along the TS/Ph transect, *Thalassia testudinum*, maintained the integrity of its photosynthetic apparatus over a broad range of conditions, and that it could adapt to the salinities it encountered during her study without a loss in photosynthetic performance. Another student documented for the first time the submerged aquatic vegetation of the Shark River along the SRS3-6 transect (Cornett 2006). She found that the benthic communities were represented by 5 well-defined species assemblages, and that these assemblages corresponded to the riverine gradients of salinity, P availability and TOC concentration. She also documented the stable C and N isotope ratios of the submerged aquatic plants in this system for use in a food web study of the West Indian Manatee.

Previous mass mortality events in the seagrasses of Florida Bay have been shown to be caused by hypoxic conditions that allow sulfide entry into the meristems of the seagrasses from the highly reducing conditions of the sediments (Borum et al. 2005). In order to assess the roles of organic-matter driven sulfate reduction on sulfide availability and the effects of sulfide on seagrasses, and the role of iron in sulfide sequestration, a manipulative experiment was carried out over 2 years at TS/Ph 10 (Ruiz-Halpern 2006). This study documented significant suppression of seagrass productivity and biomass when sulfate reduction was enhanced, and further found that iron amendments could sequester all of the excess sulfide produced under the organic matter loading treatment and protect the seagrasses from the harmful sulfide effects.

In the oligotrophic Florida Bay ecosystem, nutrients supplied by hydrological processes largely limit the biomass, and therefore productivity, of the seagrasses of the system. Previous work has shown that congregations of pisivorous birds can cause an increase in plant density and productivity in Florida Bay because of the deposition of nutrients in bird feces (Powell et al 1991). We tested whether congregations of piscivorous fish could also lead to local nutrient concentration and increased primary production (Dewsbury 2006). Over a short (1 y) period, artificial reefs placed near TS/Ph 10 attracted and held large schools of fish; these fish did increase sediment nutrients; but over the sort time scale of the experiment they did not augment primary production in the seagrass beds adjacent to the reefs. We will continue to monitor these reefs to determine the time scale of nutrient accumulation around artificial reefs in this very oligotrophic environment.

Epiphyte accumulation rates are measured quarterly on artificial blades (mylar strips, incubated for 6 weeks). 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).

2. Soils and Sediments

Soil/sediment biogeochemistry

The biogeochemistry of iron, sulfur and phosphorus is tied closely to the cycling and preservation of organic matter in soils and sediments. Annual, synoptic sampling and analysis of the physical and chemical properties of soils during FCE-I allowed us to establish a baseline context for spatial comparisons among FCE-LTER sites/transects, against which "push-press" changes in the Everglades-mangrove-Florida Bay system can be documented during FCE-II. Our data showed that the marl-dominated TS/Ph surface soils are characterized by low organic percentage, low extractable iron, low total sulfur and low total phosphorus. In contrast, peat-dominated SRS surface soils are characterized by high organic percentage, high extractable iron, low total sulfur and high total phosphorus. Mangrove soils tend to have higher concentrations of organic matter, extractable iron, total sulfur and total phosphorus than do soils from either the freshwater (Everglades) or saltwater (Florida Bay) end-members along TS/Ph and SRS transects. This effect is much more pronounced along the SRS transect. Mineral sulfide formation occurs primarily as pyrite (FeS_2, not FeS) and tends to be iron-limited in surface soils along the TS/Ph transect, but not along the SRS transect. Most inorganic phosphorus in soils from both transects occurs in the calcium carbonate pool, and most organic phosphorus occurs in the recalcitrant pool extracted by ashing/acid hydrolysis. These patterns in soil properties suggest that water flow affects delivery of nutrients and removal of reduced toxins in south Florida wetlands. To date we have documented changes in soil properties related to hurricanes (short-term, acute impact) and to availability of sediment reactive iron (longer-term, chronic impact).

Mangrove Zone Research

The mangrove vegetation landscape in the Florida Coastal Everglades (FCE) represents a combination of different mangrove ecological types distributed across a carbonate environmental setting with gradients in resources, regulators, and hydroperiod. Thus, mangrove forests structure and function in south Florida are regulated by resource competition and stress due to shifts in nutrient pools and hydroperiod across a coastal gradient. During FCE-I, the mangrove soil and sediments component of the LTER project addressed several research questions to understand soil organic matter, soil biogeochemical properties and nutrient pools dynamics along the freshwater-estuarine transect of Taylor River and Shark River Sloughs.

In this report we show the results from different studies performed during the period 2001-2006. We present a comprehensive long-term study on the spatial and temporal patterns of soil biogeochemical properties (porewater and soil nutrients, sulfides, salinity, redox potential) and hydroperiod along the freshwater-estuarine transect of Shark River (SRS4, SRS5, SRS6) and Taylor River (TsPh6, TsPh7, TsPh8). We showed the distinct spatial variability and seasonality (dry vs. wet season) in soil biogeochemical properties and hydroperiod across the mangrove vegetation landscape; we also demonstrated how hydroperiod regulates soil properties between two contrasting mangrove regions (Taylor River and Shark River). Water levels along the Shark River sites showed the influence of tidal exchange, while along the Taylor sites flooding conditions are dominant, except in the downstream site (Ts/Ph8). Along the Shark River sites, water levels during the dry season were above the surface less than 40% of the time each month, while during the wet season monthly flooding duration was between 80% and 100%. A total different scenario occurred in the Taylor sites, where flooding duration was 100% during most of the years (Ts/Ph6), while in Ts/Ph7 and Ts/Ph8 monthly flooding duration ranged from 10% to 100% (dry and wet seasons, respectively). Flooding frequency is significantly different between both regions, with an increase in tidal frequency from upstream (SRS-4) to downstream (SRS-6) locations along the Shark River estuary. In contrast, frequency of inundation in Taylor River is negligible upstream (Ts/Ph6 and Ts/Ph7) and downstream (Ts/Ph8). Tidal range in this region is less than 0.1 m and is frequently masked by wind forcing.

We also showed how concentrations of soil nitrogen (N) and phosphorus (P), and N:P ratios were closely related to patterns of productivity. Phosphorus (P) concentrations along the Shark River sites showed a distinct gradient that decrease with distance from the marine end member (SRS6) (range: 22 to 93 g m^{-2}), while concentrations along the Taylor River showed similar values (range: 20 to 40 g m^{-2}). N:P ratios < 25 in SRS6 were indicative that P is not a limiting nutrient for mangrove productivity, while in the upstream sites of Shark River (SRS4 and SRS5) and all Taylor sites, N:P ratios > 40 indicated P-limited conditions. Results from this study support our hypothesis that a combination of different hydrological regimes and gradients in nutrient resources and regulators constrain mangrove forest productivity and growth along the freshwater-estuarine transects of both Shark and Taylor Rivers. In addition Cesium-137 specific activity measurements showed that accretion rates along Shark River are in the range observed in other mangrove forest in the Neotropics (2-3 mm yr^{-1}).

We evaluated tidal and seasonal variations in concentrations and fluxes of nitrogen (NH_4^+, NO_2+NO_3, total nitrogen) and phosphorus (soluble reactive phosphorus, total phosphorus) in a riverine mangrove forest (SRS6) using the flume technique during the dry (May, December 2003) and rainy (October 2003) seasons in Shark River. We further demonstrated how the distinct seasonality in nutrient concentrations in the flume and the adjacent tidal creek are closely coupled with Ponce de Leon Bay (i.e., Gulf of Mexico), which is the main source of SRP and N+N into the mangrove forests for this region.

Our mangrove soil processes/formation studies continued to focus on belowground root production and decomposition and their effects on root nutrient stoichiometry, particularly during decomposition of fine roots. This information contributed to estimations of ecosystem level carbon budgets. We evaluated the spatial patterns of belowground biomass and productivity along Shark River and Taylor River Sloughs. We performed two separate field experiments (from December 2000 to December 2002 and from December 2002 to February 2006) to evaluate standing crop root biomass, belowground productivity, and root distribution at different depths (top: 0-45 cm and bottom: 45-90 cm), using the sequential coring and ingrowth core techniques. Belowground biomass varied significantly among sites and depths, with higher values in the Taylor than in Shark River. Higher productivity rates were observed in Shark River

(SRS5 > SRS4 > SRS6) compared to Taylor River (TsPh6 > TsPh8 > TsPh7), with higher rates in the top section (0-45 cm) than in the bottom section (45-90 cm) for all sites. These results confirmed our hypothesis that mangroves under P-limited conditions such in the Taylor River sites and one upstream site in Shark River (SRS4) allocate more resources to roots when compared to downstream Shark River (SRS-6), where the highest soil P concentrations (93 g m^{-2}) were observed.

A fine root decomposition study showed that rates for ambient roots were significantly different among the FCE-LTER sites (SRS-4, SRS-5, SRS-6) ($p < 0.001$). Losses at the end of the incubation period (7 months) ranged from 25% to 50% for the ambient roots across six sites. The highest losses among the ambient roots occurred along the Shark River transect in SRS5 (50% loss), SRS4 (45% loss) and SRS6 (43% loss). The lowest losses occurred along the Taylor Slough transect in Ts/Ph7 (35% loss), Ts/Ph8 (31% loss) and Ts/Ph6 (25% loss). In general, ambient root decay was lower among Taylor Slough sites than in the Shark River sites, with the exception of Ts/Ph7.

Finally, we contribute data from our carbon dynamic and ecological modeling studies to prepare two review papers in collaboration with other colleagues from different institutions. The first manuscript (Global Biogeochemical Cycles, in review) reviews carbon budgets for mangrove forests and propose several research venues to determine other carbon sources to account for ~30-40% of "missing" carbon in current budgets for this coastal ecosystem; another paper reviews the state of the art of individual-based mangrove modeling in the Neotropics (Aquatic Botany, accepted).

Organic geochemistry research

We have spent a considerable effort during the FCE-LTER-1 funding cycle in assessing organic matter sources in Everglades' wetland and estuarine environments. These studies were primarily based on molecular marker fingerprints and were initiated through the identification of biomass-specific molecular markers or molecular proxies in wetland vegetation. As such the application of *n*-alkane distributions proved to be quite useful for this purpose, as the relationship between long- and mid-chain *n*-alkanes were quite characteristic for different biomass components (Mead et al., 2004; Neto et al., 2005). Other biomass specific biomarkers such as the C_{20} highly branched isoprenoids (HBIs), identified in the FCE as markers for periphyton (likely from cyanobacteria) were successfully applied to better assess periphyton/floc transport throughout the system (Jaffe et al., 2001; Xu et al., 2006). Other biomarkers such as the kaurenes were identified in wetland vegetation, particularly *Cladium*, and initially thought to be markers for fungi (Neto et al., 2005). While this may still be the case, it looks like the best application for these markers is as indicators of belowground *Cladium* biomass as they were particularly abundant in the roots of *Cladium* (but not of *Eleocharis*) (Gao, 2007).

In addition, molecular distributions of *n*-alkanes as well as *n*-alkane-2-ones were found to be quite characteristic for seagrasses and thus applied to trace seagrass-derived OM throughout FCE estuaries (Hernandez et al., 2001; Jaffe et al., 2001; Xu et al., 2006a). To better understand the dynamics of OM in FCE estuaries, the sources and transformations of sedimentary organic matter along a salinity gradient of the estuarine Shark River Slough were assessed using such a biomarker approach. In general, the freshwater marsh endmember samples had a different overall composition compared to the estuarine sediment extracts (Jaffe et al., 2001, Jaffe et al., 2006). Generally, compound concentrations decrease downstream due to dilution, and alteration of organic compounds from plant waxes and coastal vegetation is obvious in sediment samples.

This is confirmed by the significant low abundance of *n*-alkanes and *n*-alkenoic acids due to biodegradation, oxidation of α-tocopherol to homophytanic acid γ-lactone, and presence of traces of dihydrolacunosic acid, a photochemical alteration product of taraxerol (Simoneit et al., 2007). OM in the estuary seemed primarily influenced by local vegetation sources, although some exchange with both freshwater and marine endmembers was observed. As such mangrove markers such as taraxerol, showed highest abundances in the mangrove dominated estuary, while biomarkers for marine diatoms (C_{25} HBIs) increased in abundance with increasing salinity along the estuary (Xu et al., 2006a; Mead, 2003). Conceptual models for OM mixing were developed for the Shark River and Taylor River estuaries based un both sediment and particulate organic matter (POM) biomarker analyses (Mead, 2003; Jaffe et al., 2001).

Temporal and spatial variations in the composition of POM from Florida Bay were also examined (Xu and Jaffe, 2007). The biomarker distribution suggested a bay-wide predominant autochthonous/marine OM source. However, several biomarker proxies indicated a spatial shift in OM sources where terrestrial OM rapidly decreased while seagrass and microbial OM markedly increased along a northeastern to southwestern transect. This trend was more marked in surface sediments (Xu et al., 2006a). POM collected during the dry season was enriched in terrestrial constituents relative to the wet season, likely as a result of reduced primary productivity of planktonic species and seagrasses during the dry season. Hydrological fluctuations and seasonal primary productivity fluctuations are the drivers controlling the POM composition in the Bay. For sediments a clear NE to SW gradient was observed in regards to OM sources, which changed from terrestrial/mangrove derived to mainly seagrass/plankton derived along this transect. Paleoecological studies performed on Florida Bay sediment cores suggested a clear relationship between recent human induced environmental changes and biomass production and distribution (Xu et al., 2007; Xu et al., 2006b).

In a continued pursuit of biomass specific OM tracers in the FCE we further investigated a suite of C_{20} and C_{25} HBIs and C_{30} highly branched isoprenoids (7,11-cyclobotryococcanes; Xu, 2005) hydrocarbons as potential microbial indicators for cyanobacteria, diatoms and green sulfur bacteria respectively. In addition, an exceptionally high abundance of the isoprenoid hydrocarbons, botryococcenes, with carbon skeletons from 32 to 34 were detected in the Florida Everglades freshwater wetlands (Gao et al., 2007). This is the first report that botryococcenes occur in the Everglades freshwater wetlands where the presumed source organisms of these compounds, *Botriococcus braunii*, have not been reported. While their origin remains unknown in this ecosystem, paleoenvironmental assessments showed that their abundance has significantly increased over the past 40 years suggesting a response to anthropogenic impacts, possibly increased nutrient inputs, on these wetlands.

Present and past environmental conditions and paleo-environmental changes were assessed in freshwater wetland soils of the Everglades using organic geochemistry techniques. Organic matter in both peat and marl soil cores was characterized by geochemical means. Samples were selected along nutrient and hydrology gradients with the objective to determine the historical sources of organic matter as well as the extent of its preservation and the environmental factors which control it (Gao, 2007; Saunders et al., 2006). Thus short-term sub-aqueous decomposition patterns of aboveground and belowground produced organic matter from two freshwater vascular plants (*Cladium jamaicense* and *Eleocharis cellulosa*) were investigated at two marsh sites, while mangrove leaf and root decomposition was determined in estuarine areas. The bulk chemical composition of fresh, decomposing litter, and soils was estimated by elemental analysis and solid state ^{13}C NMR spectroscopy. Optical properties of extracted humic substances and degradation of lignins were also determined as proxies of OM degradation. The results suggest that *Eleocharis* derived OM was more liable compared to *Cladium*. Relative to aboveground litter, root and rhizome litterbag experiments showed that the belowground biomass of both species was more resistant to degradation, and that rhizomes were more labile than roots.

The soil organic matter (SOM) preservation was assessed through elemental analysis and molecular characterizations of bulk ^{13}C stable isotopes, solid state ^{13}C NMR spectroscopy, UV-Vis spectroscopy, and tetramethyl ammonium hydroxide (TMAH) thermochemolysis-GC/MS. The relationship of the environmental conditions and degradation status of the soil organic matter (SOM) among the sites suggested that both high nutrient levels and long hydroperiod favor organic matter degradation in the soils. This is probably the result of an increase in the microbial activity in the soils which have higher nutrient levels, while longer hydroperiods may enhance physical/chemical degradation processes. The most significant transformations of biomass litter in this environment are controlled by very early physical/chemical processes and once the OM is incorporated into surface soils, the diagenetic change, even over extended periods of time is comparatively minimal, and SOM is relatively well preserved regardless of hydroperiod or nutrient levels. SOM accumulated in peat soils is more prone to continued degradation than the SOM in the marl soils. The latter is presumably stabilized early on through direct air exposure (oxidation) and thus, it is more refractory to further diagenetic transformations such as humification and aromatization reactions.

Regarding OM preservation in mangrove forests, peat/soil cores were collected from the estuarine zones of Shark River Slough (SRS) and Taylor Slough (TS), the two major drainage basins of ENP. These two regions differ in soil type, forest structure, tidal influence and water residence time, and sites within these regions lie along nutrient and salinity gradients. Lipid biomarker analyses revealed that in addition to mangroves, fungi and cyanobacteria may be among the autochthonous sources of organic matter to mangrove soils. The high abundance of a series of ring-A-degraded triterpenoids in soil extracts suggests that microbial activity within the soils is high and/or another diagenetic pathway for the chemical alteration of the parent 3-oxy-triterpenoids may exist. Preliminary results from lignin phenol and ^{13}C-NMR analyses show that, similarly to the case of OM in freshwater marsh environments, after surficial diagenetic processes occur the chemical signature of mangrove-derived organic matter is well preserved in the sediments. This work is presently on-going (Cloutier, 2007).

Effective molecular proxies were developed to differentiate the relative input of organic matter from different biological sources to wetland soils. Thus historical vegetation shifts and hydroperiods were reconstructed using those proxies (e.g. Saunders et al., 2006; Gao, 2007). The data show good correlations with historical water management practices starting at the turn of the century and during the mid 1900's. Overall, significant shortening of hydroperiods during this period was observed.

In summary, the first six year cycle of the FCE-LTER program resulted in a wealth of information regarding organic matter characterization and dynamics in this ecosystem. Hardly any organic geochemical information had previously been available on this important wetland-estuarine system and the LTER work has provided a solid background on OM characteristics and molecular tools have been developed to better assess OM dynamics in the system. However, these dynamics are still far from being fully understood and additional research is required to better characterize the transport and mixing of OM from different sources, particularly in the FCE estuarine regions, and to develop models allowing the prediction of Everglades restoration efforts on OM production, transport (export), and preservation. Among key research issues is the biochemistry of 'floc' or flocculent OM, widely distributed in the system, and whose dynamics (sources, transport and fate) are complex (Neto et al., 2005) and still poorly understood. This will be one focal point for the organic geochemistry research during the FCE-LTER-2 funding cycle.

3. Nutrients and DOM

The Nutrients and DOM working group research during FCE I was driven by a two-part central question: How is the quality and/or quantity of DOM or the quantity of inorganic nutrients in source water altered by changing freshwater flow versus internal processes occurring at a given location in the landscape? How are local ecosystem processes controlled by changes in source water DOM or inorganic nutrients? We collected data on water quality, bacterial community structure and productivity, and dissolved organic matter (DOM) dynamics at all 17 FCE sites and conducted experiments to address these questions.

Water Quality

FCE's water quality program collected tri-daily composite water samples from the 14 wetland sites (SRS 1-6, TS/Ph 1-8) using ISCO autosamplers, and monthly grab samples from the 3 Florida Bay sites (as part of a water quality program funded by other sources). Tri-daily water samples from the 14 wetland sites were analyzed for total nitrogen (TN), total phosphorus (TP), and salinity. Additionally, monthly grab samples were analyzed for TN, TP, NO_2^-, NO_3^-, NH_4^+, soluble reactive P (SRP), dissolved organic carbon (DOC), and total organic carbon (TOC) at the wetland sites. We also quantified rainfall at all freshwater sites, and periodically collect event-related surface water samples during major rain events. Water quality at the 3 Florida Bay sites (TS/Ph 9-11) was sampled monthly and analyzed for TN, TP, NO_2^-, NO_3^-, NH_4^+, SRP, TOC, temperature, salinity, dissolved oxygen, silicate, chlorophyll *a*, and alkaline phosphatase activity. Additionally, we took monthly measurements of phytoplankton biomass, deconvoluted as bluegreen, brown, and green algae, using the PAM fluorometric method and phytoplankton primary production, deconvoluted as bluegreen, brown, and green algae, using the PAM fluorometric method. We conducted quarterly incubation experiments for bioavailability of DOC and DON at all accessible LTER sites.

Our water quality data support the "upside down estuary" model, which is the central premise of FCE research. By "upside down", we mean simply that the marine end-member - the Gulf of Mexico - supplies the limiting nutrient (P) to our estuaries. Along the Shark River Slough transect, the mangrove estuary is directly connected to this marine source of P whereas along the southern Everglades transects the mangrove estuarine sites are isolated from the GOM by Florida Bay. We completed a detailed analysis of water quality data from 1996 - 2006 from all 17 LTER sites, and related these long-term patterns to water management and climatological forcing during this time. Notably, we reported for the first time a consistent El Niño effect on precipitation in south Florida: During ENSO events, the Everglades typically experiences dry wet seasons and wet dry seasons, but with no substantive change in total annual rainfall. This "washout" of the seasonality of precipitation and freshwater inflow affects nutrient concentration patterns along both of our estuarine transects. This paper was written by invitation, and was published in Limnology and Oceanography (Childers et al. 2006b).

We characterized the phosphorus and nitrogen content of suspended particles in the water column of oligotrophic and eutrophic freshwater marshes across the Everglades hydroscape. Particulate phosphorus can be a large proportion of total phosphorus in the water column (23-

47%) and this proportion is correlated with total suspended sediment concentrations. The 0.45 to 2.7 µm fraction was the dominant size of particulate phosphorus at all sites. In contrast, particulate nitrogen was a small proportion of total nitrogen in surface water (2-7%) and was larger (mostly 2.7 to 10 µm size class). We also characterized the composition and concentration of suspended particles in the water column of Everglades wetlands. This information is being used to develop models of particulate dissolved nutrient transport in the Everglades and other wetlands.

We estimated the flux of nutrients (P and N) to the surface waters of the Southern Everglades from groundwater discharge. Nutrient concentrations are often higher in groundwater than in surface water due to longer water-rock interaction times, and can be a source of nutrients to the surface water in groundwater discharge areas. During the summer of 2003, 14 existing groundwater wells and 9 surface water samples were sampled across the seawater-freshwater mixing zone in the southern Everglades (an area for potential groundwater discharge) for TP and TN. Total P concentrations ranged from 0.5 to 2.3 µM (16 – 73.6 µg/L-P). Concentrations of TP in the overlying surface water were consistently lower and ranged from 0.16 to 0.45 µM (5.1 – 14.4 µg/L-P). Total N concentrations in both surface water and groundwaters were higher than TP values and ranged from 44.5 to 149.5 µM. The average surface water TN concentration was 71.9 ± 11.2 µM. In the groundwater, the average TN concentration was 89.9 ± 33.4 µM. Groundwater TP concentrations were consistently higher than the surface water at all locations sampled in the southern Everglades. In addition, groundwater TP concentrations increased toward the coastline. Conversely, both groundwater and surface water concentrations of TN decreased toward the coastline. There was a strong positive correlation between groundwater TP and salinity (R2=0.6). The results of this investigation indicate enhanced P concentrations within mixing zone groundwaters underlying the southern Everglades. Groundwater discharge across the region has been estimated to range from 2 to 25 cm/yr. At these discharge rates, the groundwater can contribute between 0.1 to 3.5 mg-P m-2 yr-1 to the overlying surface water of the coastal Everglades. Although these values are small compared to published estimates of the atmospheric contribution of total phosphorus to the Everglades, they represent an additional input of phosphorus to a nutrient limited ecosystem. The observed low concentration of phosphorus in the surface waters of the southern Everglades suggest that the additional groundwater source of phosphorus may be retained within the sediments and/or biota of the Everglades.

Bacterial Community Structure and Productivity

Microbial parameters were quantified monthly at all 17 sites. We monitored bacteria counts using epifluorescent microscopy and bacterial production using 3H-thymidine uptake at all 17 FCE LTER sites. We investigated the change in sediment bacterial community structure (BCS) along FCE LTER gradients using PCR-DGGE. Many different types of bacteria inhabited the soils and sediments along the gradient (50-60 bands). Cluster analysis showed that BCS first divided into two clusters: an estuarine Florida Bay group and a terrestrial wetland group. The Florida Bay cluster was further subdivided into Eastern and Central Bay group and a Western Bay group. The wetland cluster was also subdivided into a freshwater marsh group and a mangrove forest group. These results suggest that habitat types along with nutrient conditions are important drivers in BCS in coastal wetlands, whereas, in the estuary, BCS is mostly affected by the strong nutrient gradient. Sequence analysis of the DGGE bands indicated that the major bacteria associated with every region was *Actinobacteria*, which was retrieved from wide range of habitats. In addition, the bacteria associated with sulfur cycling were also detected in every region. *Chloroflexi*, *Verrucomicrobia*, and *Nitrospirae* were characteristic bacteria in Everglades (marsh and mangrove), while *Cyanobacteria*, *Cytophagales*, and *Spirochaeta* were more prevalent in Florida Bay.

We evaluated the effects of N and P gradients on sediment bacterial communities across the estuarine nutrient gradient in Florida Bay. Eastern Florida Bay is strongly P limited while western bay is more N limited. Sediment samples were collected at six sites across the bay where control, N, P, and N+P application plots have been established. DNA was extracted and the eubacterial communities delineated using PCR-DGGE analysis of the 16S rDNA. Based on the DGGE patterns, many different types of bacteria were found to inhabit the sediments irrespective of sampling sites and fertilizer applications (47-56 bands). Shannon-Weaver index showed that bacterial diversity in the east, as influenced by the runoff from Everglades, was higher than in western bay. Cluster analysis of PCR products showed that the bacterial communities changed largely according to the natural E-W nutrient gradient existing in Florida Bay. Sediment fertilization effects were overshadowed by natural ecosystem nutrient and salinity gradient. The addition of N had no effect on sediment bacterial community structure. Significant changes in bacterial community structure were found for P and NP application plots across the bay, irrespective of water column nutrient status. P addition caused convergence in bacterial community structure across the gradient to a more common type, enhancing populations of Fe (III) reducers and S oxidizers in the east and augmenting S oxidizers and the organic degrader community throughout the bay. The overall effect was one of increased capacity to degrade and recycle C, S, and Fe under anaerobic conditions.

Dissolved Organic Matter (DOM) Dynamics

The molecular characterization of DOM at the FCE LTER sites used a multi-methods approach in combination with the monitoring of several optical and chemical parameters. The molecular characterization was performed both on biannual sampling events for ultrafiltered DOM (UDOM; e.g. Maie et al., 2005) and monthly for bulk DOM characterizations (Jaffe et al., 2004; Lu et al., 2003; Maie et al., 2006b). The former was intended to produce data representative for the dry and wet season in the Everglades ecosystem. The techniques we used included solid state ^{13}C-NMR and ^{15}N-NMR, on line pyrolysis-GC/MS, TMAH chemothermolysis, and analysis of hydrolyzed sugars by GC/MS, 2D-electrophoresis of proteins, amino acid analyses and size exclusion chromatography (Maie et al., 2005; Maie et al. 2006a; Jonse et al., 2005, 2006; Maie et al., 2007a). Our results showed clear differences in the DOM composition along the SRS and TS/Ph transects, which seem to relate to DOM source changes as well as to diagenetic transformations of the DOM (Scully et al., 2004; Maie et al., 2006c). In this respect, DOM inputs from canals (i.e. more highly degraded DOM) and DOM freshly leached from local biomass, in conjunction with bio- and photo-degradation processes, seem to strongly influence the molecular composition relative to position of a water mass in the landscape.

We also quantified optical properties (UV-Vis and fluorescence), total protein content, total carbohydrates, humic and non-humic substances, and molecular weight distribution of DOM from monthly samples collected at all SRS and TS/Ph sites (Parish et al., unpublished). These parameters allowed us to assess both seasonal and geographic variations in DOM composition and relate these variations to the contributions of canal, freshwater marsh, mangrove fringe and coastal derived DOM in the system.

Dissolved organic nitrogen (DON) is believed to play a key role in fueling the microbial loop in the FCE. However, little is known about its molecular characteristics. A combination of techniques, including ^{15}N cross-polarization magic angle spinning nuclear magnetic resonance (^{15}N CPMAS NMR) and X-ray photoelectron spectroscopy (XPS), were used to analyze the N components of ultrafiltered DOM (Maie et al., 2006a). The concentrations and compositions of total hydrolysable amino acids (HAAs) were analyzed to estimate UDOM bioavailability and diagenetic state. Optical properties (UV-visible and fluorescence) and the stable isotope ratios of C and N were measured to assess the source and dynamics of UDOM. Spectroscopic analyses consistently showed that the major N species of UDOM are in amide form, but significant contributions of aromatic-N were also observed. XPS showed a very high pyridinic-N concentration in the FCE-UDOM (21.7±2.7%) compared with those in other environments. The sources of this aromatic-N are unclear, but could include soot and charred materials from wild fires. Relatively high total HAA concentrations (4±2 %UDOC or 27±4 %UDON) are indicative of bioavailable components, and HAA compositions suggest FCE-UDOM has not undergone extensive diagenetic processing. These observations can be attributed to the low microbial activity and a continuous supply of fresh UDOM in this oligotrophic ecosystem. Marsh plants appear to be the dominant source of UDOM in freshwater regions of the FCE, whereas seagrasses and algae are the dominant sources of UDOM in Florida Bay.

To better understand the environmental dynamics of DOM in the FCE, experiments were conducted which addressed the effect of increased salinity on flocculation of DOM, the effect of photolysis on the chemical structure of DOM (Jaffe et al., 2004), and on the microbial bioavailability of the DON component (Boyer et al., 2007) from sawgrass marsh, mangrove forest, and seagrass beds. No significant flocculation or precipitation of DOM occurred with increased salinity. Therefore, terrestrial DOM remains in the water column where it subjected to extended photolysis, estuarine mixing, and transport. Simulated sunlight had a significant effect on the chemical characteristics of DOM. While the DOM concentration did not change significantly during photo-exposure, its optical characteristics were modified (Scully et al., 2004). The environmental implications of this are conflicting as photo-induced polymerization may stabilize DOM by reducing its bioavailability while photolysis may make the DOM more labile. The DON bioavailability was relatively low in this region. Under estuarine salinity conditions, the percent of bioavailable DON (BDON), from the freshwater wetland was higher (9.2%) than from both mangrove (4.8%) and seagrass sites (3.5%). This implies that faster DON transport from freshwater wetlands to the bay may have a more pronounced impact on the N cycle than is currently the case. Although the BDON is low, the DON concentrations are high relative to the DIN pool. Therefore, if the median DIN concentration for the estuarine site is 4.6 μM while amount supplied by BDON is 1.6 μM, then amount of N supplied by DON recycling may become a significant portion of the total DIN pool in the estuary (Boyer et al., 2007).

One potential biogeochemical process affecting DOM (and DON) particularly in the fringe mangrove dominated estuaries of the FCE is the fate and reactivity of tannins. While it is known that a significant amount of tannins is leached from abscised mangrove leaves in aquatic environments, there are no detailed biogeochemical studies on their environmental dynamics. Therefore, we studied the fate of mangrove leaf tannins in the FCE and their possible influence on dissolved organic nitrogen (DON) cycling. Tannins were extracted and purified from senescent yellow leaves of the red mangrove (*Rhizophora mangle*) and used for a series of model experiments to investigate their physical and chemical reactivity in natural environments. Physical processes investigated included self-aggregation, adsorption to organic matter-rich sediments, and co-aggregation with DON in natural waters (Maie et al., 2007b). Chemical reactions included structural change, which was observed by excitation-emission matrix fluorescence spectra, and the release of proteins from tannin-protein complexes under solar simulated light exposure. Our results suggest that a large portion of tannins can be physically eliminated from aquatic environments by precipitation at high salinity (> 15%) and also by binding to sediments. DON in natural water can co-precipitate with tannins, suggesting that mangrove swamps can be a sink of DON in estuarine environments. The chemical reactivity of tannins in natural waters was also very high, with a half-life of less than 1-d. Proteins were released gradually from tannin-protein complexes incubated under light conditions but not under dark conditions, suggesting a potentially buffering role of tannin-protein complexes on DON recycling in mangrove estuaries. Therefore, although tannins are not detected at a significant level in natural waters, they are considered to play an important role in biogeochemical processes and may influence the dynamics of DON in mangrove ecosystems and possibly other coastal wetlands.

While detailed DOM characterization studies were needed to further understand DOM biogeochemistry in the FCE, simple optical properties monitoring on DOM can provide valuable information regarding spatial and seasonal dynamics (Maie et al., 2006b). For this purpose, water samples were collected monthly from a total of 73 sampling stations in the FCE estuaries for over two years. Spatial and seasonal variability of CDOM characteristics were investigated for geomorphologically distinct sub-regions within Florida Bay (FB), the Ten Thousand Islands (TTI), and Whitewater Bay (WWB). These variations were observed in both quantity and quality of CDOM. TOC concentrations in the FCE estuaries were generally higher during the wet season (June-October), reflecting high freshwater loadings from the Everglades in TTI, and a high primary productivity of marine biomass in FB. Fluorescence parameters suggested that the CDOM in FB is mainly of marine/microbial origin, while for TTI and WWB a terrestrial origin from Everglades' marsh plants and mangroves was evident. Variations in CDOM quality seemed mainly controlled by tidal exchange/mixing of Everglades freshwater with Florida Shelf waters, tidally controlled releases of CDOM from fringe mangroves, primary productivity of marine vegetation in FB and diagenetic processes such as photodegradation (particularly for WWB). The source and dynamics of CDOM in these subtropical estuaries is complex and found to be influenced by many factors including hydrology, geomorphology, vegetation cover, landuse and biogeochemical processes. Simple, easy to measure, high sample throughput fluorescence parameters for surface waters can add valuable information on CDOM dynamics to long-term water quality studies which can not be obtained from quantitative determinations alone. Similar studies are now being performed using more advanced 3-D fluorescence techniques in combination with Parallel Factor Analysis to further improve our understanding on DOM dynamics in the FCE. These studies include groundwater samples.

Overnight Sampling Trips and Experiments

We conducted an overnight sampling trip to Shark River and Taylor Slough LTER sites in March 2001 and March 2002 where we conducted a multidisciplinary study of the hydrology of the estuary, DOM characterization, nutrient dynamics, microbial activities, and phytoplankton responses to diurnal and tidal exchanges. The trip included rapid water sampling surveys from mouth to head at slack low and high tides as well as a fixed time series site at houseboat moored at SRS-5 for 24 hours.

We conducted sampling for 24 hour sampling periods at 2 FCE LTER sites in Florida Bay in 2004 and 2006. These metabolic measurements are part of a study of gas exchange in Florida Bay (an LTER-leveraged grant funded by NOAA). To better understand of sediment water column exchanges and production, we conducted seasonal benthic flux experiments at TS/Ph 10. This is a highly active site with high TOC concentration, bioavailability with a high degree of geomorphic isolation. We also conducted seagrass organic matter incubations and bioassays with both the seagrass groups and the organic matter research groups (NOAA grant) in order to elucidate bioavailability of freshly leached seagrass exudates.

4. Trophic Dynamics and Community Structure

Food-web structure illustrated by standing crop

We tracked standing crops of fishes in freshwater and oligohaline sites throughout FCE 1 to determine if their dynamics were consistent with a role of regional nutrient dynamics in shaping their productivity. While standing stock may not reflect secondary production, it was considered proxy for that number in the absence direct measures (see below). This work indicated that standing crops were inconsistent with patterns of primary productivity in the oligohaline zone. Standing crops in the Shark River oligohaline zone were lower than those in the Taylor Slough oligohaline zone, and all were lower than in freshwater sites upstream (Green et al. 2006). We hypothesized that these patterns resulted from a role for higher connectivity between oligohaline and freshwater habitats in Taylor Slough than in Shark River Slough; standing crops and species composition in the littoral zone of Shark River were consistent with a harsh habitat that is somewhat isolated from nearby freshwater marshes. In contrast, the oligohaline zone in Taylor Slough was dominated by freshwater fishes in the wet season, and more salt-tolerant ones in the dry season.

Challenges for studies of secondary production: open communities

Techniques to estimate secondary productivity often sampling data typically assume closed populations, for example those used by fisheries biologists to estimate secondary productivity from ‘catch curves.’ We tracked radio-tagged Florida gar at our long-term study sites to demonstrate that they annually move long distances (in excess of 12 kms) in response to marsh drying (Wolski et al., in prep). A few fish tagged in the wet season in northern Shark River Slough (near SRS-1) moved the length of slough to send the dry season in Rookery Branch, just downstream from SRS-3. These data illustrate that our oligohaline study sites receive substantial seasonal influx fish biomass, precluding methods assuming closed populations. Isotopic data gathered from bull sharks further support the open-system concept, in this case from the marine end. Work planned for FCE 2 will estimate movements more fully and help us produce realistic models that can be used to estimate secondary production.

Food webs illustrated by stable isotopes

We examined food web structure using carbon and nitrogen stable isotopic signatures in consumers. Two studies were conducted during FCE 1; we examined the relationship between trophic position of three key consumers to nutrient status and hydroperiod at long-term study sites in the freshwater Everglades (Williams and Trexler 2006) and we documented long-term stability of tissue isotopic values in the oligohaline zone (Green and Trexler, work in progress). These studies found evidence that hydroperiod but not nutrient status affected trophic position in freshwater systems of the southern Everglades. Our study sites in the southern Everglades did not include areas with extreme nutrient enrichment as found in the northern Everglades, where eutrophication and anaerobic conditions are relatively common. In the oligohaline zone, we found marked differences in the isotopic signatures of our Shark River, Taylor River, and Joe Bay study regions, reflective of different roles of mangrove and marine detrital contributions to these ecosystems. Shark River and Joe Bay were relatively enriched in C^{13} compared to Taylor River. These differences were stable over a 5-year period.

Brian Delius and Mike Heithaus used stable isotopes to determine if juvenile bull sharks collected at our downstream SRS study sites were deriving their energy from oligohaline or marine sources. Past work suggests that these fish may move downstream to seagrass beds to feed at night and return during the day to the relative safety from predators provided by oligohaline sites. Their data supported a major role of marine-derived foods in growth of juvenile bull sharks, consistent with the hypothesis that these fish provide allochthonus nutrients to the oligohaline zone in their daily migrations.

We also conducted laboratory and field experiments on the effect of salinity on the match of fish isotopic composition of liver and muscle tissue to their diets (Green, MS thesis). These studies supported the use of carbon isotopes in tracing diets across a range of salinity conditions. However, nitrogen fraction was sensitive to the relationship of environmental salinity to optimal physiological salinity for two species. These fish never attained the expected nitrogen isotopic composition after a diet switch when maintained at salinities that differed from their optimum. This raises a new source of concern for interpretation of nitrogen isotopic data in estuarine fishes.

5. Ecological Modeling

We summarized P standing stocks (g P m-2) and net P fluxes for the major ecosystem components (i.e., water, algal, plant, consumer, and detrital pools) along both FCE transects. These models have been parameterized separately for Cladium-dominated and wet prairie-dominated marshes at each FCE LTER site. These models are calibrated with site-specific FCE data and are used to determine the 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). We have also been using these models to investigate future scenarios of water management, including changes in water depth and P loading rates, to ENP.

Additionally, we developed a simulation model to hindcast historic changes in Cladium biomass in ENP. The model predicts Cladium biomass as a function of water depth using a complex algorithm based largely on empirical data our FCE LTER sites in Shark River Slough. To calibrate and test the model, we are now quantifying profiles of Cladium seeds, a proxy for Cladium biomass, as part of a project funded from other sources. We recently summarized this paleo-ecological approach to forecasting ecological change under various restoration scenarios. These data are presented in a paper that appeared in our FCE LTER Special Issue of Hydrobiologia in 2006 (Saunders et al. 2006).

Finally, we worked closely with the developers of the Everglades Landscape Model, (ELM) and of several ecological models of seagrass dynamics at SFWMD. The ELM now has an extended period of simulation (1965-2000), an extended useful simulation domain that includes topography and tidal exchanges in southwest mangrove region of greater Everglades, and enhanced documentation for ease of use and for independent peer review of ELM application to greater Everglades restoration planning.

6. Abiotic Factors

Because of the climatic impacts of increasing ambient carbon dioxide levels, scientists throughout the world are studying the contribution of the biosphere in sequestering carbon. The resulting knowledge is utilized to constrain levels of atmospheric carbon dioxide. One biome that has yet to be investigated for its carbon uptake capabilities is the mangrove forests. Mangrove ecosystems potentially represent significant carbon sinks because of year-round physiologically active foliage, and carbon exchanges at the estuary interface and continuous accretion of sediments.

During June 2003, a 30-m tall triangular tower was established in a riverine mangrove forest to use as a platform to deploy flux measurement systems. This research is a collaborative effort between researchers at the University of Virginia (Jose Fuentes), the Louisiana State University (Robert Twilley and Victor Rivera-Monroy), and other FCE scientists. The study site is located along the Shark River in the western region of the Florida Everglades, at FCE-LTER site SRS-6. The dominant tree species around the tower include red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Languncularia racemosa*) mangroves. The average tree height for this forest canopy is 15 m but trees as high as 25 m can be found randomly scattered throughout the landscape. A raised 200-m long boardwalk was installed to provide tower access from the shore. The boardwalk protects prop roots, seedlings, and the soil from repeated disturbances. The tower is currently instrumented to define the micrometeorological conditions inside and just above the canopy, and to study mangrove physiology. Current measurement and data acquisition systems are powered with a combination of solar panels and batteries.

Continuous field measurements from an eddy covariance (EC) system provide the net exchange of carbon dioxide across the forest-atmosphere interface at half-hourly intervals. The EC system consists of a 3-dimensional sonic anemometer and a fast response open-path gas analyzer. When measured over days and weeks, these measurements provide the magnitude of the net carbon exchange between atmosphere and forest, sediment accretion, and estuary exchange. Several key local climate variables are also continuously measured from the tower. These variables control carbon sequestration on short (half-hourly) time scales, and are being used in a coupled forest-atmosphere biophysical exchange model to predict forest productivity. Additional tower instruments include radiometers to measure light levels, anemometers to measure atmospheric turbulence, air thermometers, hygristors to measure humidity, and soil thermometers. These measurements, combined with tidal and salinity information, are elucidating the response of the mangrove biome to climate change (e.g. sea level rise) and changes in the quantity and quality of freshwater flow from the greater Everglades.

7. Information Management

The mission of the Florida Coastal Everglades (FCE) Information Management System (IMS) has been to facilitate the site's scientific work and ensure the integrity of the information and databases resulting from the site's coastal Everglades ecosystem research. Throughout FCE I, the Information Management (IM) team has provided 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. 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.

FCE cross-referenced project information, such as site location information, datasets, sampling attributes and publications, and minimal research data metadata stored in the FCE Oracle10g database drive the site's web site. The FCE web site (http://fcelter.fiu.edu) serves as the primary portal for dissemination of information about FCE, for distribution of datasets, to coordinate our Education and Outreach activities, and to aid FCE scientists and students in their research.

The FCE IMS has been committed to the collection and organization of FCE project information. Over the past 3 years, a 'Project' section has been added to the formal FCE data management policy mandating project information submission by researchers to the FCE Information Manager must occur no later than 6 months of notification of project funding. The FCE IMS group developed a web-based project and information management application (http://fcelter.fiu.edu/research/projects/ and http://fcelter.fiu.edu/research/projects/sampling.htm) for FCE researchers and FCE management groups to help with future experimental designs, publication discovery, and intra-site syntheses.

Over the past 6 years, the FCE IMS have been active participants 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 was also a data contributor to the EcoTrends project managed by the Jornada Basin LTER.

FCE IMS developed an EML metadata converter tool and template called Excel2EML and this tool has been made available to the LTER network and broader ecological community via the LTER CVS repository and a download link on the FCE web site (http://fcelter.fiu.edu/data/tools/).

The FCE information manager, Linda Powell, was an invited keynote speaker at the RED-MEX ILTER All Scientists Meeting in March of 2006, held in Autlán de Navarro, Jalisco, Mexico. She talked about the importance of establishing a strong information management system and gave examples of how the FCE LTER program handled different aspects of project and information management.

8. Education and Outreach

During FCE I we developed an Education & Outreach program that communicates our research findings to K-12 students, teachers, and the community of south Florida. We have developed a variety of programs to assess the most effective approaches to disseminate FCE LTER research findings and to educate the public about the ecology and importance of the Everglades. These approaches have included: television segments; a website; video conference presentations; a high school student internship program; a science ranger education program with Everglades National Park; paired field with schoolyard activities; and classroom presentations.

In 2001, our first Education & Outreach program, supported high school students and teachers while working in the laboratory of an FCE scientist. The program focused on Felix Varela Senior High School, but also included teachers from at least two other local high schools.

This particular program also included travel support for both teachers and students to attend the Estuarine Research Federation Conference in St. Petersburg, FL, in November 2001.

In 2003, Susan Dailey, Ph.D., became the FCE LTER Education and Outreach Coordinator. She participated in the development workshop for the Schoolyard LTER Workbook held at the Konza Prairie LTER site in April 2003. Two years later in August 2005, Susan left FIU to begin teaching high school biology at Felix Varela High Senior School. During that time, she was able to gain an "insider's" view while enhancing and promoting the visibility and use of FCE data and results within the Miami-Dade County Public School science curriculum. Nicholas Oehm assumed the duties of FCE LTER Education and Outreach Coordinator in the fall of 2006. He is also a classroom teacher Felix Varela Senior High School and is a former FCE Research Experience for Teachers (RET) participant.

EdEn Venture

The FCE LTER Education program utilized funds from the NSF EdEn Venture supplement to hire Doug Vogel, a volunteer ranger from Everglades National Park, to develop a curriculum-based presentation. As a former public school teacher, Doug was the perfect choice to implement the presentation in camp classrooms at Everglades National Park and within "Slough Slogs" at the Shark River Valley Tram and Visitor Center. Doug was also able to use his presentation during school visits where he was able to teach FCE research techniques to elementary, middle, and high school students.

In addition, Doug also participated in many other FCE-related activities such as participating in FCE LTER samplings and visiting many of our research sites. Doug used many of these experiences to establish our own *Schoolyard Long Term Ecological Research* sites through our "Hands on the Everglades". Sandy Dayhoff, Shark Look Environmental Education Center Coordinator, called our *Schoolyard* sites a "realistic eye" for students. "Hands on the Everglades" was presented to nearly all of the 4th and 5th graders that will later attend Felix Varela Senior High School which is adjacent to the freshwater Everglades.

The EdEn Venture and Hands on the Everglades resulted in a large number of presentations throughout south Florida including Miami-Dade, Broward and Monroe counties. At the completion of our EdEn grant period, we had 1,691 student contacts from our ForEverglades classroom program. Foreverglades also included many hands-on activities such as periphyton observation and community structure determination, water budget exercises, and collecting and observing animals of the Everglades (various bones, tree snail collection, woodstork skull, turtle shell). In addition to the ForEverglades contacts, an additional 1500 contacts were made through Doug's tram tours, special programs, and Slough Slogs.

Surveys from our classroom visits revealed an overwhelming positive response to the programs and both the quantity and quality of the information delivered. Teachers were very impressed with the hands-on activities that the students were able to conduct during and after the classroom presentations.

Classroom Visits

In 2003, FCE scientists and our EdEn Venture Ranger conducted classroom visits to present curriculum-based ecology lectures. These lectures were presented for Advanced Placement, Honors, General Education, Gifted, and Marine Biology, Environmental Science, and Agriscience classes with students in grades 9-12. Subsequently, some of those students visited FCE laboratories and participate in a variety of lab activities. The presentations were well received by the students and the practical lab experience was the most popular component. Many students continued to participate in FCE labs as volunteers to fulfill a program requirement for practical experience.

We continued our classroom visits through 2007 and FCE researchers gave several presentations on topics such as invasive exotic plants, general ecology and genetics, and algal dynamics in the Florida Coastal Everglades. Students were then tested on each of the presentations and demonstrated an enhanced understanding of the research presented.

Undergraduate Internship Programs

NOAA provided the funds for an Educational Internship program for undergraduate students from FIU. The program activities began in January 2004, and several of the participants were directly associated with the FCE-LTER program. In addition, many FCE scientists and students participate in an NSF-funded UMEB program hosted at FIU.

Hands on the Everglades

Our "Hands on the Everglades" was a cooperative program that FCE offered with Everglades National Park and ran from 2003-2005. This program was a combination of Schoolyard LTER and EdEn Venture components including teacher workshops and field samplings. In each activity, participants received a lecture and instructed on the use of *Hands on the Everglades* materials. Teachers were provided with instructional materials on Florida Coastal Everglades Ecology and sampling procedures.

Students also participated in *Hands on the Everglades* activities and were able to visit SLTER plots in Everglades National Park for comparison with others at the Florida International University Preserve.

Two classes from a Hialeah Elementary School visited our study sites. Half of the students visited a hardwood hammock in Everglades National Park and the other half visited a hammock in the Florida International University Preserve. The students visited their assigned sites on three different field days during both the wet and dry seasons. During those visits the students collected data on invertebrates, abiotic factors, soils, water availability, tree and plant biomass data collections and litterfall. FCE personnel were on-hand throughout the activity to help conduct the data collection and identify litterfall within the study plots. Teachers then followed up with a visit to evaluate the experience and gave overwhelmingly positive response. Subsequently, the methods and field activities were published on our website.

High School Intern Program

Our High School Intern Program began in 2003 with a group of students that were enrolled in the Agriscience Academy at Felix Varela Senior High School. The students used the FCE Intern program to fulfill part of their program requirements. The FCE Intern program provided the students with: research experience; career training; and professional mentoring. Students were also expected to participate in a series of lectures given by FCE scientists before they were allowed to shadow scientists in the laboratory. Throughout the internship students were tested on the material presented during the lectures and culminated in a final research project. At the end of the semester students gave an oral presentation of their research project to their peers and an interpretive presentation at nearby middle schools.

After reflecting on the success of our initial Intern program, several changes were made in 2005. Although we continued to work with classroom teachers, we began to deliver a more intensive program with fewer students. Our first student, worked very closely with a graduate student studying belowground biomass and production of sawgrass. The high school intern received high school credit for his course work and presented his research in a poster at the local science fair. Winning several awards, this student advanced to the state science fair where he won the First Place title and over $17,000 in prizes and scholarships against a total pool of over 350, 000 students.

Through the evolution of our High School Intern program, it has been renamed Research Experience for Secondary Students (RESSt) and grown to include 12 active interns and over 20 alumni. Students are working with FCE scientists in the following areas: seagrass dynamics, algal culture, sawgrass growth and seed variation with respect to soil history, nitrogen dynamics, and phytoplankton dynamics. Students work between 5 and 10 hours per week while others exceed twenty hours a week. Many of these students continue to work on their projects over multiple years, present their work in their science classes, travel to elementary and middle schools to give presentations, present posters at our annual ASM meetings, and compete in local, state and international science fairs.

In January 2007 we added a segment to our webpage where people can sign up to receive a presentation from one of our most outgoing interns. We have two students that participated in the Dade County Science Fair and both won "Superior" and advanced to the state competition. One of these students is competing for the Silver Knight Award, an award for local community service. Three of our interns gave oral presentations as part of our Education and Outreach update for the 2006 FCE LTER All Scientists Meeting and their presentations were posted on our web pages.

Research Experience for Teachers (RET Program)

In 2005, our first RET worked in various laboratories throughout the summer, participated in field work, and assisted with a metabolism study, received GIS training, performed nutrient and oxygen data collection, gained QA/QC experience, and summarized our accomplishments on the FCE LTER education website. The second RET worked closely with the Education & Outreach Coordinator, and FCE scientists to adapt classroom activities to include information about the Everglades and South Florida ecology references.

Through our RET program, we provided an opportunity for teachers to develop hands on activities and instructional materials that they tested and evaluated in the fall of the 2006 school year. Using those evaluations, the RET continued to create and adapt presentations which he gave in several middle and high school classes, the local community college and in dual enrollment classes for FIU. In addition, the RET was able to participate in field and lab work while familiarizing himself with several areas of FCE LTER research. Through these experiences, he was instrumental in the growth of our RESSt program by placing several students with FCE scientists.

Research Experience for Undergraduates (REU) Program

The FCE Research Experience for Undergraduates (REU) program is funded annually by supplements from NSF. We funded 2-3 students most summers from 2001-2006, except 2005 when we didn't receive supplemental funding for our REU program. In all cases, the students bring $750 in supply funds and receive $750 to travel to a scientific meeting and present their results. Virtually all of our past REU students have presented posters of their findings at meetings.

Web site

In August 2004, after in house evaluation, reviews and comments from researchers, we published our web pages. Through our website we receive requests from both teachers and students for field trips, general Everglades information, and several questions about Everglades ecology from students ranging from the elementary college level.

FCE LTER Curriculum Development

A major focus of our Year 6 FCE LTER Education and Outreach Program was the development of curriculum formal education for their ecology modules. The primary target audience was high school but we expanded to give lectures in FCE findings and research to college courses. We had several test groups for the newly developed curricula including 9th and 10th grade honors and general biology classes, AP biology classes and AP statistics class. The curriculum developed between the Education and Outreach Coordinator and RETs were tested in the classroom during the fall of 2006.

These new materials were developed to increase the understanding of the LTER network and the range of biomes that they represent. Three new presentations were generated. The first presentation is used to introduce ecology and the LTER Network while the remaining presentations examine terrestrial and aquatic biomes. We have also develop a three day take home assignment, examination and in class activity.

Each of these products were distributed to classrooms in the Miami-Dade County Public School and Sarasota School systems, Miami Dade College and Florida International University and reached to over 1900 students. The evaluations of these new materials show an increase in the understanding and application of information about biomes and ecosystems. Students from both the high school classes and college classes showed a marked increase in the understanding of the Florida Coastal Everglades and the importance of the ecosystem. All of these new curricula are being revised and adapted to publish on our FCE LTER education and outreach pages.

Partnership development

In 2002, the FCE Schoolyard program focused on a cooperative arrangement with the Miami Museum of Science. Working with the Museum staff we were able to put together a "virtual field trip" program for inner-city, secondary school students. Through this program students were able to interact with scientists through a real-time webcam broadcast from the field to a classroom at the Museum. Students were able to ask the scientist questions and explore the complexity of biospheres of the FCE LTER site by showing them live plants, animals, and periphyton. The program was well-received with a great deal of positive feedback on our contribution to the museum's videoconferencing program and the students were very excited to interact with the FCE scientists from the museum classroom.

In 2006, we developed a working relationship with "Shake-A-Leg Miami". This program provides summer and after school care to all students, but is geared towards underrepresented and disabled children. Shake-A-Leg contacted FCE through our webpage to request an FCE presentation. The Education and Outreach Coordinator and our RETs developed a two-day workshop with presentation of our "ForEverglades" presentation and two hands-on activities. The first activity was used to engage students in a discussion of controlling water flow through a 5 m by 8 m map of the Everglades and a second activity had several exploratory stations where students were able to examine plants, animals, rocks, and soils of the Everglades. In the end, we gave the giant Everglades map to Shake-A-Leg for their continued use with the ForEverglades presentation in their winter, spring and fall programming schedule.

We are currently exploring and developing two new partnerships with the Fort Lauderdale Museum of Science and Discovery and the Florida Rock and Sand Company. Our new museum partnership has the focus of transferring information from our new FCE II working dimensions with a global change focus. The Florida Rock and Sand partnership is to bring new high school interns to a restored Everglades wetland to conduct data collections with a similar focus to our FCE LTER data collections.

Television and Video

In early 2005, we filmed a short children's film called "Kidz Corner" that was aired on WLRN The Learning Channel, Closed circuit TV in the Miami Dade County Public School television station and childrens' pediatrics hospital units of Florida. This television program was developed and is produced by high school students, and our episode featured a trip to the Florida Coastal Everglades and Everglades National Park. We assisted in both the script and scene development for months prior to the filming of the episode, and had several FCE researchers who "starred" in the film.

Beginning in October 2006 we started a project to develop data file education movies for the classroom. The purpose of these videos is to generate interest for the use of the datasets published on the FCE LTER web pages. These products will be distributed to teachers and trailers to the movies will be made available on our Education and Outreach web pages during FCE LTER year seven. Distribution of these combined products to science department heads in Miami Dade schools will enable us to increase awareness of our web published FCE LTER research beyond the website or our existing contacts.

B. FINDINGS

The following publication summarizes findings for the first phase of Florida Coastal Everglades research.

Childers, D.L. 2006. A synthesis of long-term research by the Florida Coastal Everglades LTER program. Hydrobiologia, 569(1): 531-544.

Hydrobiologia (2006) 569:531–544
J.C. Trexler, E.E. Gaiser & D.L. Childers (eds), Interaction of Hydrology and Nutrients in Controlling Ecosystem Function in Oligotrophic Coastal Environments of South Florida
DOI 10.1007/s10750-006-0154-8

A synthesis of long-term research by the Florida Coastal Everglades LTER Program

Daniel L. Childers
Department of Biological Sciences & Southeast Environmental Research Center, Florida International University, Miami, FL 33199, USA
(Tel.: +1-305-348-3101; Fax: +1-305-348-4096; E-mail: childers@fiu.edu)

Key words: Everglades, LTER, synthesis, estuary, oligohaline, oligotrophic, ecosystem

Abstract

This paper synthesizes research conducted during the first 5–6 years of the Florida Coastal Everglades Long-Term Ecological Research Program (FCE LTER). My objectives are to review our research to date, and to present a new central theme and conceptual approach for future research. Our research has focused on understanding how dissolved organic matter (DOM) from upstream oligotrophic marshes interacted with a marine source of the limiting nutrient, phosphorus (P), to control productivity in the oligohaline estuarine ecotone. We have been working along freshwater to marine transects in two drainage basins located in Everglades National Park (ENP). The Shark River Slough transect (SRS) has a direct connection to the Gulf of Mexico, providing this estuarine ecotone with a source of marine P. The oligohaline ecotone along our southern Everglades transect (TS/Ph), however, is separated from this marine P source by the Florida Bay estuary. We originally hypothesized an ecosystem productivity peak in the SRS ecotone, driven by the interaction of marine P and Everglades DOM, but no such productivity peak in the TS/Ph ecotone because of this lack of marine P. Our research to date has tended to show the opposite pattern, however, with many ecosystem components showing enhanced productivity in the TS/Ph ecotone, but not in the SRS ecotone. Water column P concentrations followed a similar pattern, with unexpectedly high P in the TS/Ph ecotone during the dry season. Our organic geochemical research has shown that Everglades DOM is more refractory than originally hypothesized. We have also begun to understand the importance of detrital organic matter production and transport to ecotone dynamics and as the base of aquatic food webs. Our future research will build on this substantial body of knowledge about these oligotrophic estuaries. We will direct our efforts more strongly on biophysical dynamics in the oligohaline ecotone regions. Specifically, we will be focusing on inputs to these regions from four primary water sources: freshwater Everglades runoff, net precipitation, marine inputs, and groundwater. We are hypothesizing that dry season groundwater inputs of P will be particularly important to TS/Ph ecotone dynamics because of longer water residence times in this area. Our organic geochemical, biogeochemical, and ecosystem energetics work will focus more strongly on the importance of detrital organics and will take advantage of a key Everglades Restoration project, scheduled for 2008 or 2009, that will increase freshwater inputs to our SRS transect only. Finally, we will also begin to investigate the human dimensions of restoration, and of a growing population in south Florida that will become increasingly dependent on the Everglades for critical ecosystem services (including fresh water) even as its growth presents challenges to Everglades sustainability.

Introduction

This special issue is a compendium of the research conducted during the first 5–6 years of the Florida Coastal Everglades Long-Term Ecological Research Program (FCE LTER). Synthesizing this work, and presenting a conceptual basis for future research, was both an exciting and daunting task.

My objectives for this synthesis are (1) to review the research to date in the context of the original central theme and primary research hypotheses; (2) to synthesize our findings in the context of a new central theme and conceptual approach, and; (3) to demonstrate how future research will build on our current knowledge of (a) the coastal Everglades landscape; (b) efforts to restore coastal ecosystems, and; c) estuarine and coastal ecosystems in general.

Research in the oligotrophic coastal everglades

Our research to date has focused on biophysical dynamics in the estuarine ecotone regions of the coastal Everglades. Our central theme and organizing hypotheses, presented, below, focused on understanding how dissolved organic matter from upstream oligotrophic marshes interacted with a marine source of phosphorus, the limiting nutrient, to control estuarine productivity where these two influences meet – in the oligohaline ecotone. This dynamic was affected by the interaction of local ecological processes and landscape-scale drivers (hydrologic, climatological, and human; Fig. 1). Our organizing theme has been *that regional processes mediated by water flow control population and ecosystem level dynamics at any location within the coastal Everglades landscape*. From this theme, we have investigated the following hypotheses:

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

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

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

We have tested these hypotheses along freshwater to marine gradients represented by landscape transects in two Everglades drainage basins in Everglades National Park (ENP). The Shark River Slough transect (SRS) is anchored at canal

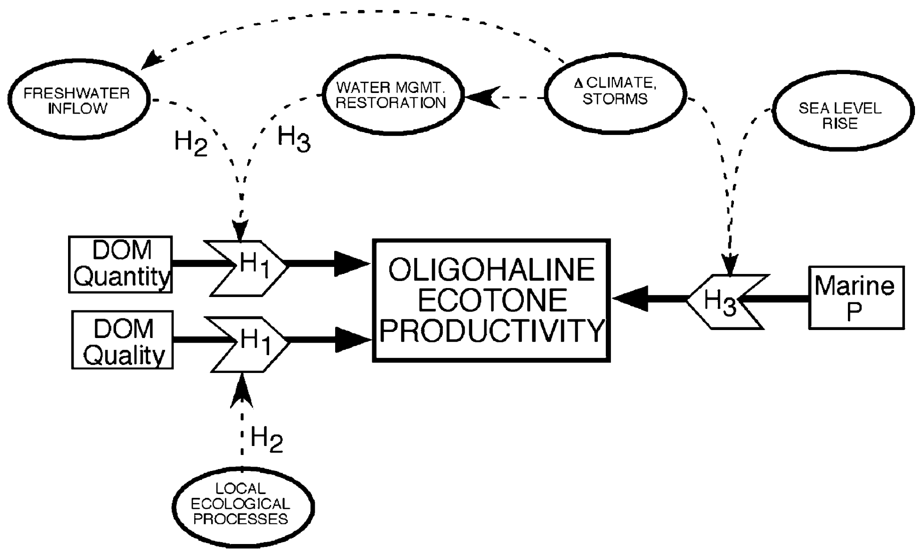

Figure 1. A conceptual simplification of the central theme and three main hypotheses that have been driving our research to date. The ovals represent key hydrologic, climatological, ecological, and human drivers. The small rectangles are the inputs thought to most strongly control ecosystem productivity in the oligohaline ecotone. H_1, H_2, and H_3 refer to the three main hypotheses (see text).

inflow points along the Tamiami Trail and extends through the mangrove estuary to Florida's southwest coast. Historically, most of the water draining the Everglades flowed through this system. The Taylor Slough/ENP Panhandle transect (TS/Ph) is anchored at two main canal inflow points, and extends through the oligohaline ecotone and Florida Bay estuary to the same coastal ocean endpoint. This is a smaller, more localized drainage basin (see Trexler & Gaiser, 2006, for a more detailed description of the transects and a site map). Because the freshwater Everglades is a highly oligotrophic, phosphorus (P) limited system (Noe et al., 2001), freshwater inflow to both estuaries is very nutrient-poor. In fact, the source of P to Everglades estuaries is marine water from the Gulf of Mexico, not the upstream watersheds (Fourqurean et al., 1992; Chen & Twilley, 1999; others), such that these systems are biogeochemically "upside-down" (Childers et al., 2006).

Data from the 1990s suggested a generalized ecosystem productivity peak in the oligohaline ecotone region of our SRS transect, where tidal inputs of marine P meet organic matter-rich inputs from the freshwater Everglades, but no such peak in the southern Everglades ecotone (our TS/Ph transect), because Florida Bay is so efficient at sequestering marine P (Fig. 1). This central theme directed our research at the oligohaline ecotone regions of both transects, but also required us to learn more about biophysical dynamics both upstream (freshwater Everglades) and downstream (the Shark River mangrove estuary and Florida Bay) of the ecotone.

Primary production

The guiding question for our primary production research has been: How are patterns and magnitudes of primary production controlled by freshwater flow and the concentrations and

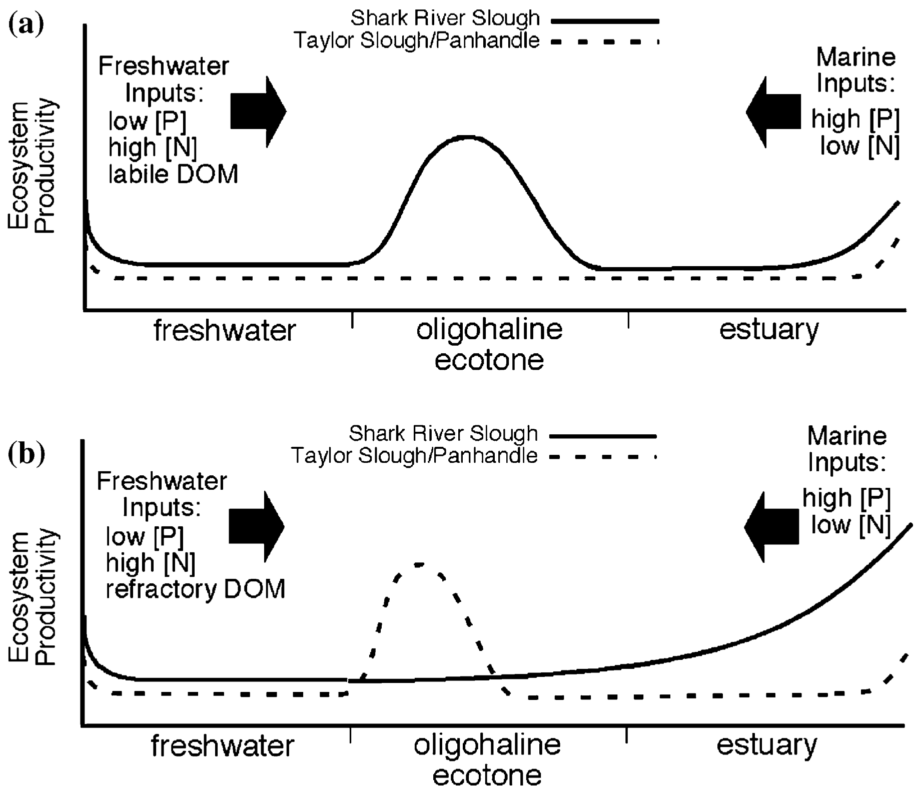

Figure 2. (a) Generalized landscape-scale patterns of our expectations for how ecosystem productivity would vary along the Shark River Slough (solid line) and southern Everglades (TS/Ph; dashed line) transects in response to the interactions shown in Figure 1. (b) Generalized landscape-scale patterns of how ecosystem productivity actually varied along the Shark River Slough (solid line) and southern Everglades (TS/Ph; dashed line) transects, based on the results presented in this issue and synthesized in this paper.

characteristics of nutrients and organic matter in the source water? At the scale of our two landscape transects, mangrove aboveground net primary production (ANPP) was higher along the SRS transect than along the TS/Ph transect while sawgrass ANPP was not different and periphyton production was higher in the TS/Ph basin (Ewe et al., 2006). However, the contribution of periphyton to overall ANPP at the freshwater sites was considerably greater in the southern Everglades (the TS/Ph transect; Ewe et al., 2006; Iwaniec et al., 2006). Our central theme predicted an oligohaline productivity peak in SRS (Fig. 2a), but our ANPP data actually showed a "wedge" of increasing productivity towards the marine endmember (Fig. 2b). The same marine-directed increase in ANPP has been seen in Florida Bay (Fourqurean et al., 1992), and we saw some indications of higher ANPP in the oligohaline ecotone along this same transect (TS/Ph; Ewe et al., 2006). Our ANPP data did not generally support our original hypothesis about landscape-scale patterns in ecosystem productivity.

Along the SRS transect, mangrove production closely paralleled soil P content (Ewe et al., 2006; Chambers & Pederson, 2006), with both increasing from the oligohaline ecotone to the Gulf of Mexico. Krauss et al. (2006) integrated a mangrove productivity mesocosm study with field observations from our SRS mangrove sites. They found a close positive coupling of hydroperiod and soil P content, and suggested that this is likely driven by tidal inputs of marine P. They further concluded that the negative response of mangrove production to increased hydroperiod may be offset by the P subsidy provided by this increased tidal inundation. In a different mesocosm experiment, Cardona-Olarte et al. (2006) found higher production in mangroves receiving variable inundation, simulating tides, compared with mangroves that were permanently flooded. Soils in the former treatment had lower soluble reactive P concentrations, either because of uptake associated with the higher productivity because of physical flushing of P from the mesocosm soils.

In their focus on the shorter hydroperiod TS/Ph transect, Childers et al. (2006) showed that sawgrass ANPP was typically highest at the estuarine ecotone sites, but was also sensitive to interannual variation in salinity. Productivity was negatively related to (1) maximum salinity; (2) number of days with measurable salinity, and; (3) annual mean salinity. Across all southern Everglades sites, sawgrass ANPP was negatively related to water depth and hydroperiod, and there was a significant negative relationship between spikerush stem densities and sawgrass ANPP (Childers et al., 2006). Saunders et al. (2006) were able to infer historical patterns in the SRS freshwater macrophyte community from down-core soil profiles of seeds and plant-specific organic biomarkers (see also Hajje & Jaffé, 2006). Their data suggested an increase in sawgrass biomass and cover in some regions of SRS in the last 25 years, probably due to management-induced declines in hydroperiod and water depth during this time. Saunders et al. (2006) found that sawgrass responds positively to a general drying of the landscape. Childers et al. (2006) suggested that a general decline in sawgrass may occur where long-term hydrologic management causes a wetter landscape, and this decline will likely be accompanied by a community shift to deeper water species, such as spikerush. In upper Taylor Slough (our TS/Ph transect), Armentano et al. (2006) demonstrated a similar, relatively rapid shift from short hydroperiod to longer hydroperiod plant species since 1979, followed by [the beginnings of a] shift back to shorter hydroperiod species after 1999. They linked both to changes in the management of Taylor Slough hydrology, which made the system wetter after 1979, then drier after 1999. This coupling of vegetation community dynamics to hydrologic change has also been reported for SRS (Ross et al., 2003). In all cases, it seems clear that the freshwater marsh plant community responds dramatically to water management and restoration.

Our results have also shed considerably more light on the regulation of primary production at more site-specific scales. In the freshwater marsh, periphyton productivity was higher at sites nearest canal inflows at times, but these events were generally short-lived and associated with initial rewetting at the onset of the wet season (Iwaniec et al., 2006). Periphyton tissue nutrient content is the most rapidly responding indicator of long-term P enrichment (Gaiser et al., 2005), and while Iwaniec et al. (2006) found low periphyton tissue N:P ratios at these sites, they found little indication of long-term eutrophication. In Florida Bay, epiphytic diatom community structure was related to salinity and local nutrient availability, and diatom species distributions were good indicators of spatial variation in water masses across the bay (Frankovich et al., 2006). Across Florida Bay, benthic microalgal biomass was 6–10 times greater than epiphytic algal biomass, and production by both was strongly controlled by P availability – particularly in the eastern bay (Armitage et al., 2005, 2006). The nutrient enrichment experiments that demonstrated this pattern also showed that epifaunal biomass doubled when P was added, and these grazers had a top-down effect on algal responses to nutrient additions (Gil et al., 2006).

Trophic dynamics

The guiding question for our trophic dynamics research has been: How does freshwater flow or the source of this water control secondary production and trophic dynamics? At the landscape scale, we found that fish biomass and species richness were both considerably lower at the intertidal, non-ecotone SRS mangrove sites relative to the oligohaline ecotones of either transect (Green et al., 2006). Green et al. (2006) also reported higher fish biomass at the ecotone sites relative to upstream freshwater marsh sites. They presented a conceptual model for this landscape-scale pattern that relates fish habitat connectivity to topographic differences between the SRS and TS/Ph ecotones and to major differences in inundation regime. Astronomical tides drive the SRS estuary, where mangrove wetlands typically flood twice daily, while high wet season water levels in the southern Everglades estuarine ecotone more closely resemble one [or a few] long-duration inundation events per year. Overall, our fish standing stock data showed an ecotone peak along both transects, suggesting that the consumer data supported our original hypothesis about landscape-scale patterns in ecosystem productivity in SRS but not the southern Everglades (Fig. 2b). This, in turn, suggests that we should focus future work on a better understanding of the TS/Ph ecotone region.

Work by Lorenz & Seraty (2006) in this southern Everglades oligohaline ecotone (TS/Ph transect) related declines in freshwater inflows to this region since the 1960s, higher ecotone salinities, lower numbers of demersal fish, and declines in the populations of wading birds that are dependent on those fish. They further suggested that a [relatively rapid] northward expansion of the dwarf mangrove ecotone in the southern Everglades the last 50 years (Gaiser et al., 2006; Ross et al., 2000) may have contributed to declines in forage fish numbers and in wading bird populations. In spite of this long-term decline, fish standing stocks in oligohaline ecotone wetlands were higher than either upstream or downstream sites (Green et al., 2006).

Further upstream, Rehage & Trexler (2006) investigated fish community responses to canal inflows of fresh water. They found that animal densities tended to increase with distance from canal inflow points, but this increase occurred within 5 m of the canal for many taxa. They suggested that this pattern may be a bottom-up response to higher soil P (Chambers & Pederson, 2006) and primary productivity at these sites (Childers et al., 2006; Iwaniec et al., 2006), such that this stimulation of secondary production may compensate for higher predation at canal edges by large fish. Overall, food webs in the freshwater marsh consumer community appear to be based on detrital food sources, not direct grazing on live plant material (Williams & Trexler, 2006).

Experimental research conducted at more localized scales has shed considerable light on consumer dynamics. Dorn et al. (2006) reported on top down effects in SRS freshwater marshes. They found that [experimental] removal of large fish predation increased the numbers of smaller fish and decreased numbers of invertebrate meiofauna within periphyton mats. This removal had no effects on periphyton mat biomass, but it did coincide with an increase in detrital P content. Their results were independent of hydroperiod and macrophyte density. Liston (2006), however, studied the infaunal communities living within periphyton mats and found that community structure was related to productivity while infaunal densities were related to hydroperiod. The community structure of infauna living within the benthic flocculent organic matter layer was also tied to hydroperiod. More specifically, Liston (2006) suggested that trophic dynamics in long hydroperiod freshwater wetlands may be regulated by top-down dynamics (as per Dorn et al., 2006) while bottom-up dynamics are more important in short hydroperiod wetlands.

Soil dynamics

The guiding question for our soil dynamics research has been: How do changes in freshwater flow or the content of source water control organic matter accumulation in freshwater and mangrove wetland soils? In the oligotrophic, P-limited Everglades, soil P is an excellent long-term indicator of P supply and availability. Chambers & Pederson (2006) found somewhat higher bulk soil P at the sites adjacent to canal inflows. For example, total P levels at the TS/Ph sites nearest to canals averaged 92 μg P cm^{-3} compared with only 40 μg cm^{-3} at the interior freshwater marsh sites. This pattern was consistent with past results from SRS and Taylor Slough (Childers et al., 2003). At the landscape scale, bulk soil P increased from freshwater marsh sites to those closest to the Gulf of Mexico (Florida Bay along the TS/Ph transect and the mangrove sites along the SRS transect; Chambers & Pederson, 2006). This trend held for bulk P in the soils, as well as for the 3 forms of P most likely to be available to plants – inorganic P (P-I), inorganic P bound to Fe and Mg minerals (P-II), and Ca-bound inorganic P (P-III). Along the SRS transect, total soil P increased from approximately 97 μg P cm^{-3} (freshwater marsh sites) to 132 μg cm^{-3} in the ecotone to 250 μg cm^{-3} at the estuarine [mangrove] sites. In the southern Everglades, total soil P pools increased from about 40 μg cm^{-3} at the interior freshwater marsh sites to 146 μg cm^{-3} in the ecotone (Chambers & Pederson, 2006). Generally, soil and sediment P content did not support our original hypothesis about landscape-scale patterns in ecosystem productivity (Fig. 2a), but rather followed the general patterns in Fig. 2b.

Soil and sediment P content is affected by both local and more distant sources of organic matter and organic nutrients. Jaffé et al. (2001) used a biomarker-based assessment of sources of particulate organic matter (POM) to the SRS and TS/Ph estuaries. Their conceptual model suggested different processes controlled POM mixing in these two systems. Mead et al. (2005) refined this model by showing that simple end-member models do not work well in Everglades estuaries. Much of the POM in these systems is not suspended in the water column, but rather is found as a flocculent detrital layer above the soil surface. Neto et al. (2005) reported that much of this "floc" was locally produced, which greatly complicates traditional 2-source allochthonous mixing models.

Within Florida Bay sediments, Xu et al. (2006) found that organic markers for mangrove organic matter decreased towards the Gulf of Mexico while seagrass markers increased. Carbon isotope signatures (δ^{13}C) confirmed this, with δ^{13}C enrichment increasing along this northeast to southwest gradient, from roughly −20 to −13.5 per mil (Xu et al., 2006). Water column organic matter sources (based on the prevalence of algal and bacterial geochemical markers) were more important in the basins of the central bay, which are more hydrologically isolated from either ecotone (mangrove) or marine sources, suggesting that the sediments in this region are most strongly influenced by locally derived organic matter.

Nutrient and dissolved organic matter (DOM) dynamics

The guiding questions for our biogeochemical and organic geochemical research has been: (1) How is the quality and/or quantity of DOM or the quantity of inorganic nutrients in source water altered by changing freshwater flow versus internal processes occurring at a given location in the landscape? (2) How are local ecosystem processes controlled by changes in source water DOM or inorganic nutrients? At the broadest scale, we addressed these questions with our long-term water quality data. Total P concentrations were quite low at the freshwater sites (often 0.2 μM), reflecting the oligotrophic nature of these marshes (Childers et al., 2006). Concentrations of TP increased from the ecotone to the Gulf of Mexico in the SRS estuary, reflecting the marine source of this limiting nutrient. We found no evidence for higher oligohaline P availability, as was originally hypothesized (Fig. 2). In the southern Everglades, we saw a similar pattern of higher TP concentrations near the marine P source, but only at the Florida Bay sites (Childers et al., 2006). The estuarine ecotone along our TS/Ph transect has negligible astronomical tidal influence, and does not have the direct connection to marine P that we see in the SRS ecotone. However, during the dry season we routinely found high TP concentrations at our

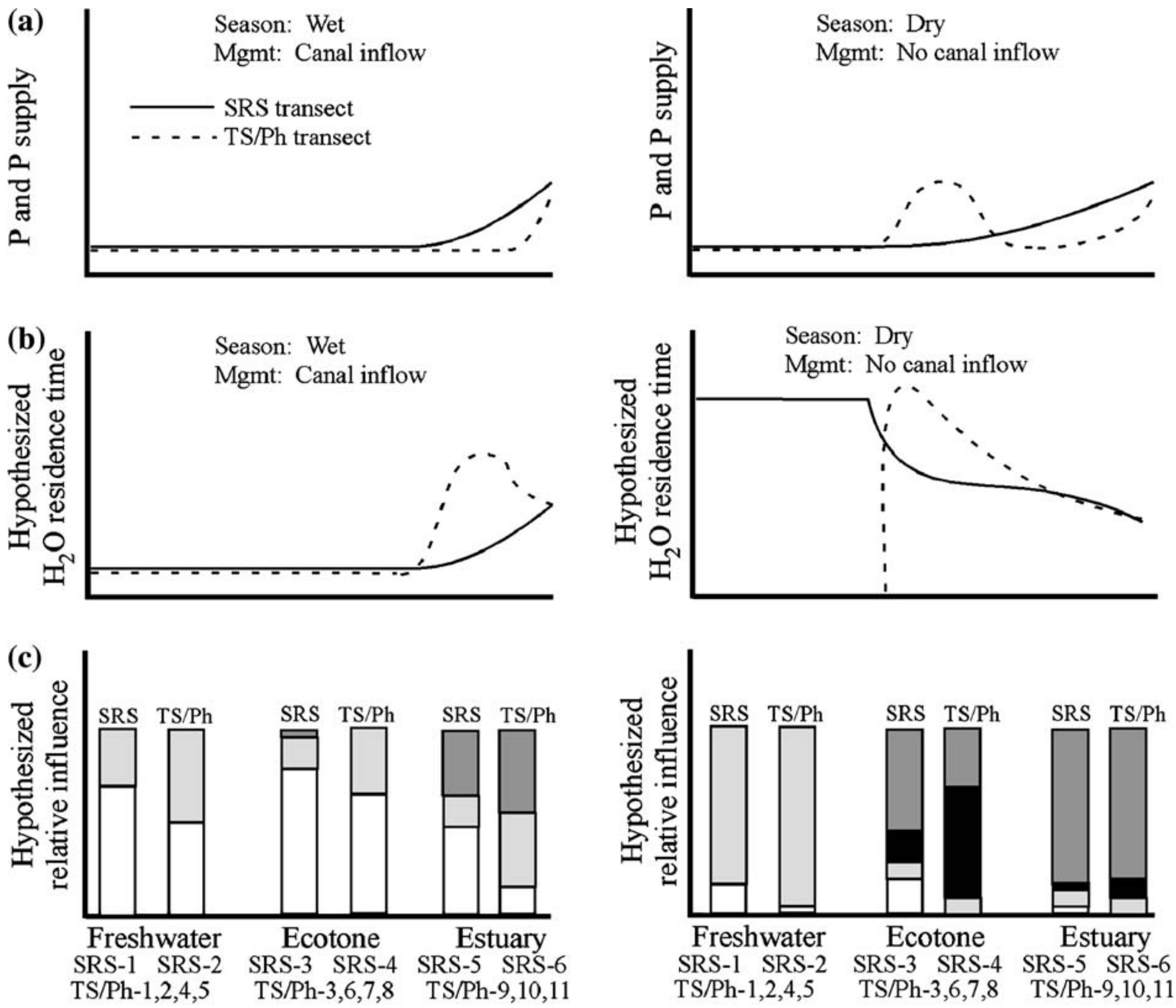

Figure 3. Note that the *x*-axis labels for a–c is shown in C. (a) Generalized landscape-scale patterns of water column P concentrations in the wet season (left panel) and dry season (right panel) along the Shark River Slough (solid line) and southern Everglades (TS/Ph; dashed line) transects (note the similarity to Figure 2b). (b) Hypothesized landscape-scale patterns of water residence time in the wet season (left panel) and dry season (right panel) along the Shark River Slough (solid line) and southern Everglades (TS/Ph; dashed line) transects. Dry season water residence time in the southern Everglades ecotone is long without freshwater inflow or tidal flushing. Residence time in freshwater SRS marshes is long, but is dramatically shorter in the ecotone because of regular tidal flushing. (c) The relative influence of four main water sources that we hypothesize are driving oligohaline ecotone dynamics. For each landscape component (freshwater marshes, estuarine ecotone, and estuary), the SRS and TS/Ph transects are shown with separate bars. white = freshwater inflow, dark gray = marine water, light gray = net precipitation, black = groundwater. The major difference between the 2 transects is in the ecotone in the dry season, when we hypothesize that groundwater inputs to the TS/Ph transect are relatively large compared with the SRS transect.

ecotone sites (see Fig. 3a for a summary of these P patterns). Although our long-term nutrient concentration patterns did not generally support our original hypothesis about landscape-scale patterns in ecosystem productivity (Fig. 2), these data are central to the new hypotheses and approaches we will take in the future (discussed below).

Everglades estuaries are unique not only because they are ‘‘upside-down’’ – that is, because the source of limiting P is the ocean not the watershed – but also because water flowing from freshwater Everglades wetlands is virtually free of suspended sediments. The only exogenous source of POM to the estuarine ecotone is downstream transport of “floc”. Interest in the dynamics and importance of floc has grown in recent years (Jaffé et al., 2001; Mead et al., 2005; Neto et al., 2005; Wood, 2005; Leonard et al., 2006), but much of our organic geochemical research has focused on DOM dynamics (Jaffé et al., 2004). In fact, we hypothesized a productivity peak in the oligohaline zone of the SRS transect because this is where DOM-rich Everglades water first encounters the marine source of P (Figs. 1 and 2a).

Considerable effort has been spent studying the sources, transport, and fate of DOM along our FCE transects (Lu et al., 2003; Jaffé et al., 2004; Maie et al., 2005, 2006). Davis et al. (2006) and Maie et al. (2006) quantified the release of dissolved organic carbon (DOC) and inorganic nutrients as leachate during plant decomposition. They found that the leaching of DOC and P from senesced mangrove, spikerush, and sawgrass leaves was primarily a physical process, but mobilization of nutrients – particularly P – by microbes on the leaves becomes more important later in the decomposition process (Davis et al., 2003; Romero et al., 2005; Maie et al., 2006; Rubio & Childers, 2006). The same was true of the seagrass decomposition process (Fourqurean & Schrlau, 2003). Of the major ecotone plant litter examined, DOC leaching rates were greatest from mangrove leaves. Davis et al. (2006) combined their leaching data with leaf litterfall rates (mangrove) and leaf mortality rates (sawgrass and spikerush) and estimated that this process may be an important vector for moving soil nutrients – particularly P – into the water column. Additionally, Scully et al. (2004) found different rates of physico-chemical processing, photodegradation, and microbial degradation for DOM leached from different vegetation sources, suggesting the need for a more detailed molecular characterization of DOM (Jones et al., 2004; 2006).

The nitrogen component of DOM is important because of relatively large inputs of dissolved organic nitrogen (DON) to Everglades estuaries from the P-limited freshwater system. Canal water flowing into freshwater marshes appears to contain primarily refractory DON (Lu et al., 2003), while these marshes themselves are a source of more labile [proteinaceous] DON (Lu et al., 2003; Jones et al., 2005; 2006). However, it appears that most of the DON input to Everglades estuaries is relatively refractory (J. Boyer, Florida International Univ., unpubl. Data). Some of this DON appears to be bacterial in origin (Jones et al., 2005), and much of the bio-available DON has been consumed or transformed before reaching the estuarine ecotone.

Interestingly, in some places in Florida Bay it appears that the availability of labile DOC may limit microbial production. Where cyanobacterial blooms periodically occur, waterborne bacteria compete with phytoplankton for both inorganic nutrients (often N, not P, because these blooms typically occur near the Gulf of Mexico margin) and DOC. In central Florida Bay, ectoenzyme activity suggested that bacterial production was limited by DOM availability while near the estuarine ecotone P availability was the primary control (Williams & Jochem, 2006). Maie et al. (2006) studied seasonal variation of one form of DOC (chromophoric DOC) in both FCE estuaries, and found higher concentrations in the wet season in both estuaries. In Florida Bay, chromophoric DOC was primarily autochthonous while these pools reflected both freshwater marsh and mangrove wetland sources in the SRS estuary.

The tidal efflux of DOM from mangrove wetlands has been well documented in previous studies. Tidally mediated exchanges of DOC from our SRS mangrove wetlands appear to be driven by inundation time and by water source. During the wet season, when salinities in this estuary were lowest, mangroves exported DOC and, in particular, the fringing mangroves released DOC on both flooding and ebbing tides (Romigh et al., 2006). As such, tidal exchanges of DOC appeared to be controlled by freshwater inflow and tidal amplitude.

Disturbance and landscape-scale dynamics

The guiding question for our disturbance and larger-scale research has been: How do long-term changes in freshwater flow (primarily manifest through Everglades restoration) interact with long-term changes in the climatic and disturbance regimes to modify ecological pattern and process in coastal landscapes? The dominant disturbances on the coastal Everglades are hurricanes and fire, which affect the landscape at a range of spatial scales (Lockwood et al., 2003), and hydrologic extremes (droughts and floods, mediated or exacerbated by human activities), which tend to preferentially affect animal and upland communities (Trexler et al., 2005). Sea level rise is also a disturbance that has gradual effects (i.e., "press-type") rather than event-based impacts (i.e., "pulse-type"). We define our oligohaline ecotone as the region where freshwater marsh plants (primarily sawgrass and spikerush) co-exist with mangroves. Sea level rise and hurricane-induced storm surges tend to force the estuarine boundary of the ecotone up-slope while fire, of which mangroves are highly intolerant, moves the landward ecotone boundary seaward. Everglades Restoration will also increase freshwater inflows into the estuarine ecotone in the future, and the long-term spatial dynamic of this region will continue to be a key focus of our disturbance research.

Freshwater inflows to the southern Everglades have declined dramatically in the last 50 years (Light & Dineen, 1994), but have recently increased after a hydrologic restoration project removed a key levee along the C-111 Canal (which anchors the eastern leg of our TS/Ph transect; Parker, 2000). During this period of reduced freshwater inflow, the mangrove ecotone has expanded north considerably (Ross et al., 2000). Long-term peat accretion in these relatively new mangrove wetlands has been considerably higher (approximately 3 mm yr^{-1}) than the marl soil accretion by the freshwater marshes that were replaced (about 0.8 mm yr^{-1}; Gaiser et al., 2006). This rate of peat production is roughly equal to the rate of eustatic sea level rise in south Florida. Short-term sediment deposition rates [in the ecotone] associated with specific storm events can be considerably higher, however (Davis et al., 2004). For example, the storm surge from Hurricane Wilma, a Category 3 hurricane that tracked northeast directly along our SRS transect on October 24 2005, deposited over 3 cm of carbonate mud in the mangrove forests of this system. Long-term peat accretion estimates plus episodic surficial deposition during storms suggest that these oligohaline ecotones may be able to maintain themselves in this transgressive environment – at least in the near term.

Hurricane winds can have a significant effect on mangrove forests, particularly along our SRS transect where the trees are taller (Chen & Twilley, 1999; Simard et al., 2006). In their analysis of mangrove forest recovery after the 1992 Hurricane Andrew, Ward et al. (2006) noted that these forested wetlands appear to follow size-structured organizing principles similar to those described for recovering upland forests. The distribution of woody debris (Krauss et al., 2005) and its decomposition (Romero et al., 2005) are important feedbacks to biogeochemical cycling and organic matter dynamics. Seedling dynamics play an important role in how mangrove forests recover from canopy damage. Cardona-Olarte et al. (2006) found that white mangrove (*Laguncularia racemosa*) seedlings – generally considered to be the "pioneer" species – were considerably more sensitive to variation in salinity and hydroperiod than were red mangrove (*Rhizophora mangle*) seedlings; as such, white mangrove seedlings had a competitive advantage only under conditions of low [hydrologic and salinity] stress. The 2005 hurricane season was particularly active in south Florida. Our LTER sites were directly affected by Hurricanes Dennis (early July), Katrina (late August), Rita (mid-September), and Wilma (late October). These large-scale disturbances present a unique opportunity of evaluate how hurricanes regulate mangrove forest productivity, particularly in the SRS estuary where mangrove forests grow to considerable stature. We will continue to analyze the ecological effects of these disturbances at various spatial scales in our future research.

Future research focusing on the oligohaline ecotone

Our research to date has focused on understanding ecological dynamics along two experimental transects. Our original conceptual model detailed this focus, and demonstrated the importance of quantifying the major flows of energy and nutrients in the freshwater marsh, the estuarine ecotone wetlands, and the subtidal Florida Bay. Most of the ecosystem components we studied showed only equivocal support for our original hypothesis (Fig. 2). Rather, patterns of ecosystem production (Fig. 2b) tended to follow the generalization of water column P availability shown in Fig. 3a. As I discuss above, the lack of a peak in P concentrations or productivity in the oligohaline ecotone of the SRS transect is likely because the dissolved organic matter supplied by the freshwater Everglades is less labile than we originally hypothesized. We also learned that the downstream transport of particulate organics may be an important vector of nutrients and energy from the freshwater Everglades to the SRS oligohaline ecotone (Jaffé et al., 2001; Mead et al., 2005; Neto et al., 2005; Wood, 2005). Interestingly, most movement of this particulate organic matter occurs as slow-moving bedload of the nearly neutrally buoyant material that we refer to as "floc" (Leonard et al., 2006). Williams & Trexler (2006) reported that the small fish and invertebrate food webs are detrital-based, rather than grazer-based, so this "floc" may be an important base for these food webs. It is thus possible that the dominant supply of labile organic matter from the freshwater Everglades is as particles consumed directly by animals rather than as DOM coupled with microbial loop transformations. As such, we will focus our future research more strongly on the particulate ("floc") component of organic matter production, fate, and transport.

In the southern Everglades estuarine ecotone, we found an unexpected peak in P concentrations and productivity during the dry season. We are hypothesizing that this is partially a result of the long residence time of water, which allows P produced by internal recycling to accumulate (Fig. 3b). Another cause for this pattern may be relatively P-rich groundwater inputs to this oligohaline ecotone during the dry season (Fig. 3c). Price et al. (2006) quantified the upward movement of shallow brackish groundwater during the dry season, when water levels in the southern Everglades were relatively low and the upstream freshwater head was minimal (these freshwater marshes dry down during this time). Furthermore, they reported that this groundwater had concentrations of P ranging from 1 to 2.3 μM, compared with surface water concentrations that were typically less than 1 μM (Childers et al., 2006; Price et al., 2006). We hypothesize that the input of this P-rich groundwater, at the time of year when surface water residence time appears to be longest, plays a strong role in the P concentration and productivity peaks we have observed in the southern Everglades estuarine ecotone. We will address this hypothesis with enhanced measures of groundwater dynamics at our estuarine ecotone sites.

For several reasons, hydrology will become a more important component of our future research as we focus our efforts more closely on biophysical dynamics in the estuarine ecotone (Fig. 4). To test the hypotheses I present above (Figs. 3b, c), we will be quantifying water residence times in both ecotone regions. We expect relatively long water residence times in the southern Everglades ecotone during the dry season because this system has no astronomical tidal energy to drive exchange with the estuary proper (Fig. 4). We will be measuring groundwater P inputs to this oligohaline ecotone, and studying the fate of this P relative to macrophyte production (particularly belowground production), microbial dynamics, and higher food webs. The supply of "floc" to the estuarine ecotone, and its energetic fate in the ecotone, will be an important new focus not just for our hydrologic research, but for our organic geochemical and food web work as well. As a final, overarching reason for our enhanced focus on hydrology, we expect freshwater inflow to increase markedly along our SRS transect during this next phase of our research. In 2008 or 2009, nearly 5 km of the Tamiami Canal levee along the northern boundary of Shark River Slough will be removed. As part of this, a 3.2 km bridge will be built at the northern anchor of our SRS transect. The removal of this levee will permit a considerable increase in freshwater inflow at this site, and along our entire SRS transect. This "Grand Hydrologic Experiment" will not take place along our southern Everglades (TS/Ph) transect, but it will still provide us with an excellent opportunity to study the effects of increased freshwater inflows to one of our estuarine ecotone regions.

Our future research will also include a human, or societal dimension. The FCE LTER is located entirely within Everglades National Park, which is immediately adjacent to Miami-Dade and Monroe Counties and to more than 2 million people. The Everglades is an excellent system to study human-natural interactions. This expansive wetland landscape provides freshwater to 95% of south Florida's 6 million residents by recharging the shallow Biscayne Aquifer with clean drinking water. Yet this growing human population is so close to the natural system on which it depends that adverse human impacts are increasing and worsening. Conflicts seem inevitable between human

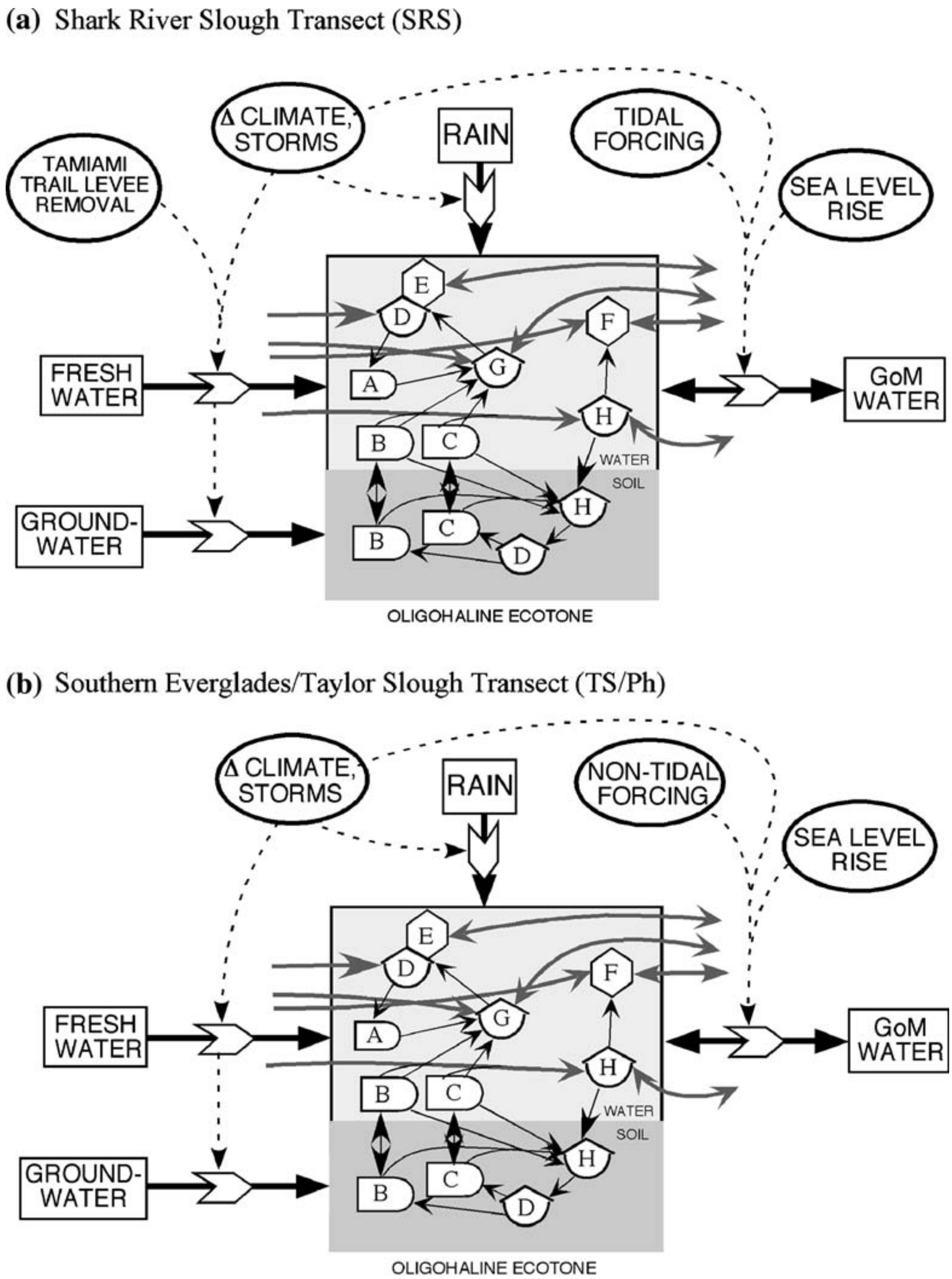

Figure 4. Conceptual depiction of the future direction of our research. Note the focus on estuarine ecotone dynamics along both transects. Rectangles = hydrologic drivers (= key water masses), ovals = climatic/environmental drivers, and heavy gray arrows crossing the ecotone boundaries (and box) = key exchanges with upstream (freshwater Everglades wetlands) and downstream (Florida Bay and the Shark River estuary) systems. Abbreviations for components of the ecosystem conceptual model within each oligohaline ecotone box: (A) periphyton or phytoplankton; (B) emergent herbaceous vegetation (typically sawgrass or spikerush); (C) mangroves; (D) inorganic nutrients (P & N); (E) bacteria; (F) fish; (G) DOM; (H) POM (“floc” in water compartment, soil OM in soil compartment).

dependence on key ecosystem services and human stresses on the purveyance of those services by the Everglades. Our future research will address these conflicts by examining trends in land use change and human demographics in south Florida. We will couple this with a quantitative assessment of the economic values of ecosystem services being provided by the Everglades. The former requires a strong sociological understanding of human behavior and decision-making while the latter requires biophysical understanding of how ecosystems provide key services to humans. With this approach, we hope to better understand the human-natural interactions that are the foundation of the major drivers in our system (Fig. 4). This work may even enable the ''Grand Experiment'' known as Everglades Restoration to expand and include key feedbacks between the Everglades and south Florida's human population.

Acknowledgements

This paper is single-authored for only one reason – it would be impossible to have the number of co-authors who truly deserve to be recognized here. This diverse and high quality science has been produced by a large number of students, staff, and Ph.D. level scientists, all of whom deserve credit and recognition for their contributions to the FCE LTER Program, to Everglades science and management, and to environmental science in general. Thanks to the FIU Wetland Ecosystems Ecology Lab, Tiffany Troxler Gann, Rudolf Jaffé, and Joel Trexler for helpful comments on earlier drafts of this paper. The research synthesized in this paper has been supported by the National Science Foundation through the FCE LTER Program (DEB-9910514) as well as by numerous grants from agencies such as Everglades National Park, the EPA, NOAA, and the South Florida Water Management District to numerous FCE scientists. This is contribution #317 of the Southeast Environmental Research Center at Florida International University.

References

Armentano, T. V., J. P. Sah, M. S. Ross, D. T. Jones, H. C. Cooley & C. S. Smith, 2006. Rapid responses of vegetation to hydrological changes in Taylor Slough, Everglades National Park, Florida, USA. Hydrobiologia 569: 293–309.

Armitage, A. R., T. A. Frankovich, K. L. Heck Jr. & J. W. Fourqurean, 2005. Experimental nutrient enrichment causes complex changes in seagrass, microalgae, and macroalgae community structure in Florida Bay. Estuaries 28(3): 422–434.

Armitage, A. R., T. A. Frankovich & J. W. Fourqurean, 2006. Variable responses within epiphytic and benthic microalgal communities to nutrient enrichment. Hydrobiologia 569: 423–435.

Cardona-Olarte, P., R. R. Twilley, K. W. Krauss & V. Riverva-Monroy, 2006. Responses of neotropical mangrove seedlings grown in mono and mixed cultures under treatments of hydroperiod and salinity. Hydrobiologia 569: 325–341.

Chambers, R. M. & K. A. Pederson, 2006. Variation in soil phosphorus, sulfur, and iron pools among south Florida wetlands. Hydrobiologia 569: 63–70.

Chen, R. & R. R. Twilley, 1999. Patterns of mangrove forest structure and soil nutrient dynamics along the Shark River estuary, Florida. Estuaries.

Childers, D. L., R. F. Doren, R. Jones, G. B. Noe, M. Rugge & L. J. Scinto, 2003. Decadal change in vegetation and soil phosphorus patterns across the Everglades landscape. Journal of Environmental Quality 32: 344–362.

Childers, D. L., J. N. Boyer, S. E. Davis, C. J. Madden, D. T. Rudnick & F. H. Sklar, 2006. Nutrient concentration patterns in the oligotrophic ''upside down'' estuaries of the Florida Everglades. Limnology and Oceanography 51(1): 602–616.

Childers, D. L., D. Iwaniec, D. Rondeau, G. Rubio, E. Verdon & C. J. Madden, 2006. Responses of sawgrass and spikerush to variation in hydrologic drivers and salinity in Southern Everglades marshes. Hydrobiologia 569: 273–292.

Davis, S. E., C. Coronado-Molina, D. L. Childers & J. W. Day, 2003. Temporally dependent C, N, and P dynamics associated with the decay of *Rhizophora mangle* L. leaf litter in oligotrophic mangrove wetlands of the Southern Everglades. Aquatic Botany 75(3): 199–215.

Davis, S. E., J. E. Cable, D. L. Childers, C. Coronado-Molina, J. W. Day, C. D. Hittle, C. J. Madden, D. Rudnick, E. Reyes & F. Sklar, 2004. Importance of episodic storm events in controlling ecosystem structure and function in a Gulf Coast Estuary. Journal of Coastal Research 20(4): 1198–1208.

Davis, S. E. III, D. L. Childers & G. B. Noe, 2006. The contribution of leaching to the rapid release of nutrients and carbon in the early decay of wetland vegetation. Hydrobiologia 569: 87–97.

Dorn, N. J., J. C. Trexler & E. E. Gaiser, 2006. Exploring the role of large predators in marsh food webs: evidence for a behaviorally-mediated trophic cascade. Hydrobiologia 569: 375–386.

Ewe, S. M. L., E. E. Gaiser, D. L. Childers, D. Iwaniec, V. H. Rivera-Monroy & R. R. Twilley, 2006. Spatial and temporal patterns of aboveground net primary production (ANPP) along two freshwater-estuarine transects in the Florida Coastal Everglades. Hydrobiologia 569: 459–474.

Fourqurean, J. W., J. C. Zieman & G. V. N. Powell, 1992. Phosphorus limitation of primary production in Florida

Bay: evidence from the C:N:P ratios of the dominant seagrass *Thalassia testudinum*. Limnology and Oceanography 37: 162–171.

Fourqurean, J. W. & J. Schrlau, 2003. Changes in nutrient content and stable isotope ratios of C and N during decomposition of seagrasses and mangrove leaves along a nutrient availability gradient in Florida Bay, USA. Chemistry and Ecology 19(5): 373–390.

Frankovich, T. A., E. E. Gaiser, J. C. Zieman & A. H. Wachnicka, 2006. Spatial and temporal distributions of epiphytic diatoms growing on *Thalassia testudinum* Banks *ex* König: relationships to water quality. Hydrobiologia 569: 259–271.

Gaiser, E. E., J. C. Trexler, J. H. Richards, D. L. Childers, D. Lee, A. L. Edwards, L. J. Scinto, K. Jayachandran, G. B. Noe & R. D. Jones, 2005. Cascading ecological effects of low-level phosphorus enrichment in the Florida Everglades. Journal of Environmental Quality 34(2): 717–723.

Gaiser, E. E., A. Zafiris, P. L. Ruiz, F. A. C. Tobias & M. S. Ross, 2006. Tracking rates of ecotone migration due to saltwater encroachment using fossil mollusks in coastal South Florida. Hydrobiologia 569: 237–257.

Gil, M., A. R. Armitage & J. W. Fourqurean, 2006. Nutrient impacts on epifaunal density and species composition in a subtropical seagrass bed. Hydrobiologia 569: 437–447.

Green, D. P. J., J. C. Trexler, J. J. Lorenz, C. C. McIvor & T. Philippi, 2006. Spatial patterns of fish communities along two estuarine gradients in southern Florida. Hydrobiologia 569: 387–399.

Hajje, N. & R. Jaffé, 2006. Molecular characterization of *Cladium* peat from Florida Everglades: biomarker associations with humic fractions. Hydrobiologia 569: 99–112.

Iwaniec, D. M, D. L. Childers, D. Rondeau, C. J. Madden & C. Saunders, 2006. Effects of hydrologic and water quality drivers on periphyton dynamics in the southern Everglades. Hydrobiologia 569: 223–235.

Jaffe, R., R. Mead, M. E. Hernandez, M. C. Peralba & O. A. DiGuida, 2001. Origin and transport of sedimentary organic matter in two subtropical estuaries: A comparative, biomarker-based study. Organic Geochemistry 32(4): 507–526.

Jaffe, R., J. N. Boyer, X. Lu, N. Maie, C. Yang, N. M. Scully & S. Mock, 2004. Source characterization of dissolved organic matter in a subtropical mangrove-dominated estuary by fluorescence analysis. Marine Chemistry 84(3–4): 195–210.

Jones, V., C. J. Ruddell, G. Wainwright, H. H. Rees, R. Jaffe & G. A. Wolff, 2004. One-dimensional and two dimensional polyacrylamide gel electrophoresis: a tool for protein characterization in aquatic samples. Marine Chemistry 85(1–2): 63–73.

Jones, V., M. J. Collins, K. E. H. Penkman, R. Jaffe & G. A. Wolff, 2005. An assessment of the microbial contribution to aquatic dissolved organic nitrogen using amino acid enantiomeric ratios. Organic Geochemistry 36(7): 1099–1107.

Jones, V., K. Parish, A. Thomson, G. A. Wolff, N. Maie & R. Jaffé, 2006. Molecular characterization of proteinaceous material in the Florida coastal Everglades. Hydrobiologia 569: 129–133.

Krauss, K. W., T. W. Doyle, R. R. Twilley, V. H. Rivera-Monroy & J. K. Sullivan, 2006. Evaluating the relative contributions of hydroperiod and soil fertility as growth of south Florida mangroves. Hydrobiologia 569: 311–324.

Krauss, K. W., T. W. Doyle, R. R. Twilley, T. J. Smith, K. R. T. Whelan & J. K. Sullivan, 2005. Woody debris in the mangrove forests of South Florida. Biotropica 37(1): 9–15.

Leonard, L., A. Croft, D. Childers, S. Mitchell-Bruker, H. Solo-Gabriele & M. Ross, 2006. Characteristics of surface-water flows in the ridge and slough landscape of Everglades National Park: implications for particulate transport. Hydrobiologia 569: 5–22.

Liston, S. E., 2006. Interactions between nutrient availability and hydroperiod shape macroinvertebrate communities in Florida Everglades marshes. Hydrobiologia 569: 343–357.

Light, S. S. & J. W. Dineen, 1994. Water control in the Everglades: a historical perspective. In Davis, S. M. & J. C. Ogden (eds.), Everglades: The Ecosystem and its Restoration. St. Lucie Press, FL.

Lockwood, J. L., M. S. Ross & J. P. Sah, 2003. Smoke on the water: the interplay of fire and water flow on Everglades restoration. Frontiers in Ecology and the Environment 1(9): 462–468.

Lorenz, J. J. & J. E. Seraty, 2006. Subtropical wetland fish assemblages and changing salinity regimes: Implications for everglades restoration. Hydrobiologia 569: 401–421.

Lu, X., D. L. Childers, J. V. Hanna, N. Maie & R. Jaffe, 2003. Molecular characterization of dissolved organic matter in freshwater wetlands of the Florida Everglades. Water Research 37(11): 2599–2560.

Maie, N., C. Yang, T. Miyoshi, K. Parish & R. Jaffe, 2005. Chemical characteristics of dissolved organic matter in an oligotrophic subtropical wetland/estuarine ecosystem. Limnology and Oceanography 50(1): 23–35.

Maie, N., R. Jaffe, M. Toshikazu & D. L. Childers, 2006. Quantitative and qualitative aspects of dissolved organic carbon leached from senescent plants in an oligotrophic wetland. Biogeochemistry (in press).

Mead, R. N., Y. Xu, J. Chong & R. Jaffe, 2005. Sedimentary organic matter source assessment in a sub-tropical wetland and estuarine environment using the molecular distribution and carbon isotopic composition of *n*-alkanes. Organic Geochemistry 36(3): 363–370.

Neto, R., R. N. Mead, W. J. Louda & R. Jaffe, 2005. Organic biogeochemistry of detrital flocculent material (floc) in a subtropical, coastal wetland. Biogeochemistry (in press).

Noe, G., D. L. Childers & R. D. Jones, 2001. Phosphorus biogeochemistry and the impacts of phosphorus enrichment: why is the Everglades so unique. Ecosystems 4(7): 603–624.

Parker, F. M. P. III, 2000. Quantifying spatial and temporal variability in marsh–water column interactions in a southern Everglades Marsh. MS Thesis, Florida International University.

Price, R. M., P. K. Swart & J. W. Fourqurean, 2006. Coastal groundwater discharge – an additional source of phosphorus for the oligotrophic wetlands of the Everglades. Hydrobiologia 569: 23–36.

Rehage, J. S. & J. C. Trexler, 2006. Assessing the net effect of anthropogenic disturbance on aquatic communities in wetlands: community structure relative to distance from canals. Hydrobiologia 569: 359–373.

Romero, L. M., J. W. Fourqurean & T. J. Smith, 2005. Changes in mass and nutrient content of wood during decomposition in a South Florida mangrove forest. Journal of Ecology 93(3): 618–631.

Romigh, M. M., S. E. Davis III, V. H. Rivera-Monroy & R. R. Twilley, 2006. Flux of organic carbon in a riverine mangrove wetland in the Florida Coastal Everglades. Hydrobiologia 569: 505–516.

Ross, M. S., J. F. Meeder, J. P. Sah & G. J. Telesnicki, 2000. The Southeast Saline Everglades revisited: 50 years of coastal vegetation change. Journal of Vegetation Science 11: 101–112.

Ross, M. S., D. R. Reed, J. P. Sah, P. L. Ruiz & M. Lewin, 2003. Vegetation:environment relationships and water management in Shark Slough, Everglades National Park. Wetlands Ecology and Management 11(5): 291–303.

Rubio, G. A. & D. L. Childers, 2006. Decomposition of *Cladium jamaicense*, *Eleocharis* sp., and *Juncus roemerianus* in the estuarine ecotones of the Florida Everglades. Estuaries (in press).

Simard, M., K. Zhang, V. H. Rivera-Monroy, M. Ross, P. Ruiz, E. Castañeda-Moya, R. R. Twilley & E. Rodriguez, 2006. Mapping height and biomass of mangrove forests in Everglades National Park with SRTM elevation data. Photogrammetric Engineering & Remote Sensing (in press).

Scully, N. M., N. Maie, S. Dailey, J. Boyer, R. D. Jones & R. Jaffe, 2004. Early diagenesis of plant-derived dissolved organic matter along a wetland, mangrove, estuary ecotone. Limnology and Oceanography 49(5): 1667–1678.

Trexler, J. C., W. F. Loftus & S. Perry, 2005. Disturbance frequency and community structure in a twenty-five year intervention study. Oecologia 145(1): 140–152.

Ward, G. A., T. J. Smith III, K. R. T. Whelan & T. W. Doyle, 2006. Regional processes in mangrove ecosystems: spatial scaling relationships, biomass, and turnover rates following catastrophic disturbance. Hydrobiologia 569: 517–527.

Williams, C. J. & F. J. Jochem, 2006. Ectoenzymes kinetics in Florida Bay: Implications for bacterial carbon source and nutrient status. Hydrobiologia 569: 113–127.

Williams, A. J. & J. C. Trexler, 2006. A preliminary analysis of the correlation of food-web characteristics with hydrology and nutrient gradients in the southern Everglades. Hydrobiologia 569: 493–504.

Wood, A. D., 2005. Dynamics of detrital particulate organic material in the ridge & slough landscape. MS Thesis, Florida International University.

Xu, Y., R. N. Mead & R. Jaffé, 2006. A molecular marker-based assessment of sedimentary organic matter sources and distributions in Florida Bay. Hydrobiologia 569: 179–192.

C. TRAINING AND DEVELOPMENT

FCE I Education, Outreach, and Diversity Activities

During FCE I, we developed an Ed & Outreach program that communicates our research findings to K-12 students, teachers, and the community of South Florida (which is over 60% Hispanic). Our K-12 classroom effectiveness assessments have shown that 89% of the students we have impacted were Hispanic. We have developed a variety of programs to assess the most effective approaches to disseminate FCE LTER research findings and to educate the public about the ecology and importance of the Everglades. These approaches have included television segments, a website, video conference presentations, a high school student internship program, a science ranger education program with ENP, paired field and schoolyard activities, and classroom presentations. Our most widely distributed product has been the ForEverglades presentation (http://fcelter.fiu.edu/schoolyard) that explains the importance of the timing, distribution, and quality of water to the Everglades ecosystem. This presentation has reached over 3500 individuals across South Florida via FCE personnel, classroom visits, and our website.

One of our most successful components has been our high school internship program, the The Research Experience for Secondary Students (RESSt). This program pairs high school students with FCE researchers who mentor students by providing hands-on experience with the science, tools and details of FCE research. In 2005, one of our interns entered his project on belowground production in FCE sawgrass marshes in the high school science fair and proceeded to win the county, regional, and state science fair competitions! After winning these prestigious awards, he went on to make presentations of his FCE LTER internship experience to 491 high school students and their teachers. In 2006, several high school interns also won awards at the regional and state science fairs. The REESt program has grown to include over ten high school students working with FCE scientists.

FCE Graduate Student Activities and Productivity

The FCE Affiliated Students Group has grown in size, influence, and activities since its inception in the fall of 2000. There are currently 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 graduate students have also been very active at the network level. In February 2005, 7 FCE graduate students attended the Ecosystem-based Management Workgroup, National Center for Ecological Analysis and Synthesis (NCEAS), Santa Barbara, CA. Several of these students established Ecotank, an ecological think tank for students inspired by their experiences at NCEAS, at FIU. Tiffany Troxler-Gann co-organized the First LTER Graduate Student Collaborative Research Symposium at H.J. Andrews LTER, in Blue River, Oregon in April 2005 and 4 FCE students attended the symposium. Tiffany also served as the co-chair of the LTER Network student group and, as such, was a member of the LTER Network Coordinating Committee from 2001-2005. FCE students earned 22 MS theses and 11 Ph.D. dissertations from 2000-2006.

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 58 outreach presentations and over 440 conference presentations from 2000-2006. The FCE Education and Outreach program hosted teacher workshops and conducted a training session on nutrient cycling for Everglades National Park rangers. In 2003, we held the Hands on the Everglades teacher workshop. We also displayed and presented information about the FCE LTER program at GIS Day at Florida International University and at NSF at Florida Atlantic University in 2003. In 2005, Dan Childers participated in several workshops hosted by ENP and SFWMD, in which FCE LTER research was integrated into restoration and management challenges. The LTER Network Office publications staff assisted us with a site brochure in 2000, and FCE researchers have distributed these brochures during conferences, meetings, and outreach activities.

FCE research has been featured on several television programs and videos. In 2004, Tim Grahl and Dan Childers were featured on an episode of New Florida, produced by Florida Public Television. The topic of the episode was Everglades Restoration, FCE LTER research, and the importance of the Everglades ecosystem to the people of Florida. The WFSU-TV program 'Florida Crossroads' show #1610: 'Everglades: Ebb & Flow' featured interviews with FCE researchers. In early 2005, we filmed a short children's film called 'Kidz Corner' that was aired on WLRN The Learning Channel, Closed circuit TV in the Miami-Dade public school television station and childrens' pediatrics hospital units of Florida. Our short film contributions for the Kidz Corner television show will reach a wide audience that has been estimates to be as much as 120,000 people in the South Florida Area. Beginning in October 2006 we started a project to develop data file education movies for the classroom. The purpose of these videos is to spark interest for the use of the datasets published on the FCE LTER web pages. These products will be distributed to teachers and trailers to the movies will be made available on our Education and Outreach web pages during FCE LTER year seven. Distribution of these combined products to science department heads in Miami Dade schools will enable us to increase awareness of our web published FCE LTER research beyond the website or our existing contacts.

The FCE LTER Program also reaches out to the public is through our web site. In first the 6 years of the FCE Program, we have been reaching a steadily growing number of new web clients, suggesting a strong positive trajectory for our web-based public outreach. We have received numerous general questions from our visitors and requests for schoolyard visits and presentations. Additionally, visitors to the data section of our website downloaded 1352 datasets from May 2000 - February 2007.

Finally, all FCE scientists and students are, to some degree, also involved with Everglades restoration. Several FCE scientists participated in preparation of the Interim Operations Program report to Congress with scientists and managers at Everglades National Park. FCE researchers have also been involved with RECOVER (Everglades Restoration planning) with scientists and managers at the South Florida Water Management District.

III. PUBLICATIONS AND OTHER SPECIFIC PRODUCTS

A. Publications

Anderson, W.T. and J.W. Fourqurean, 2003. Intra- and interannual variability in seagrass carbon and nitrogen stable isotopes from south Florida, a preliminary study. Organic Geochemistry, 34(2): 185-194.

Anderson, W.T., L.S.L. Sternberg, M.C. Pinzon, T. Troxler-Gann, D.L. Childers, and M. Duever, 2005. Carbon isotopic composition of cypress trees from South Florida and changing hydrologic condition. Dendrochronologia, 23(1): 1-10.

Armentano, T.V., J.P. Sah, M.S. Ross, D.T. Jones, H.C. Cooley, and C.S. Smith, 2006. Rapid responses of vegetation to hydrological changes in Taylor Slough, Everglades National Park, Florida, USA. Hydrobiologia, 569(1): 293-309.

Armitage, A.R., T.A. Frankovich, K.L. Heck, Jr., and J.W. Fourqurean, 2005. Experimental nutrient enrichment causes complex changes in seagrass, microalgae, and macroalgae community structure in Florida Bay. Estuaries, 28(3): 422-434.

Armitage, A.R., T.A. Frankovich, and J.W. Fourqurean, 2006. Variable responses within epiphytic and benthic microalgal communities to nutrient enrichment. Hydrobiologia, 569(1): 423-435.

Baber, M.J., D.L. Childers, K.J. Babbitt, and D.H. Anderson, 2002. Controls on fish distribution and abundance in temporary wetlands. Canadian Journal of Fisheries and Aquatic Sciences, 59(9): 1441-1450.

Barr, J.G., J.D. Fuentes, N. Wang, Y. Edmonds, J.C. Zieman, B.P. Hayden, and D.L. Childers, 2003. Red mangroves emit hydrocarbons. Southeastern Naturalist, 2(4): 499-510.

Barr, J.G., J.D. Fuentes, T.L. O'Halloran, D. Barr, and J.C. Zieman, 2006. Carbon assimilation by mangrove forests in the Florida Everglades. Amalgam, 1: 27-37.

Bazante, J., G. Jacobi, H. Solo-Gabriele, D.R. Reed, S. Mitchell-Bruker, D.L. Childers, L. Leonard, and M.S. Ross, 2006. Hydrologic measurements and implications for tree island formation within Everglades National Park. Journal of Hydrology, 329(3-4): 606-619.

Borum, J., O. Pedersen, T. Greve, T.A. Frankovich, J.C. Zieman, J.W. Fourqurean, and C.J. Madden, 2005. The potential role of plant oxygen and sulphide dynamics in die-off events of the tropical seagrass, Thalassia testudinum. Journal of Ecology, 93(1): 148-158.

Boyer, J.N., S.K. Dailey, P.J. Gibson, M.T. Rogers, and D. Mir-Gonzalez, 2006. The role of dissolved organic matter bioavailability in promoting phytoplankton blooms in Florida Bay. Hydrobiologia, 569(1): 71-85.

Boyer, J.N. 2006. Shifting N and P limitation along a north-south gradient of mangrove estuaries in South Florida. Hydrobiologia, 569(1): 167-177.

D.E. Busch and J.C. Trexler, (eds.) 2003. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, D.C.. 447 pp.

Cardona-Olarte, P., R.R. Twilley, K.W. Krauss, and V.H. Rivera-Monroy, 2006. Responses of neotropical mangrove seedlings grown in monoculture and mixed culture under treatments of hydroperiod and salinity. Hydrobiologia, 569(1): 325-341.

Chambers, R.M., J.W. Fourqurean, S.A. Macko, and R. Hoppenot, 2001. Biogeochemical effects of iron availability on primary producers in a shallow marine carbonate environment. Limnology and Oceanography, 46(6): 1278-1286.

Chambers, R.M. and K.A. Pederson, 2006. Variation in soil phosphorus, sulfur, and iron pools among south Florida wetlands. Hydrobiologia, 569(1): 63-70.

Chick, J. and J.C. Trexler, 2004. Spatial scale and abundance patterns of large fish communities in freshwater marshes of the Florida Everglades. Wetlands, 24(3): 652-664.

Childers, D.L., R.F. Doren, G.B. Noe, M. Rugge, and L.J. Scinto, 2003. Decadal change in vegetation and soil phosphorus patterns across the Everglades landscape. Journal of Environmental Quality, 32: 344-362.

Childers, D.L., J.N. Boyer, S.E. Davis, C.J. Madden, D.T. Rudnick, and F.H. Sklar, 2006. Relating precipitation and water management to nutrient concentration patterns in the oligotrophic "upside down" estuaries of the Florida Everglades. Limnology and Oceanography, 51(1): 602-616.

Childers, D.L., D. Iwaniec, D. Rondeau, G.A. Rubio, E. Verdon, and C.J. Madden, 2006. Responses of sawgrass and spikerush to variation in hydrologic drivers and salinity in southern Everglades marshes. Hydrobiologia, 569(1): 273-292.

Childers, D.L. 2006. A synthesis of long-term research by the Florida Coastal Everglades LTER program. Hydrobiologia, 569(1): 531-544.

Daoust, R.J. and D.L. Childers, 2004. Ecological effects of low-level phosphorus additions on two plant communities in a neotropical freshwater wetland ecosystem. Oecologia, 141(4): 672-686.

Davis, S.E., C. Coronado-Molina, D.L. Childers, and J.W. Day, 2003. Temporally dependent C, N, and P dynamics associated with the decay of Rhizophora mangle L. leaf litter in oligotrophic mangrove wetlands of the Southern Everglades. Aquatic Botany, 75(3): 199-215.

Davis, S.E., D.L. Childers, J.W. Day, D.T. Rudnick, and F.H. Sklar, 2003. Factors affecting the concentration and flux of materials in two southern Everglades mangrove wetlands. Marine Ecology Progress Series, 253: 85-96.

Davis, S.E., J.E. Cable, D.L. Childers, C. Coronado-Molina, J.W. Day, C.D. Hittle, C.J. Madden, D. Rudnick, E. Reyes, and F. Sklar, 2004. Importance of Episodic Storm Events in Controlling Ecosystem Structure and Function in a Gulf Coast Estuary. Journal of Coastal Research, 20(4): 1198-1208.

Davis, S.M., D.L. Childers, J. Lorenz, and T.E. Hopkins, 2005. A conceptual model of ecological interactions in the mangrove estuaries of the Florida Everglades. Wetlands, 25(4): 832-842.

Davis, S.E., D.L. Childers, and G.B. Noe, 2006. The contribution of leaching to the rapid release of nutrients and carbon in the early decay of wetland vegetation. Hydrobiologia, 569(1): 87-97.

Davis, S.E. and D.L. Childers, 2007. Importance of water source in controlling leaf leaching losses in a dwarf red mangrove (Rhizophora mangle L.) wetland. Estuarine, Coastal and Shelf Science, 71(1-2): 194-201.

DeAngelis, D.L., J.C. Trexler, and W.F. Loftus, 2005. Life history trade-offs and community dynamics of small fishes in a seasonally pulsed wetland. Canadian Journal of Fisheries and Aquatic Sciences, 62(4): 781-790.

Dorn, N.J., J.C. Trexler, and E.E. Gaiser, 2006. Exploring the role of large predators in marsh food webs: evidence for a behaviorally-mediated trophic cascade. Hydrobiologia, 569(1): 375-386.

Evans, S.L., W.T. Anderson, and F.J. Jochem, 2006. Spatial variability in Florida Bay particulate organic matter composition: combining flow cytometry with stable isotope analyses. Hydrobiologia, 569(1): 151-165.

Ewe, S.M.L. and L.d.S.L. Sternberg, 2005. Growth and gas exchange patterns of the invasive exotic Schinus terebinthifolius contrasted with native species under controlled saline conditions. Trees, 19(2): 119-128.

Ewe, S.M.L., E.E. Gaiser, D.L. Childers, D. Iwaniec, V.H. Rivera-Monroy, and R.R. Twilley, 2006. Spatial and temporal patterns of aboveground net primary productivity (ANPP) along two freshwater-estuarine transects in the Florida Coastal Everglades . Hydrobiologia, 569(1): 459-474.

Ewe, S.M.L. and L.d.S.L. Sternberg, 2007. Water Uptake Patterns of an Invasive Exotic Plant in Coastal Saline Habitats. Journal of Coastal Research, 23(1): 255-264.

Ewe, S.M.L., L.d.S.L. Sternberg, and D.L. Childers, (In Press). Seasonal plant water uptake patterns in the saline southeast Everglades ecotone. Oecologia

Farber, S., R. Costanza, D.L. Childers, J. Erickson, K. Gross, M. Grove, C. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren, and M. Wilson, 2006. Linking Ecology and Economics for Ecosystem Management. Bioscience, 56(2): 117-129.

Fourqurean, J.W., J.N. Boyer, M.J. Durako, L.N. Hefty, and B.J. Peterson, 2003. Forecasting the response of seagrass distribution to changing water quality: statistical models from monitoring data. Ecological Applications, 13(2): 474-489.

Fourqurean, J.W. and J. Schrlau, 2003. Changes in nutrient content and stable isotope ratios of C and N during decomposition of seagrasses and mangrove leaves along a nutrient availability gradient in Florida Bay, USA. Chemistry and Ecology, 19(5): 373-390.

Fourqurean, J.W., S.P. Escorcia, W.T. Anderson, and J.C. Zieman, 2005. Spatial and seasonal variability in elemental content, d13C and d15N of Thalassia testudinum from south Florida and its implication for ecosystem studies. Estuaries, 28(3): 447-461.

Frankovich, T.A. and J.C. Zieman, 2005. Periphyton light transmission relationships in Florida Bay and the Florida Keys. Aquatic Botany, 83(1): 14-30.

Frankovich, T.A., E.E. Gaiser, J.C. Zieman, and A. Wachnicka, 2006. Spatial and temporal distributions of epiphytic diatoms growing on Thalassia testudinum Banks ex Konig: Relationships to water quality. Hydrobiologia, 569(1): 259-271.

Gaiser, E.E., J.C. Trexler, J.H. Richards, D.L. Childers, D. Lee, A.L. Edwards, L.J. Scinto, K. Jayachandran, G.B. Noe, and R.D. Jones, 2005. Cascading ecological effects of low-level phosphorus enrichment in the Florida Everglades. Journal of Environmental Quality, 34(2): 717-723.

Gaiser, E.E., J.H. Richards, J.C. Trexler, R.D. Jones, and D.L. Childers, 2006. Periphyton responses to eutrophication in the Florida Everglades: Cross-system patterns of structural and compositional change. Limnology and Oceanography, 51(1): 617-630.

Gaiser, E.E., A. Zafiris, P.L. Ruiz, F. Tobias, and M.S. Ross, 2006. Tracking rates of ecotone migration due to salt-water encroachment using fossil mollusks in coastal South Florida. Hydrobiologia, 569(1): 237-257.

Gil, M., A.R. Armitage, and J.W. Fourqurean, 2006. Nutrient impacts on epifaunal density and species composition in a subtropical seagrass bed. Hydrobiologia, 569(1): 437-447.

Gottlieb, A.D., J.H. Richards, and E.E. Gaiser, 2006. Comparative study of periphyton community structure in long and short-hydroperiod Everglades marshes. Hydrobiologia, 569(1): 195-207.

Green, D., J.C. Trexler, J.J. Lorenz, C.C. McIvor, and T.E. Philippi, 2006. Spatial patterns of fish communities along two estuarine gradients in southern Florida . Hydrobiologia, 569(1): 387-399.

Hajje, N. and R. Jaffé, 2006. Molecular characterization of Cladium peat from the Florida Everglades: biomarker associations with humic fractions. Hydrobiologia, 569(1): 99-112.

Hall, R.O., S.E. Thomas, and E.E. Gaiser, 2007. Measuring primary production in freshwater ecosystems . In T.J. Fahey and A.K. Knapp, (eds.) Principles and Standards for Measuring Net Primary Production in Long-Term Ecological Studies. Oxford University Press.

Iwaniec, D., D.L. Childers, D. Rondeau, C.J. Madden, and C.J. Saunders, 2006. Effects of hydrologic and water quality drivers on periphyton dynamics in the southern Everglades. Hydrobiologia, 569(1): 223-235.

Jaffé, R., R. Mead, M.E. Hernandez, M.C. Peralba, and O.A. DiGuida, 2001. Origin and transport of sedimentary organic matter in two subtropical estuaries: A comparative, biomarker-based study. Organic Geochemistry, 32(4): 507-526.

Jaffé, R., J.N. Boyer, X. Lu, N. Maie, C. Yang, N.M. Scully, and S. Mock, 2004. Source characterization of dissolved organic matter in a subtropical mangrove-dominated estuary by fluorescence analysis. Marine Chemistry, 84(3-4): 195-210.

Jaffé, R., A.I. Rushdi, P.M. Medeiros, and B.R.T. Simoneit, 2006. Natural product biomarkers as indicators of sources and transport of sedimentary organic matter in a subtropical river. Chemosphere, 64(11): 1870-1884.

Jones, V., C.J. Ruddell, G. Wainwright, H.H. Rees, R. Jaffé, and G.A. Wolff, 2004. One-dimensional and two dimensional polyacrylamide gel electrophoresis: a tool for protein characterization in aquatic samples. Marine Chemistry, 85(1-2): 63-73.

Jones, V., M.J. Collins, K.E.H. Penkman, R. Jaffé, and G.A. Wolff, 2005. An assessment of the microbial contribution to aquatic dissolved organic nitrogen using amino acid enantiomeric ratios. Organic Geochemistry, 36(7): 1099-1107.

Jones, V., K. Parish, A. Thomson, G.A. Wolff, N. Maie, and R. Jaffé, 2006. Molecular characterization of proteinaceous material in the Florida coastal Everglades. Hydrobiologia, 569(1): 129-133.

Knapp, A.K., J.M. Briggs, and D.L. Childers, 2007. Estimating aboveground net primary production in grassland and herbaceous dominated systems . In T.J. Fahey and A.K.

Knapp, (eds.) Principles and Standards for Measuring Net Primary Production in Long-term Ecological Studies. Oxford University Press.

Krauss, K.W., T.W. Doyle, R.R. Twilley, T.J. Smith, K.R.T. Whelan, and J.K. Sullivan, 2005. Woody Debris in the Mangrove Forests of South Florida. Biotropica, 37(1): 9-15.

Krauss, K.W., R.R. Twilley, T.W. Doyle, and E.S. Gardiner, 2006. Leaf gas exchange characteristics of three neotropical mangrove species in response to varying hydroperiod. Tree Physiology, 26: 959-968.

Krauss, K.W., T.W. Doyle, R.R. Twilley, V.H. Rivera-Monroy, and J.K. Sullivan, 2006. Evaluating the relative contributions of hydroperiod and soil fertility on growth of south Florida mangroves. Hydrobiologia, 569(1): 311-324.

Leonard, L., A.L. Croft, D.L. Childers, S. Mitchell-Bruker, H. Solo-Gabriele, and M.S. Ross, 2006. Characteristics of surface-water flows in the ridge and slough landscape of Everglades National Park: implications for particulate transport. Hydrobiologia, 569(1): 5-22.

Liston, S.E. and J.C. Trexler, 2005. Spatiotemporal patterns in community structure of macroinvertebrates inhabiting calcareous periphyton mats. Journal of the North American Benthological Society, 24(4): 832-844.

Liston, S.E. 2006. Interactions between nutrient availability and hydroperiod shape macroinvertebrate communities in Florida Everglades marshes. Hydrobiologia, 569(1): 343-357.

Lockwood, J.L., M.S. Ross, and J.P. Sah, 2003. Smoke on the water: the interplay of fire and water flow on Everglades restoration. Frontiers in Ecology and the Environment, 1(9): 462-468.

Lorenz, J.J. and J.E. Serafy, 2006. Subtroprical wetland fish assemblages and changing salinity regimes: Implications for Everglades restoration. Hydrobiologia, 569(1): 401-422.

Lu, X.Q., N. Maie, J.V. Hanna, D.L. Childers, and R. Jaffé, 2003. Molecular characterization of dissolved organic matter in freshwater wetlands of the Florida Everglades. Water Research, 37(11): 2599-2606.

Maie, N., C. Yang, T. Miyoshi, K. Parish, and R. Jaffé, 2005. Chemical characteristics of dissolved organic matter in an oligotrophic subtropical wetland/estuarine ecosystem. Limnology and Oceanography, 50(1): 23-35.

Maie, N., R. Jaffé, M. Toshikazu, and D.L. Childers, 2006. Quantitative and qualitative aspects of dissolved organic carbon leached from senescent plants in an oligotrophic wetland. Biogeochemistry, 78(3): 285-314.

Maie, N., J.N. Boyer, C. Yang, and R. Jaffé, 2006. Spatial, geomorphological, and seasonal variability of CDOM in estuaries of the Florida Coastal Everglades. Hydrobiologia, 569(1): 135 - 150.

Maie, N., K. Parish, A. Watanabe, H. Knicker, R. Benner, T. Abe, K. Kaiser, and R. Jaffé, 2006. Characterization of dissolved organic nitrogen in an oligotrophic subtropical coastal ecosystem. Geochimica et Cosmochimica Acta, 70(17): 4491-4506.

Maie, N., N.M. Scully, O. Pisani, and R. Jaffé, 2007. Composition of a protein-like fluorophore of dissolved organic matter in coastal wetland and estuarine ecosystems. Water Research, 41: 563-570.

Mead, R.N., Y. Xu, J. Chong, and R. Jaffé, 2005. Sedimentary organic matter source assessment in a sub-tropical wetland and estuarine environment using the molecular distribution and carbon isotopic composition of n-alkanes. Organic Geochemistry, 36(3): 363-370.

Neto, R., R.N. Mead, W.J. Louda, and R. Jaffé, 2006. Organic biogeochemistry of detrital flocculent material (floc) in a subtropical, coastal wetland. Biogeochemistry, 77: 283-304.

Noe, G.B., D.L. Childers, A.L. Edwards, E. Gaiser, K. Jayachandran, D. Lee, J. Meeder, J. Richards, L.J. Scinto, J.C. Trexler, and R.D. Jones, 2002. Short-term changes in an oligotrophic Everglades wetland ecosystem receiving experimental phosphorus enrichment. Biogeochemistry, 59(3): 239-267.

Noe, G.B., L.J. Scinto, J. Taylor, D.L. Childers, and R.D. Jones, 2003. Phosphorus cycling and partitioning in oligotrophic and enriched Everglades wetland ecosystems: A radioisotope tracing study. Freshwater Biology, 48(11): 1993-2008.

Noe, G.B. and D.L. Childers, 2007. Phosphorus budgets in Everglades wetland ecosystems: The effects of hydrology and nutrient enrichment. Wetlands Ecology and Management, 15: 189-205.

Poret, N., R.R. Twilley, V.H. Rivera-Monroy, and C. Coronado-Molina, 2007. Belowground Decomposition of Mangrove Roots in Florida Coastal Everglades. Estuaries and Coasts. Estuaries and Coasts, 30(3): 491-496.

Price, R.M., P.K. Swart, and J.W. Fourqurean, 2006. Coastal groundwater discharge - an additional source of phosphorus for the oligotrophic wetlands of the Everglades. Hydrobiologia, 569(1): 23-36.

Rehage, J.S. and J.C. Trexler, 2006. Assessing the net effect of anthropogenic disturbance on aquatic communities in wetlands: Community structure relative to distance from canals. Hydrobiologia, 569(1): 359-373.

Rivera-Monroy, V.H., R.R. Twilley, D. Bone, D.L. Childers, C. Coronado-Molina, I.C. Feller, J.A. Herrerra-Silviera, R. Jaffé, J.E. Mancera, E. Rejmankova, and J.E. Salisbury, 2004. A conceptual framework to develop long-term ecological research and management objectives in the wider Caribbean Region. BioScience, 54(9): 843-856.

Rivera-Monroy, V.H., R.R. Twilley, J.E. Mancera, A. Alcantara-Eguren, E. Castaneda-Moya, Casas O. Monroy, P. Reyes, J. Restrepo, L. Perdomo, E. Campos, G. Cotes, and E. Villoria, 2007. Adventures and Misfortunes in Macondo: Rehabilitation of the Cienaga Grande. Ecotropicos, 19(2): 72-93.

Rogers, M.T., J.N. Boyer, and F.J. Jochem, (In Press). Bacterial abundance, growth rates, and grazing losses in Florida Bay. Aquatic Microbial Ecology

Romero, L.M., J.W. Fourqurean, and T.J. Smith, 2005. Changes in mass and nutrient content of wood during decomposition in a South Florida mangrove forest. Journal of Ecology, 93(3): 618-631.

Romigh, M.M., S.E. Davis, V.H. Rivera-Monroy, and R.R. Twilley, 2006. Flux of organic carbon in a riverine mangrove wetland in the Florida Coastal Everglades. Hydrobiologia, 569(1): 505-516.

Ross, M.S., D.R. Reed, J.P. Sah, P.L. Ruiz, and M. Lewin, 2003. Vegetation:environment relationships and water management in Shark Slough, Everglades National Park. Wetlands Ecology and Management, 11(5): 291-303.

Ross, M.S., S. Mitchell-Bruker, J.P. Sah, S. Stothoff, P.L. Ruiz, D.R. Reed, K. Jayachandran, and C.L. Coultas, 2006. Interaction of hydrology and nutrient limitation in the ridge and slough landscape of the southern Everglades. Hydrobiologia, 569(1): 37-59.

Rubio, G.A. and D.L. Childers, 2006. Controls of Herbaceous Litter Decomposition in the Estuarine Ecotones of the Florida Everglades. Estuaries and Coasts, 29(2): 257-268.

Saunders, C.J., M. Gao, J. Lynch, R. Jaffé, and D.L. Childers, 2006. Using soil profiles of seeds and molecular markers as proxies for sawgrass and wet prairie slough vegetation in Shark Slough, Everglades National Park. Hydrobiologia, 569(1): 475-492.

Saunders, C.J., J.P. Megonigal, and J.F. Reynolds, 2006. Comparison of belowground biomass in C3- and C4-dominated mixed communities in a Chesapeake Bay brackish marsh. Plant and Soil, 280: 305-322.

Scully, N.M., N. Maie, S. Dailey, J. Boyer, R.D. Jones, and R. Jaffé, 2004. Early diagenesis of plant-derived dissolved organic matter along a wetland, mangrove, estuary ecotone. Limnology and Oceanography, 49(5): 1667-1678.

Simard, M., K. Zhang, V.H. Rivera-Monroy, M.S. Ross, P.L. Ruiz, E. Castaneda-Moya, R.R. Twilley, and E. Rodriguez, 2006. Mapping Height and Biomass of Mangrove Forests in

Everglades National Park with SRTM Elevation Data. Photogrammetric Engineering and Remote Sensing, 72(3): 299-311.

Sobrado, M.A. and S.M.L. Ewe, 2006. Ecophysiological characteristics of Avicennia germinans and Laguncularia racemosa coexisting in a scrub mangrove forest at the Indian River Lagoon, Florida. Trees - Structure and Function, 20(6): 679-687.

Stevenson, C. and D.L. Childers, 2004. Hydroperiod and seasonal effects on fish decomposition in an oligotrophic Everglades marsh. Wetlands, 24(3): 529-537.

Thomas, S.E., E.E. Gaiser, M. Gantar, and L.J. Scinto, 2006. Quantifying the response of calcareous periphyton crusts to rehydration: a microcosm study (Florida Everglades). Aquatic Botany, 84: 317-323.

Thomas, S.E., E.E. Gaiser, and F. Tobias, 2006. Effects of shading on calcareous benthic periphyton in a short-hydroperiod oligotrophic wetland (Everglades, FL, USA). Hydrobiologia, 569(1): 209-221.

Tobias, F. and E.E. Gaiser, 2006. Taxonomy and distribution of taxa in the genus Gomphonema from the Florida Everglades, U.S.A.. Diatom Research, 21: 379-405.

Torres, L.G., M.R. Heithaus, and B. Delius, 2006. Influence of teleost abundance on the distribution and abundance of sharks in Florida Bay, USA. Hydrobiologia, 569(1): 449-455.

Trexler, J.C., W.F. Loftus, and S. Perry, 2005. Disturbance frequency and community structure in a twenty-five year intervention study. Oecologia, 145(1): 140-152.

Trexler, J.C., E.E. Gaiser, and D.L. Childers, 2006. Interaction of hydrology and nutrients in controlling ecosystem function in oligotrophic coastal environments of South Florida. Hydrobiologia, 569(1): 1-2.

Trexler, J.C., W.F. Loftus, and J. Chick, 2003. Setting and monitoring restoration goals in the absence of historical data: The case of fishes in the Florida Everglades . Pages 351-376 In D.E. Busch and J.C. Trexler, (eds.) Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, D.C..

Trexler, J.C. and D.E. Busch, 2003. Monitoring, assessment, and ecoregional initiatives: a synthesis . Pages 405-424 In D.E. Busch and J.C. Trexler, (eds.) Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, D.C..

Troxler Gann, T. 2002. Response of Everglades tree islands to increased freshwater flow (Florida). Ecological Restoration, 20(3): 211-212.

Troxler Gann, T., D.L. Childers, and D. Rondeau, 2005. Ecosystem structure, nutrient dynamics, and hydrologic relationships in tree islands of the southern Everglades, Florida, USA. Forest Ecology & Management, 214(1-3): 11-27.

Troxler Gann, T. and D.L. Childers, 2006. Relationships between hydrology and soils describe vegetation patterns in seasonally flooded tree islands of the southern Everglades, Florida. Plant and Soil, 279(1-2): 271-286.

Twilley, R.R. and V.H. Rivera-Monroy, 2005. Developing performance measures of mangrove wetlands using simulation models of hydrology, nutrient biogeochemistry, and community dynamics. Journal of Coastal Research, 40: 79-95.

Wachnicka, A. and E.E. Gaiser, (In Press). Morphological characterization of Amphora and Seminavis (Bacillariophyceae) from South Florida, U.S.A.. Diatom Research

Ward, G.A., T.J. Smith, K.R.T. Whelan, and T.W. Doyle, 2006. Regional processes in mangrove ecosystems: spatial scaling relationships, biomass, and turnover rates following catastrophic disturbance. Hydrobiologia, 569(1): 517-527.

Wetzel, P., A.G. van der Valk, S. Newman, D.E. Gawlik, T. Troxler-Gann, C. Coronado-Molina, D.L. Childers, and F.H. Sklar, 2005. Maintaining tree islands in the Florida Everglades: nutrient redistribution is the key. Frontiers in Ecology, 3(7): 370-376.

Williams, A.J. and J.C. Trexler, 2006. A preliminary analysis of the correlation of food-web characteristics with hydrology and nutrient gradients in the southern Everglades. Hydrobiologia, 569(1): 493-504.

Williams, C.J. and F.J. Jochem, 2006. Ectoenzyme kinetics in Florida Bay: Implications for bacterial carbon source and nutrient status. Hydrobiologia, 569(1): 113-127.

Xu, Y., R.N. Mead, and R. Jaffé, 2006. A molecular marker based assessment of sedimentary organic matter sources and distributions in Florida Bay. Hydrobiologia, 569(1): 179-192.

Xu, Y., R. Jaffé, A. Wachnicka, and E.E. Gaiser, 2006. Occurrence of C25 highly branched isoprenoids in Florida Bay: Paleoenvironmental indicators of diatom-derived organic matter inputs. Organic Geochemistry, 37(7): 847-859.

Xu, Y., C.W. Holmes, and R. Jaffé, 2007. Paleoenvironmental assessment of recent environmental changes in Florida Bay, USA: A biomarker based study. Estuarine, Coastal and Shelf Science, 73(1-2): 201-210.

Xu, Y. and R. Jaffé, 2007. Lipid biomarkers in suspended particulates from a subtropical estuary: Assessment of seasonal changes in sources and transport of organic matter. Marine Environmental Research

Zieman, J.C., J.W. Fourqurean, and T.A. Frankovich, 2004. Reply to B. E. Lapointe and P. J. Bariles comment on our paper Seagrass die-off in Florida Bay: long term trends in abundance and growth of turtlegrass, Thalassia testudinum.. Estuaries, 27(1): 165-172.

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 nearly 500 such presentations from 2000-2006.

We continue to dedicate significant 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 completed of a novel GIS-based data and project search engine that interfaces our LTER website with our Oracle database. This facility allows anyone to conduct a multi-layered search of our LTER database using spatial identifiers--that is, to show on a map of Everglades National Park the regions for which they want to search data. This interactive map is accessible via http://fcelter.fiu.edu/gis/everglades-map/.

We have 273 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.

Human Resource Product

Nagamitsu Maie received a Japanese Science award for his cumulative research on DOM. The award: 2004 Incentive Award from the Japanese Society of Soil Science & Plant Nutrition, for his work on dynamics of dissolved organic matter in natural environments.

Software (or netware)

Mike Rugge (FCE Program Manager) and Linda Powell (FCE Information Manager) developed, coded, and tested a new program that allows information to be entered into an Excel spreadsheet and converted to EML. This Perl application was very gladly received by the IM committee. Mike and Linda have distributed this application to any LTER site that requested it, and it is currently being used at several LTER sites. The application is open source and available for download from the Florida Coastal Everglades LTER website (http://fcelter.fiu.edu/research/information_management/tools/).

C. INTERNET DISSEMINATION

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

IV. CONTRIBUTIONS

A. CONTRIBUTIONS WITHIN DISCIPLINE

Abiotic Factors

Our carbon flux tower research team developed new research methodologies to investigate mangrove forest-atmosphere interactions. Such methodologies enabled us to study the production of biogenic hydrocarbons by mangroves and to investigate the mangrove carbon sequestration capacity in response to environmental regulator gradients such as sea-level rise and salinity.

Primary Production

We developed a method to recover seeds of *Cladium*, *Rhyncospora*, and other species in soils from ENP (FCE LTER sites) for use as paleoindicators of vegetation change over the last 100 years (roughly the time of hydrologic modifications in the Everglades). Despite its potential importance in restoration and management, there are very few data of this sort (published or unpublished) for most of the Everglades.

We have been assembling and proofing a geospatial database of fire history within Everglades National Park relative to the response of an endangered species, the Cape Sable Seaside Sparrow, to fire and water management actions.

We made the first isotopic measurement of cypress tree rings from the Everglades system, and discovered a new potential tool for reconstructing hydroperiods.

The periphyton group hosted the 17th North American Diatom Symposium in Islamorada, FL in October 2003. Over 120 diatom taxonomists and ecologists from the US and other countries (Belgium, Netherlands, Australia, New Zealand, Canada, Colombia, Puerto Rico) attended the meeting. The meeting consisted of invited speakers and general symposia. FCE students presented papers on (1) diatom taxonomic and ecological database for South Florida, (2) links between South Florida diatom flora and Caribbean islands, and (3) inferences of sea-level rise and salt-water encroachment in coastal Florida from sedimented diatoms.

The periphyton group also created a searchable on-line database that includes photos, ecological and taxonomic information for over 600 diatoms and 150 other algae that is now being used regularly by other investigators in South Florida and elsewhere. It provides the basis for instigating biogeographic explorations of algae in the Caribbean basin.

We've learned new information about the belowground biomass of mangroves and gained a better understanding of the relative partition of aboveground and belowground biomass and productivity in coastal forested wetlands. The aboveground: belowground ratio is not fixed in mangrove forests; but follows the resource-use hypothesis of increased foraging under low nutrient conditions.

We've gained new insights into the flow of water in mangrove trees – transpirational flux in coastal forests is sensitive to tidal hydroperiod, and varies among mangrove species. These new values have been used to correct previous estimates of a hydrology budget for mangrove forests. This is an important consideration in hydrologic restoration of mangroves.

Sharon Ewe, Dan Childers, and Leonel Sternberg measured the seasonal water use patterns of dominant macrophytes co-existing in the coastal southern Everglades ecotone (in Taylor River) to determine if plant water use differed spatially across the soil profile between the wet and dry seasons. Using stable isotopes of water ($\delta^{8}O$ and δD) from the soil and plant xylem, we demonstrated that there was a seasonal shift in red mangrove (*Rhizophora mangle*) water uptake patterns that was not observed for sawgrass (*Cladium jamaicense*). In the dry season, when the surface water was hypersaline, the mangrove was able to tap into deeper, less saline groundwater. The sawgrass however used only shallow surface water, regardless of salinity (annual range: 0-40 PSU). Although little is known of the salinity tolerance of sawgrass, it is unlikely that long-term exposure to high salinity is conducive to the persistence of this freshwater marsh sedge. This study (in press, Oecologia) increases our ecological understanding of how water uptake patterns of individual plants can contribute to ecosystem levels changes, not only in the southeast saline Everglades, but also in estuaries in general in response to global sea level rise and human-induced changes in freshwater flows.

Trophic Dynamics and Community Structure

Contributions by our Trophic Dynamics group include improved analysis of invasions by non-native fishes in the Everglades and oligohaline zone of South Florida, analyses of the relationship of hydrological fluctuation and fish community succession; and relationship of fish dispersal and metacommunity dynamics.

Evelyn Gaiser and Joel Trexler received an international research supplement in 2006 for travel to the Yucatan peninsula to conduct food web research that parallels their approach in the FCE. FCE students Josette LaHee and Cliff Ruehl also participated in the research. They used similar techniques to measure periphyton and consumer abundance and composition in freshwater calcareous wetlands along in Quintana Roo (specifically the Sian Ka'an Biosphere Reserve and El Eden Research Station). They found similar patterns to those in the Everglades, with consistently high biomass of calcareous periphyton mats and paradoxically low biomass of aquatic invertebrates and fish. They are continuing to analyze compositional data and are planning another collecting trip to similar wetlands in Belize for Spring 2007.

Nutrients and DOM

The DOM organic geochemistry group has made significant contributions to the understanding of the dynamics of OM in wetlands and estuarine systems by combining molecular and isotope proxies to trace biomass-specific OM in such systems. This was the first data of its kind for the greater Everglades ecosystem. We also made a significant contribution to biogeochemistry by detailing the molecular characterization of DON via a combination of advanced analytical techniques thanks to the collaboration of a suite of scientists who joined our efforts on this project (Maie et al., 2006a). Through this collaboration, we also published the first data on protein fingerprinting in natural water samples (see Jones et al., 2004; Jones et al., 2006) and enhanced our knowledge on DON characteristics in the system (e.g. Lu et al., 2003; Jones et al., 2005; Maie et al., 2007a).

Molecular level DOM characterizations proved to be useful in assessing sources and transformations of DOM (Maie et al., 2005, 2006c; Scully et al., 2004) and proved that DOM in complex ecosystems such as the FCE presents bioavailability profiles that are hard-to-predict and somewhat unconventional, due to multiple source inputs and associated variability in their transformation pathways (see also: Boyer et al., 2007). To better assess the DOM dynamics in the FCE we have worked arduously to determine the most adequate analytical tools that provide pertinent biogeochemical information, but also allow for large sample number throughput needed to cover spatially and temporally the large study area. As such, a significant number of publications were produced based on more labor intensive techniques focused on ultrafiltered DOM (UDOM) to provide background molecular characteristics for FCE DOM. This was followed up by intense, spatial and temporal studies using high throughput techniques such as optical properties measurements (UV-Vis and fluorescence) and more recently 3D Fluorescence (Excitation Emission Matrices or EEM) in combination with parallel factor analysis (PARAFAC). The applications of theses techniques and particularly the EEM-PARAFAC has allowed us to better understand DOM dynamics, particularly in Florida Bay and estuarine areas on the FCE (Jaffé et al., 2004; Maie et al., 2006b).

Rudolf Jaffé in collaboration with Diane McKnight, organized and hosted a LTER DOM Workshop at Florida International University in the Fall 2005. Analyses of DOM in over 130 water samples from over 15 LTER sites nationwide showed a clear lack of correlation between OM quantity and quality, but clear trends in quality and quantity along environmental gradients were observed. The importance in determining the composition (i.e. quality) of DOM in addition to quantitative measurements in long tern ecological research was clearly established based on this data set and a manuscript is being elaborated for publication on this topic (Jaffé et al., 2007).

Our water quality-climate analysis made a linkage between ENSO events and the Everglades via ENSO effects on precipitation seasonality and hydrology. This linkage had been documented for dry season climate and the south Florida fire regime, but never for the entire year or for a 40 year time period.

Greg Noe characterized the composition and concentration of suspended particles in the water column of Everglades wetlands. This information is being used to develop models of particulate dissolved nutrient transport in the Everglades and other wetlands.

Soils and Sediments

A molecular marker (or biomarker) approach was used to characterize sources, fate ans transport of soil/sediment OM in the FCE. This approach, that had previously not been applied in this system, was very successful both for present day OM dynamics assessments (Hernandez et al., 2001; Jaffé et al., 2001; Mead et al., 2004; Neto et al., 2005; Jaffé et al., 2006; Hajje and Jaffé, 2006; Xu et al., 2006a; Xu and Jaffé, 2007; Gao et al., 2007; Simoneit et al, 2007) as well as for paleoenvironmental assessments both in wetland (Saunders et al., 2006) and estuarine environments (Xu et al., 2006b; Xu et al., 2007). The observed correlations between C_{25} highly branched isoprenoids and diatom fossils in sediment cores from Fl. Bay showed the first data of its kind as to the application of such biomarkers to reconstruct recent environmental histories of diatom inputs in coastal ecosystems (Xu et al., 2006b). Soil characteristics regarding OM preservation was assessed for the first time in the FCE and correlated with hydroperiod, soil type and nutrient availability (Gao, 2007).

Ecological and Social Modeling

Colin Saunders developed a dynamics model, using STELLA modeling software, of ecosystem P dynamics. This model is being used as a catalyst for analyzing and integrating data sets on P stocks and fluxes (e.g., from periphyton, flocculant matter, plants, and soil) from the FCE LTER sites and other potential sources. We also developed a method to recover seeds of *Cladium*, *Rhyncospora*, and other species in soils from ENP (FCE LTER sites) for use as paleoindicators of vegetation. Despite its potential importance in restoration and management, there are very few data of this sort (published or unpublished) for most of the Everglades.

Carl Fitz updated the Everglades Landscape Model (ELM): extended period of simulation (1965-2000); extended useful simulation domain to include topography and tidal exchanges in southwest mangrove region of greater Everglades; enhanced documentation for ease of use and for independent peer review of ELM application to greater Everglades restoration planning.

Jose Fuentes developed new biophysical numerical modeling systems to investigate the unique features of energy and mass exchanges between coastal ecosystems and overlying atmosphere.

Other Contributions within Discipline

In March 2003, NSF held its first 3-year external review of the FCE LTER Program. Our approach to this exercise was somewhat non-traditional in several aspects, and [we feel that] the positive response by both the review team and the LTER community in general makes these new approaches a contribution. First, we dedicated most of the first day to an intensive field trip that allowed the review team to see virtually all of our sampling sites (by both boat and air). We were eager to communicate the spatial magnitude of our research, and we wanted to introduce the review team to our work by seeing it first-hand. At each site stop, either a graduate student or a postdoc presented a poster of their research relevant to that site. We ended the day with a poster session, social, and banquet at Fairchild Tropical Garden. As with the field trip, this evening event featured student and postdoc research. This approach was unconventional because: a) we began our site review with the field trip, and; b) we dedicated nearly a day of our review to the trip. The “field trip first” approach was subsequently used by several other LTER sites hosting their 3-year reviews in 2003. Our second, non-traditional approach involved presenting an over-arching synthesis of our findings to date, relative to our original hypothesis, in four concise oral presentations held in a town-hall meeting environment. Discussions about the presentations included many of the FCE scientists and students present, but the agenda was short as it included only 4 formal powerpoint presentations. Again, this approach (rather than an entire day of back-to-back 15 minute talks) was used by several LTER sites for their 2003 site reviews.

Evelyn Gaiser participated as the FCE site representative in network-level meetings relevant to the planning grant.

Tiffany Troxler-Gann organized a workshop entitled “Biogeochemical complexity across LTER sites: the what, where and how” at the 2006 LTER All Scientists Meeting in Estes Park, CO.

Tiffany Troxler-Gann served on the planning committee for the 2006 LTER All Scientists Meeting in Estes Park, CO.

B. CONTRIBUTIONS TO OTHER DISCIPLINES

In 2003, Joel Trexler served as a Technical Lead in preparation of a report for the U.S. Congress on the Interim Operations Program (IOP) in management of water deliveries to Everglades National Park. The IOP was intended to improve water deliveries to the Park for sustaining nesting populations of the Federally listed Cape Sable Seaside Sparrow.

The theme of the 2003 Botanical Society of America meetings was wetlands; as Secretary of the Society, Jenny Richards interacted with symposia and keynote speakers, many of whom were involved in wetland research or policy, representing both FIU and the FCE LTER in this context, as well as presenting some portion of LTER research in the symposium she was in.

Joe Boyer attended the Association of Marine Laboratories of the Caribbean from July 14-18, 2003 in Port of Spain, Trinidad. He was also a member of the Florida Keys Feasibility Study Modeling Sub-team. He’s published numerous technical reports on the water quality of Florida Bay and the Florida Keys.

Joe Boyer served on two technical advisory committees:

1. The Florida Keys National Marine Sanctuary Technical Advisory Committee is composed of 24 scientists and resource managers involved in the South Florida ecosystem and provides advice and assistance to NOAA and EPA on the prioritization and design of the research and monitoring programs. It also assists with research RFP's, serves to integrate the research and monitoring efforts, and serves to integrate interagency efforts.

2. The Southeast Florida Coral Reef Initiative, Land-Based Sources of Pollution (LBSP) Focus Team was formed to addresses impacts to corals resulting from both point and non-point land based sources of pollution. Many of these point and non-point sources of pollution result in unintentional but very real stresses on coral reef ecosystem health. The aim of the projects in the local action strategy for this focus area is characterize the extent and condition of the coral reef tract and to quantify, characterize, and prioritize the land-based sources of pollution that need to be addressed based on identified impacts to the reefs. Due to the research nature of many of the LBSP projects, the LBSP Team has a Technical Advisory Committee formed by leading research scientist in the fields of coral reef ecology, water quality, geology, chemistry, and biology.

Joe Boyer participated as a panel member of the Florida Oceans Science Workshop which was tasked to create a framework for research institutions and resource managers to set research priorities to ensure that Florida's coastal ocean remains a significant environmental and economic asset in the future. He also participated in the Florida Water Quality Monitoring Council Retreat, the goal of which was to foster collaboration, communication, and cooperation among the water quality monitoring community, thereby facilitating improved efficiency and management of Florida's water resources.

Joe Boyer was an active member of the CERP-RECOVER Southern Estuaries Module which serves to advise and recommend adaptive management strategies for CERP. He also participated in the South Florida Ecosystem Restoration Task Force, Science Evaluation Group, Biotic Indicators group, which is tasked to develop and recommend specific indicators of ecosystem health for use is assessing overall restoration activities in South Florida.

Joe Boyer is the FIU representative to the Florida Coastal Ocean Observing System Consortium, the Southeast Coastal Ocean Observing Regional Association, and the Gulf of Mexico Coastal Ocean Observing System. The overall mission of these organizations is to establish a sustained observing systems to provide observations and products needed by users in this region for the purposes of 1) detecting and predicting climate variability and consequences, 2) preserving and restoring healthy marine ecosystems, 3) ensuring human health, 4) managing resources, 5) facilitating safe and efficient marine transportation, 6) enhancing national security, and 7) predicting and mitigating against coastal hazards.

Julie Lockwood, Mike Ross and Jay Sah have been collaborating on the effect of fire and water management on marl prairies within the Everglades. Their efforts concern the interaction of physical drivers (water and fire) on plant community dynamics, and how these interactions influence the fate of an endangered species (Cape Sable Seaside Sparrow).

Randy Chambers participated in a Florida Bay biogeochemistry modeling workshop at the Estuarine Research Federation meeting held in Seattle, WA in 2003.

Dan Childers was involved in a NCEAS working group on Ecosystem Services that used FCE as a case study. He also served as the faculty advisor for an FCE graduate student group who participated in a NCEAS-based Distributed Graduate Seminar on Ecosystem-based Management (funded by the Packard Foundation). This seminar included a full week's visit to NCEAS by all 7 participating graduate students in early February 2005.

Dan Childers co-hosted a human dimensions workshop at the University of Vermont in April that focused on ecosystem services and the Everglades. He was active with the coupled human-natural systems working group in LTER Network Planning activities, as well as in NEON Design Consortium activities.

Rudolf Jaffé served as session chair at ASLO 2007 aquatic sciences meeting in Santa Fe organizing the "Dissolved Organic Matter Quality: Linking Environmental Dynamics to Molecular Structure" session.

Evelyn Gaiser presented FCE-related data to the South Florida Water Management District and Everglades National Park. The paleoecological data is allowing calculations of the rate of salt-water encroachment that will be used to determine the quantity of freshwater to be relocation in the Biscayne coastal wetlands. This work was presented at a public forum at Biscayne National Park in spring 2003. Her work on periphyton in the marl prairie shows how hydroperiod, soils and plants interact with periphyton to determine habitat suitability for the endangered Cape Sable Seaside Sparrow (CSSP). These results were presented at the annual CSSP and fire management meetings held at Everglades National Park in fall 2003. Some results from this work appear in the report from Everglades National Park to congress about the Interim Operations Procedures for water management in ENP. Her group's work on periphyton dynamics C-111 basin will be presented at a meeting at the South Florida Water Management District in February 2004 in order to help guide restoration activities in that basin. She has contributed data, analysis and models for the construction of hydoperiod and nutrient "Periphyton Performance Measures" required by the SFWMD to determine metrics for success in restoration activities.

In 2004, Greg Noe communicated data on particulate phosphorus characterization and transport to SFWMD to improve the monitoring and effectiveness of STAs.

Carl Fitz updated the Everglades Landscape Model (ELM): extended period of simulation (1965-2000); extended useful simulation domain to include topography and tidal exchanges in southwest mangrove region of greater Everglades; enhanced documentation for ease of use and for independent peer review of ELM application to greater Everglades restoration planning.

In 2004, Sharon Ewe accompanied and assisted SFWMD Florida Bay researchers (3-days) to measure sediment accretion within Taylor River mangroves. She also conducted field expedition to look for entomological biocontrol agents of three invasive exotic plants in Florida (*Schinus terebinthifolius*, *Ardisia elliptica*, *A. crinata*).

Victor H. Rivera-Monroy participated in several meetings of the LTER MEXICAN Network program since its creation in 2001, and is currently one the Executive Committee members coordinating this program at the national level; he is also the co-coordinator of one of the LTER sites located in the Yucatan Peninsula (ECOPEY-Celestum). This Mexican site has similar geomorphological and hydrological characteristic as the FCE LTER site. A current activity involves the organization of ecological comparisons of mangrove wetlands in coastal FLorida, Mexican coastal regions of the Gulf of Mexico and the Mexican Caribbean. This effort is part of the FCE LTER Caribbean initiative framework developed by the FCE-LTER program in 2003-2004. This initiative was published as a paper in 2004 (A conceptual framework to develop long-term ecological research and management objectives in the wider Caribbean Region. Rivera-Monroy et al. BioScience, 54(9): 843-856). Also, during 2003-2004, Victor H. Rivera-Monroy developed close collaborations with researchers at additional Mexican LTER sites (La Mancha, Veracruz, Ecosistemas Costeros, Jalisco, Arrecifes del Pacifico, Pacific Ocean) for future student and research exchanges and intersite comparisons with the FCE-LTER program.

Joel Trexler was the Technical lead of the Aquatic Ecology Group, IOP Congressional Report, Everglades National Report (2003-2004). For this group, he edited a section of a report going to the US Senate Appropriations Committee about progress in the restoration. He also served on the Technical Review Committee, Miami-Dade County Watershed Study (2003-2005). He is serving on a panel that is reviewing progress in a study that seeks to anticipate impacts of future growth of human populations in southern Dade County and assess its impact on the environment, primarily Biscayne National Park. This project interfaces with CERP in many ways and it is currently in the newspaper a good bit because it might be seen as an impediment to expanding the Urban Development Boundary (for example, by discouraging letting Florida City annex lands between US-1 and Card Sound Road).

Laura Ogden attended the LTER Network Social Science meeting in Athens, Georgia, August 2005, a meeting where LTER site representatives developed recommendations for integrating social science research and approaches into the LTER Planning Grant process. Ogden served as a member of the LTER Planning Grant's Research Initiatives Subcommittee and participated in the ISSE writing team meeting in Madison, Wisconsin during June 2006.

The FCE LTER Program has contributed to involvement of Robert Twilley (LSU) as a PI of the Coastal Louisiana Ecosystem Assessment & Restoration project, which is completing the science program for the Louisiana Coastal Area Comprehensive Restoration Plan. Notably, Fred Sklar (SFWMD) was on the independent advisory board of experts for the LCACRP. Robert Twilley's involvement has expanded to include numerous post-Katrina environmental issues affecting south Louisiana.

The Comprehensive Everglades Restoration Plan (CERP) is moving forward. Many FCE scientists have been involved in the planning and development of this massive restoration effort, and are now involved in the Monitoring and Assessment Program (MAP) that will help CERP managers determine restoration success. The number of participants, activities, committees, and workshops that have been part of this effort are too numerous to detail in this report.

C. Contributions to Education and Human Resources

The FCE Schoolyard LTER program and the FCE EdEn Venture effort, joint with Environmental Education at Everglades National Park and several local schools, highlight our K-12 human resource development. We detail these programs elsewhere in this report.

In addition to our regular Schoolyard program, FCE scientists are also actively involved in the FIU-based, NSF-funded Undergraduate Mentoring in Environmental Biology (UMEB) Program (J.Francisco-Ortega and L.Collins, Co-PIs) and a NOAA Educational grant that provides research internships for undergraduate students (ESRIP). Because FIU is a majority-minority institution, many of the undergraduates we impact are Hispanic or other minorities.

Graduate education is a very important component of the FCE LTER program, and our graduate students maintain their own very active FCE Affiliated Student Group. We currently have nearly 40 graduate students, from more than 8 different universities, who are affiliated with FCE. Between 2000 and 2006, 33 graduate degrees (22 MS theses and 11 Ph.D. dissertations) were conferred from FCE-based thesis/dissertation research. Many of these graduate students are from under-represented minority groups. Our student group (which also includes interested undergraduate and high school students) meets monthly to discuss their LTER research or a current scientific topic of their choice. They receive funding support from the FIU Student Government Association, and they are very active in student governance at the Network level. Tiffany Gann, a former FCE student, served as the co-chair of the LTER Network student group from 2001-2005.

D. Contributions to Resources for Science and Technology

Research sites

Our research plan focuses on 17 permanent sampling sites located on 2 large transects that cover most of Everglades National Park. At each site, we have constructed platform, boat dock, and boardwalk facilities that are available to any permitted researcher who wishes to use them (after requesting permission). To date, many academic and agency scientists are taking advantage of these field facilities, and the FCE LTER Program continues to support expanded use of our facilities through Letters of Support for proposals (8-10 such formal letters are written each year).

Ecotank

Several FCE students established Ecotank (http://ecotank.fiu.edu/), an ecological think tank at Florida International University, in 2005 based on their positive experiences at NCEAS. Ecotank's mission is 'to advance the state of ecological knowledge through a collaborative, interdisciplinary intellect and to improve graduate student culture through community creativity and cooperation.' The Ecotank room provides a space for graduate student reading groups, discussions, presentations, and meetings.

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 1352 datasets from May 2000 - February 2007.

E. Contributions Beyond Science and Engineering

Our group has become very active in human dimensions aspects of south Florida ecology, and the field in general. Dan Childers was involved in a NCEAS working group on Ecosystem Services that used our FCE site as a case study. He also served as the faculty advisor for an FCE graduate student group who participated in a NCEAS-based Distributed Graduate Seminar on Ecosystem-based Management (funded by the Packard Foundation). This seminar included a full week's visit to NCEAS by all 7 participating graduate students in early February 2005. Dan Childers also co-hosted a human dimensions workshop at the University of Vermont in April that focused on ecosystem services and the Everglades. He was active with the coupled human-natural systems working group in LTER Network Planning activities, as well as in NEON Design Consortium activities.

We have an active Human Dimensions group, headed up by Laura Ogden (Anthropology, FIU) that includes 8 social scientists from several universities. The FCE Human Dimensions group submitted a 2007 Social Science Supplemental Request for cross-site activities that would allow us to 'jump-start' our FCE research by taking advantage of the depth and breadth of social science expertise across the LTER Network.

Laura Ogden attended the LTER Network Social Science meeting in Athens, Georgia, August 2005, a meeting where LTER site representatives developed recommendations for integrating social science research and approaches into the LTER Planning Grant process. Ogden served as a member of the LTER Planning Grant's Research Initiatives Subcommittee and participated in the ISSE writing team meeting in Madison, Wisconsin during June 2006.

V. REFERENCES

Boyer J.N., Dailey S.K., Maie N. and Jaffé R. (2007). Physical and microbial processing of dissolved organic nitrogen (DON) in the Florida Coastal Everglades, USA. *Hydrobiologia*. Submitted.

Borum, J., O. Pedersen, T. Greve, T.A. Frankovich, J.C. Zieman, J.W. Fourqurean, and C.J. Madden, 2005. The potential role of plant oxygen and sulphide dynamics in die-off events of the tropical seagrass, Thalassia testudinum. Journal of Ecology, 93(1): 148-158.

Byron, Dorothy A. 2006. Determining the physiological response of a subtropical seagrass, Thalassia Testudinum, to salinity stress using pulse amplitude modulated (PAM) fluorometry. Master's thesis, Florida International University.

Childers, D.L., D. Iwaniec, D. Rondeau, G.A. Rubio, E. Verdon, and C.J. Madden, 2006a. Responses of sawgrass and spikerush to variation in hydrologic drivers and salinity in southern Everglades marshes. Hydrobiologia, 569(1): 273-292.

Childers, D.L., J.N. Boyer, S.E. Davis, C.J. Madden, D.T. Rudnick, and F.H. Sklar, 2006b. Relating precipitation and water management to nutrient concentration patterns in the oligotrophic "upside down" estuaries of the Florida Everglades. Limnology and Oceanography, 51(1): 602-616.

Cornett, Virginia C. 2006. Spatial distribution of submerged aquatic vegetation in the Shark River Estuary and implications for understanding movement and feeding patterns of manatees (Tichechus manatus latirostris). Master's thesis, Florida International University.

Dewsbury, Bryan M. 2006. Artificially induced aggregation of fish and their effects on nutrient regimes and primary producers in an oligotrophic subtropical estuary. Master's thesis, Florida International University.

Ewe, S.M.L., E.E. Gaiser, D.L. Childers, D. Iwaniec, V.H. Rivera-Monroy, and R.R. Twilley, 2006. Spatial and temporal patterns of aboveground net primary productivity (ANPP) along two freshwater-estuarine transects in the Florida Coastal Everglades . Hydrobiologia, 569(1): 459-474.

Frankovich, T.A., E.E. Gaiser, J.C. Zieman, and A. Wachnicka, 2006. Spatial and temporal distributions of epiphytic diatoms growing on Thalassia testudinum Banks ex Konig: Relationships to water quality. Hydrobiologia, 569(1): 259-271.

Gao, 2007. Chemical characterization of soil organic matter in an oligotrophic, subtropical, freshwater wetland system: sources, diagenesis and preservation. Ph.D. dissertation, Florida International University.

Gao M., Simoneit B.R.T. and Jaffé R. (2007). Occurrence and distribution of botryococcanes in the Florida Everglades. *Chemosphere*. In press.

Green, D., J. C. Trexler, J. Lorenz, C. McIvor, and T. Philippi. 2006. Spatial patterns of fish communities along two estuarine gradients in southern Florida. Hydrobiologia 569:387-399.

Hajje N. and Jaffé R. (2006). Lipids associated with peat humic fractions from Everglades National Park (USA). *Hydrobiologia*. 569: 99-112.

Hernandez M.E., Mead R., Peralba M.C. and Jaffé R. (2001) Origin and transport of n-alkane-2-ones in a sub-tropical estuary: Potential biomarkers for seagrass-derived organic matter. *Organic Geochemistry*, 32, 21-32.

Iwaniec, D., D.L. Childers, D. Rondeau, C.J. Madden, and C.J. Saunders, 2006. Effects of hydrologic and water quality drivers on periphyton dynamics in the southern Everglades. Hydrobiologia, 569(1): 223-235.

Jaffé R., Boyer J.N., Lu X., Maie N., Yang C., Scully N. and Mock S. (2004) Sources characterization of dissolved organic matter in a mangrove-dominated estuary by fluorescence analysis. *Marine Chemistry* 84, 195-210.

Jaffé R., Hernandez M.E., Mead R., Peralba M.C. and DiGuida O.A. (2001) Origin and transport of sedimentary organic matter in two sub-tropical estuaries: A comparative, biomarker-based study. *Organic Geochemistry*, 32, 507-526.

Jaffé R., McKnight D., Maie N., Cory R., McDowell W.H., Campbell J.L (2007). Importance of DOM in ecosystems: Quality matters. *JGR Biogeosciences*. To be submitted.

Jaffé R., Rushdi A.I., Medeiros P.M. and Simoneit B.R.T. (2006). Natural product biomarkers as indicators of sources and transport of sedimentary lipids in a subtropical river. *Chemosphere* 64: 1870-1884.

Jones V., Collins M.J., Penkman K.E.H., Jaffé R. and Wolff G.A. (2005). An assessment of the microbial contribution to aquatic dissolved organic nitrogen using amino acid enantiomeric ratios. *Organic Geochemistry* 36: 1099-1107.

Jones V., Parish K., Thompson A., Wolff G.A., Maie N and Jaffé R. (2006). Molecular characterization of proteinaceous material in the Florida coastal Everglades. *Hydrobiologia* 569: 129-133.

Jones V., Ruddell C.J., Wainwright G., Rees H.H., Jaffé R., Wolff G.A. (2004) Application of one-dimensional and two-dimensional gel electrophoresis on aquatic samples: A tool for the characterization of dissolved organic nitrogen. *Marine Chemistry* 85, 63-73.

Juszli, Gregory M. 2006. Patterns in belowground primary productivity and belowground biomass in marshes of the Everglades' oligohaline ecotone. Master's thesis, Florida International University.

Lu X.Q., Maie N., Hanna J.V., Childers D. and R. Jaffé (2003) Molecular characterization of dissolved organic matter in freshwater wetlands of the Florida Everglades. *Water Research,* 37, 2599-2606.

Maie, N., C.-Y. Yang, T. Miyoshi, K. Parish, and R. Jaffé (2005). Chemical characteristics of dissolved organic matter in an oligotrophic subtropical wetland/estuarine ecosystem. *Limnology & Oceanography* 50(1), 23-35.

Maie N., Parish K., Watanabe A., Knicker H., Benner R., Abe T., Kaiser K. and Jaffé R. (2006a). Chemical characteristics of dissolved organic nitrogen in an oligotrophic subtropical coastal ecosystem. *Geochimica et Cosmochimica Acta* 70: 4491-4506.

Maie N., Boyer J.N. Yang C. and Jaffé R. (2006b). Spatial, geomorphological and seasonal variability of CDOM in estuaries of the Florida Coastal Everglades. *Hydrobiologia* 569: 135-150.

Maie N., Jaffé R., Miyoshi T. and Childers D. (2006c). Quantitative and qualitative aspects of dissolved organic carbon leached from plants in an oligotrophic wetland. *Biogeochemistry* 78: 285-314.

Maie N., Scully N.M., Pisani O. and Jaffé R. (2007a). Composition of a protein-like fluorophore of dissolved organic matter in coastal wetland and estuarine ecosystems. *Water Research* 41: 563-570.

Maie N., Pisani O. and Jaffe R. (2007b). Mangrove tannins in aquatic ecosystems: their fate and possible role in dissolved organic nitrogen cycling. *Limnology & Oceanography* in press.

Maie N., Scully N.M., Pisani O. and Jaffé R. (2007). Composition of a protein-like fluorophore of dissolved organic matter in coastal wetland and estuarine ecosystems. *Water Research* 41: 563-570.

Mead, 2003. Organic matter dynamics in the Florida coastal Everglades: A molecular marker and isotopic approach. Florida International University.

Mead R.N., Xu Y., Chong J. and Jaffé R. (2004). Sedimentary organic matter source assessment in a sub-tropical wetland and estuarine environment using the molecular distribution and carbon isotopic composition of n-alkanes. *Organic Geochemistry* 36: 363-370.

Neto R., Mead R.N., Louda W. and Jaffé R. (2005). Organic biogeochemistry of detrital flocculent material (floc) in a subtropical, coastal wetland. *Biogeochemistry* 77: 283-304.

Rubio, G.A. and D.L. Childers, 2006. Controls of Herbaceous Litter Decomposition in the Estuarine Ecotones of the Florida Everglades. Estuaries and Coasts, 29(2): 257-268.

Ruiz Halpern, Sergio 2006. Response of the seagrass Thalassia testudinum to experimental manipulations of sedimentary iron and organic matter in a subtropical carbonate environment. Master's thesis, Florida International University.

Saunders C., Gao M., Lynch J., Jaffé R. & Childers D. (2006). Using soil profiles of seeds and molecular markers as proxies for sawgrass and wet parairie slough vegetation in Shark Slough, Everglades National Park. *Hydrobiologia* 569: 475-492.

Scully N.M., Maie N., Dailey S., Boyer J.N., Jones R.D. and Jaffé R. (2004). Photochemical and microbial transformation of plant derived dissolved organic matter in the Florida Everglades. *Limnology & Oceanography* 49(5), 1667-1678.

Simoneit B.R.T., Xu Y., Neto R.R., Cloutier J. and Jaffé R. (2007). Photochemical alteration of 3-oxy-triterpenoids: Implications for the origin of des-A-triterpenoids in aquatic sediments and soils. *J. Photochem. & Photobiol.* Submitted.

Williams, A. J., and J. C. Trexler. 2006. A preliminary analysis of the correlation of food-web characteristics with hydrology and nutrient gradients in the southern Everglades. Hydrobiologia 569: 493-504.

Xu, 2005. Origin, transport and fate of organic matter in Florida Bay: A biomarker record of historical environmental changes. Ph.D. dissertation. Florida International University.

Xu Y. Mead R.N. and Jaffé R. (2006a). A molecular marker-based assessment of sedimentary organic matter sources and distributions in Florida Bay. *Hydrobiologia* 569: 179-192.

Xu Y., Wachnicka A., Gaiser E.E. and Jaffé R. (2006b). Occurrence of C_{25} highly branched isoprenoids in Florida Bay: Paleoenvironmental indicators of diatom-derived organic matter inputs. *Organic Geochemistry* 37:847-859.

Xu Y., C. Holmes and R. Jaffé (2007). A lipid biomarker record of environmental change in Florida Bay over the past 150 years. *Estuarine, Coastal & Shelf Sci.* 73: 201-210.

Xu Y. and Jaffé R. (2007). Lipid biomarkers in suspended particulates from a subtropical estuary: Assessment of seasonal changes in sources and transport of organic matter. *Marine Environmental Research*. In Press.