

THREE YEAR REVIEW REPORT
PREPARED FOR THE
NATIONAL SCIENCE FOUNDATION SITE REVIEW TEAM



FLORIDA COASTAL EVERGLADES
LONG-TERM ECOLOGICAL RESEARCH PROGRAM

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Miami, FL



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EXECUTIVE SUMMARY

The Florida Coastal Everglades LTER Program (FCE) was funded in May 2000. This report summarizes our scientific, educational, and organizational accomplishments in the first three years of NSF support. Since our inception, we have effectively doubled the number of senior scientists, institutions/organizations, and total number of personnel affiliated with the FCE program. We now have 35 – 40 students involved in LTER research, including high school, undergraduate, and graduate students. Since May 2000, we have amassed nearly 125 legacy publications and 15 publications that directly cite FCE support, with the latter showing an exponential trend with time. In this time, our scientists and students have presented FCE results in nearly 140 conference presentations. The cumulative number and amount of proposals written and funded that are linked to the FCE LTER Program has increased steadily since 2000, and our current leveraging ratio is 4.75. The FCE LTER Program office and our Information Management program are well established and expanding. FCE scientists and students have been very active in network-level research, governance and other activities and our education and outreach activities are both meeting NSF's goals. Our website statistics suggest the broad impact that FCE research can have, even remotely. The organization of our program administration is solid and clear, and leadership and governance are both stable and functional.

The research program at FCE is focused on the central idea that *regional processes mediated by water flow control population and ecosystem level dynamics locally in the coastal Everglades landscape; this phenomenon is best exemplified in the oligohaline zone, where phosphorus-poor fresh water mixes with water from the more nitrogen limited coastal ocean*. In the first 3 years of FCE research, we have accomplished many key objectives. Our field observational network—with 17 sites, including 14 wetland and 3 open water sites—is in place. We have been collecting observational data on key ecological parameter, such as primary production, soil dynamics, water quality, organic matter characteristics, consumer/trophic dynamics, and on key physical/environmental parameters, such as water levels, rain levels, and salinity. We have a number of [both new and ongoing] experimental research activities that are focused, to varying degrees, on the FCE central concept. Many of these experiments are being conducted by students and postdocs, and some already constitute long-term projects. This spring, we will be constructing three carbon flux (eddy covariance) sampling towers that will allow us to directly quantify ecosystem-scale carbon fluxes and to calibrate traditional methods of measuring primary productivity and soil carbon dynamics. These experiments will be conducted in a tall mangrove forest (at site SRS-6), a dwarf mangrove forest (at site TS/Ph-7), and a sawgrass marsh (at site TS/Ph-1). We integrate these observational and experimental data in several ways, including our own synthesis activities and through close collaborations with several major modeling efforts already underway. We address questions about the long-term effects of climate change and disturbance with these synthetic activities.

FCE research is steadily becoming more important to the science of Everglades Restoration—in no small part thanks to the many agency scientists (ENP, NAS, SFWMD, USGS) who are associated with the FCE LTER Program. Restoration will bring long-term changes that are key drivers in our central hypothesis. At the same time, FCE scientists and students are involved in research efforts that are critical to determining how to best conduct this restoration, and if the products of restoration are ecologically successful. Thus, in a very short time, the FCE LTER Program has become a critical “hub” of Everglades science.

I. INTRODUCTION

A. The History of the FCE LTER Program

The Florida Coastal Everglades (FCE) LTER Program was funded through the 1999 NSF initiative to add three new coastal sites to the existing 21-site LTER Network. This initiative represented a re-allocation of funding for the Land-Margin Ecosystems Research (LMER) Program to more permanent coastal ecological programs. The result of this 1999 competition was three new LTER programs: The Georgia Coastal Ecosystems (GCE) LTER based at the University of Georgia, the Santa Barbara Coastal (SBC) LTER based at the University of California – Santa Barbara, and the FCE LTER Program based at Florida International University. Our funding began in May 2000, and in this report we summarize our activities, findings, and accomplishments during the first 2.5 years of that funding. More specifically, this report deals primarily with the observational data and findings that make up the core science of the FCE Program. At the site visit, we will focus on our experimental work (at the evening poster session and on the field trip) and on synthesis and integration as it relates to our central hypotheses (at the Science Morning session). This report is rich with hyperlinks to relevant data and web pages, and we encourage you to read the document “interactively”, while on line.

The FCE LTER research program focuses on landscape-scale connectivity of the freshwater and coastal/estuarine systems of the Florida Everglades—our [original proposal](#) is posted on the website. Our central idea is that: **Regional processes mediated by water flow control population and ecosystem level dynamics at any location within the coastal Everglades landscape. This phenomenon is best exemplified in the dynamics of an estuarine oligohaline zone where fresh water draining phosphorus-limited Everglades marshes mixes with water from the more nitrogen-limited coastal ocean.** The Everglades system is unique in many ways, including that the entire landscape is oligotrophic and phosphorus-limited and that the source of the limiting nutrient (P) is the Gulf of Mexico. Our estuaries are thus “upside-down” relative to other U.S. coastal systems, which receive [often bountiful supplies of] nutrients from upstream watersheds. We focus on the oligohaline zone because this is where water rich in organic matter—flowing from the freshwater Everglades marshes—meets relatively P-rich water from the Gulf of Mexico. Where this occurs, we have hypothesized a low-salinity peak in ecosystem productivity. Our experimental design follows this central hypothesis with two transects that track water flow, from canal inputs to the Gulf of Mexico (see Figure I.A.1 and [maps and photos](#) of the transects and sites). We hypothesize an oligohaline productivity peak along the Shark River Slough transect, because the freshwater Everglades and Gulf of Mexico are directly connected. Along the other transect, through the Southern Everglades (the Taylor Slough/Panhandle, or TS/Ph transect), we hypothesize no such productivity anomaly because Florida Bay is between the Gulf of Mexico and fresh water inflows, and this shallow subtidal estuary is adept at sequestering oceanic P before it can reach the oligohaline zone (see the [central hypothesis conceptualization](#)). Both transects are wholly located in Everglades National Park, and thus our 17 FCE LTER sites cover much of the 4300 km² of the park.

Our research program is organized around the five primary questions that we asked in our proposal. These five questions closely parallel the five core areas that are required of all LTER sites: Primary production, consumer and trophic dynamics, soils and organic matter, nutrient dynamics, and disturbance. A different Working Group focuses on each of these questions, and the Research section of this report (Section II.) is organized in this manner. While the transect

approach and two-transect design are central, FCE research may also be visualized in a different way: Working Group research also focuses on how ecological dynamics are controlled by: 1) various hydrologic parameters (e.g. hydroperiod, water flow, salinity); 2) freshwater-estuarine connectivity and landscape position; 3) biogeochemical parameters (P and N inputs), and; 4) disturbance (hurricanes, fire, sea level rise). Whether viewed from the Working Group perspective or from this “large-scale control” perspective, it has become clear that FCE research is central to the science of Everglades Restoration. A great deal of credit for this influence goes to the many agency scientists (SFWMD, USGS, ENP, NAS) who are associated with the FCE LTER Program. These scientists generally receive little if any direct support from FCE; in fact, they often fund FCE-related research through their own positions. The long-term changes that restoration will bring to our study system are key drivers behind our central hypothesis. At the same time, FCE scientists and students are involved in research efforts—both within and outside the bounds of the FCE program—that are critical to determining how to best conduct this restoration, and if the products of restoration are ecologically successful. In a very short time, the FCE LTER Program has become a critical “hub” of Everglades science.

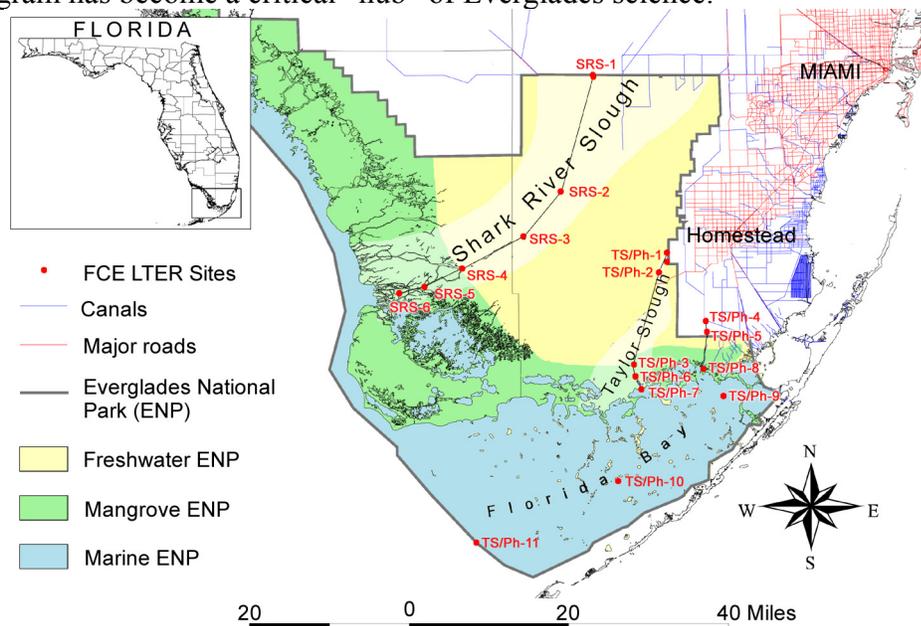


Figure I.A.1. Site map of Everglades National Park (ENP) showing the 17 FCE LTER study sites, identified by their site names.

B. FCE LTER Productivity

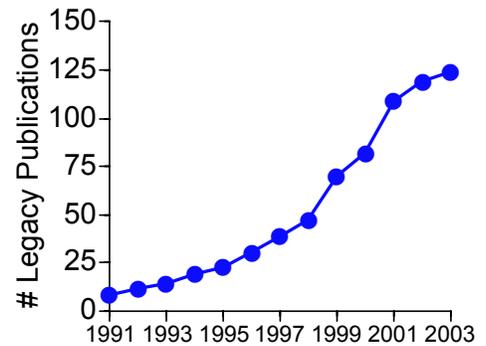
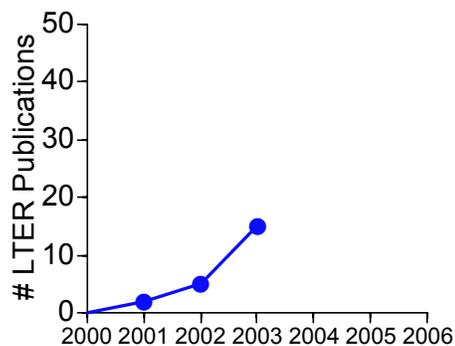
In March 2000, we hosted our first FCE LTER All Scientists Meeting at FIU (notably, this Year 1 ASM was held before our funding had officially begun). This ASM had two primary objectives: Organizing ourselves so that we could “hit the ground running” with our LTER research, and goal-setting for our first 6 years of NSF funding. An important component of our 3-Year Review process and of this report is to revisit these goals. Among them were to have 25 LTER-based publications by the end of our third year of funding and to increase our LTER-leveraged research funding in every year. In this section, we address our progress towards these two goals, as well as our productivity in several other categories. This section is thus analogous

to the “Results of Prior NSF Support” section that will begin our renewal proposal in 3 more years.

Publications are the most important form of productivity, and we have divided ours into two categories: Those papers that directly cite NSF support through the FCE LTER Program ([LTER Publications](#)) and those papers that are related to FCE research or were integral to our original proposal ideas ([Legacy Publications](#)). Since 2000, FCE scientists and students have published 15 peer-reviewed LTER publications (Figure I.B.1a) and we have cataloged 124 peer-reviewed Legacy publications (Figure I.B.1b). Although it appears that we will not be able to meet our goal of 25 LTER publications by the end of our third year, there are two trends in Figure I.B.1 that are reassuring. First, the increase in publications in 2003 compared with 2002 is substantial, in spite of the fact that 2003 was only 6 weeks old when these data were compiled! It is quite probable that we will meet our Year 3 goal for publications by the end of 2003. The next goal is to maintain the non-linear (seemingly exponential) increase in publications seen in Figure I.B.1a. The second reassuring trend is that the LTER Legacy publication rate clearly began to level off beginning in 2001, suggesting a shift from publishing papers related to the LTER to publishing papers on FCE-based research that acknowledge FCE LTER support. This trend also speaks to buy-in by critical scientists.

Figure I.B.1: :Publications productivity data

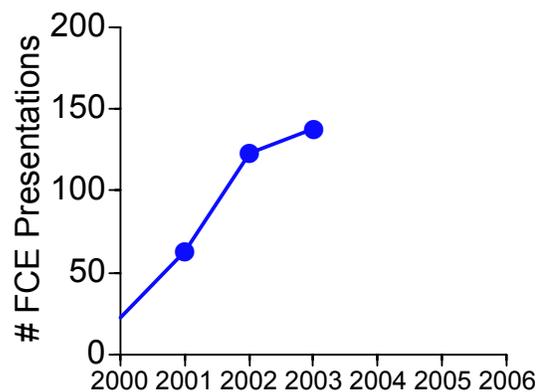
[Presentations](#) at scientific meetings or in departmental seminars are also an important form of research productivity that we track (note that we typically classify other types of presentations as FCE



outreach, which is covered in the Education/Outreach section of this report). Since 2000, FCE scientists and students have presented LTER results a total of 138 times (Figure I.B.2).

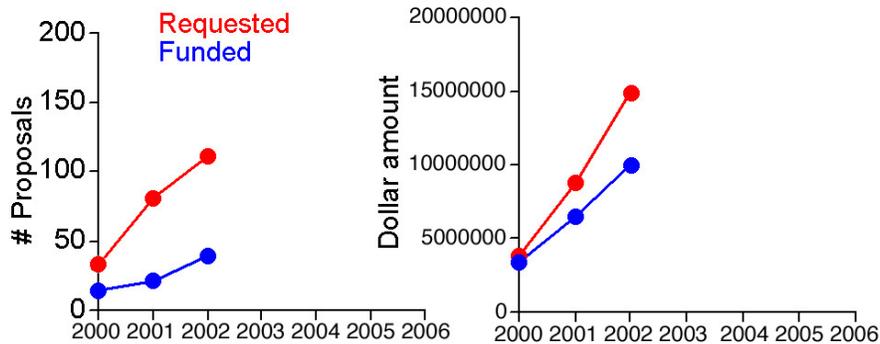
An important characteristic of the FCE LTER Program is that it builds on a number of pre-existing and ongoing research and observational studies by many FCE scientists. These existing projects, and the data and publications that they continue to generate, were a key selling point for the original FCE LTER proposal. Our [LTER-related funding](#) productivity was quite high in 2000 (Year 1) because of these pre-existing grants (Figure. I.B.3). However, some of this Year 1 funding productivity was directly leveraged using the FCE LTER Program, and our leveraging success generated a steady increase in funding in 2001 and 2002. We have

Figure I.B.2: Presentations productivity data



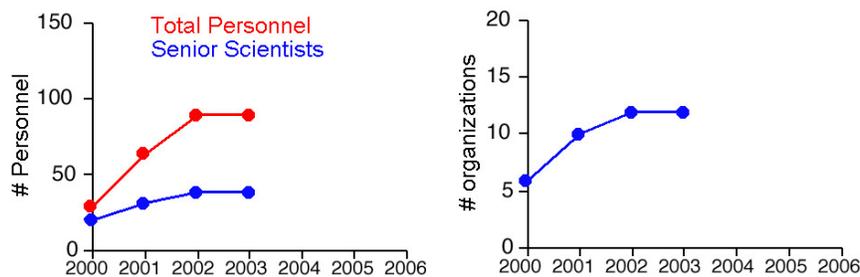
clearly met our goal of increasing our leveraged funding each year. With a cumulative total of \$9,960,000 in FCE-leveraged funding, our ratio to NSF base funding (\$700,000 per year, or \$2,100,000 cumulative to date) is 4.75—which is quite respectable for a new LTER site in its first 3 years of activity. Between May 2000 and February 2003, 20 letters of support have been written on behalf of the FCE LTER Program in support of proposals directly connected to FCE research.

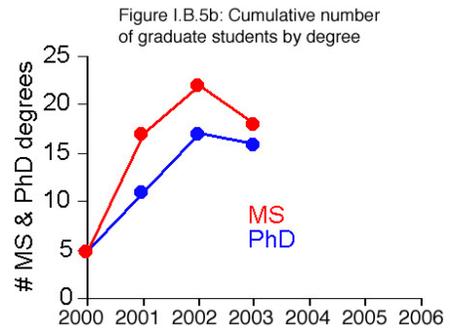
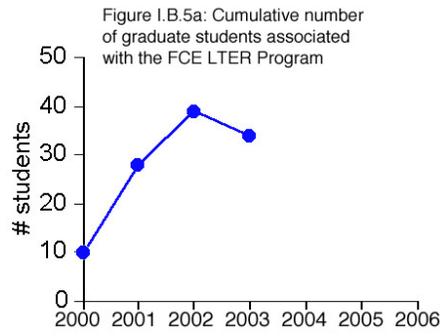
Figure I.B.3: Funding productivity data



Collaboration-building and network-support are also forms of productivity for LTER programs, and this is a particularly important measure of progress at FCE because of our central involvement with the Everglades restoration effort. The number of Ph.D.-level senior scientists and total collaborating personnel have grown steadily since 2000 (to 40 and 90, respectively; Figure I.B.4a). The number of institutions and government agencies affiliated with the FCE LTER Program has also grown steadily, to 12 in 2002 (Figure 1.B.4b). This includes scientists and students from the University of Louisiana-Lafayette, College of William & Mary, University of Virginia, Texas A&M University, University of Miami, and University of North Carolina-Wilmington. In 2001, we saw a dramatic increase in the cumulative number of graduate students involved with the FCE program, with lesser growth in 2002 (Figure 1.B.5). The dip in 2003 student numbers is because these data were compiled in mid-February of 2003. A complete list of [FCE affiliated scientists, students, and staff](#), and a list of [affiliated universities, agencies, and organizations](#) may be accessed through the website.

Figure I.B.4: Personnel productivity data





II. RESEARCH

A. The Hydroclimatological Setting

The [marginal] tropical setting of the Florida Everglades makes the climatological history of the FCE system particularly relevant to long-term interpretation of our ecological data. It is also critical that we include hydrologic history in our interpretations, because of the dramatic changes that man has imparted on this landscape in the last 100 years. In this section, we present an example of the kinds of climatological and hydrologic histories we are using to provide context to our long-term datasets. In each figure, we show the 30 year means of monthly data (January 1973 – December 2002) within a 10th & 90th percentile envelope that depicts interannual variability during these 30 years for that month. Finally, we plot the monthly data for the first 3 years of the FCE LTER Program (January 2000- December 2002) against the historical record to facilitate comparison.

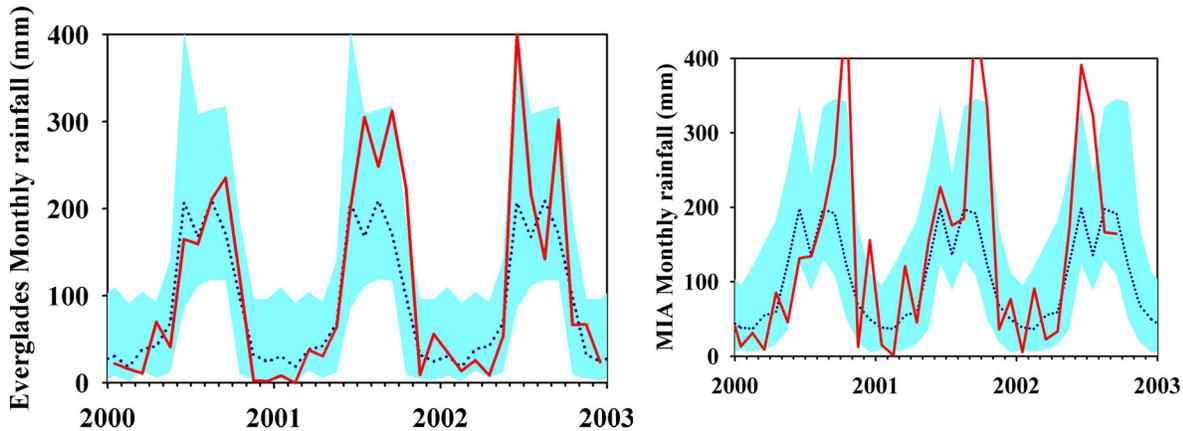


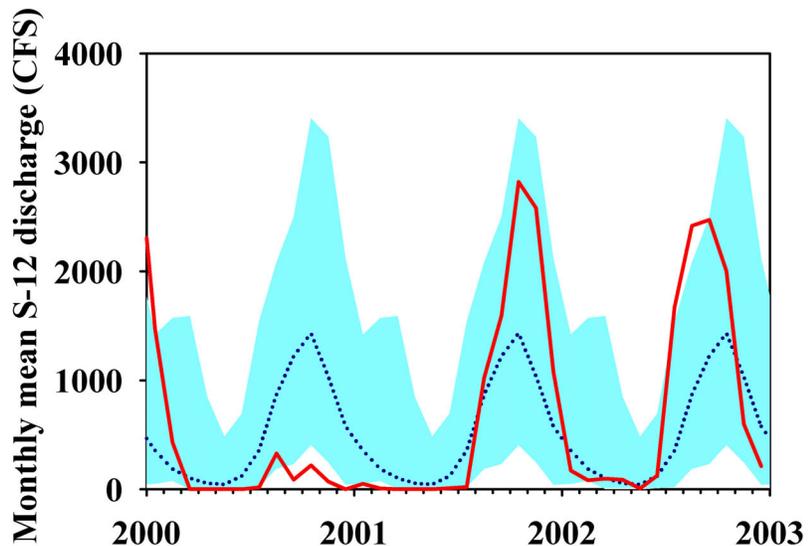
Figure II.A.1: Western Everglades (Ochopee, left panel) and downtown Miami (MIA, right panel) monthly rainfall for 2000 – 2002 (red curve), 30-year mean monthly rainfall (dashed blue line), and the 10th & 90th percentile values about that mean (light blue).

The long-term monthly precipitation data clearly show the bimodal wet season pattern that characterizes the Everglades—July is relatively dry compared to June, August, and September (Figure II.A.1). It is also notable that interannual variation in rainfall is often as great as the long-term mean rainfall. That is, the difference in total annual rainfall between dry and wet years is nearly as great as mean annual rainfall; furthermore, what Figure II.A.1 does not show is that there is a strikingly regular cycle from dry years through wet years back to dry years, with a period of approximately a decade. Thus, our climatological environment is one with large intra-annual variability in rainfall (dry vs. wet seasons), large spatial variability on small scales of much of that rainfall (the spottiness of summertime thunderstorm activity), substantial inter-annual variability (but varying in a surprisingly predictable way), and irregular major precipitation events associated with tropical weather systems (including hurricanes).

The hydrologic environment of the FCE study area is controlled by two factors: 1) precipitation (rain that falls directly onto ENP), and; 2) water management. The former we describe above. The latter focuses on relatively few points at which surface water can enter ENP

in any substantial volumes. All of these points are carefully controlled by the SFWMD and USA COE with water control structures. Shark River Slough receives freshwater inflows through the S-12A, B, C, and D gated structures along Tamiami Trail. Our SRS transect is anchored at the S-12C structure (SRS-1). Water also enters the park from the L-31W canal via the S-332D pump structure (the anchor point for one leg of our TS/Ph transect at TS/Ph-1) and from the C-111 canal via overbank flooding controlled by the S-18C gated structure (the anchor point for the other leg of our TS/Ph transect is along the levee-free portion of the C-111 canal at TS/Ph-4). There are many factors that influence and control the management of water inflows to ENP, from year to year (and many of these factors are, to some degree, political). The 2000 – 2001 water year (June 2000 – May 2001) is an interesting example (Figure II.A.2). Water flow into Shark River Slough from the S-12 structures during the wet season (June – November 2000) was dramatically lower than the 30 year mean, and was in fact nearly below the 10th percentile of water inflows since 1973. Interestingly, though, total water inflows to the park during this time were lower, but not so dramatically lower. The reason is that water was preferentially routed south along the eastern margin of ENP during much of the 2000 wet season, and entered through the Southern Everglades points rather than at Tamiami Trail points. Notably, all of Shark River Slough went dry for several months during the 2001 dry season (an event that has happened about every 10 years in the last 50-60 years, but that was probably very rare before 1900).

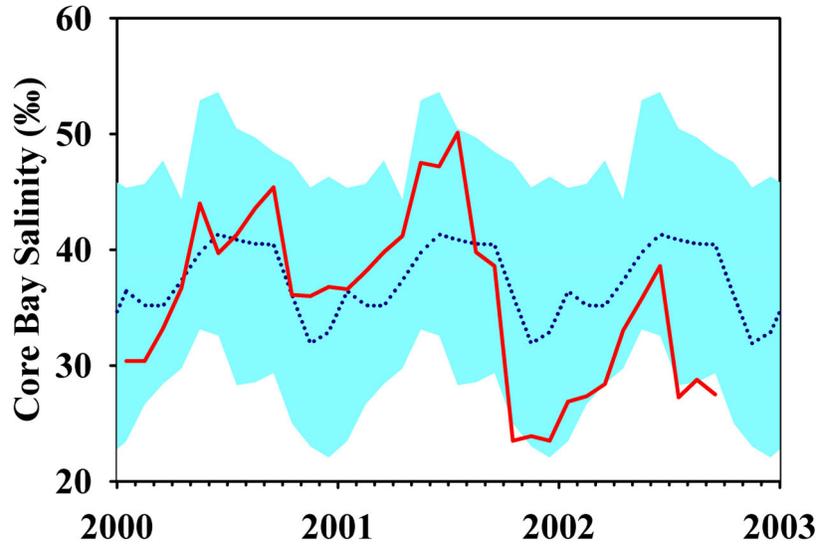
Figure II.A.2: Mean monthly discharge rates for water entering Shark River Slough (ENP) through the four S-12 structures along Tamiami Trail for 2000 – 2002 (red curve), 30-year mean discharge rates (dashed blue line), and the 10th & 90th percentile values about that mean (light blue).



The Florida Bay estuary is directly downstream of our TS/Ph transects (and of water inflows along the 2 freshwater legs), and is indirectly downstream of our SRS transect, as GOM water diluted by freshwater flows from Shark River Slough enters across the northwestern Florida Bay boundary. This region of the estuary becomes hypersaline for the last few months of the dry season in most years, but did not in Spring 2002 after two relatively wet years (Figure II.A.3). Salinity in central Florida Bay (at a site near TS/Ph-10) shows good coherence with the precipitation patterns in Figure II.A.1, and may also be related to monthly freshwater inflow rates at the southern Everglades inflow points (data not shown). It is notable that the very low freshwater flows into SRS observed in 2000 did not lead to a major hypersalinity event in Spring 2001 (when all of

SRS experienced drydown). Perhaps the central regions of Florida Bay are not tightly enough coupled to GOM exchanges to be influenced by changes in GOM salinities.

Figure II.A.3: Mean monthly salinity in central Florida Bay (near TS/Ph-10) for 2000 – 2002 (red curve), 30-year mean salinities (dashed blue line), and the 10th & 90th percentile values about that mean (light blue).

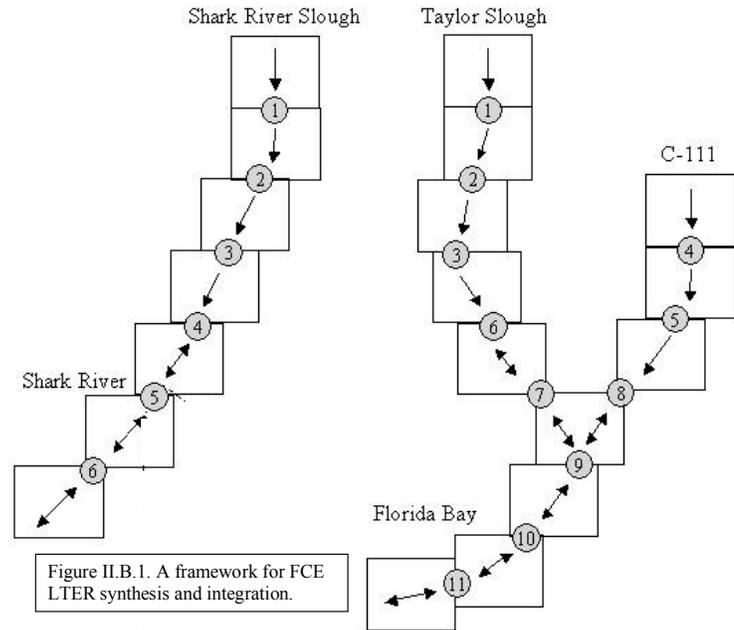


B. Modelling, Synthesis, and Landscape Analysis

Data synthesis and cross-working group synthesis is an important activity of the FCE LTER Program. This synthesis is central to addressing the question: **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?** A number of LTER sites use experimental manipulations to answer questions about disturbance and climate change (e.g. LUQ, KNZ, HUB, AND, others). Everglades National

Park has very strict limitations on large-scale manipulations of this kind, which limits our ability to experimentally test many disturbance and climate questions. Our approach to addressing these key questions is to integrate our knowledge of historical and contemporary climate and hydrologic forcings (Section A, above) with our data synthesis activities.

Much of this synthesis follows a conceptual approach that mirrors our experimental transect design (Figure II.B.1). Each numbered circle in this figure represents a FCE site. Arrows indicate advective material flow into the FCE landscape (canal inputs to Shark River Slough, Taylor Slough, and the C-111 basin) and between



FCE sites. Flows are unidirectional in the freshwater zone and bi-directional in mangrove and seagrass zones. This framework is used to synthesize empirical data from the working groups into nutrient budgets, ecosystem models and landscape models that link the freshwater marsh, mangrove, and seagrass regions of the landscape, and research in each.

Most the modeling efforts associated with FCE LTER Program get the majority of their funding from external sources. Nevertheless, they use data collected at FCE sites, they produce output relevant to a variety of LTER activities, and they all fit into the FCE conceptual framework for modeling ecological processing along water flow pathways. Although the FCE Program is not funding these modeling efforts per se, key scientists associated with each effort are affiliated with the FCE Program and FCE research is important to developing and calibrating these models (Figure II.B.2).

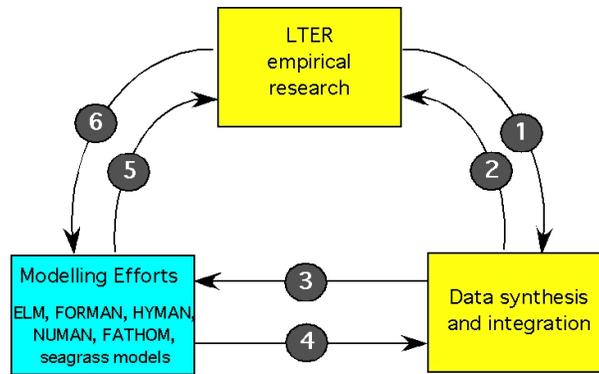


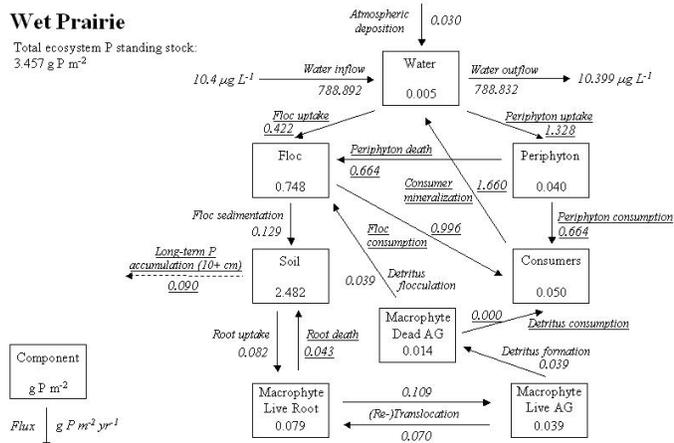
Figure II.B.2

Yellow boxes are work funded by the FCE LTER Program
 Blue box is work funded by non-LTER sources
 Arrows represent the flow of data, information, or communication.

1. Data synthesis and integration (biogeochemical budgets, unit models, etc.)
2. Research feedbacks (adaptive management)
3. Contributions of LTER syntheses to allow existing modelling efforts to address new, [perhaps] more basic questions.
4. Spatial & temporal context for site-specific budgets and other types of synthesis.
5. Research feedbacks (adaptive management) by providing simulated spatial or temporal context for specific datasets or parameters.
6. Contributions of LTER data and experimentation to allow existing modelling efforts to address new, [perhaps] more basic questions.

Nutrient Budgets

Figure II.B.3. The P budget for oligotrophic wet-prairie marsh. Boxes represent the P standing stock (both organic and inorganic) of the different ecosystem components (g P m^{-2}) and arrows indicate net annual P fluxes between components ($\text{g P m}^{-2} \text{ yr}^{-1}$). Underlined fluxes have high uncertainty.



Developing synthetic, whole-ecosystem nutrient budgets for the Everglades wetlands is a major component of this LTER. As a phosphorus-limited system, the development of P budgets is particularly important. Preliminary P budgets were developed for wet prairie (Figure II.B.3), oligotrophic *Cladium*, mixed *Cladium/Typha*, and *Typha* marsh ecosystem types. As a first approximation, the P budgets

assume steady-state conditions, 12-month hydroperiod, no mega-consumers, and no consumption of macrophyte detritus by consumers.

Mean total ecosystem P standing stocks ranged from 3.46 in wet prairie, 3.65 in *Cladium*, 7.29 in *Cladium/Typha*, to 10.44 g P m⁻² in *Typha* marsh. In wet prairie, soils (0-10 cm) held the most P in the ecosystem (72%), followed by floc (22%), live macrophyte rhizomes and roots (2.3%), aquatic consumers (1.5%), periphyton (1.2%), live aboveground macrophytes (1.1%), dead aboveground macrophytes (0.4%), and the water column (0.2%). Very large quantities of P flow in and out of a given area of oligotrophic marsh (~ 800 g P m⁻² yr⁻¹) although net uptake of P from the water column is negligible. In wet prairie marsh, slow turnover of macrophyte stems and low P standing stocks result in relatively low net annual P flux from macrophytes compared to periphyton, floc, and consumers. For example, periphyton net annual through-flux is estimated to be 1.33 g P m⁻² yr⁻¹, while live aboveground macrophyte tissues cycle 0.04 g P m⁻² yr⁻¹. However, as Everglades wetlands receive additional P loading, live and dead aboveground macrophytes store increasingly larger proportions of whole-ecosystem P standing stock. As part of FCE, these nutrient budgets will be expanded in the future to include site-specific data and nitrogen and carbon dynamics. These nutrient budgets will serve as an integrative and synthetic tool for comparing marsh, mangrove, and seagrass ecosystems.

Seagrass Modeling

A physiologically-based, dynamic simulation model of the Florida Bay seagrass community is largely supported by the Critical Ecosystems Studies Initiative (CESI), US Geological Survey and the South Florida Water Management District. The model is being used to synthesize our understanding of the ecology of the seagrass community (*T. testudinum*, *Halodule wrightii*, *Ruppia maritima*) and to predict community response to a variety of environmental conditions. Specifically pertinent to the FCE-LTER, the model can assess seagrass community response to changing fresh water and material inputs from the Everglades to the estuary. The objectives are to: 1) understand the mechanisms responsible for seagrass decline, 2) predict seagrass response to variations in magnitude, timing and variability of fresh water and water quality, and 3) extrapolate this information from a unit level to a landscape level (Figure II.B.4). A time step of 3 hr permits resolution of sub-daily variability in light, photosynthesis and plant respiration patterns, and allows for the addition of tidal and organism migration signals. The species specific unit models focus on the mechanistic, process-level approach to understanding seagrass growth. Individual unit models were developed for *Thalassia* and *Halodule*. In the future, these species models will be merged and upgraded to include interspecific competitive interactions and species succession.

Simulations were performed to investigate the influence of different stresses common to plants in Florida Bay on the performance of *T. testudinum*: high salinity, high sulfide concentrations, and elevated nutrient levels. Although all stresses produced changes in the annual cycle of plant production, elevations in nutrients and in salinity merely shifted the period of maximum biomass later in the growing season without significantly reducing peak productivity. Elevations in sediment sulfide, however, caused a steep decline in both plant biomass and productivity, resulting in a loss of over half of the annual productivity and peak standing crop.

Ecosystem Process Model South Florida Estuarine Systems

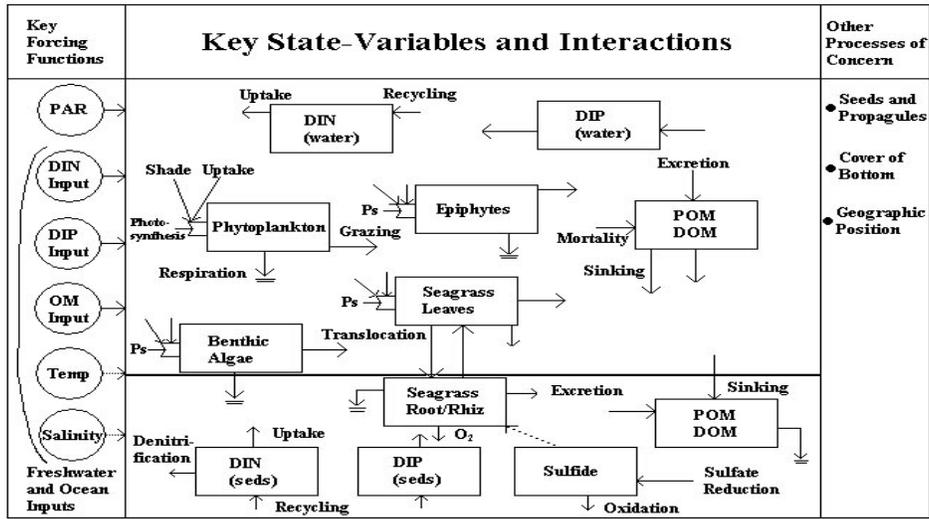


Figure II.B.4: Key state variables and flows in the seagrass ecosystem model.

Mangrove Zone Modeling

Our current research efforts are addressing two research questions: 1) How do changes in freshwater flow and/or its nutrient content control organic matter accumulation in mangrove wetlands? and 2) How are patterns and magnitudes of primary production controlled by the delivery of freshwater and the concentrations and characteristics of nutrients and organic matter in the source water? We are currently parameterizing existing mangrove models and hydrologic box models based on results from biogeochemistry and productivity studies as part of the LTER project. The FORMAN (mangrove structure), HYMAN (hydrology), NUMAN (soil formation), and SALSA (water salinity) models are used to link community development and

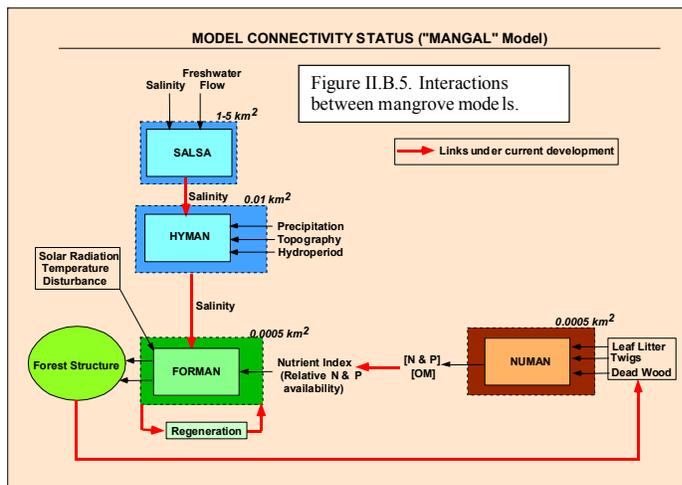


Figure II.B.5. Interactions between mangrove models.

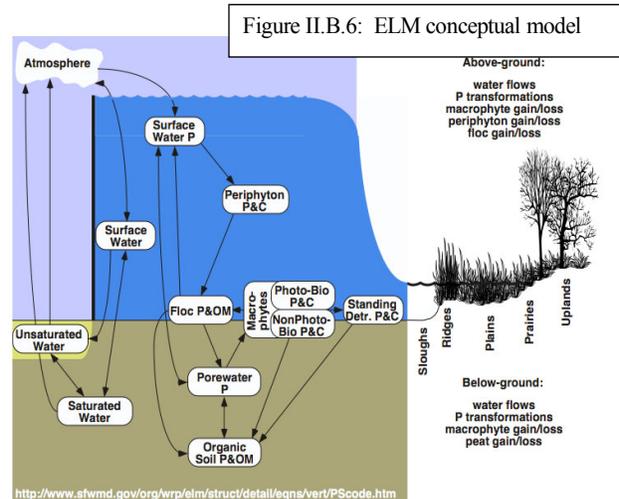
biogeochemistry of mangrove ecosystems in the South Florida region. These models are applied to project the response of mangrove stands to changes in quantity and quality of discharge in both the SRS and TS/Ph transect basins as part of the Everglades Restoration Program. The SR and TR regions are characterized by significant differences in soil TP concentrations and hydroperiod. The HYMAN model simulates soil salinity and is being calibrated using long term water level and salinity data from 1995-2002 for three sites in both regions. The FORMAN model was initially calibrated in Shark River to simulate mangrove structural changes as a function of salinity and total phosphorus (TP). The

NUMAN model uses a cohort analysis of mangrove soil formation and has helped to identify the importance of the allocation and turnover of above-and below ground biomass of mangrove forests related to soil conditions. We are coupling these models (MANGAL model; Figure II.B.5) to evaluate different scenarios of freshwater diversion as a part of the 2 x 2 South Florida Water Management model. Model simulations indicate the critical importance of TP and elevation in controlling mangrove species composition and productivity. These modeling efforts are largely supported by the Critical Ecosystems Studies Initiative (CESI), US Geological Survey.

Integrative Landscape Modeling

The [Everglades Landscape Model](#) (ELM) is a process-based, spatially distributed simulation of wetland ecosystem dynamics (Figure II.B.6). The model development has proceeded in tandem with advances in Everglades research, improving its algorithms and calibration to best capture dynamics of key landscape attributes. The model captures the spatio-temporal dynamics of hydrology, surface and ground water phosphorus, periphyton biomass and community type, macrophyte biomass and habitat type, and peat accumulation.

The ELM is being used in several modes within the FCE research program. As a regional model, spatial output of water and nutrient stocks and flows are used to evaluate hypotheses of biotic interactions under different climatic/management scenarios across the southern Everglades landscape. By integrating the ecosystem processes in spatially explicit fashion, this tool can help synthesize our ecological understanding across space and time, and help formulate/evaluate a variety of hypotheses of the ecological transitions along the spatial gradient from freshwater to estuarine habitats. These data are also useful as boundary conditions for the unit models within the FCE that focus on local-scale mangrove and seagrass dynamics. As a sub-regional, fine scale model, the ELM will also be used to evaluate the dynamic interactions among the physical, chemical, and biological variables that are the focus of synoptic and experimental research projects.



C. Primary Production

The aim of the FCE primary production group is to document patterns of production and community composition of primary producers along the two transects, and to determine relationships to source water delivery, quantity, and quality. The central question is: **How are patterns and magnitudes of primary production controlled by freshwater flow and the concentrations and characteristics of nutrients and organic matter in the source water?** We hypothesized that long-term data would reveal a productivity peak in the oligohaline zone along the Shark Slough transect, while a corresponding pattern in Taylor Slough would not be observed due to the scavenging of marine sources of P by Florida Bay. During the first 3 years of FCE funding, the group has generated a wealth of data generally supporting this hypothesis and has established a rigorous sampling protocol that will provide an important source of long-term data to address the effects of Everglades restoration on spatial patterns of primary productivity in ENP. This brief synopsis of results is organized to follow the flow of water from the upstream freshwater marsh to the downstream marine end member site along each transect.

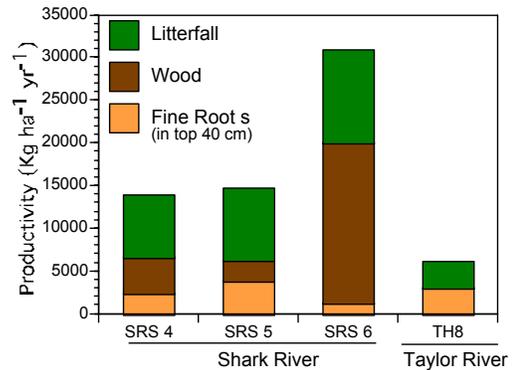
Beginning with the SRS transect, primary producer biomass in the marsh is dominated by sawgrass (*Cladium*) and periphyton. Annual production of *Cladium* is calculated from above and belowground biomass and mortality measures and periphyton by accumulation on artificial substrates and O₂ change in light-dark bottle BOD incubations. *Cladium* produces about 400-700 g dw m⁻² y⁻¹ (or roughly 200 – 350 g C m⁻² y⁻¹) while periphyton produces 25-400 g C m⁻² y⁻¹; on average periphyton accounts for about 50% of aboveground C production in the marsh (Table II.C.1). Biomass of both producers varies significantly from the site near the canal input (SRS-1) to the downstream marsh site (SRS-3). The ratio of above to below ground *Cladium* biomass decreased considerably along this gradient, perhaps indicating that plants near the canal are less nutrient limited and are able to devote more resources to light foraging rather than nutrient foraging. 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 near the canal—a phenomenon 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 (42, 79, 71 mg O₂ g⁻¹ d⁻¹, respectively) perhaps due to shading by the dense sawgrass culms at this site. Periphyton production was highest in the wet season and lowest in the dry season, while no significant interannual trends were detected. *Cladium* production was also highly seasonal and was greater in 2001 (which was a relatively dry year) than in 2002 at all sites.

Table II.C.1. *Cladium* production, belowground biomass and ratio of above:below ground biomass and periphyton production, mat biomass and ratio of epiphytic to floating periphyton biomass at SRS 1, 2 and 3. *Cladium* mass is expressed in dry grams and periphyton in grams ash-free dry mass.

Site	<i>Cladium</i> production g m ⁻² y ⁻¹	<i>Cladium</i> below mass g m ⁻²	<i>Cladium</i> Above:below ratio	Periphyton production g m ⁻² y ⁻¹	Periphyton mat mass g m ⁻²	Periphyton Epi:floating ratio
SRS-1	565	314	1.03	21.6	8	24
SRS-2	508	749	0.48	386	97	1.4
SRS-3	425	870	0.43	104	39	1.0

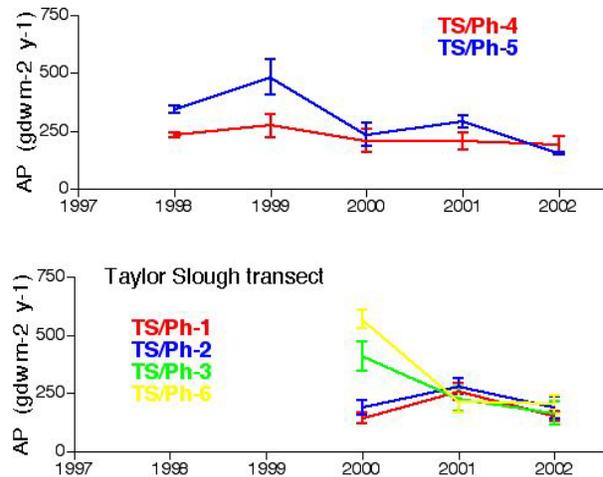
Sites SRS-4 through 6 are dominated by mangroves, which are regulated by resource competition and stress along the steep gradients of nutrient availability, hydroperiod and salinity that characterize this ecosystem. Tree growth rates (1995-2001) ranged from 0.1-10 mm y⁻¹ and varied among species depending on nutrient concentration, with the coastal *Laguncularia racemosa* (dominant in SRS-6) averaging 10 mm y⁻¹ in comparison to *Avicennia germinans*, *Rhizophora mangle* and *Conocarpus erectus* at the upstream sites (2, 3 and 2 mm y⁻¹, respectively; Figure II.C.1). Litterfall was highly seasonal (5 g dw m⁻² d⁻¹ vs. 1 g dw m⁻² d⁻¹ in the rainy and dry seasons, respectively) with the highest annual rates occurring at SRS-6 (10,000 kg dw m⁻² y⁻¹). Fine root productivity was similar among sites, ranging from 100-500 g dw m⁻² y⁻¹. Wood productivity was much higher than root productivity at SRS-6, probably due to proximity of this site to the GOM supply of P. The ratio of wood to root production at SRS-4 and SRS-5 is much lower, suggesting P limitation at these sites. Interestingly, this is the same pattern as observed in *Cladium* at sites SRS-1 through 3 of this transect.

Figure II.C.1. Productivity rates partitioned by litterfall, wood and fine roots in Shark River and Taylor Slough (2000-2002).



The Taylor Slough/Panhandle transect is bifurcated at the upstream end, containing freshwater marsh sites in both Taylor Slough and the C-111 Panhandle. The stations are similar in composition to the freshwater sites of SRS, being dominated by *Cladium* and periphyton, but because they dry more frequently and for a longer duration, they are dominated by 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 TS/Ph marsh sites relative to the SRS marsh, while culm densities are significantly higher. The ecotone sites (TS/Ph-3, 6) in Taylor Slough were significantly more productive than upstream sites in 2000 (Figure II.C.2), supporting the core FCE hypothesis that the ecotonal region would be most productive along this transect. Preliminary analysis suggests that the dramatic decline in *Cladium* production 2001 at these sites (particularly at TS/Ph-6) was due to high dry season salinities.

Figure II.C.2. Annual production (AP) of *Cladium* (sawgrass) along the TS/Ph transect.



We have used the TS/Ph-4 and 5 sites to test relationships between a changing hydrologic environment and marsh plant community structure and primary production because the C-111/ENP Panhandle region began receiving considerably more water inputs in 1997, when a key levee was removed. Our approach investigated how increasing hydroperiod, inundation depths, and other key hydrologic variables affected *Cladium* annual production and species composition

in this region. We found significant negative relationships between *Cladium* annual production (AP) and mean inundation depth ($Y = 676 - 17.1(X)$; $r^2 = 0.25$; $n = 18$; $p = 0.04$), and between *Eleocharis* culm density and *Cladium* AP ($Y = 73.4 - 0.094(X)$; $r^2 = 0.24$; $n = 18$; $p = 0.037$). The latter relationship was considerably stronger when both *Cladium* AP and mean annual water depth were used to explain *Eleocharis* culm density ($Y = 162 - 0.15(AP) - 3.92(mnWL)$; $r^2 = 0.5$; $n = 18$; $p = 0.005$). These preliminary analyses suggest that, where water levels become deeper on the average, that sawgrass will be less productive (which is expected), that sawgrass dominance will transition to deeper water species (such as *Eleocharis*), and that this transition will be rapid enough to avoid ecological disruption.

In contrast to the SRS transect, periphyton along 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 (Table II.C.2), often contributing more to total primary production than *Cladium* at the same sites. There was considerable interannual variability, with increased water levels in 2001 eliminating the calcareous mat at site TS/Ph-2 and possibly causing a temporary, early wet season replacement of this community at TS/Ph-4 by a filamentous green algal mat. Occurrence of this type of mat in the Everglades is generally indicative of increased nutrient input, which may have occurred when C-111 canal first entered the marsh in 2001.

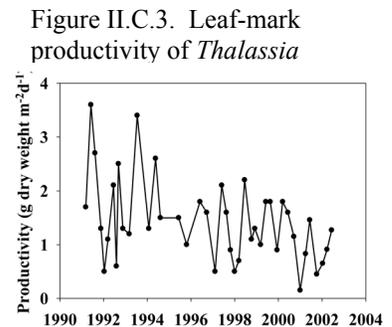
The mangroves along the TS/Ph transects (TS/Ph-6-8) contrasts the SRS system by being significantly shorter in stature and with lower rates of litterfall ($2500 \text{ kg m}^{-2} \text{ y}^{-1}$) and root production (Figure II.C.1). The current estimates of fine root productivity at TS/Ph sites reflect significant phosphorus limitation, in contrast to the SRS-6 site that is adjacent to GOM P supply and is comparatively productive. This patterns supports our hypothesis GOM sources of P are being depleted by seagrasses in shallow Florida Bay before this P can reach the mangrove-dominated estuarine ecotone.

Seagrass composition and production are measured quarterly at sites TS/Ph-9-11 in Florida Bay using *in situ* visual cover and abundance assessments, leaf marking, and PAM flurometry. There is strong seasonality in production of seagrasses that follows trends in relative abundance with summer maxima and winter minima (Figure II.C.3). Primary production follows the well-documented pattern in P availability, with 3-4 $\text{g dw m}^{-2} \text{ d}^{-1}$ of new leaves being produced at the high P TS/Ph- 11 site compared to $<1\text{-}4 \text{ g dw m}^{-2} \text{ d}^{-1}$ at TS/Ph-9. The elemental content of leaf tissue reflects this gradient in P availability and relative growth rate.

In fact, there is strong spatial and seasonal pattern in C:N:P ratios of the dominant macrophytes at all FCE sites. We are documenting this variability and testing the hypothesis that the amplitude of the seasonal pattern in elemental content can be used as an indicator of the relative availability of nutrients in seagrass-dominated ecosystems. Further, the time-series of C:N:P ratios will prove an invaluable tool to document changes in nutrient availability as water management practices change P loading to the system as well as osmotic stress with changes in freshwater delivery. To address the latter, we are using PAM flurometry to assess effects of

Table II.C.2. Periphyton Net Annual Production at the TS/Ph marsh sites ($\text{g AFDM m}^{-1} \text{ y}^{-1}$)

Site	2000	2001
TS/Ph-1	83	580
TS/Ph-2	139	
TS/Ph-3	220	531
TS/Ph-4	569	4421
TS/Ph 5	367	839



salinity fluctuation on seagrass vigor and productivity as fluorescence has been shown to be responsive to generalized stress in submerged plants.

On a larger spatial scale, we are using seagrass species occurrence and abundance data to define benthic habitat classes from 677 sampling locations throughout the Bay. Eight habitat classes were defined, and a discriminant function model revealed that mean salinity, salinity variability, light, sediment depth, and mean nutrient concentrations were important predictor variables of the habitat classes. The model predicted that the distribution of benthic habitat types in Florida Bay would likely change if water quality and delivery were changed by engineering of freshwater discharge from the Everglades. These statistical techniques should prove useful in predicting landscape-scale changes in community composition in diverse systems where communities are in quasi-equilibrium with environmental drivers.

Epiphyte accumulation rates show similar productivity patterns to their seagrass considerable variation across the three Florida Bay FCE sites. Accumulation rates are significantly higher at TS/Ph-11 compared with TS/Ph-9 and 10 at all times of the year (Figure II.C.4). Epiphyte load was found to have a significant negative effect on PAR transmission to the seagrass blade.

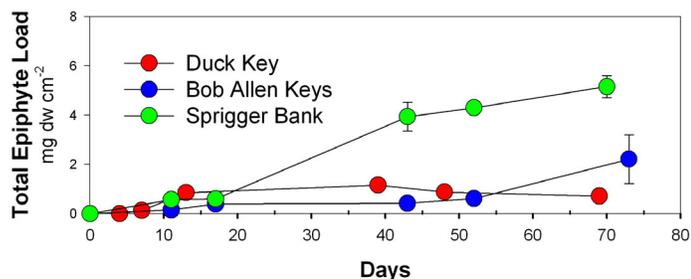


Figure II.C.4. Total epiphyte load on artificial seagrass blades (mylar strips) from March 23 to June 4 2001. Duck Key=TS/Ph-9, Bob Allen Keys=TS/Ph-10; Sprigger Bank=TS/Ph-11.

Phytoplankton biomass and productivity are quantified monthly at all FCE sites using pulse amplitude modulated (PAM) fluorometry. Along the SRS transect, algal biomass is dominated by brown algae which decrease in abundance from freshwater to estuarine sites, while productivity is highest in the cyanobacterial fraction which increases from canal to the GOM. Along the TS/Ph transect, brown algae also dominate and are most abundant at TS/Ph-3. Phytoplanktonic primary production appears equally divided across guilds along this transect. However, the TS/Ph transect has a pattern in biomass that is similar to the SRS transect, with biomass dominated by brown algae nearest the canals and decreasing towards Florida Bay and the GOM but with greater production by cyanobacteria from canal to the GOM.

In summary, the first 3 years of data collection generally supported the core FCE hypothesis that primary productivity along the two transects is controlled by the relative delivery of P and N to the ecosystem from marine and freshwater sources, respectively. Signals of a productivity maxima in the mangrove and phytoplankton communities occur in the oligohaline zone of the SRS transect. Along the TS/Ph transect, we do not observe a similar productivity peak (in seagrass and epiphytes) at the farthest marine end member site—TS/Ph-11. Spatially explicit relationships of productivity to environmental parameters are now being utilized to generate temporal predictions, which can be tested with continued long-term data collection at these sites.

D. Consumer/Trophic Dynamics

The FCE Consumer/Trophic Dynamics working group focuses its research on observational studies of the pattern of consumer standing crops along the experimental transects, and documenting food-web structure along these transects using stable isotopes. Additionally, we plan ancillary studies to help interpret standing crop data. The central question is: **How does freshwater flow or the content of source water control secondary production and trophic dynamics?** Fishes comprise a major component of consumer biomass at our FCE sites. However, quantitative sampling of consumers—particularly fishes—is particularly challenging because of their mobility and differential distribution among habitats in the freshwater and mangrove wetlands of south Florida. In the original proposal, we chose a subset of the study sites as focal areas for analysis of consumer dynamics. These are sites SRS-2, 3, 4 and 5 and TS/Ph-3, 6, and 8 along with two sites located between TS/Ph-2 and TS/Ph-3 (TS/Ph-2.5 in this report). These sites were targeted because long-term sampling studies were already underway or were planned at these sites, and because the habitats were relatively amenable to producing comparable estimates of consumer standing crops.

Standing Crops as a Surrogate for Secondary Productivity

We use standing crop data of fishes up to 8-cm in standard length (measured from the tip of the snout to the base of the caudal peduncle) as surrogate for secondary production. Species in this size class comprise the majority of biomass and abundance of fishes in the habitats we are studying. These fishes are primary and secondary consumers, primarily feeding on aquatic invertebrates, detritus, or algae. We have well-established techniques for quantifying their standing crops on a per-unit-area basis and they tend to be permanent residents of the habitats we sample (i.e., ongoing work indicates that the spatial scale of population dynamics is roughly consistent with our study areas). In contrast, larger fishes (e.g., gar [*Lepisosteus platyrhincus*] at freshwater sites and snook [*Centropomus undecimalis*] at estuarine sites) can only be quantified on a catch per unit effort (CPUE) basis, and both species make long-distance movements on a seasonal basis (more frequently for some mangrove species).

Different habitat structure requires different sampling techniques, and we are using different sampling techniques to collect fishes at the freshwater and mangrove wetland sites. It is clearly important that these methods be calibrated to allow cross-habitat comparison, and we are calibrating these methods in two ways: 1) by comparing their capture efficiencies, and; 2) by simultaneously sampling at common sites with at least two of the methods. We have completed one year of simultaneous sampling for two methods at site TS/Ph-2.5, and have estimated the clearing efficiency (proportion of fishes captured in the net that are removed) for both. We have also estimated the avoidance rate of the method used at freshwater sites. We are currently working up the remainder of these cross-method calibration data.

Just as habitat structure affects our choice of sampling gear, the presence of open water versus wetland habitats, and the influence of regular tidal inundation (as at SRS-4 through 6) versus seasonal inundation (as at most TS/Ph sites) further complicates estimates of local standing crop. The small fishes we study are forced into open water habitats during low tide and during some of the dry season; thus, their abundance is different among these habitats depending on the inundation regime. One way to address this problem is by estimating the proportion of wetland and open water habitats in a study area and weighting the contribution of each in fish

biomass estimates. The mangrove sites of SRS pose a special challenge in this respect, and a method of sampling non-wetland habitats at these sites has not yet been developed. We are not currently making this correction for biomass estimates at our freshwater marsh sites because alternative open water areas either: 1) have standing crops similar to our existing sites, or; 2) comprise a very small fraction of the habitat and are not commonly used by the fish we are sampling (alligator ponds).

Our results to date show evidence of inter-annual variation influenced by rainfall and resulting hydrological conditions. In 2000, we found elevated standing crops at mangrove sites compared to freshwater sites upstream; we observed higher standing crops at SRS sites than at TS/Ph sites (Figure II.D.1). Data collected at SRS-4 and 5 suggested much lower standing crops in the mangrove wetlands compared to upstream.

This may be because we did not sample fish in open water areas at these two sites. Current and future work is focusing on improving our sampling in creeks and development of a method to incorporate it into a framework for estimating standing crops, perhaps following the methods employed at sites TS/Ph-6 and 8.

Data from the SRS sites in 2001 were less clear than in 2000, with considerable intra-site variation. Additionally, we collected fewer fish in 2001, (note scale differences in Figure II.D.1). Notably, several of the freshwater sites along both transects dried during the dry season of 2001, yielding high fish mortality; in contrast, 2000 was a more typical year and these sites did not dry down. Analysis of a 1996-present time series from a subset of these sites suggests that more than 2 years of continuous inundation is required for recovery of the small fish community after a drydown, such as we observed in 2001.

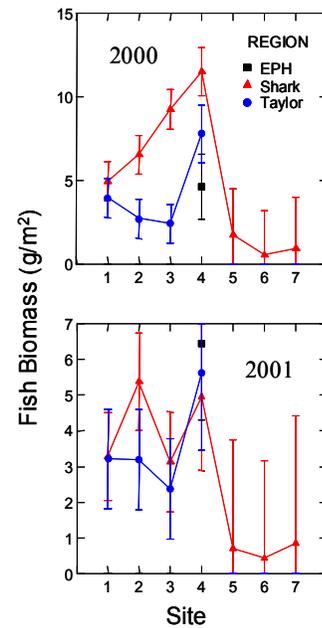


Fig 1. Annual estimates of standing crops of small fishes at each study site. Sites: SRS 1 – 4 are successively downstream with 2 = SRS 3 and 4 = SRS4. Taylor 1 – 3 are successively downstream, with Taylor 3 = TS3 and 4 = TS6. EPH stands for Eastern Panhandle and is site TS8.

Food Webs Dynamics

We are estimating food chain length to key consumers using $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ isotopes. To adjust for spatial variation in the $\delta^{13}\text{C}$ values among our sites, we are using samples of detritus, periphyton/algae, amphipods, and snails to delineate baseline values for comparison of food chain length. We have collected periphyton, detritus, amphipods

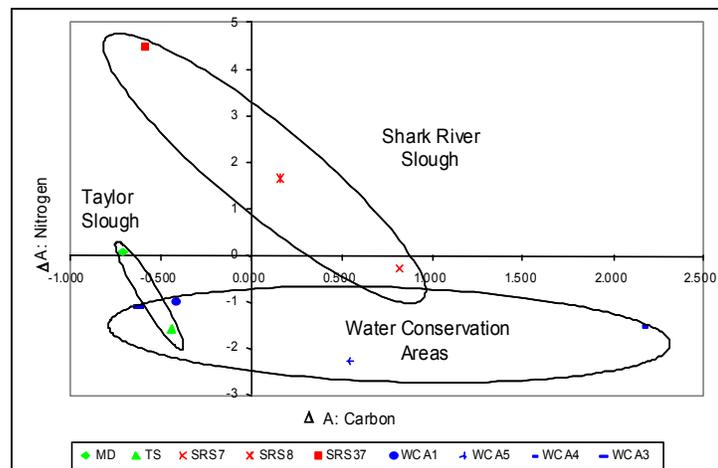


Figure II.D.2. N and C isotope values from amphipods reported as the residual from grand mean values from nine study sites.

(*Hyalella azteca*), Seminole ramshorn snails (*Planorbella duryi*), eastern mosquitofish (*Gambusia holbrooki*), grass shrimp (*Palaemonetes paludosus*), and Florida gar at SRS-2 through 4 and TS/Ph-2.5 and 3 for these analyses. Additionally, samples of grass shrimp, mosquitofish, marsh killifish (*Fundulus confluentus*), and sailfin molly (*Poecilia latipinna*) have also been collected at TS/Ph-6 and 8. We have found extensive variation in $\delta^{13}\text{C}$ values, indicating a possible shift in the relative role of detrital vs. algal components at the base of the food web among study sites. To illustrate spatial variation in isotope signatures, we adjusted the average amphipod value from each site to the grand mean for that species. These data reveal wide variation in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of amphipods both within and among our two experimental transects (Figure II.D.2). This variation may be due to changes in key environmental parameters, to a difference in amphipod diet at each site, or to both. We subtracted the amphipod residual values from data on mosquitofish collected at the same sites to compare food chain length leading to this important omnivore. After adjusting for spatial variation using amphipods, $\delta^{15}\text{N}$ values for mosquitofish varied little among sites ($\sim 2\text{-}3\text{‰}$), with the exception of SRS-4, which exhibited the lowest $\delta^{15}\text{N}$ values of any site. Mosquitofish $\delta^{13}\text{C}$ (also adjusted by amphipod numbers) varied more than $\delta^{15}\text{N}$, suggesting possible differences in the role of detrital versus algal components as the base of the food web along our experimental transects.

E. Soils and Sediments

The central question addressed by the soil/sediment working group is: **How do changes in freshwater flow or the content of source water control organic matter accumulation in freshwater and mangrove wetlands?** The FCE transects along Shark River (SRS) and in the Southern Everglades (TS/Ph) represent two regions with contrasting attributes related to nutrient concentrations, soil type, water residence time, degree of tidal influence, and magnitude of freshwater flow.

Organic matter sources, transport and fate

To assess the potential effects of changes in freshwater flow or the content of source water on soil/sediment organic matter (OM) accumulation at FCE sites, a detailed molecular characterization was performed, with the objective to assess present state OM sources, transport and fate in this system. In this respect, a combination of bulk OM parameters (%OM, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, C/N, ^{13}C NMR and respiration rates) as well as molecular characteristics of the OM (biomarker analysis by GC/MS, compound-specific $\delta^{13}\text{C}$ GC-ir-MS and bulk ^{13}C NMR) were performed on soil/sediment, floc and suspended sediment samples collected along the established FCE LTER transects. Initial molecular, biomarker-based assessments showed clear differences in OM composition and transport between the estuarine sections of the SRS and TS/Ph transects. These differences were mainly explained based on the presence of benthic vegetation and hydrological differences between the two transects. An additional, detailed molecular characterization of the entire transects and of all dominant biomass components was also performed during the 2001-2002 funding period. Our assessment so far has resulted in the calibration of a molecular proxy for the Everglades, which in combination with compound-specific isotope data resulted in an excellent classification of the OM sources within this system. Differences in OM fate were determined using triterpenoid molecular distributions, where red-ox conditions were assessed based on the relative abundance of Des-A-triterpenoids of the Oleanane, Ursane and Lupane series compared to their parent 3-oxi-triterpenoids. This study showed different red-ox conditions between the less anoxic SRS peats compared to the estuarine sediments. In addition, the difference in the molecular distribution of bacterially-derived triterpenoids between the SRS and TS/Ph estuarine environments clearly suggests higher bacterial activities in TS/Ph possibly as a result of the mixture of the mangrove OM with the more bioavailable benthic vegetation, the later of which is absent in the SRS transect.

Overall, our studies so far have resulted in the development and/or calibration of biomass-specific molecular markers and geochemical proxies to be used, in conjunction with compound specific $\delta^{13}\text{C}$ analyses and statistical analyses, as tracers of OM sources in the Everglades system. We are presently continuing to expand this work to assess sources, transformations and dynamics of particulate OM (POC) at the estuarine sites and floc materials throughout the transects. In addition, we have started to assess OM diagenesis both through litter-bag experiments and soil/sediment core analysis. This work is expected to shed light on OM accumulation in the FCE.

Sedimentation and erosion trends

Sedimentation and erosion stations were established at 17 sites within the Florida Bay fringe and basin zones. At each site, sediment elevation measurements were made using the same Sedimentation Erosion Table (SET) technique that is in use at several other coastal LTER sites and numerous coastal locations world-wide. Vertical accretion was measured as the rate of accumulation above feldspar marker horizons laid on the soil surface. Soil cores were collected at each study site to a depth of 20 cm for soil characterization. Preliminary findings suggest that all SET study sites can be grouped into three hydrological environments: dry (occasional inundation), marsh (occasional dry periods) and flooded.

All marker horizons deployed at the marsh and flooded sites indicated that deposition was greater than erosion. In contrast, the markers deployed in the dry forest sites either disappeared or were slightly buried. The rate of vertical accretion at all SET sites ranged from 0.9 to 16 mm yr⁻¹. The average vertical accretion was 2.5, 9.2 and 10 mm yr⁻¹ at the dry, marsh, and flooded environments, respectively. Elevation change for all the Taylor Slough sites was small. At the dry environment, elevation change was -1.5 mm yr⁻¹ suggesting that erosion is a dominant control. Elevation changes at the marsh and flooded environments were 0.7 and -0.1 mm yr⁻¹, respectively. Those values suggest that hydrostatic shrinking and swelling processes, along with root decomposition, may control elevation change. Due to the great variability in the data, there were no significant elevation change differences among the three environmental settings ($p > 0.05$). Shallow subsidence (the difference between accretion and elevation change) was 4, 8.5 and 10.1 mm yr⁻¹ at the dry, marsh and flooded environments, respectively.

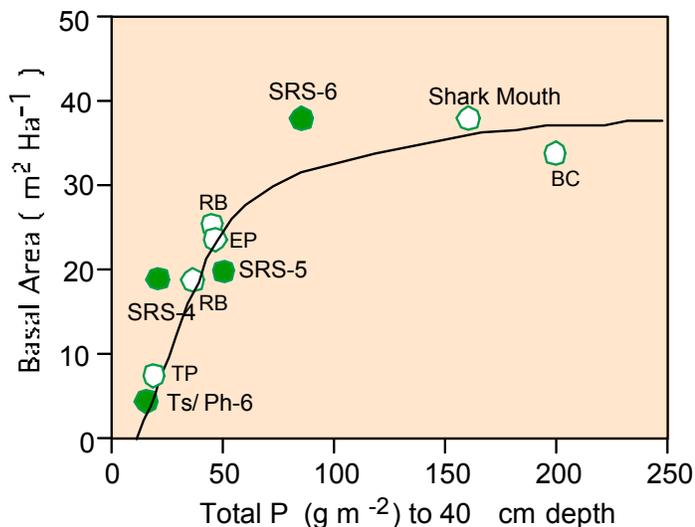
Mangrove zone research

The Everglades land-margin ecosystem in southwest Florida represents a combination of different mangrove ecological types in mainland carbonate environments with gradients in amount of nutrients, hydroperiod and salinity. 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. The mangrove component of the LTER project is addressing research questions to understand the soil organic matter and nutrient pools dynamics along the estuarine gradient in the mangrove region of south Florida.

There is a significant difference in average pore water salinities (December 2000-May 2002) between Shark and Taylor rivers. Seasonal comparisons indicate that TS/Ph salinities range from 15-30 psu during both the rainy and dry season. In contrast, SRS sites show a salinity gradient from upstream (5-10 psu at SRS-4), to downstream (20-30 psu at SRS-6); which is maintained throughout the year. Although NH₄⁺ pore water concentrations are similar in both areas, PO₄⁻ shows a distinct gradient during the rainy season when higher and lower concentrations are observed in SRS-6 (2.4 μM) and SRS-4 (0.3 μM), respectively. As in the case of inorganic nitrogen, total nitrogen was similar in all stations, but total phosphorus (TP) was significant higher in all Shark River stations. The higher TP concentration was measured in SRS-6 (100 g m⁻²) and the lowest in TS/Ph-6 (5 g m⁻²). Due to these differences in soil TP concentration, N:P ratios are higher in the Taylor river sites (>50) than in Shark River (<20). 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). Salinity values indicate that this variable is not a stressor for forest development, but can play an

important role in allowing the establishment of freshwater vegetation, which can compete with mangrove trees for space. Total phosphorous is a critical nutrient determining forest productivity and structure development in both areas. Based on results from previous work and data obtained in the period 2000-2002 we observed a strong relationship between basal area and TP concentrations. Thus landscape distribution pattern and species composition in South Florida may depend on the availability of P resources. How these patterns might be affected due to increasing N input through freshwater diversions into Florida Bay and Shark River needs to be determined and will be evaluated in future work.

Figure II.E.1. Relationship between basal area of mangrove forests and TP of mangrove soils. Data from the SRS 4-6 and Ts/Ph6 stations was obtained in the period 2000-2002. RB=Rockery Bay (Lynch 1989); BC= Boca Chica, Mexico (Lynch 1989); EP =Estero Pargo, Mexico; TP = Turkey Point, FLorida (Snedaker and Brown 1981); Shark River mouth (Chen and Twilley 1999).



Biogeochemistry of OM-iron-sulfur coupling study

The biogeochemistry of iron, sulfur and phosphorus is tied closely to the cycling and preservation of organic matter in soils and sediments. The completed description of these biogeochemical parameters can establish a baseline context within which spatial comparisons among FCE LTER sites/transects can be determined, and against which long-term changes in the Everglades-mangrove-Florida Bay system can be documented. State variable measurements (pool sizes of total organic matter and species of iron, sulfur and phosphorus) will aid in the development of process-based hypotheses to describe the coupling among organic and inorganic elemental cycles.

Our data so far show 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, the 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 (FeS₂, 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, not the iron hydroxide pool. Most organic phosphorus occurs in the recalcitrant pool extracted by ashing/acid hydrolysis. In general, our Fe-S-P biogeochemical studies document how water flow affects delivery of nutrients and removal of reduced toxins in south Florida wetlands with different hydrologic regimes.

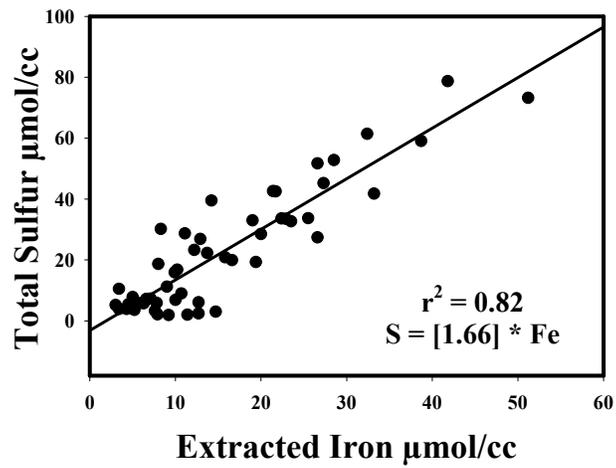


Figure II.E.2: Amongst all FCE LTER sites, the precipitation of sulfide minerals is iron-limited. The dynamics of iron and sulfide mineral formation assists our understanding of organic carbon accumulation and turnover in different wetland environments.

F. Nutrients and DOM Dynamics

Water Quality at Freshwater and Mangrove Wetland Sites

The nutrients and DOM Working Group research is 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?** Water quality samples, analyzed for total nitrogen (TN), total phosphorus (TP), and salinity, are collected using ISCO autosamplers at all wetland sites (that is, all sites except TS/Ph-9, 10, and 11). Additionally, we use the rain level actuators at all freshwater sites to trigger water sampling after rain events exceed a given threshold of duration and/or intensity (≥ 2.5 cm of rain h^{-1}). Rain event samples are collected, treated, and analyzed as all other water quality samples. When sites are visited monthly to collect these samples, we also collect a grab sample that is analyzed for NO_2^- , NO_3^- , NH_4^+ , soluble reactive P (SRP), dissolved organic carbon (DOC), total organic carbon (TOC), TN, and TP. We use these monthly grab samples to generate relationships between TP and SRP, and between TN and $NO_2^- + NO_3^- + NH_4^+$.

Shark River Slough data collection began in 2000, with the initiation of the FCE LTER Program. We focus on these data in this report. The salinity data from the 3 estuarine sites show the seasonality of freshwater inflow as well as a year-round up-estuary decline in GOM influence. During

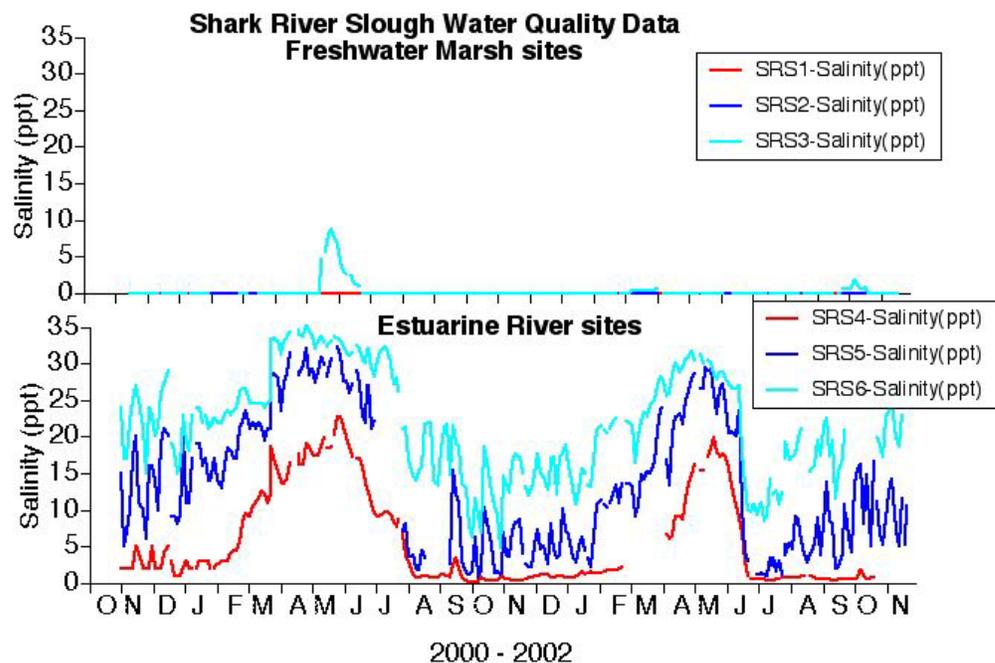


Figure II.F.1. Continuous salinity data from all 6 FCE LTER sites in SRS.

some late dry season periods, the upper oligohaline ecotone site (SRS-3) also experiences measurable salinity (Figure II.F.1). The time-series TP data show routinely higher concentrations at the canal inflow site (SRS-1) relative to the interior freshwater marsh sites (SRS-2 & 3). The SRS estuarine TP data support our central theme of an “upside down” estuary, in which the limiting nutrient is supplied to this oligotrophic estuary by the ocean—TP concentrations at SRS-6 are typically higher than at SRS-5, where they typically exceed those at the lower ecotone site (SRS-4; Figure II.F.2). Total N concentrations are considerably higher at the freshwater sites. During the wet season, we see declining TN down transect, suggesting N

uptake by the freshwater marsh when water is flowing down the slough. In the absence of flow during the dry season, though, the marsh appears to be a source of TN to the water column (likely as DON; Figure II.F.3). The estuarine TN pattern is opposite that of TP—SRS-6 typically shows the lowest TN concentrations, and TN generally increases up-estuary to the lower ecotone site (SRS-4; Figure II.F.3).

Figure II.F.2. Continuous total phosphorus data from all 6 FCE LTER sites in SRS.

With approximately one year of grab samples analyzed for all nutrients, we found a few significant relationships with TN and TP, which are sampled continuously (Table II.F.1). The canal inflow site (SRS-1) was the only freshwater site for which we found significant relationships between oxidized DIN constituents and TN, but this relationship did not hold for NH_4^+ . Interestingly, the only TN- NH_4^+ relationship occurred at SRS-5, in the central estuary. We found significant TP-SRP relationships at SRS-4 and SRS-5, but not at the site closest to the GOM (SRS-6). We found very strong relationships between TOC and DOC concentrations at all sites, and found that consistently 95 – 98% of TOC is DOC (Table II.F.1). As we continue these datasets, and begin to capture both seasonal and inter-annual patterns in dissolved versus total nutrients, we expect to see more of these surrogate relationships become significant.

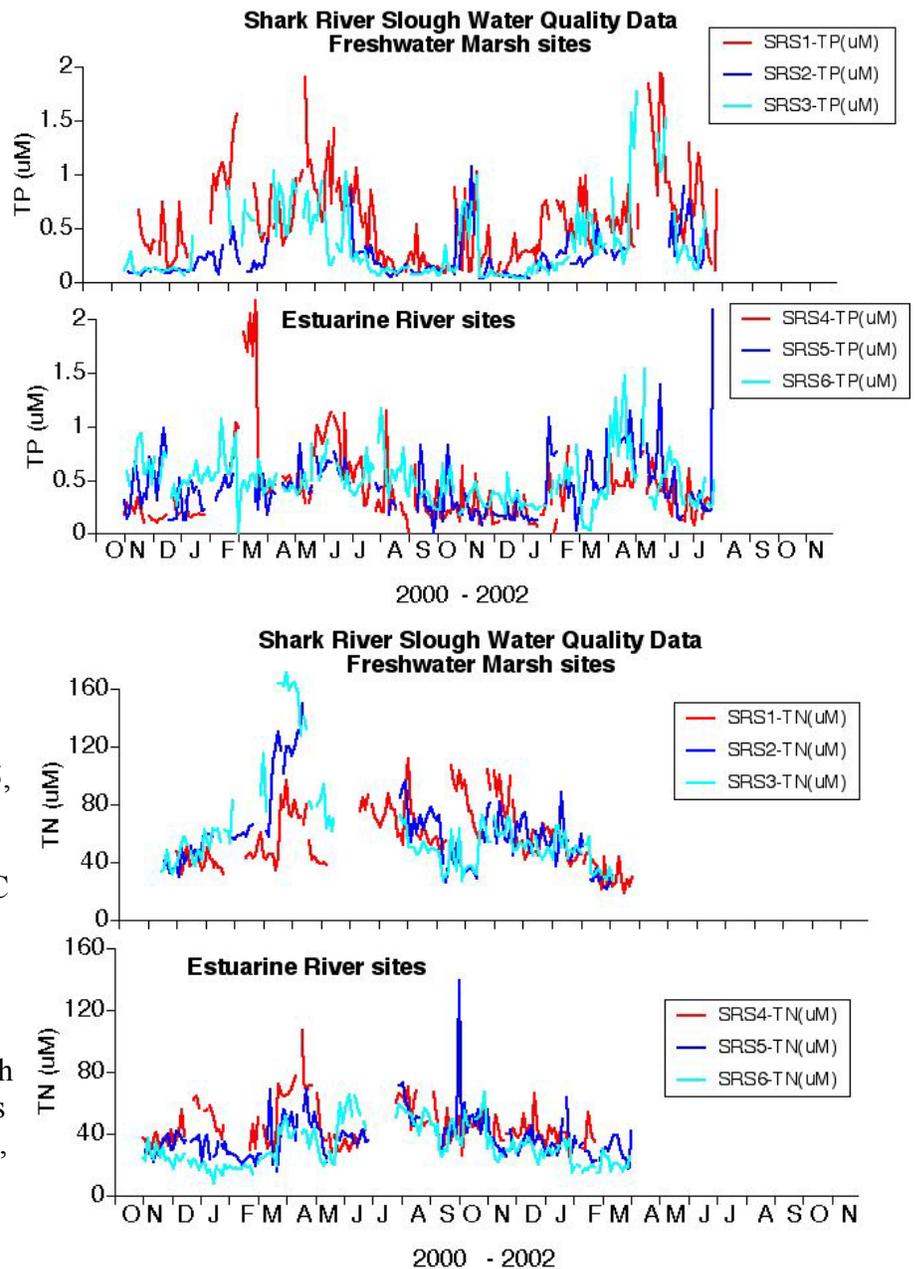


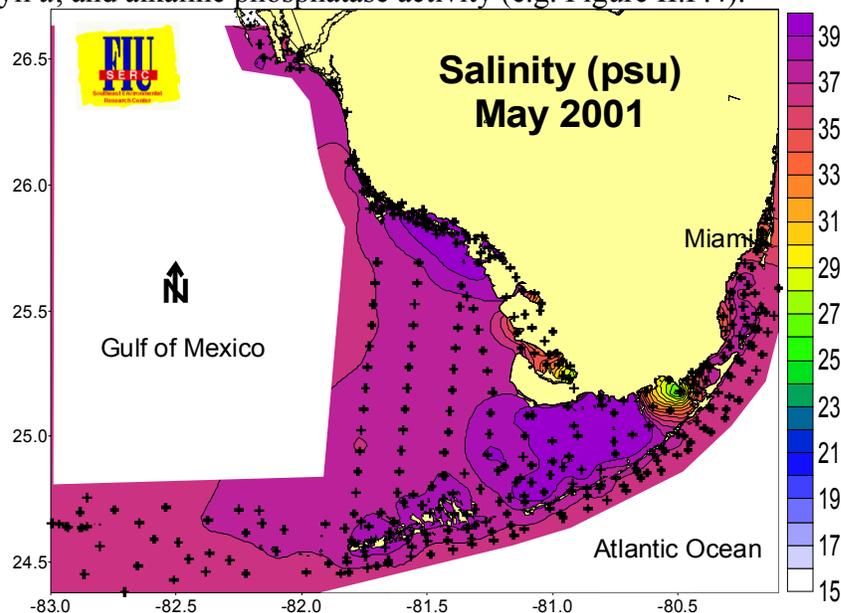
Figure II.F.3. Continuous total nitrogen data from all 6 FCE LTER sites in SRS.

Table II.F.1: Relationships among dissolved N and P constituents and TN and TP from monthly grab samples at all FCE wetland water quality sites.

Site	Equation & Variables	p-value	n	R ²
SRS-1	[NO3] = 0.08[TN] - 2.07	0.02	7	0.72
SRS-1	[NO2] = 0.007[TN] - 0.15	0.047	7	0.58
SRS-1	[NN] = 0.88[TN] - 2.22	0.02	7	0.72
SRS-1	[DOC] = 65.9 + 0.95[TOC]	<0.0001	12	0.93
SRS-2	[DOC] = 78.7 + 0.93[TOC]	<0.0001	11	0.97
SRS-3	[DOC] = 1.03[TOC] - 48.6	<0.0001	12	0.99
SRS-1, 2, & 3	[DOC] = 57 + 0.95[TOC]	<0.0001	35	0.98
SRS-4	[SRP] = 0.003 + 0.098[TP]	0.05	10	0.40
SRS-4	[DOC] = 49.2 + 0.95[TOC]	<0.0001	14	0.94
SRS-5	[SRP] = 0.13[TP] - 2.67	0.047	11	0.37
SRS-5	[NH4] = 0.18 + 0.05[TN]	0.06	8	0.47
SRS-5	[DOC] = 2.07 + 0.99[TOC]	<0.0001	14	0.97
SRS-6	[DOC] = 9.2 + 0.97[TOC]	<0.0001	14	0.98
SRS-4, 5, & 6	[SRP] = 0.008 + 0.077[TP]	0.02	29	0.20
SRS-4, 5, & 6	[DOC] = 8.5 + 0.98[TOC]	<0.0001	42	0.98

Water Quality at Florida Bay Subtidal Sites

Water quality is being characterized at TS/Ph-9, 10, and 11 on a monthly basis, and we supplement our continuous water quality data at SRS-4, 5, and 6 with similar monthly sampling, in conjunction with SFWMD funded project ([Water Quality Network](#)). Sampling includes collection and analysis for temperature, salinity, dissolved oxygen, nitrate, nitrite, ammonium, total organic nitrogen, total phosphorus, soluble reactive phosphorus, silicate, total organic carbon, chlorophyll *a*, and alkaline phosphatase activity (e.g. Figure II.F.4).



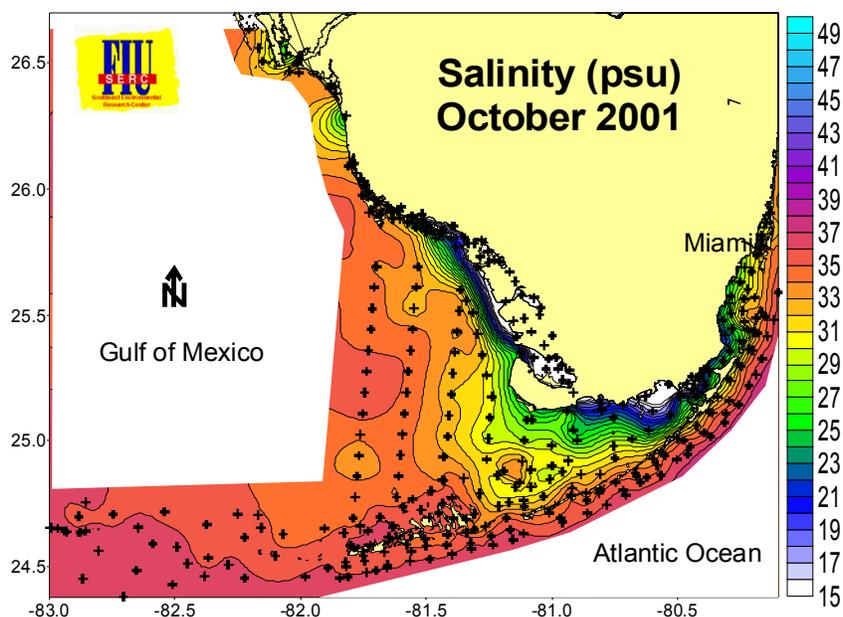


Fig. II. F. 4. Regional salinity patterns during dry and wet seasons of a highly variable year.

Molecular characterization and dynamics of dissolved organic matter (DOM)

DOM is a key component in the biogeochemical cycling of nutrients in the Everglades, and in fact is believed to fuel the microbial loop (Figure II.F.6). As such it is surprising how little attention the molecular characterization of this DOM has received. Therefore, much of our efforts during the first three years of the FCE LTER focused on this task, which is key to understanding the origin, transport, and fate of DOM and, thus, to interpreting the impact of hydrologic changes on this important water quality parameter.

The molecular characterization of DOM at the FCE LTER sites uses a multi-methods approach in combination with the monitoring of several optical and chemical parameters. The molecular characterization is being performed on biannual sampling events that intend to produce data representative for the dry and wet season in the Everglades ecosystem. It focuses on several analytical techniques used to characterize molecular features for bulk DOM isolated through ultrafiltration (>1,000 Dalton). The techniques we have used so far are solid state ^{13}C -NMR and ^{15}N -NMR, on line pyrolysis-GC/MS, TMAH chemothermolysis, analysis of hydrolyzed sugars by GC/MS and 2D-electrophoresis of proteins. Our results show 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. 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 (Figure II.F.5).

We have also been quantifying 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. These parameters allow 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.

The main sources of DOM in the FCE are a combination of plant biomass and soil leaching. Such DOM is likely affected by photochemical and microbial transformations. We have started to study these diagenetic processes and how they affect the composition of DOM in this system. In this work, we are quantifying the role of photochemical and microbial processes to the transformation of DOM derived from various plants that dominate the Florida Everglades. Plant biomass leachates are exposed to photochemical and microbial treatments and the response of the organic matter is characterized through optical, chemical, and biological analyses. We have found that protein content of DOM decreases exponentially, with microbial [dark] decay rates ranging from 1.0 day^{-1} for seagrass to 0.11 day^{-1} for sawgrass. Similar decreases in polyphenol content and dissolved organic carbon (DOC) concentration also occurred, but bacterial numbers remained relatively constant. Molecular weight (MW) analysis suggests that samples containing relatively large proportions of both high and low molecular weight structures are especially susceptible to microbial degradation processes—Both high and low MW compounds decreased exponentially over the incubation period for most samples. Conversely, medium and high MW components increased during the incubation period in mangrove leachate samples, which we attributed to a physical polymerization reaction. Our data suggest that large protein structures and smaller polyphenol compounds (two major constituents of the plant biomass at FCE sites) are consumed via different pathways. Recalcitrant polyphenol structures of plant material undergo both photochemical and microbial degradation while the major sink for large MW protein structures appears to be limited to physical and microbial processes.

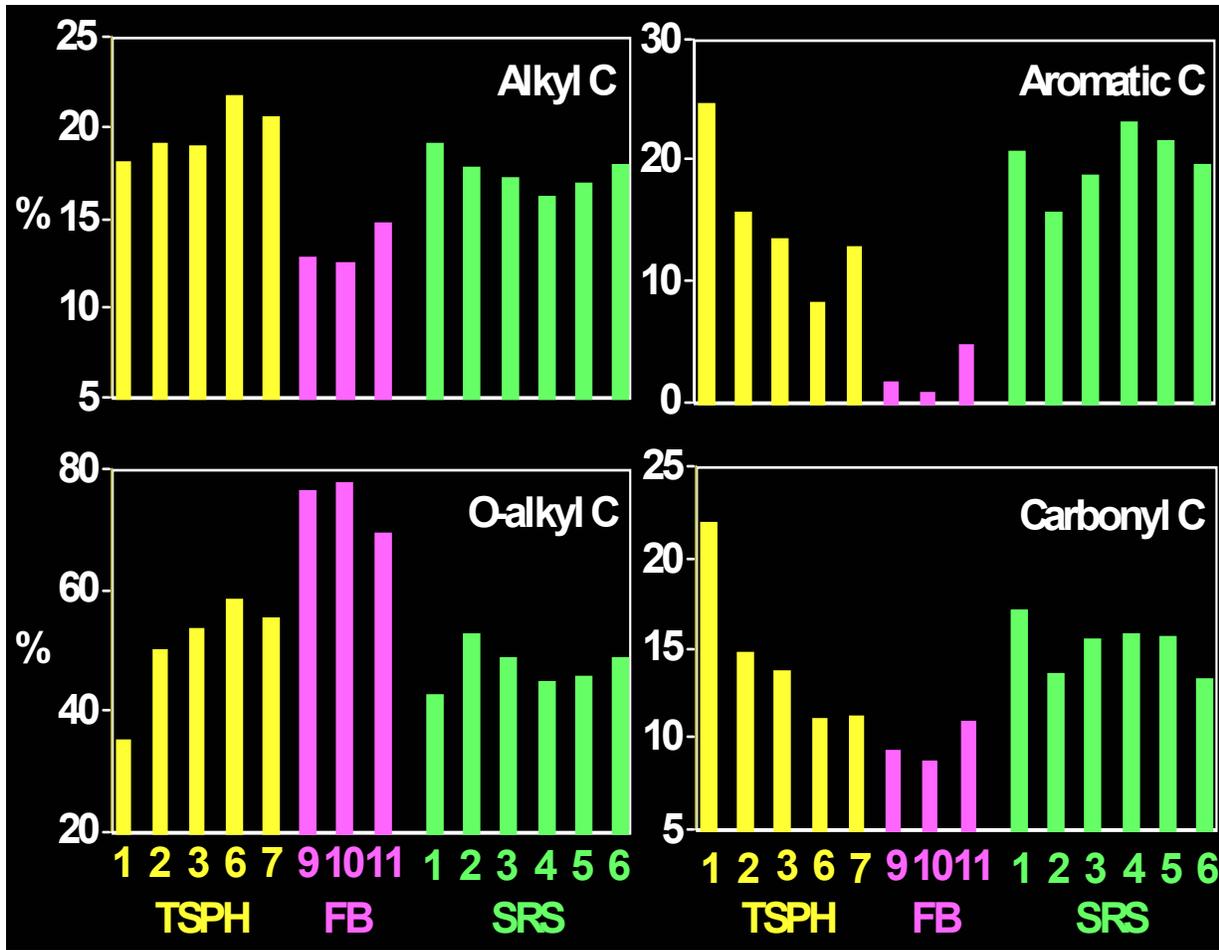


Figure II.F.5: ^{13}C -NMR based molecular characteristics of high molecular weight (> 1,000 Dalton) dissolved organic matter at the FCE LTER sites (FB corresponds to the TSPH sites 9, 10 and 11 located in Florida Bay).

Microbial Ecological Processes

Our current focus is how the microbial loop is related to organic matter cycling in the system. We hypothesize that the microbial loop operates differently in this oligotrophic ecosystem with allochthonous carbon inputs than the classic marine microbial loop driven by autochthonous inputs. Rather, it is the bioavailability of the DOM that drives the system (Figure II.F.6). Of all 17 FCE sites, we have observed the highest DOM bioavailability at the lower ecotone site of the SRS transect (SRS-4). Bacterial consumption incubations here showed a strong relationship between the loss of TOC and increase in bacterial density ($r^2=0.79$),

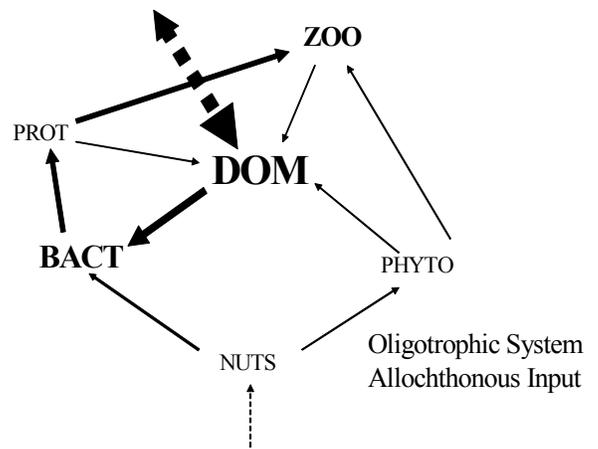


Figure II.F.6: Conceptual model of the Everglades microbial loop

suggesting a tight coupling of TOC uptake and bacterial growth where fresh and marine waters meet in SRS. We also found that the bioavailability of organic carbon in the water column is more variable at the SRS estuarine sites (SRS-4 through 6) than in Florida Bay (TS/Ph-9, 10, and 11). Along the TS/Ph transect, we found that the bioavailability of TOC was highest in central Florida Bay, at TS/Ph-10 while the lowest TOC bioavailability was in northeastern Florida Bay (TS/Ph-9). Interestingly, we also found that TOC bioavailability was temporally most consistent across at TS/Ph-11—the most marine FCE site in Florida Bay.

Bacterial counts at the 17 FCE LTER sites may be characterized as follows:

- Shark River Slough Transect Sites 1,2,3: highest bacteria count along transect at Site 1 but only in March. Drydown in May in the middle of the transect with highest bacteria numbers occurring upon rewetting of the marsh in June
- Shark River Transect Sites 4,5,6: Some evidence to suggest higher bacteria densities are associated with higher salinity (Sites 5 and 6). Peak bacteria numbers in December and July
- Taylor Slough Transect Sites 1,2,3: Bacteria numbers higher at mid freshwater transect points (Higher at sites 2 and 3 than 1).
- Panhandle Transect Sites 4 and 5: Site 5 had consistently lowest bacteria density over the sampling period and there was less of a seasonal effect at these two sites than other sites along transect.
- The Taylor River Transect Sites 6,7,8: Highest bacteria density of transect reported at Site 7 with a wet season peak in October. All three of these sites had peak bacteria density in October
- The Taylor Slough Transect Sites 9, 10, and 11: Bacteria Counts were the highest at site TS/PH 11 and lowest at site TS/PH9. Some evidence that bacteria densities increase from eastern to western end of transect (Bacteria counts increased from sites TS/PH 9-11)

Bacterial Production at the 17 FCE LTER sites

- Shark River Slough Transect Sites 1,2,3,4,5,6: Heterotrophic bacteria production is highest at SRS 1 and lowest at SRS 3. The most interior freshwater site (SRS3) consistently had the lowest bacteria production of all SRS sites. Highest heterotrophic bacteria production along SRS FCE transect observed at SRS5 in the wet season but only in 2001, and SRS 1 in the wet season in 2002
- Taylor Slough Transect Sites 1,2,3: Highest production of these three sites in Dec 2001 though same peak not observed in 2002. Drydown Jan through May 2002
- Panhandle Transect Sites 4 and 5: Highest bacteria production in wet season in both 2001 and 2002. Drydown Jan through May 2002
- Taylor River Transect 6,7,8: Highest observed bacteria production along TS transect was site FCE TS/Ph 6 during the dry season in 2002. Highest production for all 3 sites observed in dry season
- Taylor Slough Transect Sites 9, 10, and 11: Heterotrophic bacteria production highest at westernmost point along transect and lowest closest to Taylor Slough. Seasonal pattern of higher production in the wet season with peak production in 2002 wet season at all 3 TS/Ph 9,10,11 sites

III. INFORMATION MANAGEMENT

A. Information Management Objectives

The main objective of the FCE LTER Information Management System (IMS) is to provide a centralized network of information and data related to the coastal Everglades ecosystem. Given the potentially important role that the FCE LTER program may play in Everglades Restoration, another important objective is to increase public and private awareness of our Everglades research activities. The FCE Information Management Group has established a set of IMS level protocols and services for data collection, quality assurance, data organization, data archive, data access, and data distribution to facilitate our scientific work and to ensure the integrity of the information and databases resulting from the research. These are formalized in the [FCE Data Management Policy](#).

B. Information Management Facilities

The FCE LTER Office has 3 NT servers with a total storage capacity of 412 Gigabytes and an addition 160 Gigabytes of storage between two desktop workstations. Connectivity within the FCE LTER Office is a gigabit switched Ethernet Network (Florida International University Computer Science Network). The FCE Information Management Group consists of one full-time Information Manager (Linda Powell), one full-time Program Manager (Mike Rugge), and two part-time IM associates (supported on LTER related grant funds) who handle FCE systems administration and JAVA program development (Phil Bayer and David Iwaniec).

At this time, the FCE LTER data and metadata files from individual research studies are stored in a hierarchical flat file directory system. FCE project information and minimal research data metadata are stored in an MS Access database that is used to drive the FCE Web site. An Oracle9i database schema is currently in development. Once the schema is complete and the database implemented, all flat file data and metadata will be migrated to the Oracle9i relational database. It is our intent to retain the flat files so that the web site users, general public and FCE researchers, will have an option to download complete data files originally submitted by individual scientists in addition to downloading queried data from the Oracle9i database. All FCE servers and workstations undergo continual updates and patches to their operating systems. There is a secure socket layer (SSL) on all servers and all FCE computers have dynamic firewalls. The FCE IMS implements 3 levels of data protection and has a response and recovery procedure developed for 30-minute response time and 10-hour recovery time (Figure III.B.1).

Figure III.B.1: Conceptual diagram of the FCE data protection and data recovery procedures.

C. Information Management Procedures

There are data and information contributions being made to the FCE IMS from 7 designated working groups. Researchers within these workgroups are responsible for quality assurance, data entry, validation, and analysis for their respective projects. The Oracle relational database has been designed to accommodate the diverse spatial and temporal heterogeneous data submitted by the FCE researchers. Minimal data submission requirements described in the [FCE Data Submission Information Document](#) allow individual FCE

scientists to maintain their own specific research procedures and protocols that were established prior to the start of the FCE LTER program.

Data submitted to the Information Manager undergo IMS quality assurance and quality control procedures (Figure III.C.1) whereby the data and metadata are thoroughly examined to ensure that the data fields and values are correctly described by the metadata. These data are then converted into ASCII text (if not already submitted as ASCII) and loaded into the Oracle9i database. Metadata and data values are then combined into one ASCII text file for archival purposes.

It is recognized within the FCE LTER Program that our researchers have first priority for use of their data in publications but they are encouraged to make their data publicly available as soon as possible to enhance collaborations and synthesis. The FCE Information Management protocol is thoroughly described under the Data Distribution section of the [FCE LTER Program Data Management Policy](#).

Public access to the FCE LTER data and information for the scientific community at large is provided through the FCE LTER web site. Our web site has been active since March 2000 and consists of a variety of information including the FCE LTER Program overview, personnel, maps, data, publications, job announcements and Everglades related links. A comprehensive FCE LTER web site [map](#) quickly refers web users to their area of interest.

All FCE LTER personnel have access to our password protected [Intranet](#) site. Researchers can browse the site for information on field schedules, FCE personnel, publications, discussions, resources and data. The intranet [data section](#) contains data submission information, metadata template downloads, and a tool to upload data directly to the web server for storage until retrieval by the Information Manager.

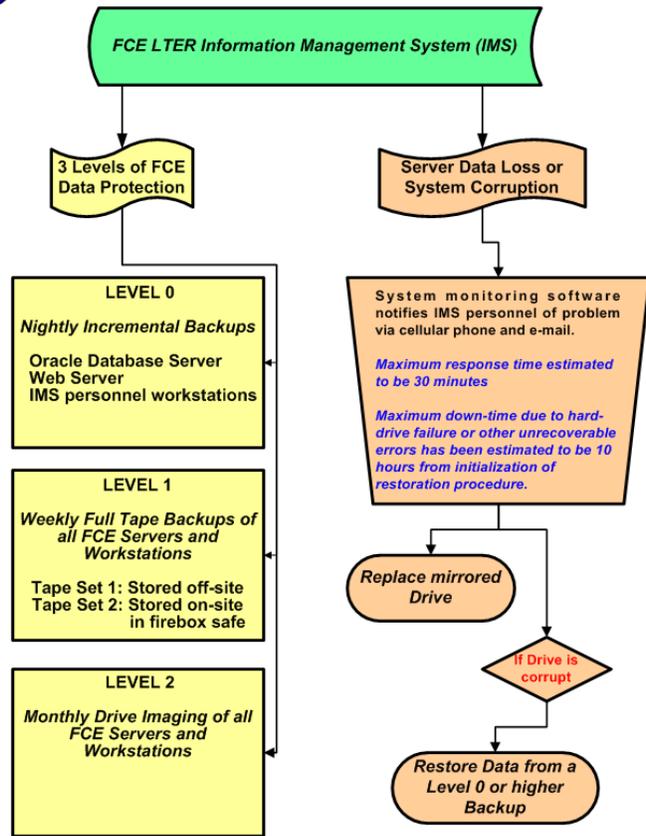
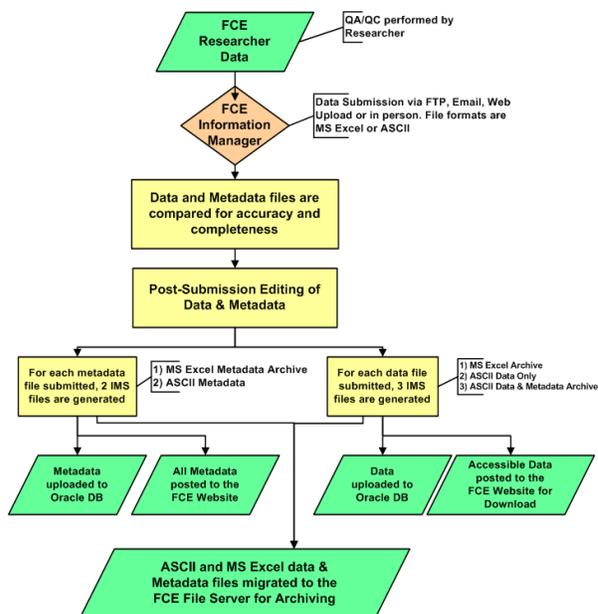


Figure III.C.1: Conceptual diagram of the FCE procedures for the submission, processing, and publishing of data.

D. Future Goals

Our largest on-going and future projects are related to the conversion of the IMS to a relational system and include completing the Oracle9i database schema, migrate the schema of existing projects and research data to the Oracle database, and develop a 3-tiered web-application for performing relational queries and database updates (Figure III.D.1). Other projects include building and adding FCE GIS data layers to the Oracle database, publishing the FCE ArcIMS project (currently in development) to our website, and adding analysis and synthesis tools to the website whereby queried FCE data could easily be manipulated real-time.

FCE LTER IMS Data Procedures



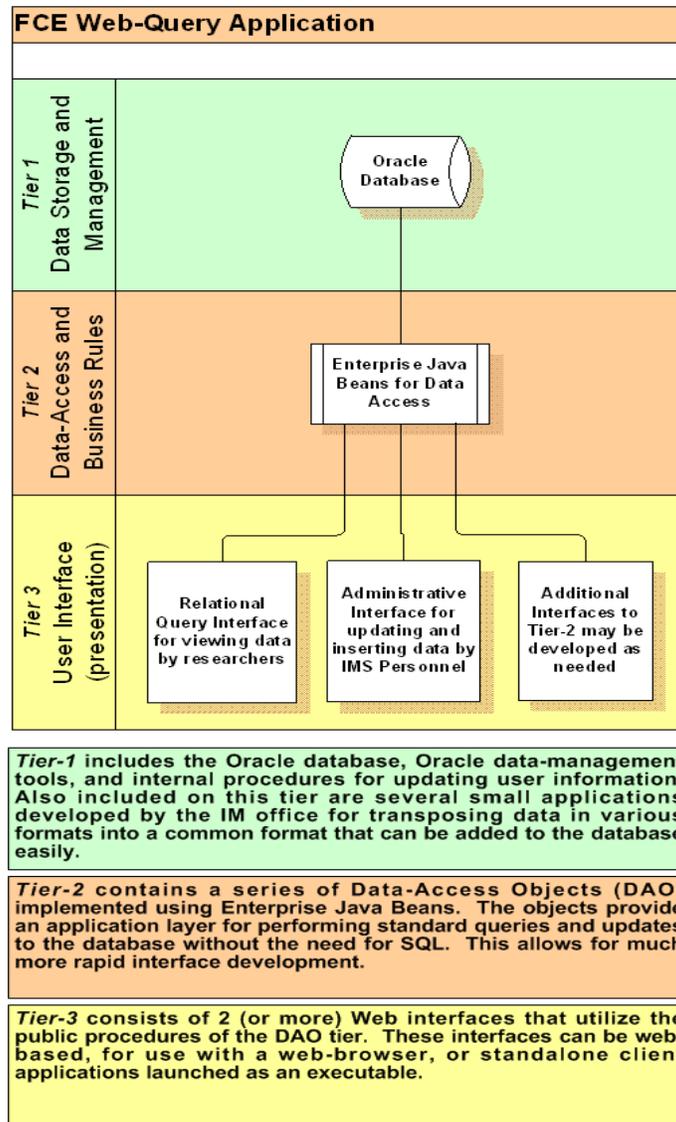


Figure III.D.1: Description of the 3-tiered web query application currently being developed and tested by FCE IM staff. This application will allow Oracle database access directly via the web with a fully interactive data query front end. It will also greatly facilitate database entry and updating procedures.

IV. EDUCATION & OUTREACH ACTIVITIES

A. Educational Activities

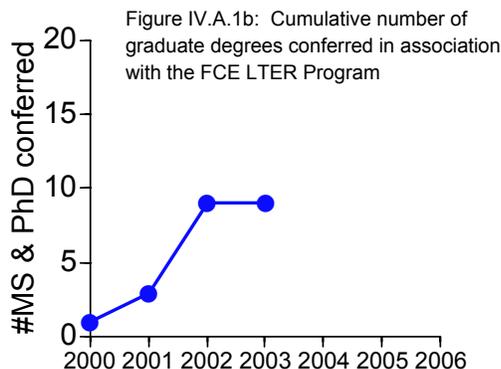
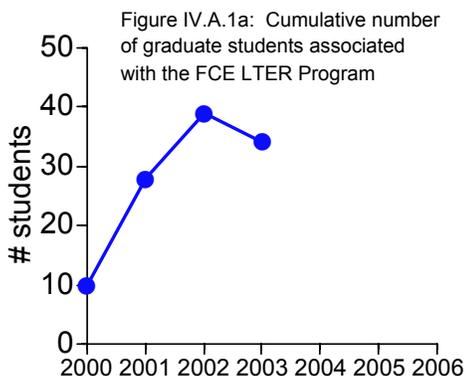
The FCE Schoolyard LTER program, funded each year with supplemental funds from NSF, is the centerpiece of our educational effort. Our first Schoolyard program, in Summer 2001, funded high school teachers and students to spend part of their summer working in the lab of an FCE scientist. Our primary focus was on Felix Varela Senior High in west Miami Dade, but teachers from at least two other local high schools also participated. The program also included travel support for both teachers and students to attend the Estuarine Research Federation Conference in St. Petersburg, FL, in November 2001. Last year's program (Schoolyard 2002) focused on a cooperative arrangement with the Miami Museum of Science. We worked with Museum staff to put together a "virtual field trip" program in which inner-city secondary school students could follow along with field trips by real-time webcam broadcast from the field to a classroom at the Museum. The objective of this program was to allow these students to experience the Everglades and field research in this unique ecosystem by taking a satellite web camera in the field rather than taking the students themselves. Our proposal for Schoolyard 2003 involves a similar collaboration with the environmental education staff at Everglades National Park. It is our expectation that this, more natural educational interaction will become more permanent, allowing us to bring stability to the FCE Schoolyard program for years into the future.

The FCE Research Experience for Undergraduates (REU) program is also funded annually by supplements from NSF. We funded 3 students in 2001 and 2002, and have requested funding for 2 students for Summer 2003 (the maximum allowed by NSF this year). In 2001, REU students worked with J. Fourqurean, R. Jaffé, and D. Childers. In 2002, W. Anderson, E. Gaiser, and J. Richards had REU students, and our 2003 supplemental proposal is to award REU support to J. Fuentes (UVA) and R. Price. 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.

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). Many UMEB students interact with the FCE LTER Program because their UMEB mentors are also FCE scientists. This synergy enhances both programs, and provides a unique 1.5-2 year research opportunity for these students that allows them to conceive, design, carry out, and complete publishable research projects. FCE scientists are also actively working with a larger group to secure IGERT funding for a program that will similarly interface with the LTER research program. All told, a total of 29 undergraduate students and 4 high school students have had some degree of interaction with the FCE LTER Program to date.

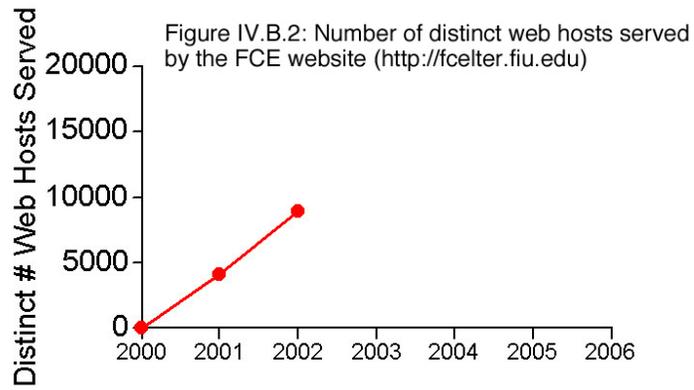
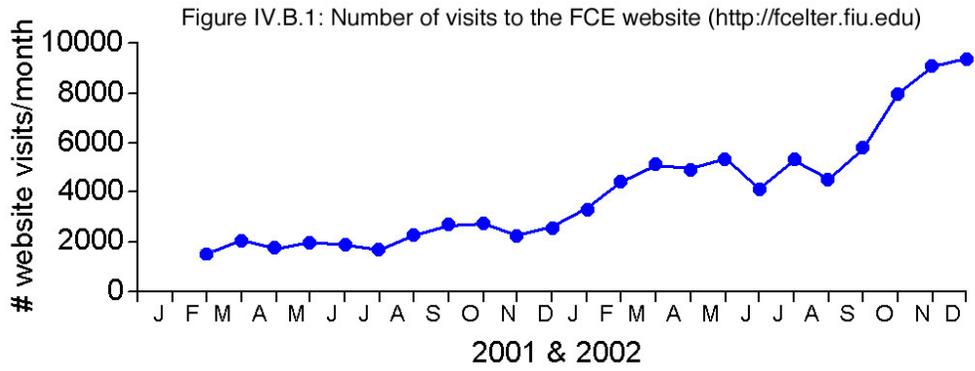
Graduate education is a very important component of the FCE LTER program, and our graduate students maintain their own very active FCE Affiliated Student Group. We currently have nearly 30 graduate students, from 7 different universities, who are affiliated with FCE (Figure IV.A.1a). Between 2000 and 2002, we have observed a non-linear increase in the cumulative number of graduate degrees conferred from FCE-based thesis/dissertation research (Figure IV.A.1b). In fact, the apparent drop in number of students (Figure IV.A.1a) is largely

related to a number of students graduating in late 2002. This group (which also includes interested undergraduate students and at least one high school student) 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 (see Section V. below).



B. 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 at 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; nearly 25 such presentations and training activities have been logged to date ([Outreach Activities](#)). The LTER Network Office publications staff assisted us with a site brochure in 2000, and we encourage all FCE scientists, students, and staff to use these as a “hand-out” tool for outreach. Another important mechanism by which the FCE LTER Program reaches out to more general audiences is through our web site. The number of visits to <http://fcelter.fiu.edu> per month has been steadily increasing since we brought the website online, although the data do follow some interesting intra-annual cyclical patterns (Figure IV.B.1). The number of datasets available through our website increased markedly in Fall 2002, and the marked increase in monthly visits in late 2002 suggest that these data resources were quickly found and utilized. A better long-term measure of the outreach capabilities of our web resources is the temporal trend in number of distinct web hosts serviced by the FCE website each year (Figure IV.B.2). In the first 2.5 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. Finally, because all FCE scientists and students are, to some degree, also involved with Everglades restoration, all of our research activities are inherently public outreach since our work should influence this [publicly-funded] restoration effort.



V. CROSS-SITE AND NETWORK-LEVEL ACTIVITIES

A. Cross-Site Activities

The third decade of LTER (2001 – 2011) has been designated “The Decade of Synthesis”. One means to this end is greater numbers of multi-site LTER activities. FCE has been involved with several types of cross-site activities: 1) those coordinated by FCE and involving many FCE scientists and students; 2) those coordinated by other sites and involving a few FCE scientists or students, and; 3) cross-site activities with non-LTER scientists or sites. The primary cross-site activity hosted by FCE, and funded by the Network Office, was a two-workshop series that we called the Caribbean Initiative. We invited scientists and coastal resource managers from a number of key coastal systems around the Caribbean first to FIU, in March 2001, then to Lafayette, LA, in March 2002. The goal was to foster cross-Caribbean collaborations, enhance interactions and activities, and to synthesize existing information about Caribbean coastal systems into a template for coordinating regional long-term research and effective management of coastal ecosystems. Scientists from Puerto Rico, Venezuela, Colombia, Panama, Belize, Mexico, and the U.S. attended. An important product of the Caribbean Initiative will be a many-authored Bioscience manuscript, which will soon be submitted (Rivera-Monroy et al., in prep.). In all, FCE scientists have been involved in eight cross-site scientific initiatives ([Cross-Site & Network Activities](#)).

B. Network-Level Activities

FCE scientists, students, and staff have been particularly active at the network-level, including governance, program development, and research enhancement ([Cross-Site & Network Activities](#)). FCE participation in Network governance includes Tiffany Gann, who was elected co-chair of the Network-wide Graduate Student Organization in Fall 2002 (and is thus a member of the Network Coordinating Committee) and Dan Childers, who was elected to the Network Executive Committee in Fall 2002. Linda Powell, the FCE Information Manager, has been very active at the Network level through her participation in ClimDB data enhancement, participation in metadata and IM workshops, and by acting as co-editor of the Network-wide Information Management newsletter “Databits”. The FCE Affiliated Student Group received a grant from the FIU Student Government Association to organize and host a mixer and workshop for coastal LTER students at the 2001 Estuarine Research Federation Conference in St. Petersburg, FL. Other Network-level activities include participation in all Science CC meetings that have been held since FCE began (as well as all CC meetings in general), regular contributions to the Network LTER Newsletter, and participation on the 2003 Network All-Scientist Meeting Program Committee (Tiffany Gann, Dan Childers; [Cross-Site & Network Activities](#)).

VI. FCE PROGRAM ADMINISTRATION AND GOVERNANCE

A. FCE Program Organization

As with all aspects FCE LTER Program administration and governance, program organization is set by the [Guidelines for Program Administration & Management](#). FCE is structured around a scheme that closely parallels the original proposal. There are seven Working Groups (WG), five of which align with the 5 core hypotheses in the proposal: Primary Production, Consumer/Trophic Dynamics, Nutrients and DOM, Soils and Sediments, and Modelling/Synthesis. In addition, we have two additional WG for Abiotic Factors (most notably of which are climate and hydrology) and Education/Outreach. All Senior Scientists and students are asked to align themselves with at least one WG, and much of the daily communications, field logistical coordinations, and data analytical discussions occur within these groups. Each Working Group has a direct link to program administration and governance through its WG leader (see below), following a democratic republic style of representation. Each WG also has access to resources through both the WG leader and through the FCE LTER Office itself. In addition to WG-specific communications, program-wide communication occurs very regularly, and is facilitated by list-serve email distribution lists for all FCE personnel, senior scientists, students, and technical staff.

We facilitate cross-WG interactions, data synthesis, and idea incubation with our annual FCE All Scientist Meetings. These meetings are traditionally held in Miami, where many [but certainly not all] FCE scientists, students, and staff are based. The first full, 2-day FCE ASM was held in March 2002 at the Kovens Conference Center on FIU's Biscayne Bay Campus ([2002 ASM](#)). The theme was "Integration and Experimentation", with the objectives of encouraging cross-WG interactions and synthesis, and highlighting existing experimental research while stimulating ideas for future experiments. The [2003 FCE ASM](#) was held in January 2003 at Fairchild Tropical Garden. The theme of this 2-day conference was "Where We've Been – Where We're Going". The objective of this Year 3 ASM was preparation for our 3-Year NSF Review.

B. FCE Program Administration and Governance

Very early on, it became clear that a stable, dependable structure for the administration, organization, and governance of the FCE LTER Program was essential. Before our NSF contract had officially begun, we had established a programmatic "constitution" called the [Guidelines for Program Administration & Management](#). These guidelines stipulate that all major programmatic decisions will be made or overseen by an Internal Executive Committee (IEC). This committee is made up of seven voting members, each of whom is a Working Group leader. At present, these members are: Evelyn Gaiser (Primary Production WG), Joe Boyer (Nutrients & DOM WG), Kelsey Downum (Ed/Outreach WG), Jim Fourqurean (Abiotic Factors WG), Rudolf Jaffé (Soils & Sediments WG), Fred Sklar (Modelling/Synthesis WG), and Joel Trexler (Consumer WG). The IEC also includes a non-voting external member, to provide objective guidance and leadership (this position is currently held by Bruce Hayden, Lead PI of the VCR LTER, Univ. Virginia), a non-voting representative of Everglades National Park (currently Robert Johnson, Director of Research at ENP), and a non-voting student representative (currently Tiffany Gann,

the FCE student representative to the Network student group). IEC membership is non-term for voting members, but members may rotate on or off the committee at the behest of their Working Group (who elect them). The IEC is responsible for such responsibilities as: 1) approving the addition of new Senior Scientists to the FCE Program; 2) approving support for related proposals via a formal Letter of Support, written by the Lead PI; 3) approving substantive changes in fiscal resource allocations; 4) approving changes in the Data Management Policy and Administrative Guidelines, and; 5) approving substantive changes in programmatic direction, among others. Votes are either majority or two-thirds majority, depending on the gravity of the decision (see [Guidelines for Program Administration & Management](#) for details).

The Lead PI is contractually responsible for the FCE LTER Program to NSF and to the FIU administration, and is thus the defacto leader of the FCE LTER Program. However, all major decisions are made by the IEC (although generally at the request of the Lead PI, who notably does not have a vote on the IEC). The Lead PI serves at the behest of the IEC, and the Lead PI may be replaced by the IEC. The lead PI is the sole site contact for communications with NSF Program Officers and contracting personnel and the LTER Network Office, and is by definition the FCE representative to the Network Coordinating Committee.

It is notable that, historically, the root cause of non-renewal of LTER sites or of renewal problems at sites (i.e. probationary status at renewal) is a void [or the appearance of a void] in leadership. At FCE, we fully recognize the extreme importance of strength, consistency, and stability in programmatic leadership and governance. The [Guidelines for Program Administration & Management](#) and the IEC provide these for governance, and the Lead PI provides these for leadership. We value the importance of long-term stability in leadership, and recognize that this requires a plan for inevitable turnover of the Lead PI position at some point. We are a relatively young group (relative to typical LTER sites, that is), and we constantly strive to bring junior level faculty into governance and leadership roles so as to provide ample options for future changes in the Lead PI position. Our approach to distributed decision-making and governance responsibilities assures that, when the time comes, we will have a number of very viable and qualified candidates to take over leadership of the FCE LTER Program.

C. FCE Infrastructure and Office

The FCE LTER Program is run through an independent office housed on the campus of FIU. The office is the home of the Program Manager (Mike Ruge) and the Information Manager (Linda Powell). The office is responsible for all primary administrative duties of the program, and is run with funds in an Infrastructure budget (see below). In addition to the website and database support already discussed, the FCE LTER Office provides a number of services to FCE personnel, including: 1) field logistical coordination and support; 2) ENP sampling permit administration; 3) travel funding and logistics; 4) communications coordination; 5) outreach support; 6) subcontract administration; 7) budget and accounting assistance to PIs, and; 8) assistance for off-site scientists and staff, among others. The office maintains key equipment and supplies that are available to all FCE personnel, including a field cell phone, a field satellite phone, field first aid/safety kits, a computer projector, a slide projector, laptops and desktop computers, and a fire-proof safe.

D. FCE Budget and Institutional Support

The annual NSF budget is divided into 8 subaccounts at FIU. The Infrastructure account is used to run the FCE LTER Office, and includes funding for: 1) staff salaries; 2) conference and meeting travel; 3) equipment replacements and upgrades (primarily for data storage and web servers); 4) supplies, including funds for poster printing and software upgrades/purchases; 5) maintenance of field support equipment (i.e. the cell and satellite phones) and helicopter time; 6) funds for the annual FCE ASM; 7) all subcontracts, and; 8) all supplemental funds received from NSF. The other 7 subaccounts are subcontracts to Randy Chambers (College of William and Mary) and Robert Twilley (University of Louisiana – Lafayette), and FIU research accounts to Joe Boyer, Dan Childers, Jim Fourqurean, Rudolf Jaffé, and Joel Trexler—each of whom was a primary PI on the original proposal. Each is the sole signatory on their own FCE research subaccount, although the Lead PI is ultimately responsible to the FIU administration and to NSF for the entire budget. The Lead PI is signatory on the Infrastructure account.

The FIU administration, through the Division of Sponsored Research and the College of Arts & Sciences, has always been very supportive of the FCE LTER Program. FIU is effectively returning all of its indirect costs to the FCE Program as institutional match. Direct cash return comes in the form of: 1) the salary of the Program Manager (including fringe benefits); 2) 25% salary for an administrative secretary and an accountant in the SERC office; 3) tuition waivers for 3 graduate students; 4) substantial travel funds, and; 5) some funding for undergraduate hourly help. FIU provides additional [-cash] programmatic support through faculty salary match and indirect costs on match.

VII. SITE REVIEW AGENDA AND SCHEDULE

Tuesday March 18:

Panel arrival day, dinner with NSF Program Officers.

Wednesday March 19:

600 AM Breakfast with NSF Program Officers at hotel
630 AM Van pickup at hotel for field trip (specific schedule and logistics TBA)
400 PM Return from field trip to hotel
530 PM Van pickup at hotel for poster social, featuring student and postdoc research, and dinner at Fairchild Tropical Gardens
1000 PM Return from dinner to hotel

Thursday March 20:

730 AM Breakfast with NSF Program Officers at hotel
830 AM Van pickup at hotel for science sessions at the Wertheim Conservatory on the Florida International University campus
900 AM Begin Science Morning (town hall meeting style with panel discussions after presentations) with welcome and FCE overview by Dan Childers
900 AM IM Panelist meets with Linda Powell in the FCE Office (ECS 253) until 1215.
930 AM Panel discussion
945 AM Synthesis of findings from the SRS transect by Robert Twilley
1015 AM Panel discussion
1030 AM Break
1045 AM Synthesis of findings from the TS/Ph transect by Jim Fourqurean
1115 AM Panel discussion
1130 AM Landscape scale synthesis of east-west transect comparisons/contrasts and disturbance research by Joel Trexler
1200 AM Panel discussion
1230 AM Lunch with students and postdocs
200 PM Panel deliberations and report preparation (a separate room at FIU with computer facilities will be provided for this)
500 PM Panel and NSF Program Officer exit discussion with key FCE PIs
600 PM Return to hotel for departures or dinner