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FCE II Proposal - 2007-2012

Florida International University

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PROJECT DESCRIPTION

1. Results of Prior LTER Support

A. FCE I Research Summary: Our research to date has focused on biophysical dynamics in the estuarine ecotone regions of the coastal Everglades. Our central theme and organizing hypotheses have focused on understanding how dissolved organic matter from upstream oligotrophic marshes interacts with a marine source of phosphorus (P), the limiting nutrient, to control estuarine productivity where these two influences meet—in the oligohaline ecotone. This dynamic is affected by the interaction of local ecological processes and landscape-scale drivers (hydrologic, climatological, and human; Fig. 1-1). The central theme of our FCE I research has been that regional processes mediated by water flow control population and ecosystem level dynamics at any location within the coastal Everglades landscape. We have tested hypotheses along freshwater to marine gradients represented by landscape transects in two Everglades drainage basins of Everglades National Park (ENP; for FCE I site map, see http://fcelter.fiu.edu/maps/). The Shark River Slough transect (SRS) is anchored at a canal inflow point along the Tamiami Trail and extends through the mangrove estuary to Florida's southwest coast. Historically, most of the water draining the Everglades flowed through this system. The Taylor Slough/ENP Panhandle transect (TS/Ph) is anchored at two main canal inflow points, and extends through the oligohaline ecotone and Florida Bay estuary to the same coastal ocean endpoint. This is a smaller, more localized drainage basin. Because the freshwater Everglades is a highly oligotrophic, P-limited system (Noe et al. 2001), freshwater inflow to both estuaries is very nutrient-poor. In fact, the source of P to Everglades estuaries is marine water from the Gulf of Mexico, not the upstream watersheds (Fourqurean et al. 1992; Chen & Twilley, 1999; others). Because of this reversal in limiting nutrient source—compared with "typical" estuaries—we refer to these systems as biogeochemically "upside-down" (Childers et al. 2006a).

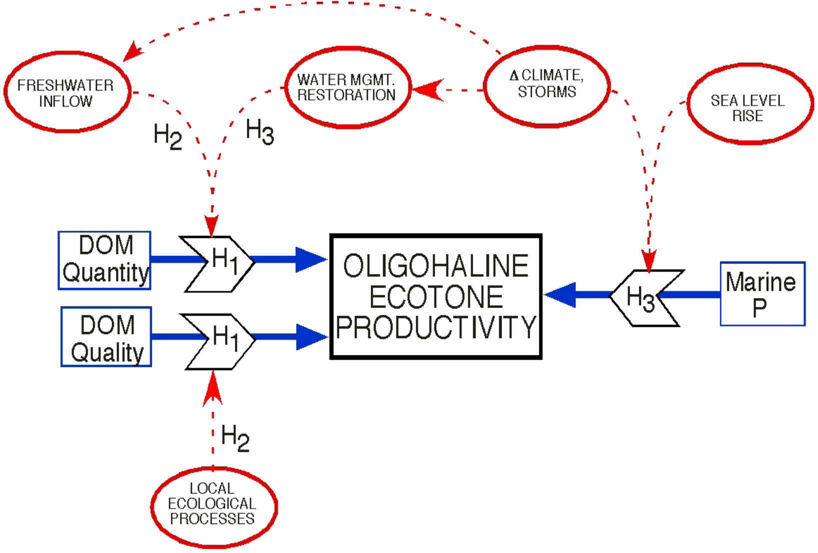


Figure 1-1: A conceptual simplification of the central theme and three main hypotheses that drove FCE I research. The ovals represent key hydrologic, climatological, ecological, and human drivers. The small rectangles are the inputs thought to most strongly control ecosystem productivity in the oligohaline ecotone. H1, H2, and H3 refer to the three central hypotheses of FCE I (see http://fcelter.fiu.edu/overview/summary.shtml for these central hypotheses).

Data from the 1990s suggested a generalized ecosystem productivity peak in the oligohaline ecotone region of our SRS transect, where tidal inputs of marine P meet organic matter-rich inputs from the freshwater Everglades. We hypothesized no such peak in the southern Everglades ecotone (our TS/Ph transect) because Florida Bay is so efficient at sequestering marine P (Fig. 1-2A). This hypothesis about estuarine productivity, and controls on that productivity, directed our research in the oligohaline ecotone regions of both transects, but also required us to learn more about biophysical dynamics both upstream (freshwater Everglades) and downstream (the Shark River mangrove estuary and Florida Bay) of the ecotone. Based on these data and this hypothesis, we focused our FCE I research on understanding how dissolved organic matter (DOM) from upstream oligotrophic marshes interacted with a marine source of the limiting nutrient, phosphorus (P), to control productivity in the oligohaline estuarine ecotone.

Our research to date has tended to show the opposite pattern, however, with many ecosystem components showing enhanced productivity in the TS/Ph ecotone, but not in the SRS ecotone (Fig. 1-2B). Aboveground net primary production (ANPP) by the dominant macrophytes showed a "wedge" of increasing productivity towards the marine endmember of our SRS transect (Ewe et al. 2006; Fig. 1-2B). The same marine-directed increase in ANPP occurs in Florida Bay (Fourqurean et al. 1992). We saw some indications of higher ANPP in the oligohaline ecotone along the TS/Ph transect, which was also contrary to our original hypothesis (Fig. 1-2; Childers et al. 2006b; Ewe et al. 2006). Water column P concentrations followed a similar pattern, with unexpectedly high P in the TS/Ph ecotone during the dry season (Childers et al. 2006a). Landscape-scale patterns of soil P content along our transects also followed the pattern shown in Fig. 1-2B rather than our original hypothesis (Fig. 1-2A; Chambers & Pederson 2006). It is well known that canal inputs of P are responsible for eutrophication patterns in Everglades wetlands (Craft & Richardson 1993; Doren et al. 1997). However, canal inflows influence ENP marshes to a lesser degree than is seen in wetlands further north (Childers et al. 2003). Along FCE transects, soil P levels at canalside sites and marine sites were similar (Chambers & Pederson 2006). At times, we did observe high periphyton productivity at our TS/Ph canal sites, but these events occurred at the onset of the wet

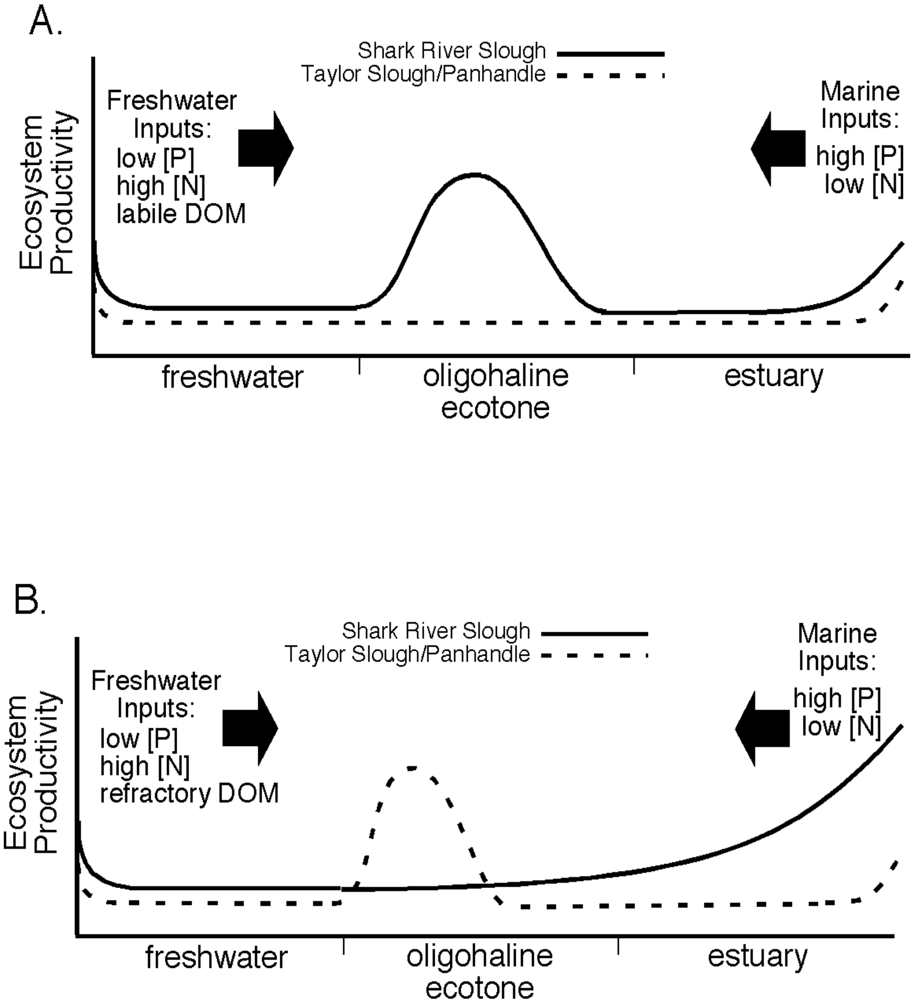


Figure 1-2: (A) Generalized landscape-scale patterns of our FCE I hypothesis about how ecosystem productivity would vary along the SRS (solid line) and southern Everglades (TS/Ph; dashed line) transects. (B) Generalized landscape-scale patterns of how ecosystem productivity actually varied along the Shark River Slough (solid line) and southern Everglades (TS/Ph; dashed line) transects, based on FCE I results.

season and were short-lived (Iwaniec et al. 2006).

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

Our organic geochemical research has shown that Everglades DOM is more refractory than originally hypothesized (Boyer et al. 2003; Lu et al. 2003; Jaffé et al. 2004; Maie et al. 2005; 2006c). We have also begun to understand the importance of detrital organic matter production and transport to ecotone dynamics (Wood 2005; Leonard et al. 2006). Jaffé et al. (2001) used a biomarker-based assessment of sources of particulate organic matter (POM) to the SRS and TS/Ph estuaries. Their conceptual model suggested different processes controlled POM mixing in these two systems. Mead et al. (2005) refined this model by showing that simple end-member models do not work well in Everglades estuaries. Much of the POM in these systems is not suspended in the water column, but rather is found as a flocculent detrital layer above the soil surface (colloquially referred to as “floc”). Neto et al. (2005) reported that much of this “floc” was locally produced, which greatly complicates traditional 2-source allochthonous mixing models. “Floc” also is the base of aquatic food webs (Williams & Trexler 2006). Interestingly, fish standing stocks showed an ecotone peak along both transects, supporting our original hypothesis about landscape-scale patterns in ecosystem productivity in SRS but not the southern Everglades (TS/Ph transect; Green et al. 2006; Lorenz & Serafy 2006).

The dominant disturbances in the coastal Everglades are hurricanes and fire, which affect the landscape at a range of spatial scales (Lockwood et al. 2003), and hydrologic extremes (droughts and floods, mediated or exacerbated by human activities), which primarily affect animal and upland communities (Trexler et al. 2005). Sea level rise is also a disturbance that has gradual effects (i.e. “press-type”) rather than event-based impacts (i.e. “pulse-type”). Long-term peat accretion in the [relatively new] transgressive mangrove wetlands of the southern Everglades has been considerably higher (approximately 3 mm yr^{-1}) than the marl soil accretion by the freshwater marshes they replaced (about 0.8 mm yr^{-1}; Ross et al. 2000; Gaiser et al. 2006). This rate of peat production is roughly equal to the rate of eustatic sea level rise in south Florida. Short-term sediment deposition rates [in the ecotone] associated with specific storm events can be considerably higher, however (Davis et al. 2004). For example, the storm surge from Hurricane Wilma, a Category 3 hurricane that tracked northeast directly along our SRS transect on October 24 2005, deposited over 3 cm of carbonate mud in the mangrove forests near the Gulf of Mexico.

Our modeling and synthesis activities have focused on understanding how ecological pattern and process in upstream freshwater Everglades marshes affected the composition of water flowing into the oligohaline ecotone. We have used a “dynamic budget” approach to simulating dynamics at a given location (Childers et al. 1993a), and have conceptually linked sites along a given FCE transect with “ribbon models” (Fig. 2-5). Decadal run output from these models has shown the highest net P accumulation in sawgrass and wet prairie marshes nearest to canal inputs (0.15 to 0.34 g P m^{-2} yr^{-1}), but near steady-state conditions in oligotrophic interior marshes (-0.02 to 0.06 g P m^{-2} yr^{-1}) and upper ecotone marshes (0.00 to 0.09 g P m^{-2} yr^{-1}; Fig. 2-6). These simulated P accumulation rates were similar to observed estimates from nutrient-enriched (0.40-0.46 g P m m^{-2} yr^{-1}) and unenriched (0.06 g P m^{-2} yr^{-1}) marshes in the northern Everglades (Water Conservation Area 2A; Craft & Richardson 1998). These “ribbon” models also predicted water P concentrations that were within the range of observed values for all areas except interior oligotrophic sawgrass marsh (Figure 2-6). Simulations generated relatively high water P concentrations in these marshes (10 to 50 μg P L^{-1}); however, when the models were modified to account for potential exchanges of waterborne and detrital P between communities, model predictions for both sawgrass and wet prairie marshes improved considerably. These results highlight the need for further investigations of the biophysical mechanisms affecting water and detrital P dynamics in oligotrophic interior marshes, especially exchanges of P between communities and ultimately downstream to ecotone marshes (see Childers 2006 for a more detailed synthesis of FCE I findings).

B. FCE I Research Productivity: The FCE LTER Program is based at FIU, which is a majority-minority institution and is one of the largest Hispanic-serving institutions in the US. The FCE program has grown to include participation by 11 other universities, by key state and federal agencies (including ENP, the South Florida Water Management District, the USGS, and NASA), and the National Audubon Society (an NGO; Appendix 2.A). There are currently 52 Ph.D.-level scientists, 43 students, and 36 technical staff affiliated with the FCE LTER Program (Appendix 2.B). During the first 5.5 years, the FCE group has published 105 peer-reviewed papers, books, and book chapters (Appendix 2.C), including 37 papers that will appear in a 2006 special issue of Hydrobiologia dedicated to FCE LTER research (see Appendix 1). Our scientists, students, and staff have made 450 presentations (Appendix 2.D) and FCE-affiliated students have generated 25 dissertations and theses (Appendix 2.E). Nearly 50 letters of support have been written for proposals on behalf of the FCE Program, and research grant funding that has been leveraged with the FCE LTER Program is now about 3-fold greater than the direct NSF budget to FCE.

C. FCE I Cross-site Activities: FCE scientists, students, and staff have been very active in LTER Network leadership and research (Appendix 2.F). Leadership roles have included the Executive Committee (Childers), Graduate Committee (Troxler Gann), Education Committee (Dailey), both the IM and IM Executive Committee (Powell), the US LTER International Committee (Madden), and the Network Planning Grant (Childers, co-PI). Our large and active graduate student group has participated in or led 6 cross-site activities, and FCE scientists have participated in or led 5 cross-site research initiatives and nearly a dozen scientific workshops (Appendix 2.F).

D. FCE I Site Management: FCE I Program Management has followed our Project Administration Guidelines (http://fcelter.fiu.edu/personnel/admin.doc). We have structured our FCE I research program with six Working Groups: Primary Production, Nutrient and Organic Matter Dynamics, Soil Dynamics, Consumer Dynamics, Modelling and Landscape Dynamics, and Abiotic Factors. D.Childers has served as Lead PI during FCE I, and will continue in this capacity into FCE II. Site governance is run by the Lead PI, with the advice and consent of our Internal

Executive Committee (IEC). The IEC is made up of the leaders of each of these six Working Groups, a representative of ENP, the Ed & Outreach Coordinator, and an outside advisor (formerly B.Hayden, VCR). Day to day administrative activities are overseen by our Project Manager (M. Rugge), who works closely with our Information Manager (L. Powell) on the website and database mechanics. Our Ed & Outreach program is run by Dr. S. Dailey, part-time coordinator.

E. FCE I Information Management: The mission of the Florida Coastal Everglades (FCE) Information Management System (IMS) is to facilitate the site's scientific work and ensure the integrity of the information and databases resulting from the site's coastal Everglades ecosystem research. Throughout FCE I, the Information Management (IM) team has provided total support of the site and network science by: 1) collecting and archiving both FCE and historical Everglades data, 2) providing comprehensive metadata for data interpretation and analysis, 3) designing and implementing tools that facilitate data management, data discovery and data access and 4) contributing to LTER network informatics activities. The formal FCE Data Management Policy (http://fcelter.fiu.edu/data/data_mgmt_policy.html) includes IMS level protocols and services for data collection, quality assurance, data organization, data archive, data access, and data distribution. The FCE website (http://fcelter.fiu.edu) has served as the primary portal for dissemination of information about FCE, for distribution of datasets, to coordinate our Education and Outreach activities (below), and to aid FCE scientists and students in their research. The number and diversity of datasets that are readily available through the FCE website continue to grow (Appendix 2.G). Actual downloads of FCE datasets have totaled nearly 1000, with well over half of these for academic research and with over one-third of these to access our biogeochemical and organic geochemical datasets (Appendix. 2.H). We have also tracked temporal patterns of dataset downloads, by month (Appendix 2.H).

F. FCE I Education, Outreach, and Diversity: During FCE I we developed an Ed & Outreach program that communicates our research findings to K-12 students, teachers, and the community of South Florida (which is over 60% Hispanic; Appendix 2.I). Our K-12 classroom effectiveness assessments have shown that 89% of the students we have impacted were Hispanic. We have developed a variety of programs to assess the most effective approaches to disseminate FCE LTER research findings and to educate the public about the ecology and importance of the Everglades. These approaches have included television segments, a website, video conference presentations, a high school student internship program, a science ranger education program with ENP, paired field and schoolyard activities, and classroom presentations. Our most widely distributed product has been the Foreverglades presentation (http://fcelter.fiu.edu/schoolyard) that explains the importance of the timing, distribution, and quality of water to the Everglades ecosystem. This presentation has reached over 3500 individuals across South Florida via FCE personnel, classroom visits, and our website. One of our most successful components has been our high school internship program. This program pairs high school students with FCE researchers who mentor students by providing hands-on experience with the science, tools and details of FCE research. Last year, one of our interns entered his project on belowground production in FCE sawgrass marshes in the high school science fair and proceeded to win the county, regional, and state science fair competitions! After winning these prestigious awards, he went on to make presentations of his FCE LTER internship experience to 491 high school students and their teachers.

2. Proposed Research

A. Introduction:

The coastal zone, including both the ecosystems and the human systems that form the terrestrial marine interface, is becoming the focus of increasing scientific interest and human concern. This past year, coastal ecosystems were in the news nearly every day, from the devastating tsunami in southeast Asia to the record-breaking hurricane season and the destruction these storms inflicted on coastal cities and communities. Approximately 50% of the U.S. population lives within 80 km of the coast. As the human population proximal to coasts continues to grow, demands for the natural resources and services that coastal ecosystems provide will also grow, further stressing these ecosystems. It is critical that we better understand how ecosystems at this land-sea interface help to mediate hydrologic, biogeochemical, sedimentary, and biotic cycles, and help to ameliorate disturbances at local, regional, and global scales. This growing understanding must also be used to assist coastal resource management through reliable forecasting of ecological and human systems.

The Florida Coastal Everglades LTER Program (FCE) is located in south Florida, where a rapidly growing human population of over 6 million people live in close proximity to—and in surprising dependence upon—the Florida Everglades. The FCE site is entirely within the boundaries of Everglades National Park (ENP), which at over 6110 km^2 is the third largest wilderness in the continental U.S. The juxtaposition of ENP and encroaching human development may appear incongruous, but cannot be ignored. The coastal Everglades is a fragile ecosystem for many reasons. Over the last century, human activity has dramatically altered the Everglades, reducing it to half its original extent and compartmentalizing the remaining system with over 2500 km of canals and levees (Davis & Ogden 1994; others). It is oligotrophic, and is thus highly susceptible to exogenous nutrient inputs. At the same time, because low-nutrient systems respond quickly and often dramatically to nutrient additions (Noe et al. 2001; Gaiser et al. 2005), this oligotrophy provides us an excellent opportunity to study biogeochemical controls on coastal systems. The coastal Everglades covers a large area that is [effectively] topographically flat, and is thus susceptible to dramatic transgressive changes in response to sea level rise. Hurricanes and storms are common, and add "pulse" disturbance features to this slow "press" of rising sea level. Both are manifestations of climate change. In addition, Everglades Restoration is expected to produce substantial hydrologic changes in the FCE system during our next funding cycle and over the next few decades.

Our FCE I research focused on understanding how dissolved organic matter from upstream oligotrophic marshes interacts with a marine source of phosphorus (P), the limiting nutrient, to control estuarine productivity where these two influences meet—in the oligohaline ecotone. This dynamic is affected by the interaction of local ecological processes and landscape-scale drivers (hydrologic, climatological, and human). During FCE I, our ideas about how these "upside-down" estuaries (Childers et al. 2006a) function has evolved, and we have modified our central theme to reflect this new understanding (see Section 1.A). Our focus in FCE II will be even more strongly on the oligohaline ecotone region of our experimental transects. For FCE II, our overarching theme is:

In the coastal Everglades landscape, population and ecosystem-level dynamics are controlled by the relative importance of water source, water residence time, and local biotic processes. This phenomenon is best exemplified in the oligohaline ecotone, where these 3 factors interact most strongly and vary over many [temporal and spatial] scales.

The important water sources are: 1) freshwater inflow from the upstream Everglades; 2) Gulf of Mexico [marine] water; 3) groundwater, and; 4) precipitation. Notably, "water source" includes its nutrient, organic matter, and biological content, and the marine component includes astronomical tidal energy. Human activities tied to water management and Everglades Restoration directly affect both freshwater and groundwater inputs. The FCE LTER site is thus an excellent laboratory for understanding how coastal ecosystem dynamics respond to, and influence, human activities in the coastal zone. As a prime example, during FCE II we expect to see a substantial increase in freshwater inputs to one of our experimental transects: In 2008 or 2009, nearly 5 km of the Tamiami Trail canal levee will be removed, dramatically increasing water flow across the northern boundary of ENP and to our Shark River Slough (SRS) transect. We do not expect freshwater inflows to our southern Everglades transect (TS/Ph) to change dramatically during this time (http://fcelter.fiu.edu/maps/). The landscape-scale hydrologic manipulation provided by this "Grand Experiment" is central to our FCE II approach. As such, our program will use this long-term BACI (Before-After Control-Intervention) experiment to answer the following three focal hypotheses:

Hypothesis 1: Increasing inputs of fresh water will enhance oligotrophy in nutrient-poor coastal systems, as long as the inflowing water has low nutrient content; this dynamic will be most pronounced in the oligohaline ecotone.

In most coastal systems, the limiting nutrient is supplied by the watershed, and from such a perspective this hypothesis seems counter-intuitive. In our "upside-down" estuaries, though, the upstream Everglades are highly oligotrophic (Noe et al. 2001; others) and the nutrient that limits ecosystem productivity (P) is supplied by the Gulf of Mexico (GOM), not freshwater inflows (Fourqurean et al. 1992; Chen & Twilley 1999; Chambers & Pederson 2006; Childers et al. 2006a). Freshwater inflows to the oligohaline ecotone suppress this marine P supply, particularly along the SRS transect, where the ecotone has a direct connection to the GOM. Freshwater inflows also enhance oligotrophy in the southern Everglades (TS/Ph) ecotone by keeping this area well flushed and by suppressing intrusions of Florida Bay waters. As such, any increase in freshwater inflows should enhance oligotrophic conditions in either ecotone, particularly during the wet season. We expect that the "Grand Experiment" that will remove part of the Tamiami Trail and increase water flow to our SRS transect, will do just this.

At this point, it is instructive to briefly define "enhanced oligotrophy". Oligotrophy is most often used in limnological settings, and using it to describe Everglades wetlands may appear antithetical because wetlands, in general, are among the most productive of ecosystems (Mitsch & Gosselink 2000). We use the term to describe the low P availability that has been well documented for the freshwater and estuarine ecosystems of FCE. These ecosystems are also characterized by low biomass and productivity, of both the dominant macrophytes and aquatic animals, in comparison to most other freshwater and estuarine wetlands. As such, "enhanced oligotrophy" refers to situations in which P availability is reduced relative to current conditions.

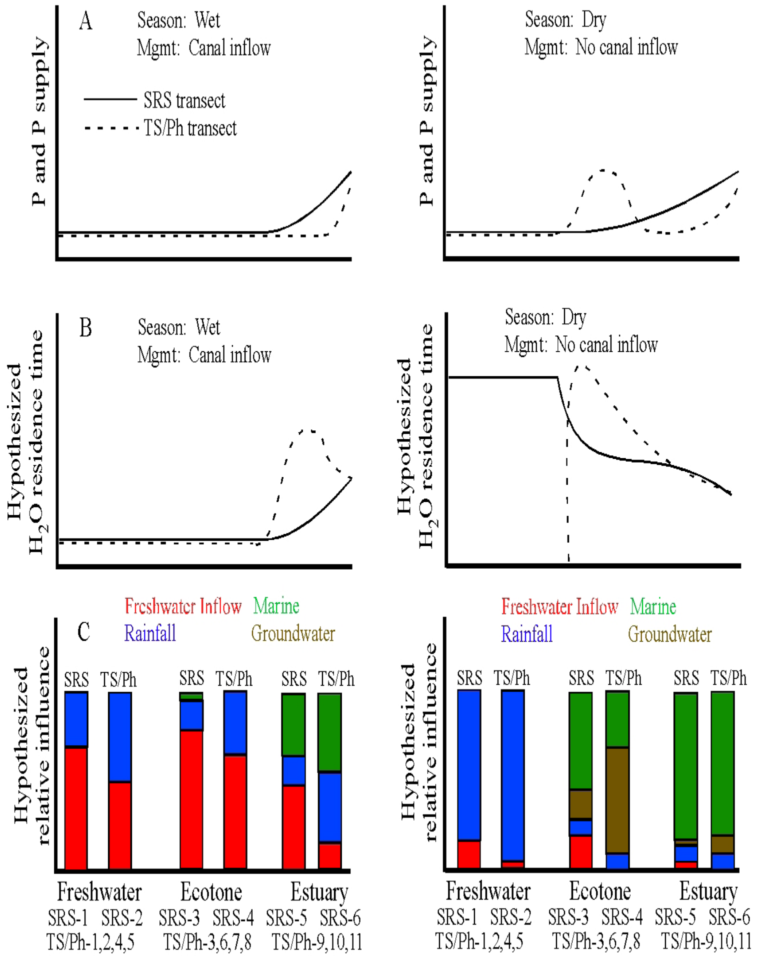


Figure 2-1: Note that the x-axis labels for A-C is shown in C. (A) Generalized landscape-scale patterns of water column P concentrations in the wet season (left panel) and dry season (right panel) along the SRS (solid line) and southern Everglades (TS/Ph; dashed line) transects (as in Fig. 1-2A; Childers et al. 2006a). (B) Hypothesized landscape-scale patterns of water residence time in the wet season (left panel) and dry season (right panel) along the SRS (solid line) and TS/Ph (dashed line) transects. Dry season water residence time in the TS/Ph ecotone is long, when upstream marshes are dry (no freshwater inflow or tidal flushing). Residence time in freshwater SRS marshes is long, but is dramatically shorter in the ecotone because of regular tidal flushing. (C) The relative influence of four main water sources that we hypothesize are driving oligohaline ecotone dynamics. For each landscape component (freshwater marshes, estuarine ecotone, and estuary), the SRS and TS/Ph transects are shown with separate bars. Red = freshwater inflow, green = marine water, blue = precipitation, brown = groundwater. The major difference between the 2 transects is in the ecotone in the dry season, when we hypothesize that groundwater inputs to the TS/Ph transect are relatively large compared with the SRS transect.

Hypothesis 2: An increase in freshwater inflow will increase the physical transport of detrital organic matter to the oligohaline ecotone, which will enhance estuarine productivity. The quality of these allochthonous detrital inputs will be controlled by upstream ecological processes.

Understanding the sources, fate, and transport of dissolved organic matter (DOM) was a strong emphasis of our FCE I research, and we have learned a great deal about each. Notably, Everglades DOM is more refractory than originally hypothesized (Lu et al. 2003; Jaffé et al. 2004; Maie et al. 2005; 2006c). During FCE I, we also began to understand the importance of detrital organic matter production and transport to ecotone dynamics (Wood, 2005; Leonard et al. 2006). Much of this particulate organic matter (POM) is not suspended in the water column, but rather is found as a flocculent detrital layer above the soil surface (colloquially referred to as “floc”; Fig. 2-2). As such, “floc” moves primarily as bedload, and we expect that increased freshwater inflows will cause more floc transport to oligohaline ecotone areas. Jaffé et al. (2001) used a biomarker-based assessment of “floc” sources in the SRS and TS/Ph estuaries. Their conceptual model suggested different processes controlled POM mixing in these two systems and Mead et al. (2005) found that simple end-member models do not work well in FCE estuaries. Neto et al. (2005) reported that much of this “floc” was locally produced, which also complicates traditional 2-source allochthonous mixing models. Wood (2005) found relatively high metabolic rates for freshwater marsh "floc", suggesting its importance to nutrient regeneration and biogeochemical cycling. Increased "floc" transport to the ecotone may increase P availability via this remineralization process. However, "floc" also is the base of our aquatic food webs (Williams & Trexler 2006)—this detrital component is important to food web dynamics and ecosystem energetics. It is possible that "floc" inputs to FCE ecotone areas will be directly consumed, rather than decomposed, thus enhancing secondary production rather than P availability. We expect increased "floc" inputs will result in both responses.

Figure 2-2: Photo of "floc" (POM) from a freshwater marsh FCE site that has been "captured" in a benthic advective sediment trap.

Hypothesis 3: Water residence time, groundwater inputs, and tidal energy interact with climatic and disturbance regimes to modify ecological pattern and process in oligotrophic estuaries; this dynamic will be most pronounced in the oligohaline ecotone.

Time-series water quality and soil P content data from FCE I show a general pattern of very low P availability along both FCE transects during the wet season, except near the marine P source. During the dry season (lower freshwater flow), the extent of this marine influence moves upstream along the SRS transect; however, we also see a dry season increase in water column P availability in the TS/Ph ecotone region (Fig. 2-1BA). This unexpected finding has led us to rethink our original FCE I concept. We expect that the peak in dry season P availability in the southern Everglades ecotone is a result of longer water residence times (Fig. 2-1B) that enhance the importance of local processes and that lead to a depletion of allochthonous sources of labile organic carbon and subsequent reduction in microbial productivity and biomass. This, combined with inputs of relatively P-rich groundwater (Price et al. 2006), contribute to increased P availability during this time (Fig. 2-1C). Water residence time in the oligohaline ecotone is controlled by precipitation, freshwater inflow, tidal energy, and storms. Our FCE II research will include an explicit and important hydrology component to address this hypothesis and to help us understand the physical results of the "Grand Experiment" that will take place at Tamiami Trail.

B. Conceptual Framework and Program Organization:

We will continue the transect-based approach in FCE II, with a transect in Shark River Slough (SRS) and a transect in the southern Everglades (TS/Ph; Fig. 2-3; Section 1.A). Our research will also continue to be strongly focused on biophysical dynamics in the oligohaline ecotone (Fig. 2-4). To ecologists, ecotones are often linear, 1-dimensional boundaries between two different communities or ecosystems. We define the oligohaline ecotone in our estuaries as that part of the landscape where freshwater and estuarine vegetation mix (typically a mix of sawgrass, spikerush, and red mangrove). These oligohaline ecotones have somewhat different spatial arrangements along our two transects: The TS/Ph ecotone forms a band 5-10 km wide that parallels the northern shore of Florida Bay while the SRS ecotone has a more dendritic ar-

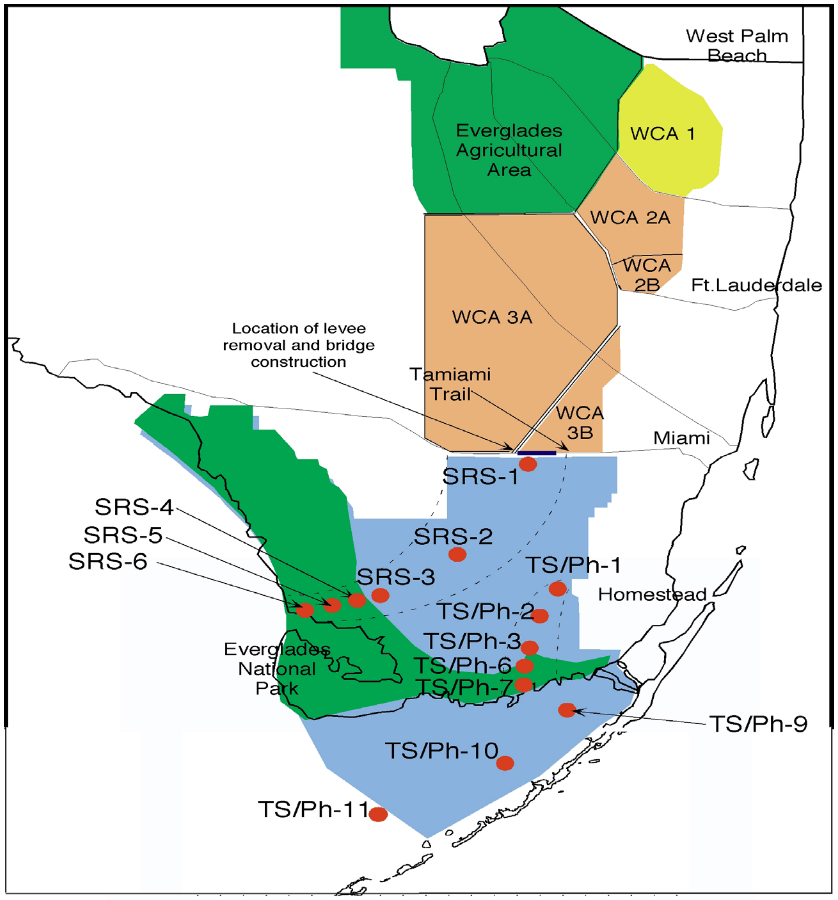
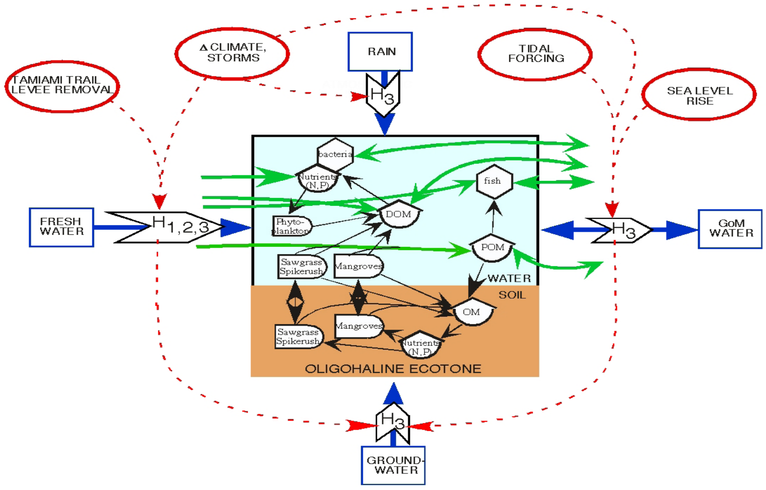


Figure 2-3: FCE II site map, including the locations of the 11 wetland sites and 3 Florida Bay sites. Everglades National Park is the colored region south of Tamiami Trail (green = mangrove estuaries; blue = freshwater Everglades wetlands or Florida Bay). Note the location of the levee removal and Tamiami Trail bridge that will be constructed in 2008 or 2009. Also note that this map differs from the FCE I site scheme (http://fcelter.fiu.edu/maps/), as sites TS/Ph-4, 5, & 8 are not part of FCE II. In order to maintain the integrity of past datasets, we have not changed the remaining TS/Ph site names.

Table 2-1: Summary of the major core datasets from FCE I and those proposed for FCE II. Note that "core" is defined here as those datasets that address obligations to the five LTER Core Areas.

Core area parameter	FCE I	FCE II
Primary production	All sites	All sites
Belowground production	Prelim. Expts.	Ecotone sites
Consumer dynamics	All but Fl. Bay, C111	All but Fl. Bay
Fish movements	none	Ecotone sites
Water quality	All sites	All sites
P & N cycling rates	Prelim. Expts,	Ecotone sites
Basic hydrology (all sites)	All but Fl. Bay	All but Fl. Bay
Groundwater discharge	None	Ecotone sites
Surface water flow	Prelim. Expts.	Select wetl. sites
Dissolved organic matter characteristics	All sites	All sites
Particulate organic matter dynamics	Prelim. Expts.	All wetland sites
Soil structure	All sites	All sites
Soil elevation change	Ecotone sites	All wetland sites
Landscape ecotone change	None	Ecotone sites

A. Shark River Slough Transect (SRS)



B. Southern Everglades/Taylor Slough Transect (TS/Ph)

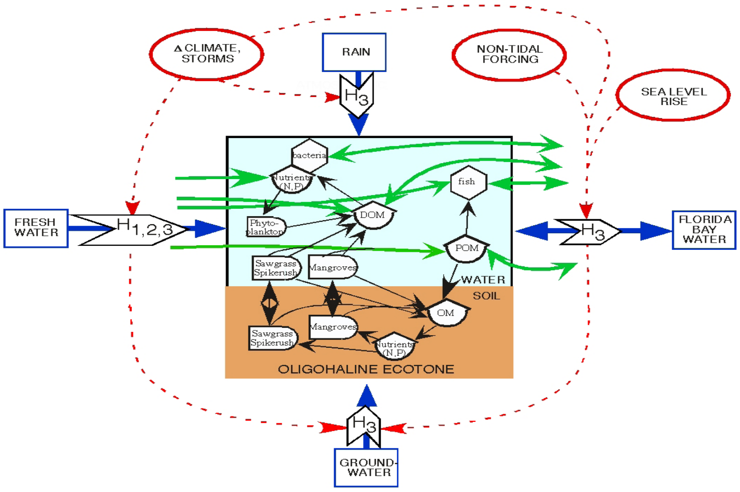


Figure 2-4: Conceptual diagram of FCE II research (note similarity to Fig.1-1). The focus is on oligohaline ecotone dynamics along both transects, and that the phytoplankton component includes periphyton. Rectangles = hydrologic drivers (=key water masses), ovals = climatic/environmental drivers, and heavy arrows crossing the ecotone boundaries (and box) = key exchanges with upstream (freshwater Everglades wetlands) and downstream (Florida Bay and the Shark River estuary) systems. The 3 focal hypotheses are shown as H_1, H_2, and H_3.

rangement along mangrove-bounded first-order tidal creeks that drain freshwater marshes (http://fcelter.fiu.edu/photos/). These ecotones are where salinity mixing first occurs (hence the term “oligohaline ecotones”). This mixing of fresh and marine waters is dynamic over short time scales (seasons, weeks, even days) in both ecotone regions. On longer time scales, these ecotones have transgressed landward in the last 50-100 years in response to both sea level rise and dramatic reductions in freshwater inflow due to Everglades drainage and water management (Davis & Ogden, 1994; Ross et al. 2000; Gaiser et al. 2006; H.Wanless, UM, pers. comm.).

Our conceptual approach for FCE II (Fig.2-4) is a refinement of our earlier concept (Fig. 1-1) based on what we learned about the coastal Everglades during FCE I. Our conceptual emphasis is on: 1) oligohaline ecotone dynamics; 2) hydrologic, climatological, and human drivers that affect those dynamics, and; 3) processes that regulate biophysical inputs to the ecotone from upstream freshwater Everglades marshes and the estuary proper. FCE II is organized around this conceptual approach and focus. Briefly, this organization has 5 Working Groups, including a new Hydrology initiative, and 3 Cross-Cutting Themes that link these Working Groups, including a new Human Dimensions initiative (see Section 3 for details). Our research team includes climatologists, ecologists, hydrologists, organic geochemists, and modelers (Appendix 2.B) from a number of universities, from state and federal science agencies in south Florida, and from non-governmental agencies (Appendix 2.A). We will continue to maintain our core datasets (e.g. primary production, soils, water quality, consumer dynamics) at non-ecotone sites through FCE II, with some modifications that we describe below (Table 2-1).

Any long-term research program must carefully balance continuity and integrity of long-term datasets with support for new ideas and initiatives (Table 2-1). In FCE II, we will meet this

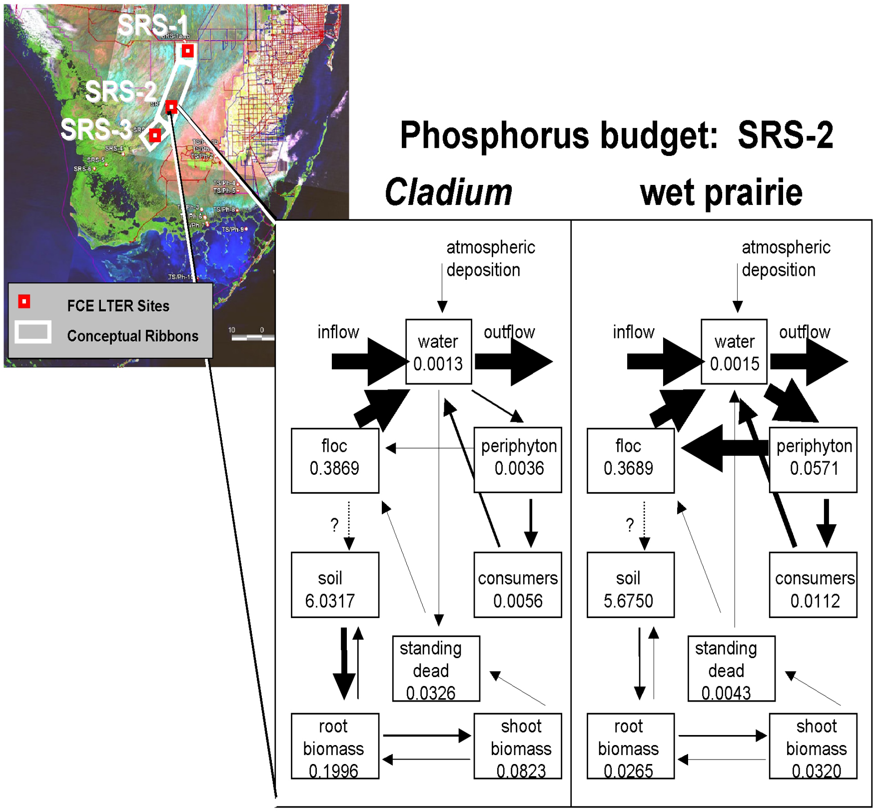


Figure 2-5. Conceptualization of "ribbon" models that simulate P standing stocks and fluxes among the major ecosystem components. This example includes linked "ribbon"models of near-canal (SRS-1), oligotrophic (SRS-2), and northern-ecotone (SRS-3) freshwater marshes along the SRS transect. Phosphorus standing stocks (g P m^{-2}) and fluxes (g P m^{-2} y^{r-1}) from FCE data are used to parameterize and calibrate the Cladium and wet prairie budgets in each "ribbon". For fluxes ≤ 2 g P m^{-2} yr^{-1}, arrow widths are scaled to reflect the flux size. "Inflow" and "outflow" are the influx and efflux of waterborne P for a given ribbon. These dynamic budget ribbon models simulate decadal changes in P stocks and fluxes in both sawgrass and wet prairie marsh ecosystems.

challenge in several ways. First, we propose to maintain this balance with "smart sampling". Analysis of many of our long-term observational datasets has shown that we can simplify our current sampling protocols in FCE II. For example, our water quality sampling program at FCE wetland sites (14 of 17) is intensive. We collect a sample every 3 days that is a composite of subsamples collected every 18 hours (such that each 3-day sample contains a noon, midnight, dawn, and dusk subsample). We used time-series wavelet analysis and a sample compositing scheme to investigate longer sampling intervals, and found that we lost no significant information about water quality variability at our non-tidal sites if we collect composite samples at 6 day intervals (Childers & Philippi, in prep.). Based on this "smart sampling" analysis, the FCE II water quality protocol will be for 6 day composite samples at our non-tidal wetland sites. Based on similar analyses, we will also be reducing our DOM characterization work at non-ecotone sites from monthly in FCE I to seasonally in FCE II. We have also decided to simplify our southern Everglades transect by eliminating the 3 sites in the C-111 Basin (TS/Ph-4, 5, and 8) in FCE II (compare http://fcelter.fiu.edu/maps/ with Fig. 2-3). A key justification for this simplified transect design is that the C-111 Basin sub-transect has only 1 ecotone site (TS/Ph-8), while the other TS/Ph wetland transect and the SRS transect both have 2 ecotone sites (TS/Ph-6 & 7; SRS-3 & 4). We will maintain the FCE I datasets from these sites, and will continue to collect observational data for most key parameters, including water quality, primary production, soils, and hydrology, with funding from the South Florida Water Management District (SFWMD; D.Childers, PI). The time, effort, and resources freed by these "smart sampling" decisions will allow us to pursue exciting new initiatives, such as hydrologic and human dimensions research, in FCE II.

We will also balance long-term continuity with new ideas by continuing to use other funding to support a number of observational programs. This strategy carries over from FCE I. As examples, our water quality sampling along the TS/Ph transect is supported with funding from ENP (for the wetland sites=TS/Ph-1, 2, 3, 6, & 7; D.Childers, PI) and SFWMD (for Florida Bay sites=TS/Ph-9, 10, & 11; J.Boyer, PI). ENP also supports our sawgrass productivity sampling along this same transect (D.Childers, PI) and our consumer dynamics sampling at all freshwater sites (J.Trexler, PI). We have a water flow monitoring station at our SRS-1 site that is being funded by ENP (H.Solo-Gabriele, PI) and the USGS operates similar flow stations near our TS/Ph-6 & 7 ecotone sites (C.Hittle, PI). Finally, ENP, USGS, and SFWMD have numerous hydrologic and meteorological monitoring stations throughout ENP and its adjoining canals. We anticipate long-term stability in these non-LTER funding sources and ancillary monitoring programs because all are closely tied to the adaptive management monitoring for the multi-decadal Everglades Restoration program (http://www.evergladesplan.org/).

C. Integration, Synthesis, and Modelling:

Integration and synthesis will continue to be a top priority for our FCE II program. We will integrate our empirical [experimental and observational] research through the cross-group linkages (Section 2.L), and by our enhanced focus on the oligohaline ecotone regions of our FCE transects. We will continue to synthesize our research findings with a number of modeling strategies. Because of Everglades Restoration, there are many ongoing modeling efforts in the Everglades. Our FCE program shares empirical information and insights, and works closely with a number of these, including the spatially-explicit Everglades Landscape Model (ELM; C.Fitz, PI; http://www.sfwmd.gov/org/wrp/elm/index.html), the Across Trophic Level System Simulation program (USGS; http://atlss.org/), seagrass ecosystem dynamics modeling (C.Madden, PI), mangrove ecosystem dynamics modeling (R.Twilley and the USGS TIME program; http://time.er.usgs.gov/), Florida Bay hydrodynamics (J.Fourqurean and W.Nuttle, PIs), and hydrologic modeling programs by ENP, SFWMD, and the USGS. We will continue our collaborations with these modeling efforts, but we do not intend to use FCE II resources to support redundant modeling efforts.

Our modeling syntheses in FCE I focused on understanding how ecological pattern and process in upstream freshwater Everglades marshes affects the composition of water flowing into the oligohaline ecotone. In this work, we have taken a “dynamic budget” approach to simulating dynamics at a given location (Childers et al. 1993a), and have conceptually linked sites along a given FCE transect with “ribbon models” (Figs. 2-5 & 6; see Section 1). In FCE II, we will shift the focus of our “dynamic budget” modeling to the ecotones themselves. Conceptually, these models will follow Fig. 2-4. Our new hydrology initiative (Section 2.D) will generate detailed data on water residence times, freshwater inflow rates, groundwater discharge, precipitation, and tidal interactions with the estuary proper. These data will be used to calibrate and validate “ribbon models” that couple adjoining ecotone sites along a given transect, and that ultimately link these ecotone models to our existing freshwater marsh models. This modeling initiative will fill an important void in Everglades modeling. As discussed above, a number of models exist for the freshwater Everglades, for tidal mangrove systems along the SW Florida coast, and for Florida Bay. Models from these 3 regions have never been effectively linked, though. In a sense, the freshwater-estuarine ecotone has always been a modeling “no-man’s land”. Our goal with this FCE II modeling approach is to fill this gap and help connect these 3 regions into a cohesive simulation approach. The product of this effort will be a valuable tool for scientists, resource managers, and restoration planning.

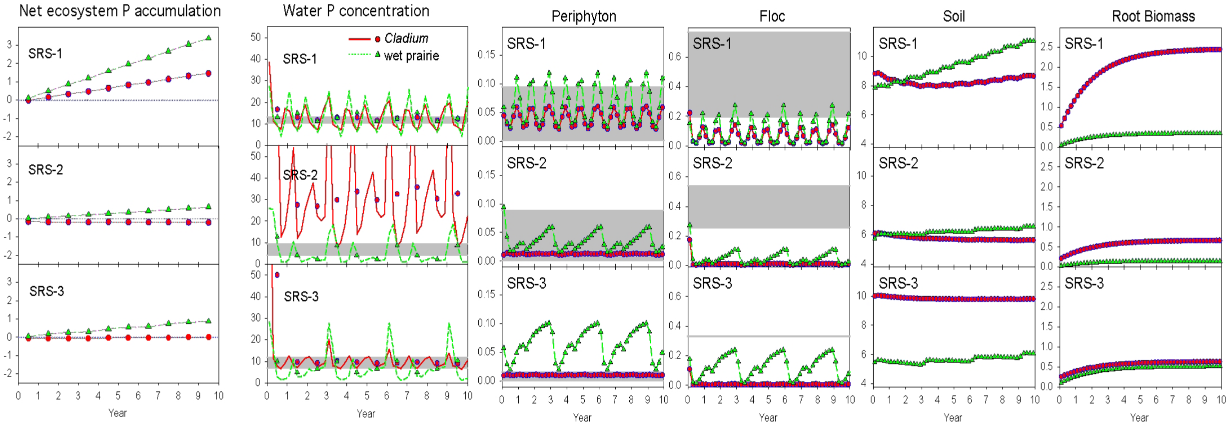


Figure 2-6. Simulated decadal changes in net ecosystem P accumulation (as deviation from initial total P stocks), water P concentration (μg P L^{-1}), and P stocks (g P m^{-2}, 2-month averages) in periphyton, floc, soil, and roots for Cladium and wet prairie communities in the SRS-1, SRS-2, and SRS-3 "ribbons". Output is shown as both annual averages and as 2-month running averages. Grey bars show the range of values for that parameter that typify the FCE dataset at that site.

D. Hydrology (co-leads – R. Price & V. Engel):

GENERAL QUESTION 1: How will the interaction of surface and groundwater inflows, tidal energy and seawater intrusion, local rainfall, and evapotranspiration control [physical and chemical] hydrologic conditions in the oligohaline ecotone under conditions of increasing freshwater inflows from the Everglades?

RATIONALE – The spatial location and the geochemical conditions of the oligohaline ecotone are a long-term result of the balance between upstream inflows and marine influences (Fig. 2-7). This balance is mediated on seasonal and annual time scales by climatological forcing (local rainfall and evapotranspiration) as well as regional water management, which together regulate surface water geochemical conditions and the underlying brackish groundwater mixing zone. Increased freshwater inflows to SRS (the "Grand Experiment") and in the long run to both transects (associated with Everglades Restoration) are likely to impact surface and groundwater hydrodynamics in the oligohaline ecotone. Seawater intrusion into the Biscayne Aquifer was first documented by Parker et al. (1955), and was attributed to canal construction in the 1920s and 1930s that reduced surface water flows from the Everglades and lowered groundwater levels in the underlying Biscayne Aquifer. Further canal construction since the 1940s, combined with periodic drought conditions, have resulted in continued seawater intrusion (Sonenshein & Koszalka 1996). This seawater intrusion, which appears to have stabilized since 1990 (Sonenshein 1997; Fitterman et al. 1999; Price et al. 2003), ranges from 10-30 km inland from the coast in the TS/Ph and SRS drainages (Fig. 2-8). Currently, brackish groundwater is being discharged into the oligohaline ecotone, particularly in the dry season (Price et al. 2006). We expect that

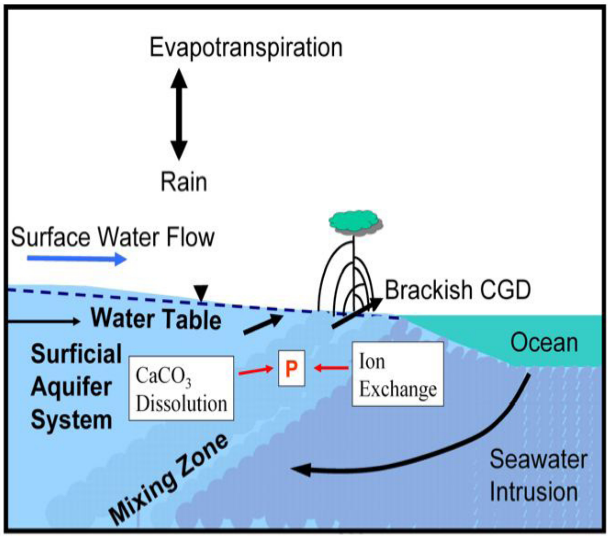


Figure 2-7. As seawater intrudes into the surficial aquifer system beneath the Everglades, it mixes with fresh groundwater to form a brackish mixing zone that discharges as brackish coastal groundwater discharge (CGD) to the surface water of the Everglades. The geochemical reactions of CaCO3 dissolution and ion exchange are believed to release P to the groundwater, increasing its P content relative to surface water (Price et al. 2006). The position of this surface water salinity mixing zone in the oligohaline ecotone is determined by the balance between freshwater inflow, groundwater discharge, and marine inputs. Evapotranspiration and rainfall affect surface and groundwater levels.

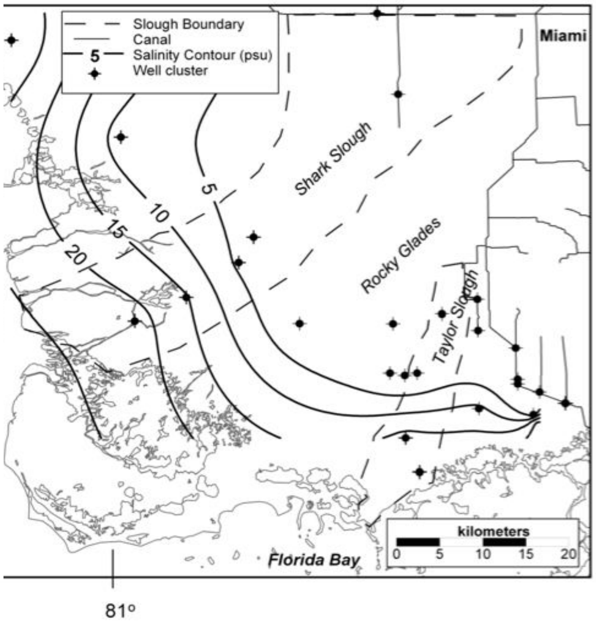


Figure 2-8. Contour plot illustrating the extent of seawater intrusion into the shallow portion (<28 m) of the Biscayne Aquifer beneath our SRS and TS/Ph transects.

increased inflows from the "Grand Experiment" will: 1) shift the location of salinity mixing in the oligohaline ecotone towards the coast; 2) suppress brackish groundwater discharge to the oligohaline ecotone, thus changing the geochemical conditions in this area; and 3) reduce water residence times in the SRS oligohaline ecotone, but these changes will not occur in the TS/Ph ecotone.

Specific Research Question 1-1: How will changing inflows from the upstream Everglades affect the position of the salinity mixing zone and alter geochemical conditions in the ecotone by suppressing brackish groundwater discharge?

The shift in the landscape position the surface water geochemistry mixing zone will likely manifest quickly (weeks to months), but the shift in the underlying aquifer will take longer (months to years). Although the "Grand Experiment" will only increase flows to the SRS ecotone, interannual differences in regional rainfall and water management (wet vs. dry years) will affect freshwater inflows to both ecotones. As such, increased inflows are expected to have a greater impact in TS/Ph, where tidal influences are negligible, compared to SRS. We expect that a reduction in seawater intrusion will lead to a decline in brackish groundwater discharge to the oligohaline ecotone.

Approach – We will use continuous measurements of surface water levels at our SRS and TS/Ph sites and data from over 40 surface water monitoring stations (maintained by ENP and USGS) and surface water discharge data from canal inflow points (SFWMD & ENP) and from stations in the TS/Ph ecotone (USGS) to detect changes in inflows from upstream freshwater environments. We will track the location of the oligohaline ecotone with surface water salinity data from our water quality monitoring sites. Monthly observations of groundwater salinity in existing wells and new wells in both ecotone regions will be used to quantify the extent of seawater intrusion in the underlying aquifer. Wells into shallow soil and upper bedrock already exist at sites SRS-3, SRS-4 and SRS-6 (USGS), and we will sample them in collaboration with T.Smith (USGS, Appendix 1). We will install an additional cluster of shallow monitoring wells in the soils and into the top of bedrock at SRS-5 to complete the groundwater monitoring along this transect. In Taylor Slough, a shallow and deep bedrock well cluster exist near TS/Ph-3 (3.6 m and 8.8 m) and TS/Ph-6 (0.6 m and 6.7 m). We will install soil and shallow bedrock wells at TS/Ph-7, and soil wells at TS/Ph-3 and 6. The USGS is collecting daily salinity data in the groundwater at their existing wells, and we will collect the same data at our wells. Both datasets will be used to detect short-term changes in salinity at these sites. We will quantify groundwater discharge with a combination of geophysical and geochemical methods: 1) mass-balance mixing models of major cations and anions run monthly and seasonally to determine the proportions of brackish groundwater discharge and surface seawater in the surface water environments (Price et al. 2006); 2) synoptic surveys of ^{222}Rn and streaming resistivity (Swarzenski & Kindinger 2003; Swarzenski et al. 2004); and 3) subsurface heat flux measurement from thermocouple sensor arrays that we will install at various depths in the soil combined with heat flux modeling as developed for river systems (Stonestrom & Constantz 2003) and near-shore marine systems (Taniguchi et al. 2003).

Specific Research Question 1-2: How will changing freshwater inflows affect water residence times in the oligohaline ecotones of Taylor and Shark River Sloughs?

The exchange of surface water between the southern Everglades and Florida Bay is confined to a handful of channels that cut through a depositional berm known as the Buttonwood Ridge. Our TS/Ph-6 & 7 ecotone sites are located along the lower reach of one of the more significant channels—Taylor River. We expect that water residence times in this TS/Ph ecotone will be relatively short (hours to days) in the wet season but considerably longer (weeks to months) in the dry season because of negligible tidal energy and restriction of surface water exchange with Florida Bay by the Buttonwood Ridge. We expect that water residence times in the SRS ecotone, though, will not vary much from the wet season (hours) to the dry season (days) because of strong tidal flushing. Therefore, changes in freshwater inflows should have the greatest effect on dry season water residence times in the TS/Ph ecotone.

Approach – We will estimate water residence times with water budgets and geochemical mass-balance mixing models. In both cases, the hydrology and modeling/synthesis groups will work closely together. Water budgets will be calculated from measurements of rainfall, evapotranspiration, surface water flow, groundwater inputs, and marine inputs to both ecotone regions. Rainfall data will come from our freshwater FCE sites and nearby ENP monitoring stations. We will measure evapotranspiration in the SRS ecotone using techniques similar to the eddy-covariance tower that we currently operate at SRS-6 in cooperation with the University of Virginia (see Section 2.L). We will estimate evapotranspiration in the TS/Ph ecotone by installing an ET 106 Weather Station (Campbell Scientific, Logan, Utah), computing reference evapotranspiration using the FAO Penman-Montieth equation (Allen et al. 2004), and computing actual evapotranspiration from reference evapotranspiration by crop coefficients calibrated for natural vegetation at our sites (e.g., Barnes & Tarboton 2002). We are currently monitoring surface water flow at several sites, including SRS-1, and will install SONTEK Argonaut acoustic flow meters at SRS-3, SRS-4, and TS/Ph-3 to collect continuous flow measurements. The USGS is currently monitoring surface water flows at various creeks in the southern Everglades, and gauges are presently located on Taylor River near our TS/Ph-6 & 7 sites (C.Hittle, USGS). We will continue to use these data to calculate nutrient fluxes and water budgets at each site and fluxes of water and nutrients between the ecotones and upstream/downstream systems.

The geochemical mass-balance mixing methods will use chloride, deuterium, and/or oxygen-18 models (Price 2001; Swart & Price 2002) and analysis of naturally-occurring Ra isotopes (^{223,224,226,228}Ra) in surface water and groundwater (Swarzenski et al. 2006). We will also periodically use inert tracers, such as SF6, to determine large-scale surface water advection and dispersion patterns (Ho et al. 2002; Caplow et al. 2003) in the tidal channels of both ecotones. We are currently testing these tracer methods in freshwater Everglades marshes.

E. Primary Production (co-leads – E.Gaiser & J.Fourqurean):

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

RATIONALE – We expect that increased freshwater inflow to the oligohaline ecotone will affect salt budgets, water residence times, and the sources, availability, and flux of organic and inorganic nutrients. Marine and groundwater discharge are the dominant sources of P to the ecotone, and both are expected to decline with increased freshwater inflow. In this scenario, we expect that primary productivity and biomass allocation in the ecotone will reflect a long-term increase in oligotrophy (Childers et al. 2006a; Price et al. 2006). The Shark River Slough ecotone, with relatively high freshwater inflows and considerable tidal energy, receives most of its P via tidal inputs directly from the Gulf of Mexico (Chen & Twilley 1999; Childers et al. 2006a). The Taylor Slough ecotone, with negligible tidal energy and distinct seasonal variability in water source and quality (Davis et al. 2003; Sutula et al. 2003), appears to receive considerable P from shallow groundwater inputs (Price et al. 2006). We expect that this “vertical” difference in the dominant P source will be reflected in differences in both primary productivity and biomass allocation between the SRS and TS/Ph ecotones (Fig. 2-9).

Specific Research Question 2-1: How does a surface water P source versus access to shallow groundwater P affect belowground production and biomass allocation in ecotone plants?

Soil P availability controls mangrove productivity in the oligohaline ecotone region (Koch & Snedaker 1997; Chen & Twilley 1999). Soil P content in lower Taylor Slough is low at TS/Ph-6 (upper ecotone) and higher at TS/Ph-7 and 8 (lower ecotone; Mancera-Pineda 2003; Chambers & Pederson 2006). However, porewater soluble reactive P (SRP) concentrations from these two sites are similar (Fig. 2-10; Rivera-Monroy unpubl.data). Since SRP concentrations in surface water are very low (Childers et al. 2006a), it seems likely that groundwater sources may provide P to these shallow peat soils (<1m depth) and thus to the mangroves. Fine root biomass at our TS/Ph ecotone sites is higher than at the SRS sites (Fig. 2-12), suggesting increased plant “foraging” for P, a subsurface P source, or both. Ratios of fine root biomass to aboveground biomass (FRB:ABG) are also greater in sites with the lowest bulk soil P content (Fig. 2-13; Twilley

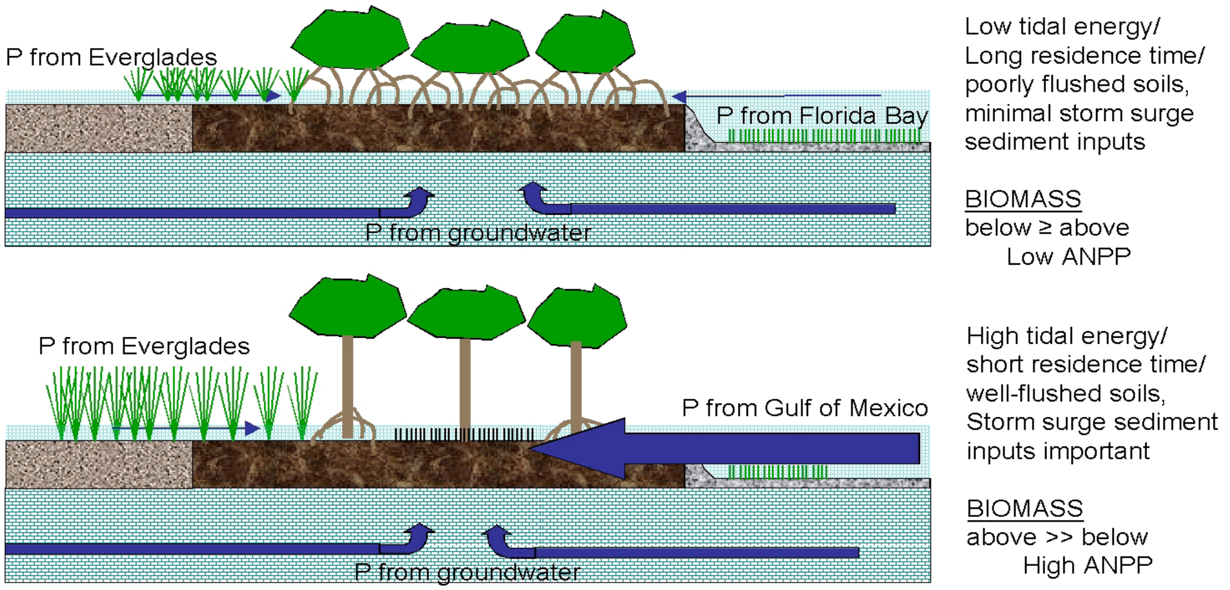


Figure 2-9. Conceptualization of how "top-down" (surface water P from GOM) versus "bottom-up" (groundwater P) sources control primary productivity and biomass allocation in TS/Ph (upper panel) and SRS (lower panel) oligohaline ecotones. Size of the arrows represents the magnitude of the P source. Note that the large marine P arrow in the SRS diagram includes both regular tidal inputs of waterborne P and episodic storm deposition of P-rich marine sediments.

unpubl.data). We also have new isotopic evidence from the TS/Ph ecotone for a strong groundwater influence in aboveground mangrove tissues, compared with no groundwater signal in sawgrass growing at the same site (Fig. 2-14; Ewe, unpubl.data). **Approach** – We will continue to measure productivity and biomass allocation at all mangrove sites (SRS-4, 5, & 6 and TS/Ph-6 & 7). We will refine methods for estimating aboveground net primary productivity (ANPP) in the dwarf red mangrove (*Rhizophora mangle* L.) trees at the TS/Ph 6 & 7 ecotone (Fig. 2-11). These methods are based on regular measurements of leaf turnover, stem elongation, and prop root growth on individual tree clusters. We will also estimate aboveground biomass with annual measurements of crown area and prop root number from 16 randomly selected tree clusters at each site using allometric equations (Coronado-Molina et al. 2004). We will continue to quantify belowground biomass and production using standard coring and in-growth core techniques.

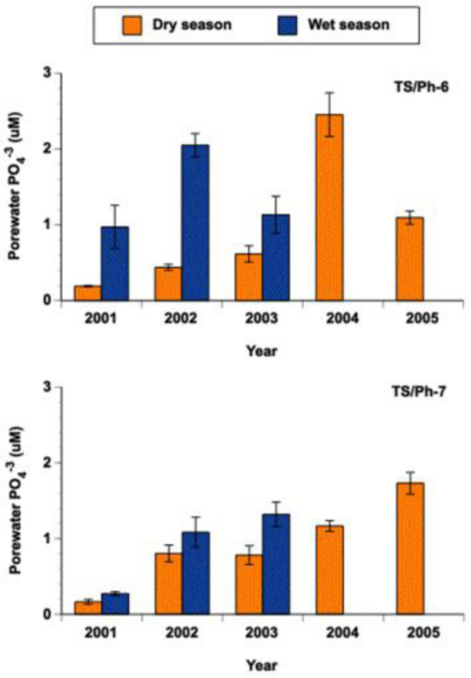


Figure 2-10. Porewater SRP concentrations (mean ± SE) in mangrove forest soils at TS/Ph-6 and 7.

In Year 2, we will initiate a small-scale fertilization experiment to better understand how P availability controls dwarf R. mangle productivity and biomass allocation. Work by Feller (1995), Feller et al. (1999), and Lovelock et al. (2004) has shown dramatic effects of nutrient addition on dwarf R. mangle growth, insect herbivory,

Figure 2-11: Aerial photo of TS/Ph 6 illustrating the distribution of dwarf R. mangle clusters (typically 2-4 m diameter) across the landscape. This landscape configuration is similar at TS/Ph-7.

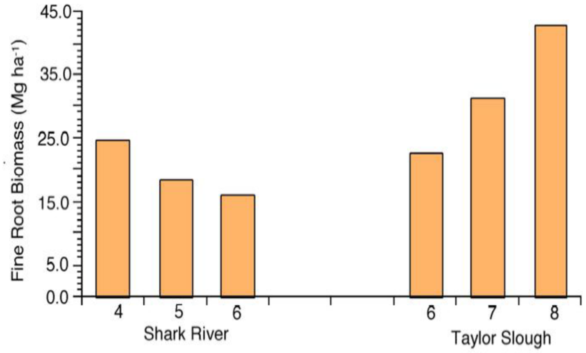


Figure 2-12. Fine root biomass at TS/Ph and SRS sites (numbers along X-axis are site numbers).

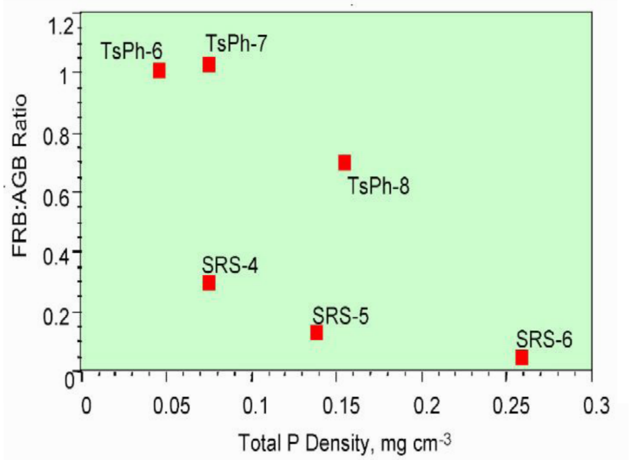


Figure 2-13. Fine root to aboveground biomass ratios (FRB:ABG) in relation to soil P density (mg cm^{-3}), which is simply a volumetric measure of bulk soil P rather than a mass-based measure.

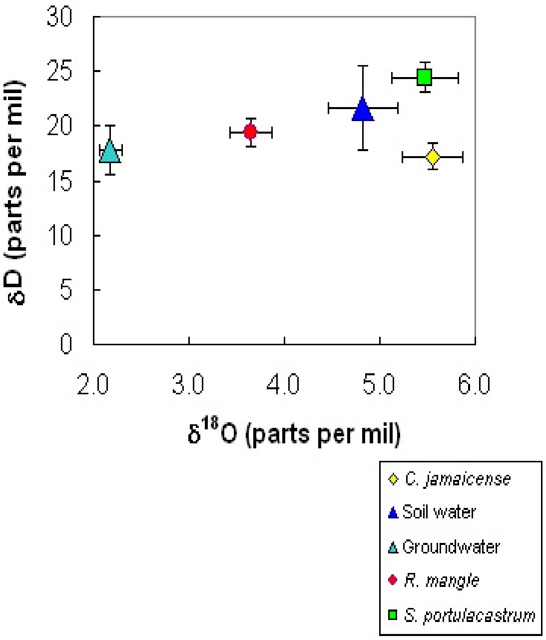


Figure 2-14. Oxygen:deuterium isotope space for water samples collected from the bottom (< 1m depth) of the peat column (=groundwater), from the top of the peat (= soil water), and water extracted from the 3 dominant macrophytes at TS/Ph-6 (2005 dry season). Note that sawgrass (C.jamaicense) and portulaca (S.portulacastrum) both are using exclusively surface water (=shallow peat water) while red mangroves (R.mangle) are using a nearly even mix of surface and groundwater.

mangrove physiology, and nutrient-use efficiency. We will select 16 tree clusters at the TS/Ph-6 ecotone site. Of those, half will receive a P-amended in-growth root core while the other half will receive in-growth cores without added P. In January, May, and September, we will collect all in-growth cores and replace each with a new core of the same treatment. Following protocols described above, we will track each experimental tree cluster for 2 years. These data will provide important insights into the seasonality of biomass allocation as modified by P availability.

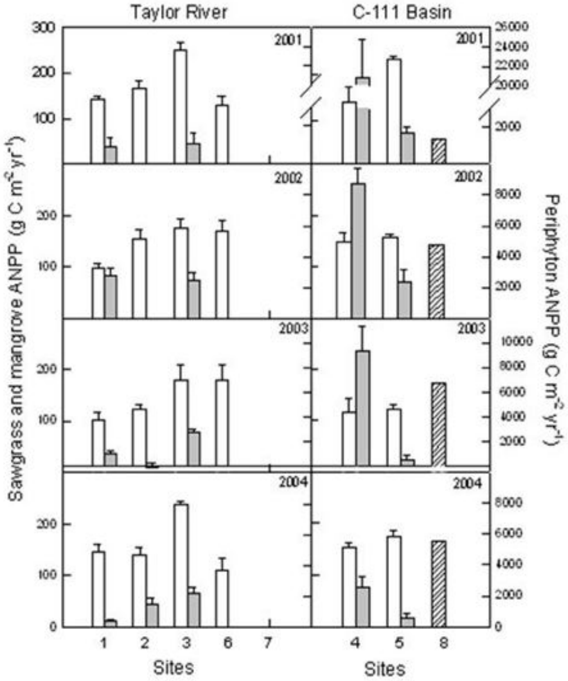


Figure 2-15. Primary production for sawgrass (open bars), periphyton (shaded bars), mangroves (single hashed), and seagrass (double hashed) at the TS/Ph wetland sites. Note that the very high average periphyton ANPP values from the canalside TS/Ph-4 site are skewed by very high productivity during the first few weeks after wetting (onset of the wet season). See Iwaniec et al. (2006) for details.

This experiment will also provide valuable pilot data that we will use to develop larger, ecosystem-scale nutrient manipulations based on our growing knowledge of how surface versus subsurface supplies of P affect mangrove ecosystem function.

Specific Research Questions 2-2a and 2-2b: How does a surface water P source versus access to shallow groundwater P affect sawgrass and periphyton productivity at the freshwater-ecotone transition? How does increased hydroperiod and decreased water residence time (as a result of increased freshwater inflows) affect productivity in this transition zone?

Primary production at freshwater FCE sites is dominated by sawgrass and periphyton, with highest rates of turnover occurring near the oligohaline ecotone, particularly along the TS/Ph transect (Ewe et al. 2006; Iwaniec et al. 2006; Fig. 2-15). In SRS, where hydroperiods are relatively longer and water residence times shorter (compared to TS/Ph), sawgrass production ranges from 300-600 g C m^{-2} yr^{-1} (Ewe et al. 2006) while periphyton production ranges from 17-60 g C m-2 yr-1 (Gaiser unpubl.data). Both of these values increase toward the ecotone, where marine P subsidizes production—particularly during the dry season. In TS/Ph, sawgrass production is lower (250-400 g C m^{-2} yr^{-1}; Childers et al. 2006b; Ewe et al. 2006) while periphyton production is one to two orders of magnitude higher (300-18000 g C m^{-2} yr^{-1}; Iwaniec et al. 2006); again, with values increasing toward the ecotone. Along both transects, we expect that higher productivity near and in the ecotone is driven by enhanced P availability relative to upstream freshwater marshes.

Increased freshwater flow should increase hydroperiod and water depth and may decrease the importance of groundwater inputs. We expect that these hydrologic changes will lead to a decline in sawgrass ANPP (Childers et al. 2006b) and a shift from soil-associated periphyton communities (where P supply is relatively enhanced) to water column or plant-associated communities (where P supply is relatively depleted). Because we expect that increased freshwater inflows will enhance oligotrophy in the ecotone regions, we expect an associated reduction in periphyton productivity (Gaiser et al. 2006) in these areas.

Approach – We will continue to measure sawgrass ANPP and periphyton productivity at freshwater FCE sites as per Childers et al. (2006b) and Iwaniec et al. (2006), with modifications suggested by Ewe et al. (2006). Specifically, we have found that quantifying periphyton productivity requires a variety of approaches, including biomass accumulation on artificial substrates and light-dark bottle biological oxygen demand (BOD), but with added emphasis on the latter method because it generates the lowest variance in estimates (Hall et al. 2006).

F. Consumer Dynamics (co-leads – M.Heithaus & J.Trexler):

GENERAL QUESTION 3: What are the implications of increased inputs of freshwater and detrital organic matter for consumers in the oligohaline ecotone, and how does this impact food webs in the greater estuary?

RATIONALE – In coastal ecosystems, consumers can be important vectors for nutrient transport in both upstream and downstream directions (e.g. Laffaille et al. 1998). We expect that consumer-mediated nutrient flux will contribute substantially to ecological processes in our nutrient-poor system—particularly in the oligohaline ecotone. Increased freshwater inflow, and expected increases of "floc", may modify animal-mediated nutrient transport if consumers change their movement patterns or habitat use in response to changes in surface water conditions (salinity or flow rates) or biotic factors (e.g. prey availability or predator abundance). We will address this question in FCE II by quantifying movements of individual consumers while continuing to study trophic interactions and food-web structure. We also recognize the value of estimating the actual flux of nutrients associated with these animal movements. We will pursue other funds for the lab studies, field population estimates, and somatic nutrient content research that is beyond the financial scope of this proposal.

During FCE I, we found that fish species richness and standing crops were higher in the TS/Ph ecotone than in the SRS ecotone (Green et al. 2006). These patterns were unexpected because primary production is higher in the SRS ecotone (Ewe et al. 2006), and may have been due to differences in small-scale topographic relief between the two ecotones (Green et al. 2006) and in tidally-driven inundation regimes. We expect that both cause increased wetland-open water habitat connectivity in the TS/Ph ecotone. Salt-tolerant species consistently dominated these SRS fish communities while in the TS/Ph ecotone we observed seasonal shifts between freshwater and salt-tolerant taxa. Using stable isotopes ($\delta^{13}C$ and $\delta^{15}N$), we also examined the impacts of gradients in hydrology and nutrient availability on trophic position of eastern mosquitofish (*Gambusia holbrooki*), riverine grass shrimp (*Palaemonetes paludosus*), and Florida gar (*Lepisosteus platyrhincus*; Williams & Trexler 2006). We found that local drying events decreased trophic position in mosquitofish and grass shrimp, but had no impact on gar because they avoided drying habitats. However, natural variation in P availability did not explain variation in trophic position of any of the study taxa. Most of the C in these food webs appears to be derived from detrital sources ("floc") that varied considerably along gradients of hydrology or nutrient availability (Williams & Trexler 2006).

We have also used $\delta^{13}C$ and $\delta^{15}N$ signatures to track temporal changes in food-web relationships of key oligohaline ecotone fish species (eastern mosquitofish, juvenile Mayan cichlid *Cichlasoma uropthalmus*, and rainwater killifish *Lucania parva*). We found that $\delta^{13}C$ and $\delta^{15}N$

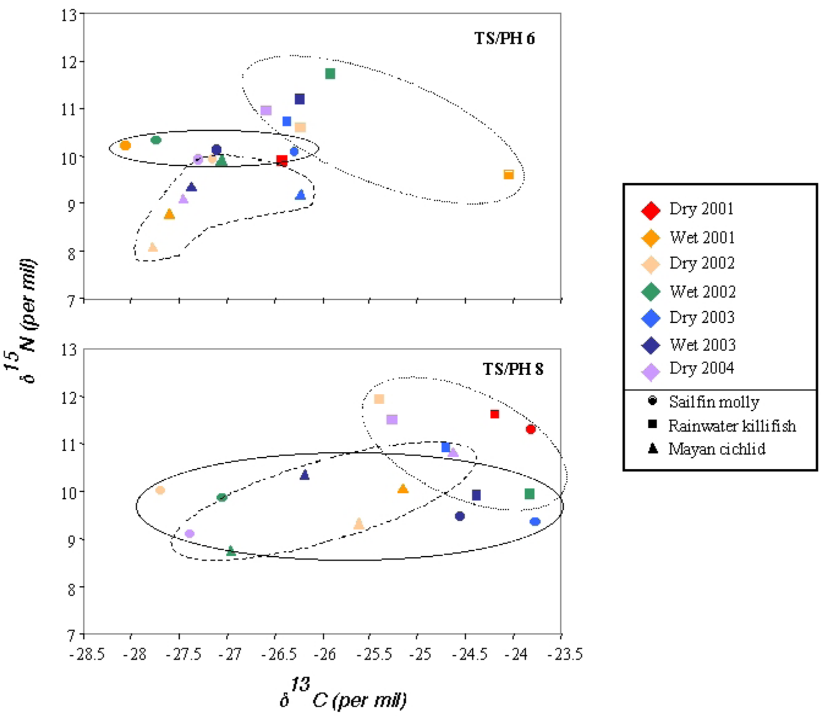


Fig. 2-16. $\delta^{13}C$ and $\delta^{15}N$ values from muscle tissues of three fish species collected at two estuarine FCE sites from wet season 2001 through dry season 2004. Sample sizes were generally 5, though varied from 2 to 6. Variability among individuals of the same species within a sample was generally small (mean CV=0.10) and is not shown to reduce clutter.

values varied considerably from 2001 to 2004, but not in patterns consistent with simple seasonal or hydrological fluctuations (Fig. 2-16; see also Fourqurean et al. 2005). Apparently, environmental effects on fish tissue composition in ecotone habitats are not simple, and our FCE II work will focus on further isotopic analyses of primary producers, primary consumers, and “floc” to learn more about these long-term temporal changes.

Specific Research Question 3-1: Do fish transport nutrients between the oligohaline ecotone and freshwater marshes or downstream marine/estuarine environments (Florida Bay and the Gulf of Mexico)?

Approach – We will use both active and passive acoustic telemetry to determine residency times and fine-scale movements of Florida gar (Lepisosteus platyrhincus), which migrate seasonally between freshwater marshes and the ecotone during wet seasons, and snook (Centropomus undecimalis), which are generally found in higher salinities but also use ecotone habitats during dry seasons. In the SRS and TS/Ph ecotones, we will deploy 16 stationary acoustic monitoring stations (VEMCO VR2) along the main channel. These units record the identity and time of every transmitter that passes within range (1.2-1.4 km detection diameter). We will thus be able to continuously monitor movements of tagged individuals along 6-8 km sections of ecotone tidal channel, including the amount of time that an individual spends within, upstream, and downstream of the array. We will track 40 individuals of each species in each ecotone. In Years 4-6 of FCE II, we will supplement this work by also actively tracking individual fishes (20 per site) to determine their patterns of microhabitat use. We will use our hydrologic and water quality data to determine how salinity, water flow, and tidal inundation affect movements of these 2 species.

Specific Research Question 3-2: How does fish community structure (standing crops and species composition) in the oligohaline ecotone change in response to increased freshwater inflow?

Approach – We will continue our sampling of fish standing stocks and species composition at FCE sites to enhance interpretation of movement data. Samples will be collected by 1-m^2 throw trap at freshwater sites (Jordan et al 1997) and 9-m^2 drop trap at mangrove sites (Lorenz et al. 1997). These two methods produce indistinguishable fish density and composition estimates when used side by side (Trexler and Lorenz, unpubl. data). Drop-trap sampling will be stratified by habitat type; 3 traps will be placed in wetlands and 3 in adjacent creek habitats at sites TS/Ph-3 and 6, and SRS-4 and 5. Seven throw trap samples will be collected at randomly identified locations in three 100 m by 100 m plots at select freshwater site (TS/Ph-2; SRS-2 and 3). Samples will be collected at least three times per year at each site (February, April, and October/ November).

Specific Research Question 3-3: How are food webs in the oligohaline ecotone affected by changes in water source, nutrient and "floc" supply, and tidal energy?

Approach – In FCE II, we will continue bi-annual sampling of isotopic composition of sailfin mollies, eastern mosquitofish, and juvenile Mayan cichlids at our ecotone sites. We will expand this work to include fish from our estuarine sites and samples of primary consumers (zooplankton and benthic invertebrates), submerged aquatic vegetation (SAV), mangrove leaves, and "floc" from all sites. We will non-destructively sample tissues from snook and Florida gar that "participate" in our movement studies. These stable isotope data will be used to assess the origins and major routes of energy flow, including the potential for allochthonous transport by these mobile predators (Post 2002). We will also continue lab and field studies on how salinity affects isotope assimilation in these fish species.

G. Biogeochemical Cycling (co-leads – A.Hartley & J.Boyer):

GENERAL QUESTION 4: How do water residence time and the magnitude of nutrient inputs, primarily from freshwater inflows, marine inputs, and groundwater, control local nutrient concentrations and cycling rates in the oligohaline ecotone?

RATIONALE – The GOM is the dominant source of P to our SRS ecotone sites, and the freshwater Everglades is the dominant source of N to both ecotone regions; however, our long-term water quality data show unexpected, regular P peaks at our TS/Ph ecotone sites during the dry season (Childers et al. 2006a; Fig. 2-17). Time-series salinity data suggest that water residence times in this area are relatively long during this time (Fig. 2-18), which could increase the importance of internal biogeochemical cycling, such as wetland-water column exchanges (Davis et al. 2001a,b; Davis et al. 2003b; Romigh et al. 2006) and organic matter decomposition (Fourqurean & Schrlau 2003; Davis & Childers in review; Davis et al. 2006; Maie et al. 2006b; Fig. 2-19). We have recently learned that inputs of relatively high P groundwater may be important to nutrient dynamics and belowground productivity, particularly during the dry season (Price et al. 2006; Ewe, unpubl.data). Long water residence times would enhance this importance. Our biogeochemical work will continue to focus on quantifying the content of surface waters influencing both ecotone regions. In FCE II, we will expand this focus to also quantify groundwater nutrient

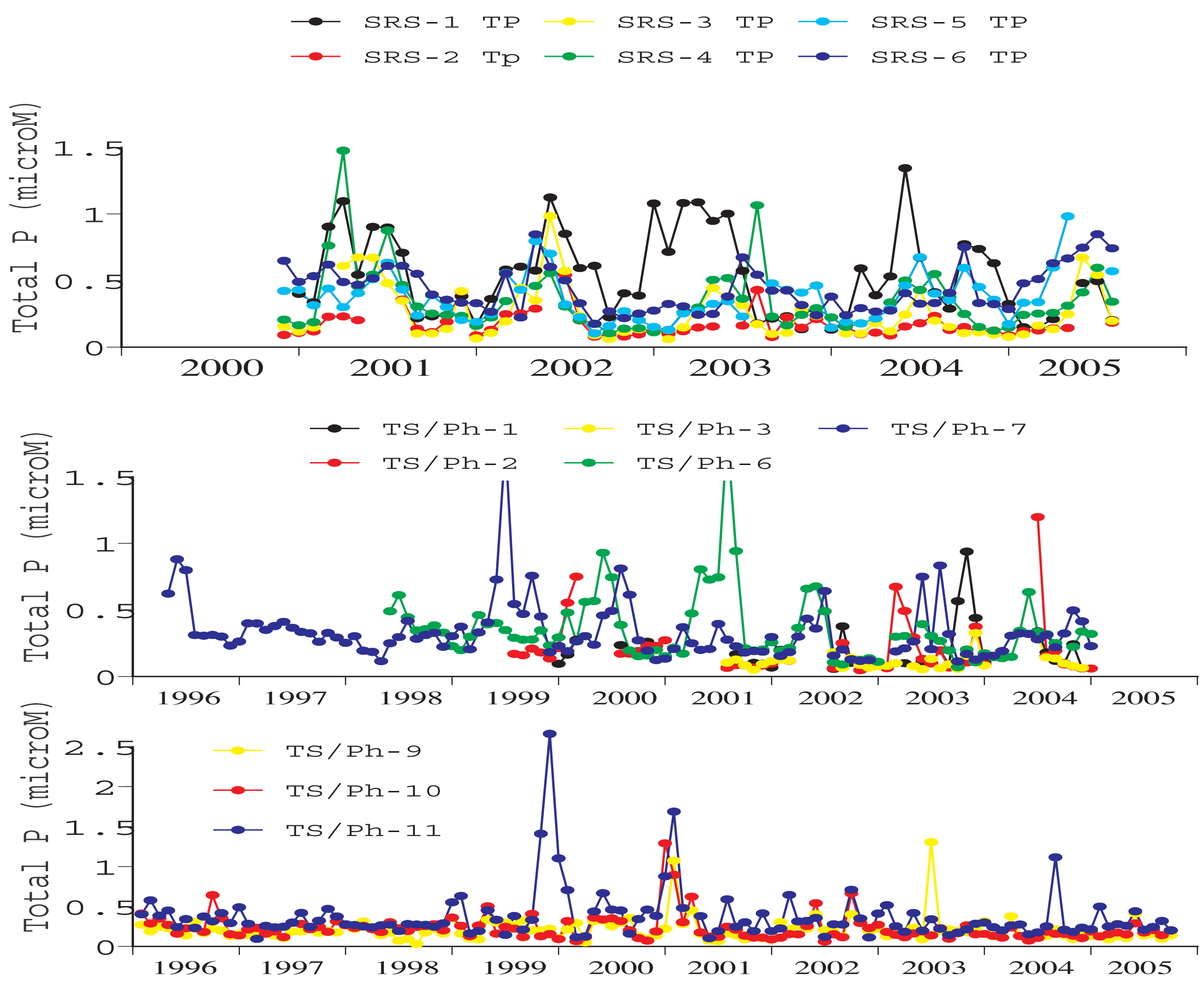


Figure 2-17: Total P concentrations at SRS sites (top panel) and the Taylor Slough sites of the TS/Ph transect (middle & lower panels). Data in upper & middle panels are monthly means of tri-daily continuous water quality samples and Florida Bay data (lower panel) are from monthly grab samples (modified from Childers et al. 2006a).

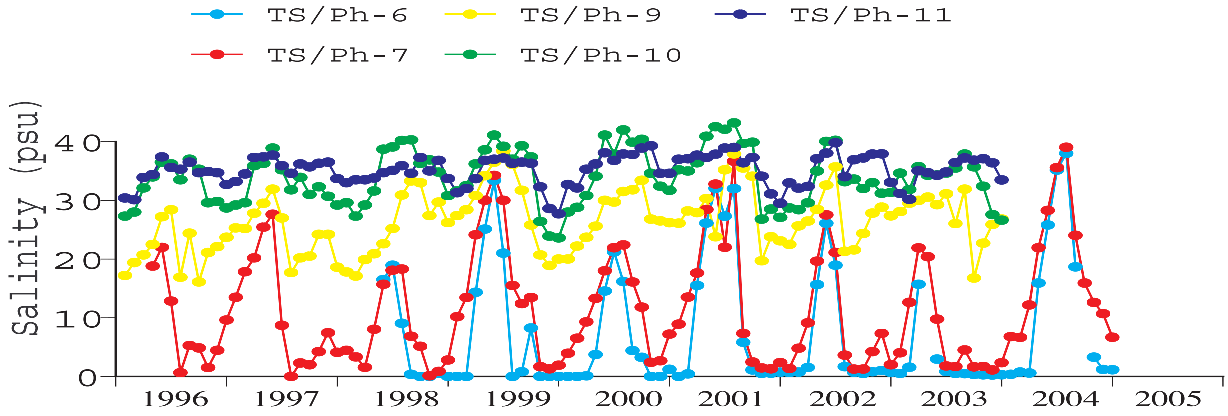


Figure 2-18: Salinity at the Taylor Slough estuarine sites of the TS/Ph transect. TS/Ph-6 & 7 data are monthly means of tri-daily continuous water quality samples and Florida Bay data (TS/Ph-9, 10, & 11) are from monthly grab samples (modified from Childers et al. 2006a).grab samples (modified from Childers et al. 2006a).

inputs, to estimate atmospheric inputs, and to better understand how N and P cycling are coupled to each other and are controlled by autochthonous versus allochthonous nutrient sources.

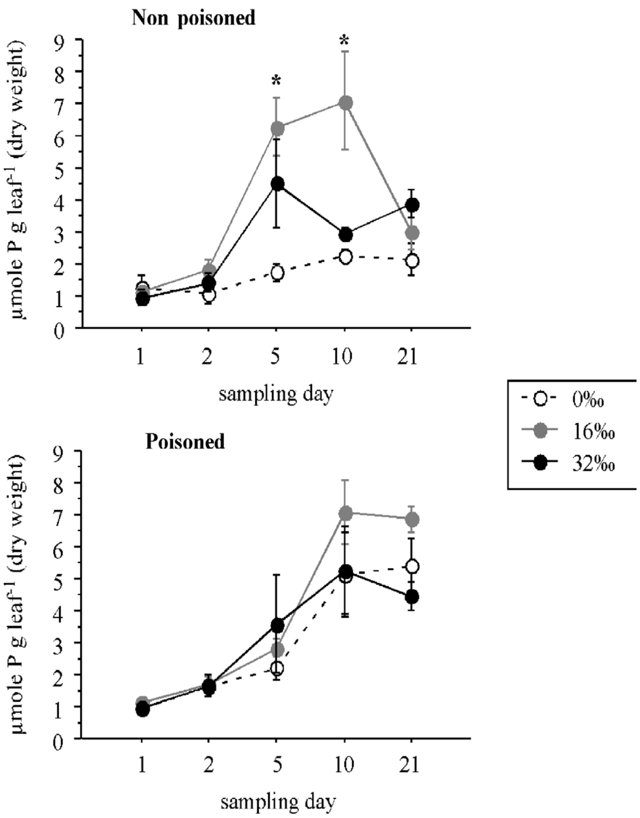
Specific Research Question 4-1: What are the mechanisms by which P availability acts to regulate N cycling rates in marshes and mangroves of the southern Everglades?

The $\delta^{15}N$ ratios in major ecosystem components of Everglades freshwater marshes (plant roots and leaves, periphyton, and soils) are highest at sites proximal to canal inflows, suggesting a strong influence of "older", heavily recycled N from canal waters. Ratios are much lighter only a few km from canal inflows, though, suggesting rapid uptake of canal-derived N by these marshes (Fig. 2-20). Mesocosm studies in freshwater and ecotone wetlands using a $\delta^{15}N$ tracer also show increased rates of N cycling between the water, periphyton, and plants when P is added (Fig. 2-21). These findings suggest that, in spite of an abundance of N in the water column (Childers et al. 2006a), N cycling rates may be regulated by P availability in our oligotrophic ecosystems. For example, even short-term increases in P concentration may release microbes from P-limitation and alter rates of nitrogen fixation, denitrification, or other assimilative N processes. We expect that this tight coupling of P and N cycling will be most apparent at our oligohaline ecotone sites, where P availability often varies over short time scales.We will investigate this coupling by examining changes in potential rates of nitrification, denitrification, and N2 fixation following P additions to soils, "floc", and periphyton from key oligohaline ecotone sites. Specifically, we expect that nitrification and denitrification potentials will be highest in soils while N-fixation potential will be highest in periphyton. We also expect that higher P availability and high salinity will stimulate N cycling rates more in the dry season compared to the wet season.

Approach – Samples of soils, "floc", and periphyton will be collected during both wet and dry seasons from key ecotone sites and incubated in the laboratory. Nitrification potential will be measured using allylthiourea, which blocks nitrification (Ginestet et al. 1998). We will measure denitrification using acetylene block technique in samples treated with chloramphenicol, which prevents overestimation of denitrification rates (Bernot et al. 2003), and will compare this method to denitrification estimates obtained from membrane inlet mass spectrometry (Kana et al. 1998). N fixation potential will be measured using acetylene reduction and calibrated with ^{15}N techniques (Seitzinger and Garber 1987). These N cycling processes will be correlated to the $\delta^{15}N$ content of soils, "floc", and periphyton to determine how $\delta^{15}N$ values are regulated by processes such as fixation of atmospheric N and selective ^{15}N uptake by microbes. Specifically, we will calibrate our N-fixation methods in Year 1, examine the effects of P additions on N-fixation (Year 2) and nitrification potential (Year 3), calibrate our denitrification methods (Year 4), examine the effects of P additions on denitrification (Year 5), and quantify P-addition effects on all 3 processes simultaneously (Year 6).

Specific Research Question 4-2: How is the soil bacterial community influenced by temporal changes in water source in the oligohaline ecotone, and how are these community shifts reflected in ecosystem processes, such as those of the N cycle?

We will address this question by first characterizing the bacterial communities present in the SRS and TS/Ph ecotones. The relative influence of various water sources (freshwater inflow, marine inputs, groundwater discharge, and precipitation) vary seasonally, and sometimes over



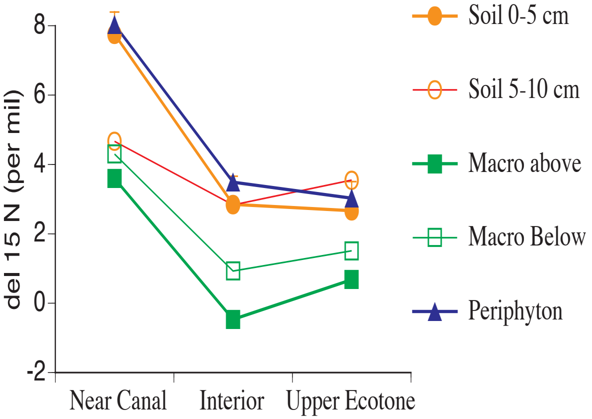


Figure 2-20: $\delta^{15}N$ natural abundance values for soils, sawgrass, and periphyton from the C-111 Basin leg of the TS/Ph transect, sampled in the 2004 wet season. Canal N, which has been repeatedly cycled, has a heavy $\delta^{15}N$ signature, and this is reflected in the soils, plants, and periphyton at the site nearest the canal. Only a few km into the marsh, though, $\delta^{15}N$ signatures are much lighter—as they are at the northern edge of the oligohaline ecotone—indicating that canal N is taken up quickly in these P-limited marshes (J.Wozniak, unpubl.dissertation data).

Figure 2-19: Daily P yield from submersed red mangrove leaves (water column P normalized to initial leaf mass) with biotic activity + physical leaching (top panel) and with only leaching (bottom panel). Salinity levels represent different sources of water (Everglades marsh water, Florida Bay marine water, and brackish water from the ecotone). Water source/salinity affected only biotically-mediated P release rates. The highest biotically-mediated release of P was observed with ecotone water between 5 and 10 days, suggesting that the microbial community in this water source had less of a demand for leached P during this period. The biotic + leaching treatment with Everglades marsh water (A) showed the lowest P yield throughout, suggesting a high P demand by epiphytic microbes (after Davis et al. 2004).

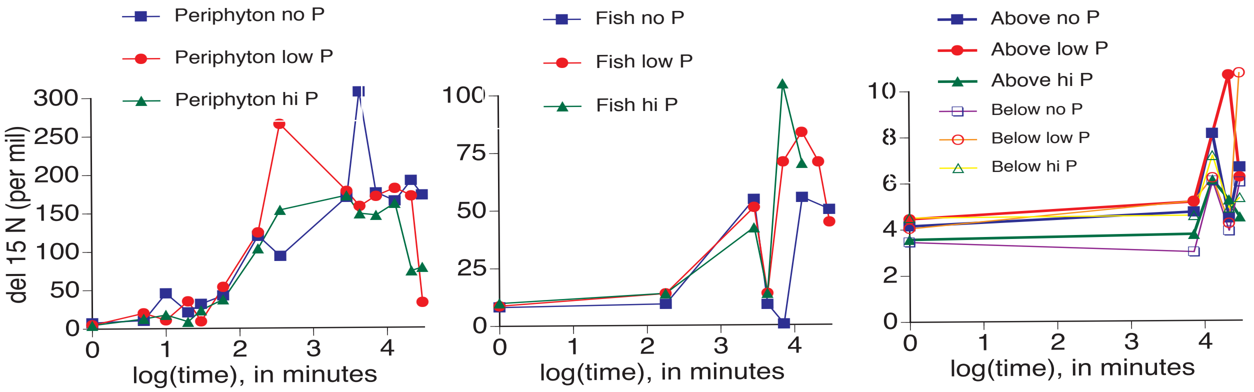


Figure 2-21: $\delta^{15}N$ abundance values for periphyton (left), *Gambusia holbrooki* (center), and sawgrass (right) collected from a 21 day in situ ^{15}N tracer mesocosm study conducted at TS/Ph-4. Six 2 m2 lexan mesocosms were deployed in the marsh, and P was added at 2 different rates to 4 of the six mesocosms (rates=6.66 mg P m2 and 66.6 mg P m^{-2}, as per Daoust and Childers 2004). Samples were collected before dosing, at 5, 10, 20, and 30 minutes, 1, 3, and 6 hours, and 2, 3, 5, 9, 15, and 21 days after P additions (note that log(t)=1 is 10 minutes, log(t)=2 is about 2 hours, log(t)=3.5 is about 2 days, and log(t)=4.5 is about 21 days). Periphyton uptake of N was stimulated dramatically in the low P dose mesocosms, with peak N uptake after only 6 hours compared to 3 days in the control chambers. This N effect was not as clear in the fish (presumed consumers of periphyton N) and plants (J.Wozniak, unpubl.dissertation data).

much shorter time periods during events. We will view this temporal dynamic as equivalent to a spatial gradient—that is, we expect that bacterial communities will show shifts in time at our ecotone sites that are similar to those observable in space along an estuarine gradient. This gradient approach has been used to quantify bacterial community changes in river sediments, in sediments away from a source of heavy metals (Feris et al. 2004, Gillan et al. 2005), in water column bacterioplankton along a salinity gradient (Crump et al. 2004), and in Antarctic marine sediments across the shelf (Bowman & McCuaig 2003).

Approach – We will use functional genomic analysis to elucidate bacterial community structure in soils and microbial mats at the TS/Ph and SRS oligohaline ecotone sites. DNA analysis may be applied at different levels of resolution: whole communities, bacterial isolates, and clones of specific genes. Low resolution and broad scale analysis of community DNA, like DNA-reassociation, allow the assessment of the total genetic diversity of bacterial communities (Torsvik et al. 1996). PCR combined with denaturing gradient gel electrophoresis (DGGE) analysis of rDNA operates at somewhat higher resolution, providing information about changes in the gross community structure (Muyzer et al. 1993). When DGGE analyses of 16S rDNA are combined with sequencing, assessment of the phylogenetic affiliation of the numerically dominant members of a community is obtained. Subsequent cloning of PCR products from 16S rDNA in whole community DNA provides significant new information about non-cultured bacteria. This approach also allows comparison of the structure of the previously cultivated fraction of a bacterial community with the total community. Finally, to discriminate at the bacterial isolate and clone levels, combined DNA fingerprinting and sequencing have been used (de Bruijn 1992, Massol-Deya et al. 1995, Stackebrandt and Rainey 1995). For our work, we will quantify organisms containing specific functional genes by real-time quantitative PCR (qPCR; i.e. for nitrogen fixation, nitrification, denitrification, and carbon fixation), and the relative expression of these select genes of ecological relevance from soils and microbial mats using quantitative real-time reverse transcription PCR (qRT-PCR). We will relate microbial community characterization to the process-based work of Question 4.1 by making these measurements in the same cores used for that work.

H. Organic Matter Dynamics (co-leads – R.Jaffé & R.Chambers):

GENERAL QUESTION 5: How are organic matter dynamics (DOM, “floc”, and soils) in the oligohaline ecotone controlled by local processes versus allochthonous freshwater, marine, and groundwater sources?

RATIONALE – We devoted considerable resources in FCE I to understanding the sources, fate, and transport of DOM in our system. We have developed methods that greatly facilitate DOM characterization (Jaffé et al. 2004; Jones et al. 2004) and are now able to identify major sources of DOM from key ecosystem components (Lu et al. 2003; Scully et al. 2004; Jones et al. 2005, 2006; Maie et al. 2005). In the last few years, interest in “floc” has increased considerably. “Floc” is generally found as a nearly neutrally buoyant bedload, not in suspension (Wood 2005). We know that “floc” is transported downstream as water flows through freshwater marshes (Leonard et al. 2006) and we have learned how to identify the sources of “floc” (Mead et al. 2005; Neto et al. 2005). The balance of “floc” transport and internal “floc” production appears to be different in our two ecotone regions (Jaffé et al. 2001), and recent evidence suggests that much of the “floc” found in the TS/Ph ecotone is produced in situ during the dry season and is subsequently exported during the wet season (G.Losada, FIU, unpubl.data). We will continue this research in FCE II. Finally, the soils of both ecotones are organic-rich peats (Chambers & Pederson 2006), suggesting a close relationship between mangrove belowground dynamics and soil dynamics. In these areas, soil sustainability in a rising sea level environment is a balance of net peat accumulation (Gaiser et al. 2006) and surficial sediment deposition, which may be predominantly storm related (Davis et al. 2004; Fig.2-22).

Specific Research Question 5-1: **Does the [allochthonous and autochthonous] supply of DOM and "floc" to the oligohaline ecotone vary seasonally, and how do hydrological, ecological, and climatological processes interact to control this supply?**

The quality of the organic matter pool is quite variable across the Everglades landscape, due to differences in vegetation (Neto et al. 2005; Mead et al. 2005), geomorphology (Jaffé et al. 2004) and seasonality of hydrology and primary productivity (K.Parish, FIU, unpubl.dissertation data; Mead 2003; Maie et al. 2006c). Ecosystem energetics, including the structures of food webs and microbial loops, are influenced by DOM, "floc", and suspended POM (SPOM) dynamics—particularly in oligohaline systems.

Approach – The dynamics of "floc" and DOM will be investigated along the SRS transect, where we expect freshwater flow rates to increase during FCE II, and along the TS/Ph transect, where we expect that water residence time plays a strong role in ecotone dynamics. We will collect samples bimonthly at several sites along both transects, emphasizing the ecotone regions. Bulk DOM, "floc", and SPOM will be collected and analyzed using biomass-specific biomarkers and stable isotope determinations (for SPOM = Hernandez et al. 2001; Mead 2003; Mead et al. 2005) and optical and chemical properties (for DOM = Lu et al. 2003; Jaffé et al. 2004; Scully et al. 2004; Maie et al. 2005, 2006c). We will estimate seasonal variation in the allochthonous OM input to each ecotone from bimonthly samples collected at end-member sites (SRS-2 and 6; TS/Ph-3 and 9) and from offshore of both estuaries. This approach will allow the application of a three-end-member mixing model (freshwater marsh-oligohaline ecotone-outer estuary/marine, as

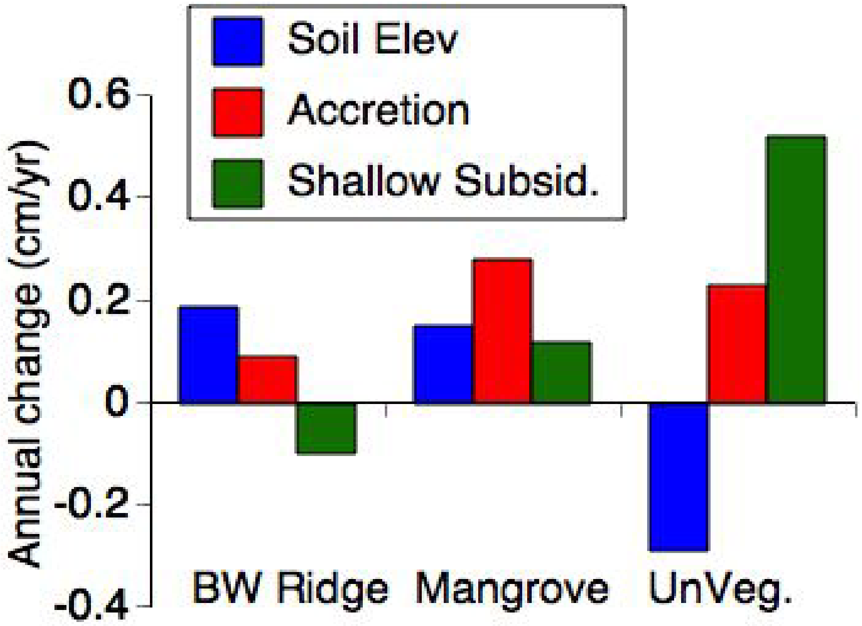


Fig 2-22: Average annual changes in absolute soil elevation, surficial accretion, and peat subsidence (peat depth < 1 m) from the TS/Ph ecotone, including Buttonwood Ridge sites, sites vegetated by dwarf red mangrove, and unvegetated areas (C.Coronado-Molina & F.Sklar, SFWMD, unpubl. data).

per Jaffé et al. 2001) using biomass-specific biomarkers, namely C20 and C25 highly branched isoprenoids from periphyton and marine diatoms respectively (Neto et al. 2005; Xu et al. 2006a; Hajje & Jaffé 2006; Saunders et al. 2006) and taraxerol for mangroves (Xu et al. 2006b; Rushdi et al. 2006). We will calibrate biomass-specific molecular markers for quantitative assessment of the contribution of each end-member source. We will also attempt to identify a molecular marker specific for the oligohaline ecotone planktonic component (possibly unsaturated C17 n-alkanes or pigments). We will continue to characterize DOM seasonally using optical properties, primarily through fluorescence-based excitation emission matrices (EEMs; Maie et al. 2006b,c) in conjunction with PARAFAC (Stedmon & Markager 2005), while DOM quality will also be assessed through chemical analyses (total hydrolysable amino acids and carbohydrates).

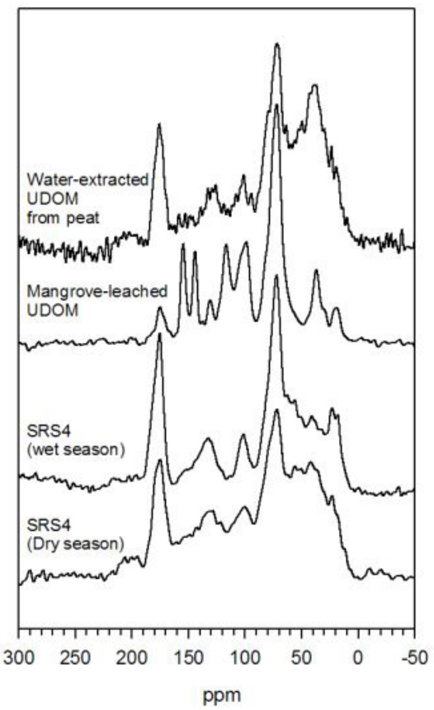


Fig 2-23: ^{13}C-NMR spectra for UDOM extracted from Everglades peat, leached from mangrove leaves, and isolated from surface waters at SRS-4 during wet and dry seasons.

Specific Research Question 5-2: **Are the chemical characteristics and quality of DOM leaching from soils discernible from groundwater DOM sources, and [if so] what is the relative contribution of each source to surface water in the oligohaline ecotone?**

Little is known about the contribution of soil-derived and groundwater derived DOM to overall DOM pools in our oligohaline ecotone regions. The increased focus on hydrology in FCE II (particularly groundwater-surface water interactions) will allow us to investigate the dynamics of groundwater DOM inputs to the ecotone using molecular characterizations of both high molecular weight (>1000 Dalton) and bulk UDOM. We expect that the characteristics and fate of groundwater DOM will be discernible and different from DOM in [either marine or fresh] surface waters.

Approach – We will characterize DOM from groundwater samples collected seasonally along both FCE transects, with particular emphasis on the ecotone regions. Samples will be analyzed as above (Specific Research Question 5-1) and a subset of samples of the high molecular weight components (UDOM, >1000 Dalton) will be run through more advanced techniques including ^{13}C-NMR (carbon composition; Maie et al. 2005; Fig. 2-23) and 14C dating (age) for their characterization. We will also quantify and characterize DOM inputs via rainwater. In addition, microcosm experiments will be set up during both wet and dry seasons using Plexiglas enclosures placed around vegetation characteristic of freshwater marsh and mangrove sites. Water within the enclosures (24 hr. experiments) will be recycled through activated carbon filters during several hours at night to remove as much existing DOM as possible (we have used this method successfully in seagrass beds). The DOM within the enclosures must come from one of 3 primary sources: 1) exudation by the plants (=”new” DOM); 2) leaching from the soils (=”old” DOM), or; 3) groundwater discharge. We will sample this DOM throughout the day for bulk characterization, and at the beginning and the end of the experiment for UDOM characterization (Maie et al. 2005) and DOM bioavailability (Boyer et al. 2006). We will continue to calibrate and will use geochemical proxies of DOM characteristics to distinguish plant derived DOM from DOM in groundwater inputs or from soil leaching (Maie et al. 2006a; Maie et al. 2006c; Fig. 2-23). We performed a number of biomass leaching experiments during FCE I (Davis et al. 2003b; Davis & Childers in review; Davis et al. 2006; Maie et al. 2006b), and will continue them, with particular emphasis on soil leaching. We will also continue to study the photo-degradation of Everglades DOM (Scully et al. 2004; Maie et al. 2006b). Our continued molecular characterization of soil and "floc" will include improvements to our molecular methods for paleoenvironmental studies (Xu et al. 2006a; Saunders et al. 2006).

Specific Research Question 5-3: **How are soil dynamics (nutrient and OM content, peat accumulation, sedimentation) in the oligohaline ecotone controlled by water source and hydrologic residence time?**

Soil properties integrate biogeochemical, ecological, and physical processes over extended time scales, much in the same way that climate is the long-term aggregate of weather conditions for a region. In FCE II, we will continue to track long-term patterns in soil dynamics and how they respond to changes in hydrology, nutrient cycling, and ecological dynamics—with emphasis on the ecotone—through transect-based analysis of bulk soil properties and soil elevation change (Fig. 2-23).

Approach – In south Florida wetlands, the processing and accumulation of soil organic matter is a function of many processes, including soil P availability, the amount of reduced sulfur (S) compounds, and the availability of reactive iron (as it influences both P and S cycles in carbonate soils; Chambers et al. 2001). We will continue to quantify the bulk properties of soils and sediments from the 14 FCE II sites annually (organic matter, bulk density, and forms of P, S, and iron; Chambers & Pederson 2006). We will also quantify wetland soil responses to the long-term interaction of nutrients, belowground production, storm deposition, and sea-level rise by measuring changes in soil elevation at our ecotone and freshwater marsh sites using SETs through continued collaborations with T.Smith (USGS; SRS-4, 5, & 6; see Appendix 1) and C.Coronado-Molina (SFWMD; TS/Ph-6 & 7; Childers et al. 1993b, Whelan et al. 2005) and using soil elevation pins at our other wetland sites (Reed 1992). In addition, molecular parameters such as biomass-specific lipid biomarkers and other geochemical proxies will be applied in paleoenvironmental assessments along the FCE transects.

I. Climate and Disturbance (lead – W.Anderson):

GENERAL QUESTION 6: How is the location and the spatial extent of the oligohaline ecotone controlled by changes in climate (precipitation, temperature, wet vs. dry years), freshwater inflow (management, restoration, and the "Grand Experiment"), and disturbance (sea level rise, hurricanes, fire)?

RATIONALE – Changing climate exerts strong controls on biophysical dynamics in the coastal Everglades, regardless of changes in freshwater delivery. Decadal, global phenomena affect precipitation patterns in south Florida at several temporal scales. El Niño events, for example, reduce the wet-dry seasonality in precipitation without affecting total annual rainfall (Childers et al. 2006a). Such changes in intra-annual rainfall patterns affect the volume and timing of surface water inflow, groundwater discharge, and wetland hydroperiod. Decreased hydroperiod increases the likelihood of fire (Lockwood et al. 2003). Also, sea level is increasing at about 2.5 mm yr-1 in south Florida (Zervas 2001), and predictions of a doubling of this rate by 2100 would increase mean sea level at FCE by nearly 40 cm (Toscano & Macintyre 2003). Even at current rates, sea level rise will have major long-term impacts on the FCE landscape since most of ENP is less than 1.5 m above mean sea level (Titus & Richman 2001). Some predictions hold that many Caribbean mangrove wetlands will be capable of maintaining their position for at least the next 50 to 100 years at the present rate of sea level rise (Ellison & Farnsworth 1997). This prediction is contentious, though.


Figure 2-24. Several cm of inorganic, carbonate-rich marine sediment deposited on a boardwalk at the SRS-6 mangrove site by Hurricane Wilma on Oct. 24 2005.

Hurricanes are an important and frequent "pulse" disturbance acting in concert with the "press" of sea level rise. In 2005 alone, our LTER sites were directly affected by Hurricanes Dennis (early July), Katrina (late August), Rita (mid-September), and Wilma (late October). Storm surges deliver marine sediments rich in Ca-bound P to mangrove wetlands (Chen & Twilley 1999; Simard et al 2006). Hurricane Wilma (Category 3, October 24, 2005) deposited 3-4 cm of marine mineral sediment on the mangrove soils at our SRS-6 site (Castaneda-Moya, LSU, unpubl.data; Fig. 2-24). Smith et al (1994) reported 1-10 cm sediment accumulation in this region after Hurricane Andrew (Category 5) in 1992. The TS/Ph ecotone, which is bounded by the shallow Florida Bay estuary, not the GOM, is likely much less affected by sedimentary P inputs associated with hurricane storm surge. When these events do occur, most of this P-rich sediment is deposited on the Buttonwood Ridge, not in the ecotone mangroves (Davis et al. 2004). Hurricane winds can have a significant effect on mangrove forests, particularly along our SRS transect where the trees are taller (Chen & Twilley, 1999; Simard et al., 2006). After a hurricane, the distribution of woody debris (Krauss et al., 2005) and its decomposition (Romero et al., 2005) are important feedbacks to biogeochemical cycling and organic matter dynamics. We will continue to track the effects of these increasingly "routine" hurricane events (Emanuel 2005; Webster et al. 2005) through FCE II.

During FCE II, we will also continue documenting long-term changes in the size and location of the oligohaline ecotone as the landscape responds to sea level rise, hurricanes, increased freshwater inflows, and fire. We expect that, over intermediate time scales (years to decades), the first two drivers will tend to force the estuarine boundary of the ecotone landward while the latter 2 drivers will either force the freshwater boundary seaward or hold it near its current location. In the long term, though (decades to a century), we expect that marine forces will prevail and the entire ecotone region will transgress landward. Nutrient inputs and the degree of oligotrophy will likely complicate this spatial dynamic in ways that aren't easily predicted—particularly as these biogeochemical controls affect peat accumulation rates in ecotone wetlands, which ultimately determine vertical sustainability of these systems in a rising sea level scenario.

Approach – We will address this question with climate and water level data collected at our FCE sites and monitoring stations operated by ENP and the USGS. Our FCE II research will also include new measurements of freshwater flows to our ecotone regions (see Section 2.A). We will evaluate landscape-scale changes in ecotone vegetation (mean plant height, crown size, and biomass; Simard et al. 2006) using LIDAR (Light Detection and Ranging) in Years 1 and 5, in collaboration with the International Hurricane Research Center, at FIU. These will include separate surveys of our SRS and TS/Ph transects, with multiple flight transects along each. We successfully used this technology in our SRS ecotone region in collaboration with M. Simard (NASA JPL; Zhang et al. 2004). We will continue to work with Zhang (FIU) and Simard (JPL) during FCE II (Zhang and Whitman, 2005). We will also continue to document vertical soil dynamics by measuring soil elevation change and surficial accretion by continuing our soil elevation table (SET) work at sites in the SRS ecotone (K.Whelan & T.Smith; USGS; Whelan et al., 2005) and the TS/Ph ecotone (F.Sklar & C. Coronado-Molina, SFWMD). Finally, we will continue to reconstruct historical changes in hydroperiod across the coastal Everglades using sedimentological (Saunders et al. 2006) and isotope-dendrological methods (Anderson et al., 2005). We will relate these records to existing teleconnection indices (NAO, NAtl, ENSO and PNA) to investigate long-term relationships between global climatic drivers and biophysical dynamics at the FCE LTER (Enfield and Alfaro, 1999; Rosenheim et al., 2005; Tan and Neelin, 2004).

J. Human Dimensions (lead – L.Ogden):

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

RATIONALE – The greater Everglades is a human-dominated ecosystem (Davis & Ogden 1994) which has experienced dramatic population growth (from less than 4,000 residents in 1900 to over 6 million residents in 2000). Associated land use change continues to have significant ecological effects on the Everglades, including (but not limited to) changes in water quality, vegetative community structure and productivity, and hydrological patterns (e.g. Fig. 2-25). Everglades Restoration may ameliorate some of these impacts; however, we believe it is critical that we understand the social, economic, and political processes that will continue to drive land use changes in south Florida (Walker & Solecki 2001; Committee on Restoration of the Greater Everglades Ecosystem 2003, 2005). Investigations of past and present land use will allow us to develop conceptual models of the social process of land use change as well as predictive models of future land use change and associated societal-ecological interactions.

Approach – Historically, agricultural lands served as critical buffers between the urban/exurban development and FCE sites in ENP. However, these ecologically significant agricultural lands are now at risk of change to urban/exurban uses due to specific and historical land use trends and socioeconomic drivers (Harwell et al. 1996; Solecki 2001). In order to understand the social processes driving this change, we will conduct qualitative and quantitative studies examining zoning characteristics, housing, real estate, and labor markets, as well as the economic, social and policy dynamics of regional farming practices. Land use changes may alter ecological functioning at an ecosystem scale, but land use change decisions take place at much smaller scales –households, local zoning boards, etc. (Brody et al. 2003; Brody et al. 2004; Brody & Highfield 2005). We will use interviews, community meetings, and quantitative surveys with residents in the rural/ag-

MIAMI-DADE

Water supply puts crisis on tap for Dade

■ Miami-Dade's long-term water plans could sink future growth, state officials warn.

BY TERE FIGUERAS NEGRETE
AND CURTIS MORGAN
tfigueras@MiamiHerald.com

State water managers warned Miami-Dade County on Thursday to come up with a new plan for supplying water to its booming population over the next two decades — one that doesn't blatantly ignore state conservation requirements and threaten to suck Everglades wetlands dry.

Miami-Dade, they said, doesn't have more water to give, at least not from the cheap source the county's utility currently taps.

The stern warning does not mean there won't be enough water to flush toilets or fill bathtubs for

• TURN TO WATER, 2B

4L | SUNDAY, JANUARY 29, 2006 SD ND BR

OPINION

JOHN S. KNIGHT (1894-1981)

JESUS DIAZ JR., **PUBLISHER** | TOM FIEDLER, **EXECUTIVE EDITOR** | JOE OGLESBY, **EDITORIAL PAGE EDITOR**

The Miami Herald | **EDITORIAL**

The end of South Florida's free ride on Everglades water

OUR OPINION: STATE'S TOUGH NEW LAWS SET RIGHT PRIORITY

Miami-Dade County commissioners and managers got a stern message from the state and the South Florida Water Management District last week: The days of business as usual are over. The message was both timely and necessary.

Business as usual means siphoning more and more water from the Everglades to slake the thirst of a growing population. The message wasn't just for Miami-Dade. It applies to Broward, Monroe and Palm Beach counties, too. To their everlasting credit, Gov Jeb Bush and the Legislature last year turned off the one-way spigot with two bills that strengthen the state's water-supply policy.

The bills link water supplies with permits for new development and protect the state and federal governments' $8 billion investment in Everglades restoration by ensuring that growth will not drain the Everglades. From now on, counties and cities must find alternative sources of drinking water to support growth.

Water linked to growth

Florida Department of Environmental Protection Secretary Colleen Castille and SFWMD Executive Director Carol Ann Wehle came to Miami-Dade last week to deliver the message. They were alarmed by the County Commission's blithe transmittal in December of eight amendments to the county's comprehensive-development plan that took no account of the new law linking water supplies to growth.

"We have the perfect storm brewing here," Ms. Castille said. "There is the county's request for a

J. ALBERT DIAZ / MIAMI HERALD STAF

Homes in Weston have been built right up to the edge of the Everglades.

PERCENTAGE OF REUSED WATER

Percentage of waste water reused in the 13 counties in the South Florida Water Management District:

- **100%:** Collier, Glades, Hendry, Okeechobee, Osceola and Polk
- **80%:** Lee County
- **77%:** Martin
- **41%:** St. Lucie
- **40%:** Palm Beach
- **6%:** Monroe
- **5%:** Broward and Miami-Dade

have resisted finding alternative water sources, apparently believing that if they held out the district would relent and approve use of more Everglades water. Ms. Castille summed up the state and district's position: "We're not taking any more water out of the Everglades. Period."

The news hit hard: Water and Sewer Department Director Bill Brandt resigned Friday. County Manager George Burgess promised to work with the DEP and the SFWMD to meet state requirements on developing alternative water supplies.

Figure 2-25. Left: Article in the January 27 2006 issue of the Miami Herald about future water supply conflicts in Miami-Dade county tied to county expectations of a 25% increase in the population (now over 2 million people) in the next 20 years. Concerns about this increase in daily water use, from 346 million gallons day-1 today to an estimated need of 450 million gallons day-1 were expressed by SFWMD and Florida Dept. Environmental Protection officials. Above: OpEd article in the January 29 2006 Miami Herald about the conflict between development and land use change in M-D county and the ablity of the Everglades to purvey its key ecosystem service: Fresh water.

ricultural buffer zones to investigate individual and community perceptions of land use change. Results of this socio-economic research will be linked to biophysical evidence (satellite imagery, aerial photography, monitoring data from FCE transects) to produce maps and models of historic and current land use change. We will relate these measures of land use change to historical changes in variables that bridge our human and natural systems, such as urban storm water runoff, groundwater sewage discharge, and fresh water flow. Our focus will be on adjacent urban-rural areas in western Miami-Dade County that have seen particularly dramatic land use changes in the last several decades, or that are predicted to show such changes in the near future. We will consider several classic land use change conceptual models (Agarwal et al. 2002 for discussion) to integrate qualitative and quantitative [raster and vector] data, and to model future land use change scenarios. This may lead to development of a hybrid FCE LTER land use model that best suits our data requirements and mapping needs.

K. Network Activities: We will maintain our investment in Network-level leadership through FCE II, including in the Network Student Group, Coordinating and Executive Committees, the Information Management Committee, the Education Committee, and the Network Science Planning Initiative. New network initiatives include cross-site IGERT programs that specifically support students to do cross-site synthesis as their dissertation research (e.g. a grassland or a coastal LTER IGERT). Scientifically, FCE has been a leader in several areas, most notably in organic geochemistry. During FCE II, we will expand the number of these cross-site studies. As an example, we will be explicitly collaborating with GCE and VCR on the cross-site initiative described below. Each site has dedicated resources to this project, which we envision growing in scope and importance during this next round of funding. To our knowledge, this is the first time that LTER sites have mutually proposed a joint cross-site collaboration in renewal proposals.

During FCE II, we will conduct a cross-site study with investigators at GCE and VCR to test the hypothesis that isolated uplands increase local-scale biological and landscape-scale biogeochemical diversity in coastal landscapes. Specifically, we expect that isolated uplands (marsh hammocks at GCE, marsh "pimples" at VCR, and tree islands at FCE) will be "hotspots" of biodiversity, analogous to isolated wetlands in terrestrial landscapes and shrub patches in grassland ecosystems of the arid southwest. These diversity "hotspots" may be manifest as a higher number of plant and animal species and higher nutrient concentrations in these isolated uplands, compared with the wetland matrix. We will test this hypothesis by measuring [plant and animal] species diversity and soil nutrient content along transects that run from wetland through uplands and back into the wetland at all 3 sites. At FCE, we will devote an REU student (plus associated lab and field costs) for one or more years as needed, and will provide senior-level assistance (T.Troxler Gann) to complete this cross-site activity. Upon the completion of this work, we will seek to expand this cross-site investigation of patterns and processes in heterogeneous landscapes to other LTER sites (i.e. arid grasslands and tundra).

L. Linkages and Significance:

Program-wide integration is critical to the success of any LTER. Our enhanced focus on the oligohaline ecotone regions of our FCE II transects is a key component to this integration—our entire FCE group will be working together in these areas. To enhance conceptual and empirical linkages among the 5 Working Groups in FCE II, we have added 3 Cross-Cutting themes (Fig. 3-1). We have also incorporated 2 new initiatives: a Hydrology Working Group, which is central to both our focal hypotheses and our conceptual approach, and a social science (Human Dimensions) Cross-Cutting Theme, because we recognize that human behaviors, motivations, and activities affect virtually everything that we study at FCE, and often in very direct and tangible ways.

Oligotrophy is a defining characteristic of the FCE LTER, and is central to our programmatic linkages. The availability and cycling of P and N directly impact primary productivity, biomass allocation, and plant community composition. Primary producers are the dominant source of "floc". Rates of "floc" decomposition, and thus its availability as a food source for higher consumers, may be controlled by P availability to microbes. The long-term accretion of peat soils is partly a function of the balance of belowground plant productivity and decomposition, both of which are regulated by nutrient availability. Any understanding of biogeochemical controls in the oligohaline ecotone will depend on accurate estimates of nutrient inputs, which are driven by hydrology. Climate and disturbance also relate to all of our questions and working group activities, primarily by their effects on water and its movement through the system from both fresh and marine end members. Even with favorable nutrient levels maintaining the oligotrophic nature of the ecotone, a major climatic disturbance may cause dramatic ecological changes, or even a state change. Our goal is to understand these changes in the climate system as related to ecosystem dynamics of our study area. Finally, the Everglades has been highly modified by people. Everglades hydrology is highly controlled, and its immediate boundaries are dense and growing human population. Interactions between humans and the Everglades are certain to become m ore complex and more intense in the future. Our integrated research in FCE II will further our understanding of coastal Everglades ecosystems and how human activities will affect these systems into the future.

Briefly, we provide two examples of integration at FCE II—one conceptual and one empirical: The first (conceptual) links our research groups by applying the conceptual model of Twilley & Rivera-Monroy (2005) to our ecotone research (Fig. 2-26). This model relates how resource availability (i.e. P limitation), hydroperiod (i.e. tidal/seasonal inundation), and an environmental regulator (i.e. salinity) interact to control mangrove tree architecture and productivity. The "production envelope" defined by these 3 environmental gradients, and their respective combinations of stress, can only be understood if we have fully integrated our primary production, biogeochemical, hydrologic, organic geochemical, and disturbance research efforts. The eddy flux tower located at our SRS-6 site (J.Fuentes & J.Zieman, UVA, PIs) is the second example (empirical) of how one synthetic project integrates our FCE work. This is the only canopy-height flux tower located in a mangrove forest in the world (Fig. 2-27). Our work here will continue to focus on in situ CO2, nutrient, water, and energy flux measurements and numerical modeling investigations. We will use these data to answer questions about whole ecosystem C budgets (and how these compare with traditional production measurements), estuary-ocean-atmosphere C exchanges, and long-term C burial in estuarine soils. This eddy flux tower research

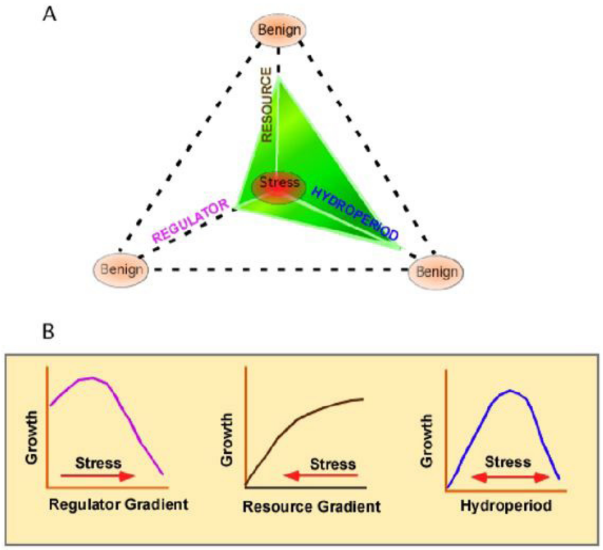


Figure 2-26. Factorial interaction of three factors controlling the productivity of coastal wetlands including regulator gradients, resource gradients, and hydroperiod. A) The production envelope associated with levels of each factor describe the response net primary productivity to these interacting subsidies and stresses. B) The definition of stress associated with how gradients in each factor control growth of wetland vegetation (from Twilley & Rivera-Monroy 2005).

Figure 2-27. Photo of the canopy-scale eddy flux tower at the SRS-6 site (J.Fuentes & J.Zieman, UVA, PIs).

will further our understanding of how coastal mangrove ecosystems respond to rapid rates of environmental change, with current emphasis on Hurricane Wilma (which passed directly over our SRS-6 site as a Category 3 storm in late October 2005). Ultimately, we will integrate these data into a coupled biospheric/hydrodynamic model to quantify and predict mangrove C dynamics and ecosystem function.

Understanding the emergent properties of coupled watershed-coastal systems requires a scientific framework that embraces the interplay among the biological, physical, and social components of such an ecosystem. Most research programs develop projects that compartmentalize system response. In contrast, FCE research uses integrative methods that span multiple temporal and spatial scales, facilitating predictions about emergent properties and forecasts of dynamic whole-ecosystem responses. An important goal of linking FCE science with Everglades Restoration is to provide reliable, continuous, and growing knowledge transfer from basic ecological theory to the development of more effective environmental management and restoration/rehabilitation programs. As such, FCE II will continue to be an integrated program of systems analysis and hypothesis testing working in concert with the design and implementation of a large-scale restoration project. Lessons learned will improve our understanding of the complex and increasingly stressed environments at the land-sea interface.

M. Response to FCE I Site Review:

Our FCE I 3-Year Site Review took place on March 19 & 20 2003, and the review team report provided to us on April 21 2003 was both complimentary and helpful. We responded to the 3 most pressing issues from this report in our May 12 2003 letter, and will not revisit those here. We briefly discuss here how our transition to FCE II resolves other substantive issues from this report. Our new central theme and hypotheses are based on what we learned about our system during FCE I, and have an enhanced focus on the low-salinity regions of our coastal Everglades transects. Our core direction has a strong foundation in major hydrologic changes that we expect during FCE II. For this reason, we have added a new hydrology initiative to FCE II and now have a Hydrology Working Group to help us answer these new questions. We have also focused our disturbance research considerably in FCE II, with an emphasis on climate-driven events that act as both “press” and “pulse” disturbances. Recognizing the ever-growing pressure from human activities, we have also expanded FCE II to include human dimensions initiative as one of our Cross-Cutting Themes. We have made significant contributions to DOM research across the network, and will continue to grow our network activities into FCE II. We have also been actively involved in the strategic planning for future LTER science (D.Childers is a co-PI on the Network Planning Grant). Finally, at the review team’s recommendation we have added a Project Information component to our IM Program (Section 4) and our website.

3. Site Management

At FCE II, our site management approach and style will continue to focus on leadership, continuity, diversity, and inclusion of junior faculty. D.Childers will continue as the Lead PI into FCE II, with a plan for a leadership transition during this next phase of funding. We anticipate that this transition will be under way at the time of our next Mid-Term Review (expected in Spring 2009), so that Childers and the newly chosen Lead PI can function as co-leads during this activity. Additional cover page PI leadership will be provided to the FCE II Program by E. Gaiser, M.Heithaus, R.Jaffé, and R.Price. Shortly after the FCE II 3 Year Review, we will complete this leadership transition—in plenty of time to prepare for the FCE III renewal process. We have not yet decided who the next Lead PI will be, and the process for this choice is clearly documented in our Program Administrative Guidelines (http://fcelter.fiu.edu/admin.doc). We do expect, however, that the new FCE Lead PI will be an FCE II cover page PI.

An important goal of FCE II program management is to balance the continuity of experience that is critical to any long-term program with the active involvement of “rising star” junior faculty in the leadership and management of the program. We will accomplish this goal in two ways. First, we have expanded our subcontracted institutions to include S.Davis (TAMU), a “rising star” who will work closely with R.Twilley (LSU) on mangrove research, and M.Rains, a “rising star” at USF who will work with our new Hydrology Working Group. We have also expanded our FCE Working Group structure to include five Working Groups and three Cross-Cutting Themes (Fig.3-1). The FCE II Working Groups each have co-leads—a cover page PI from our original FCE I proposal and a “rising star” junior faculty. The exception to this is our new Hydrology Working Group. These co-leads are:

1. Hydrology: René Price, FIU and Vic Engel, ENP
2. Primary Production: Evelyn Gaiser, FIU and Jim Fourqurean, FIU
3. Consumer Dynamics: Mike Heithaus, FIU and Joel Trexler, FIU
4. Biogeochemical Cycling: Anne Hartley, FIU and Joe Boyer, FIU
5. Organic Matter Dynamics: Rudolf Jaffé, FIU and Randy Chambers, W&M.

The FCE II Cross-Cutting themes will each have one lead, again with representation from experience and continuity (F.Sklar, who was an FCE I Internal Executive Committee member) and “rising star” junior faculty:

1. Modelling and Synthesis: Fred Sklar, SFWMD
2. Climate and Disturbance: Bill Anderson, FIU
3. Human Dimensions: Laura Ogden, FIU.

We will be expanding the Internal Executive Committee to include one lead from each Working Group (rotating positions), the leads of the Cross-Cutting Themes, the Education & Outreach Coordinator, a student representative, and two outside advisors (K.McGlathery, VCR and C.Hopkinson, PIE). The Working Group leads, Cross-Cutting Theme leads, and Ed & Outreach coordinator will be voting positions (9 total votes). The FCE II IEC will continue to function under the guidelines provided in our Project Administrative Guidelines, and we have expanded our FCE I organizational structure to include the 5 new Working Groups and 3 Cross-

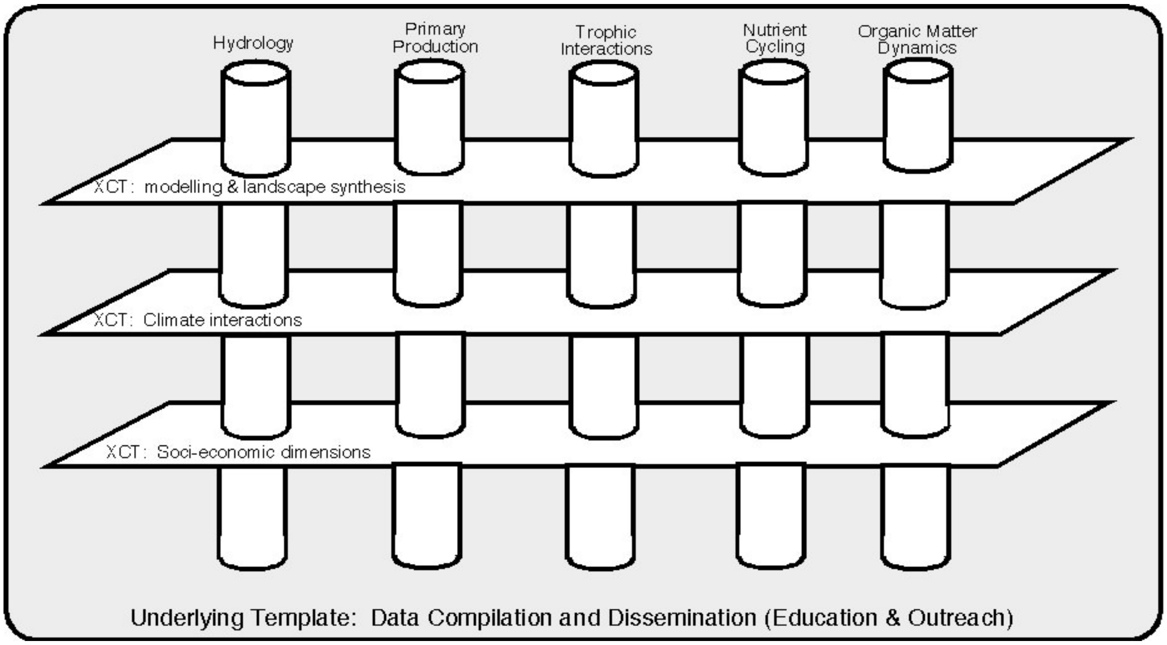


Fig 3-1: Schematic of the FCE II scientific program organization, showing the 5 Working Groups as "pillars" and the 3 Cross-Cutting Themes as "platforms" that link the pillars. The entire structure rests on an underlying template that includes information management & dissemination, and education & outreach.

Cutting Themes plus to elevate the overall importance of the Ed & Outreach Coordinator and the Affiliated Student Group (Fig. 3-2).

Day to day administrative activities will continue to be overseen by our Project Manager (M. Rugge), who works closely with our Information Manager (L. Powell) on the website and database mechanics. Rugge will continue to be responsible for central office accounting and procurement, including maintenance of all FCE office hardware and software and all non-field related travel. Powell will continue to manage the FCE datasets and information dissemination activities (see Section 4). Our Ed & Outreach program will continue to be run by our part-time coordinator (S. Dailey), who recently took a job teaching high school with the Miami-Dade Public School system. Dailey has continued her part-time coordination of this important program, and her "inside" position at MDPS has already begun to open new doors and present new opportunities for integrating FCE research findings into local secondary education (see Section 5).

FCE II Program Administration and Management Flow Chart

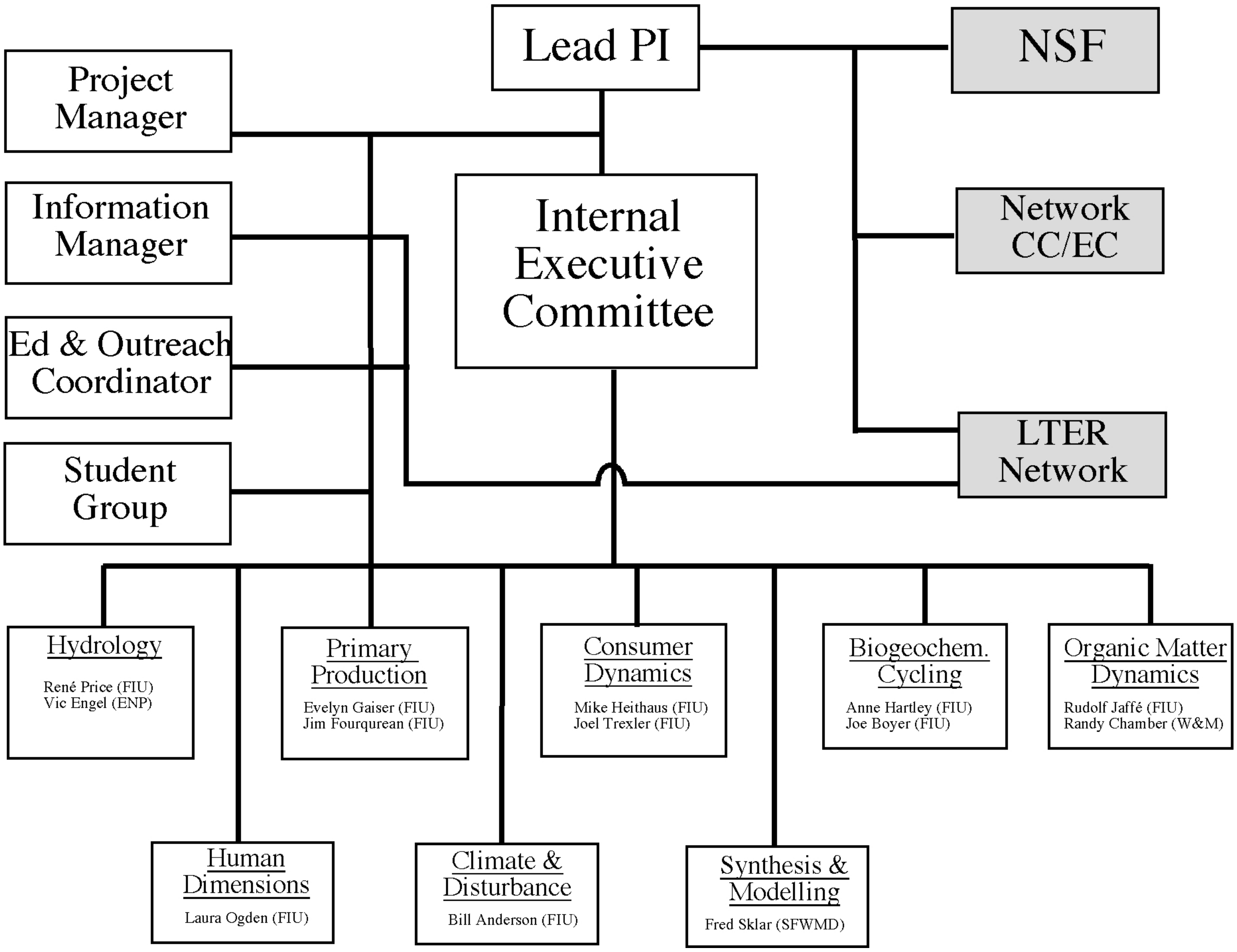


Fig 3-2: Organizational chart for the FCE II Program Administration. Lines represent communications and connections for key decisions.

4. Information Management

A. Florida Coastal Everglades Information Management System (IMS)

The mission of the Florida Coastal Everglades (FCE) Information Management System (IMS) is to facilitate the site's scientific work and to ensure the integrity of the information and databases resulting from the site's coastal Everglades ecosystem research. To assure total support of the site and network science, the FCE Information Management (IM) team has established a set of primary goals: 1) design and implement a IMS to handle research contributions from several large FCE research laboratories, 2) collect and archive both FCE and historical Everglades data, 3) provide comprehensive metadata for data interpretation and analysis, 4) design and implement tools that facilitate data management, data discovery and data access and 5) contribute to LTER network informatic activities.

B. Information Management System (IMS) Scope

All of the FCE LTER core data and metadata files from individual research studies are stored in a hierarchical flat file directory system (http://fcelter.fiu.edu/data/). FCE project information and minimal research data metadata are stored in an Oracle database that is used to drive the FCE Web site. The IM team is in the process of migrating research data into the Oracle9i database. This hybrid system (flat file and database) will give FCE researchers, network scientists, and the general public an option to download complete original data files submitted by individual FCE scientists in addition to downloading queried data from the Oracle9i database. Core data are made available to the public within two years of data collection and are accessible on-line in accordance with the FCE Data Management Policy (http://fcelter.fiu.edu/data/data_mgmt_policy.html).

FCE publications are updated frequently and are searchable on-line by querying on any combination of date, author, keyword, and publication type (http://fcelter.fiu.edu/publications/). Presentations are listed on the FCE website, and in some cases, users may view a presentation via a document link (http://fcelter.fiu.edu/publications/presentations/). Limited GIS and raster data are available for download via our Everglades interactive map application (http://fcelter.fiu.edu/gis/everglades-map/).

C. Information Management System Design

Data and information contributions will continue to be made to the FCE IMS by the Working Groups and Cross-Cutting Themes. Researchers within these workgroups are responsible for quality assurance, quality control, data entry, validation, and analysis for their respective projects. The Information Manager schedules quarterly data collection dates (Jan 1, April 1, July 1, & October 1) throughout the year when electronic collection reminders, with the appropriate data submittal information, are sent out via email to all participating researchers. Data are submitted to the Information Manager via our secure Intranet site (https://fcelter.fiu.edu/intranet) and undergo IMS quality assurance and quality control procedures. 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 and loaded into the Oracle database (Fig. 4-1). The Oracle relational database has been designed to accommodate the diverse spatial and temporal heterogeneous data submitted by the FCE researchers. The database and flat file integrity is maintained through access passwords and user privileges and roles. Metadata and data values are

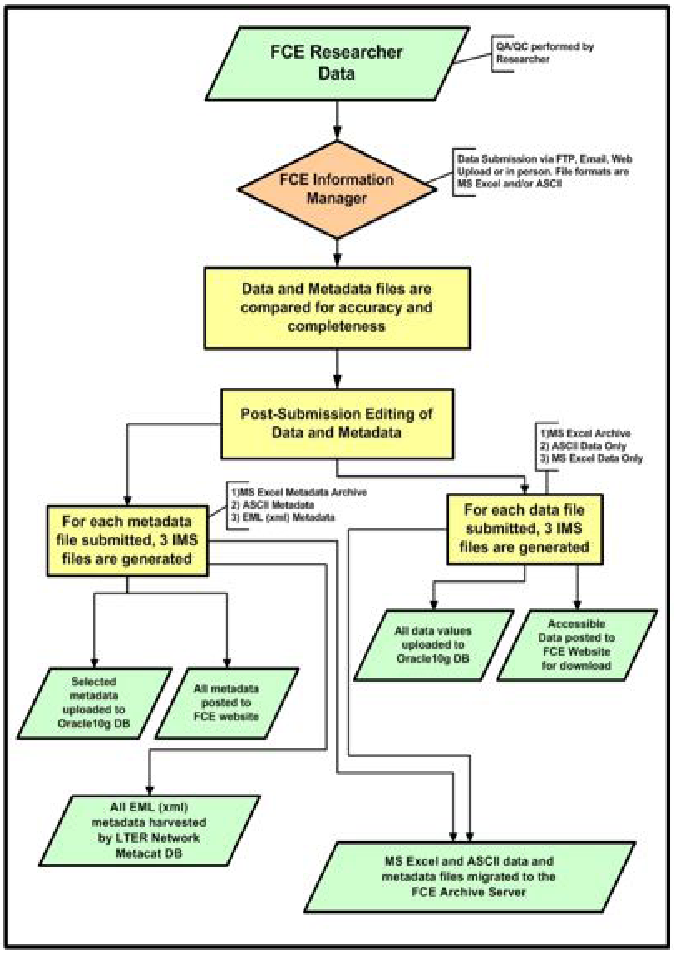


Figure 4-1. FCE IMS Data Procedures.

then combined into one ASCII text file for archival purposes.

The FCE LTER Office has 4 Windows servers and 1 Linux server with a total storage capacity of 1.941 Terabytes and an additional 400 Gigabytes of storage between two desktop workstations. The servers housing the development and production versions of the FCE Oracle9i database are equipped with RAID5 technology (Redundant Array of Independent Disks). Connectivity within the FCE LTER Office is a gigabit switched Ethernet Network (FIU Computer Science Network). The FCE IMS implements 3 levels of data protection: 1) nightly incremental backups to external drives, 2) daily incremental (Web), weekly full backups to tape with one set being stored offsite, and 3) full weekly (Oracle9i DB) and bi-monthly (Web) hard drive images.

The FCE Information Management System (IMS) is committed to collection and organization of FCE LTER project information and the IMS group has developed a web-based interactive mapping application called the ‘FCE LTER Interactive Everglades Map’ to their website (http://fcelter.fiu.edu/gis/everglades-map/) to facilitate information and project management. Our researchers and information management group can use this application to help with future experimental designs, publication discovery, and intra-site syntheses as the FCE project information, site location information, datasets, sampling attributes and publications are crossreferenced. Additionally, the FCE project has added verbiage to its data management policy that mandates project information submission by researchers to the FCE Information Manager no later than 6 months of notification of project funding.

D. Information Management System Team

The FCE Information Management team consists of a full-time Information Manager, Linda Powell, and a full-time Project Manager, Mike Rugge. Powell and Rugge provide continuity to the FCE LTER project's IMS as they have held their positions with the project since its inception in 2000. L.Powell has a Master's degree in Geology and has a strong background in GIS, remote sensing and system administration. M.Rugge has a Master's degree in plant biology and specializes in web development and GIS. Both Powell and Rugge serve as database and system administrators and Rugge serves as the project programmer.

E. Information Management System Support for Science

The FCE web site provides outstanding support for site and network science. The site's home page (http://fcelter.fiu.edu/) design provides a simple, user-friendly gateway a wide variety of information ranging from the FCE LTER project overview to links to additional research related websites. The FCE 'Data' web page provides users access to the Data Table of Contents (searchable by data contributor, workgroup, sample location, data type or keyword), FCE data tools, the FCE Data Management Policy, Ancillary Data, and links to other sources of LTER related and Everglades data (http://fcelter.fiu.edu/data/ancillary/). An individual 'Data Summary Table' is generated for each FCE data file to facilitate data discovery and access; this table is the portal for data and metadata downloads. The FCE IM team lends its expertise to site and network researchers when necessary by providing application support (Excel2EML), assistance with metadata entry, data submissions, individual project database design, collaborations on GIS work and research graphics.

F. Information Management System Metadata

Since the inception of the Florida Coastal Everglades (FCE) LTER in May of 2000, FCE researchers have adhered to a data submission policy that requires all data submissions to be accompanied by metadata. As a result, the FCE IMS has a very robust archive of research metadata. With the LTER Network implementing Ecological Metadata Language (EML) as its metadata content and format standard, one of the biggest challenges for the FCE IM team in the EML implementation process was finding a way that FCE researchers could continue to collect metadata using an Excel metadata template and easily produce EML (XML) documents. In response to this challenge, M. Rugge developed a Perl application that converts the FCE Excel metadata into a valid EML (XML) documents. The FCE IMS has fully adopted the LTER network metadata standard Ecological Metadata Language (EML) and one hundred percent of the FCE tabular data are accompanied by a Level 5 (Data Identification, Discovery, Evaluation, Access and Integration) EML (XML) metadata documents. FCE EML documents are harvested daily to the LTER network metacat XML database.

G. Information Management System LTER Network and Community Activities

L. Powell has just completed a term as an elected member of IMExec and has attended and contributed to the annual LTER Information Managers (IM) committee meetings since 2000.

Additionally, her duties on IMExec have included managing the logistics for the 2004 and 2005 annual IM committee meetings. She has also served as editor of the fall 2001 and spring 2002 issues of DataBits, the LTER network's electronic newsletter. Both members of the FCE IMS team have attended workshops relating to either EML implementation or GIS. The Excel2EML metadata converter tool and template has been made available to the LTER network and broader ecological community via the LTER CVS repository and a download link on the FCE web site (http://fcelter.fiu.edu/data/tools/). Data contributions have been made regularly to the following LTER network databases: 1) ClimDB, 2) SiteDB, 3) All Site Bibliography, 4) Personnel, 5) Metacat XML database and 6) Data Table of Contents.

H. Information Management System Future Initiatives

Our largest on-going and future projects are related to completing the migration of the flat file data into the Oracle9i database. Once the relational half of the hybrid IMS is fully functional, we anticipate adding analysis and synthesis tools to the website whereby queried FCE data could easily be manipulated real-time.

5. Education, Outreach, and Diversity

The FCE II Ed & Outreach Program will continue to provide a unique resource of researchers, datasets, and experience to both secondary schools and south Florida community. In FCE I we were able to establish a diverse blend of widely received education and outreach programs (Appendix 2.I). These programs included television programs, classroom videoconferences, classroom presentations, and permanent schoolyard research plots. The common themes of all FCE Ed & Outreach programs will continue to be: 1) the ecology of the Everglades; 2) FCE research results, and; 3) communicating the vital importance of the Everglades as the purveyor of drinking water to 95% of south Florida's human population (now 6 million people, and growing). In addition to our existing programs, we propose 3 additional initiatives for our FCE II Ed & Outreach Program:

A. Curriculum development: We will expand our K-12 curriculum development in order to reach a broader spectrum of the educational community and the general public. As with FCE I, we will use the Working Group structure and Research Questions presented in Sections 2 and 3 to explain the complex interrelationships of Everglades ecology to audiences. We will use the FCE II working group model as a template for disseminating information about FCE research findings and about Everglades ecology in general. In particular, we will incorporate the interpretations and datasets generated by the Hydrology, Human Dimensions, and Climate and Disturbance Working Groups into this curriculum expansion. Our new curricula will be designed to fit Florida's educational standards (Sunshine State Standards). We will make this curriculum available via the FCE Ed & Outreach web portal (http://fcelter.fiu.edu/schoolyard) so that it may be used by high school teachers to plan their daily ecology learning units, which takes up approximately 4 weeks of a typical biology class. Beginning in Fall 2006, Miami-Dade County Public Schools (MDPS) will begin using the same textbook and curriculum in all high school biology classrooms. We are working now to incorporate FCE research findings into these mandated standards, with the ultimate goal of creating a user-friendly package of materials on Everglades-related issues that can be used across a county that currently teaches nearly 450,000 students. This will include adding an FCE-based curriculum component to each of the lessons in the MDPS ecology unit, created in two versions: The first version will be created for the classroom, with specific objectives and activities that can be modified to fit specific classroom or teacher needs. The second version will be developed with the public as the audience to facilitate our web-based distribution of information (omitting classroom objectives and specific educational standards). Notably, S.Dailey (the FCE Ed & Outreach Coordinator) recently became a MDPS high school teacher. Her "inside" knowledge, connections, and research experience in the Everglades (her dissertation research focused on Everglades biogeochemistry) are critical to meeting this new FCE II goal.

B. Mentoring: We will expand our highly successful student-researcher mentoring program (see Section 1.F). This program will continue to pair interested and motivated MDPS high school students with FCE researchers who will mentor the students by providing hands-on experience with the science, tools, and research of FCE LTER. Students participating in our FCE high school internship program have routinely provide valuable linkages back to their own schools and to the elementary and middle schools that feed into their high school. These linkages are very personal: The high school participants actually visit these “feeder” schools and talk about their experiences conducting lab and field research and about the importance of the Everglades ecosystem. This networking of FCE student interns with their peers, teachers, and with “feeder” school students generates unparalleled excitement—we have seen first-hand how contagious their enthusiasm can be!

C. Bilingual Outreach: We will continue to expand the reach of all aspects of our FCE Ed & Outreach Program to the Hispanic population in south Florida by adding a bilingual component to our website and to the outreach products that we disseminate throughout the community.
The Latin American diversity of the South Florida community provides both opportunities and challenges to disseminate FCE research findings and information. In MDPS classrooms, many Spanish-speaking students receive bilingual instruction, but outside the classroom English-only information is often lost on many adults in our predominantly Hispanic community. By going bi-lingual, we believe that we will be taking an important step towards informing everyone in south Florida about the value of the Everglades and about the fact that this beautiful ecosystem is the sole provider of the water that they drink.