Mid-Term Review Report

Prepared for the
National Science Foundation Site Review Team

Florida Coastal Everglades
Long Term Ecological Research Program

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FCE LTER

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I. Overview of the FCE LTER Program

The Florida Coastal Everglades LTER Program (FCE) is dedicated to long-term studies of how changing patterns of freshwater availability interact with climate variability to affect ecosystem structure and processes in the estuarine ecotone regions of the coastal Everglades. Our research domain is the remnant of a once-larger Everglades ecosystem, the majority of which has been profoundly transformed through hydrologic engineering, regional water management and altered land use. The Everglades provides an excellent laboratory for studying how coastal ecosystem dynamics respond to, and influence, human activities. FCE research is highly trans-disciplinary and includes scientists, students, and staff from academic and agency partners in the fields of anthropology, climatology, ecology, geochemistry, hydrology, modeling, and political science. As a long-term study in the context of a landscape-level experiment (Everglades restoration), our research tests general theories about coastal ecosystem transformation while addressing critical linkages between science and water management decisions and developing new frameworks for discoveries in coastal ecosystem and restoration science.

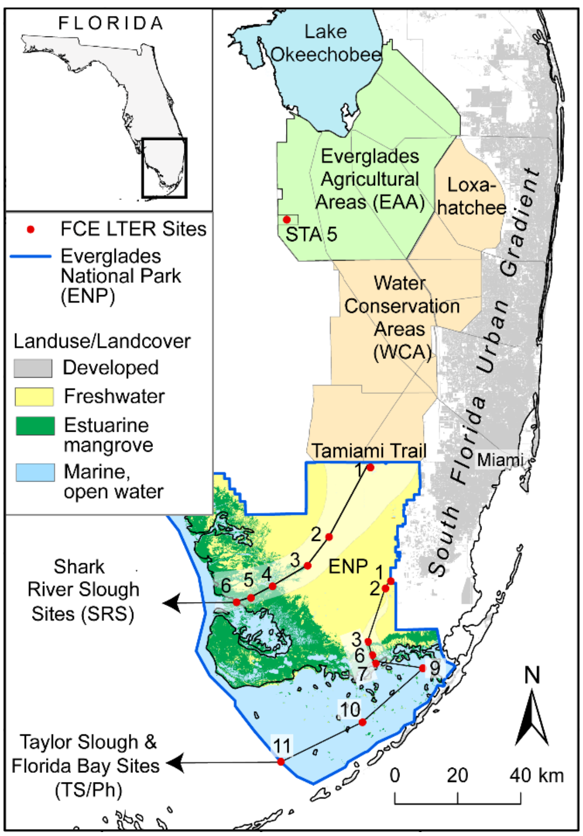


Figure 1. FCE study area, indicating locations of our research sites along transects through Shark River Slough and Taylor Slough within Everglades National Park (ENP). Cross-cutting research extends beyond these into the South Florida Urban Gradient to examine social-ecological underpinnings of past, current and future conditions in the oligohaline ecotone (where yellow color meets green in ENP).

History: FCE research began in 2000 with a focus on coastal ecosystem processes while also developing a persistent, collaborative platform for the wider Everglades research community. Our goal was to determine how freshwater from oligotrophic marshes interacts with a marine source of the limiting nutrient, phosphorus (P), to control productivity in the oligohaline ecotone – the zone where freshwater and marine supplies meet in the coastal Everglades (yellow-green boundary in Fig. 1 at left). We hypothesized that ecosystem productivity would be greatest in this ecotone, where freshwater, higher in nitrogen (N) and dissolved organic matter (DOM) relative to coastal waters, meets marine waters where P is more available. A sampling design was established to allow us to track water flow and ecosystem properties along the main drainages in Everglades National Park (ENP) −Taylor Slough-Panhandle (TS/Ph) and Shark River Slough (SRS) −from freshwater canal inputs at the northern Park boundaries to the Gulf of Mexico. FCE I research confirmed a productivity peak in the oligohaline ecotone of the TS/Ph transect, due to brackish groundwater delivery of P to ecotone plant communities (Price et al. 2006). In contrast, the SRS transect exhibited a wedge of increasing productivity toward the coast (Ewe et al. 2006), where tidal influences were greatest (Fig. 2).

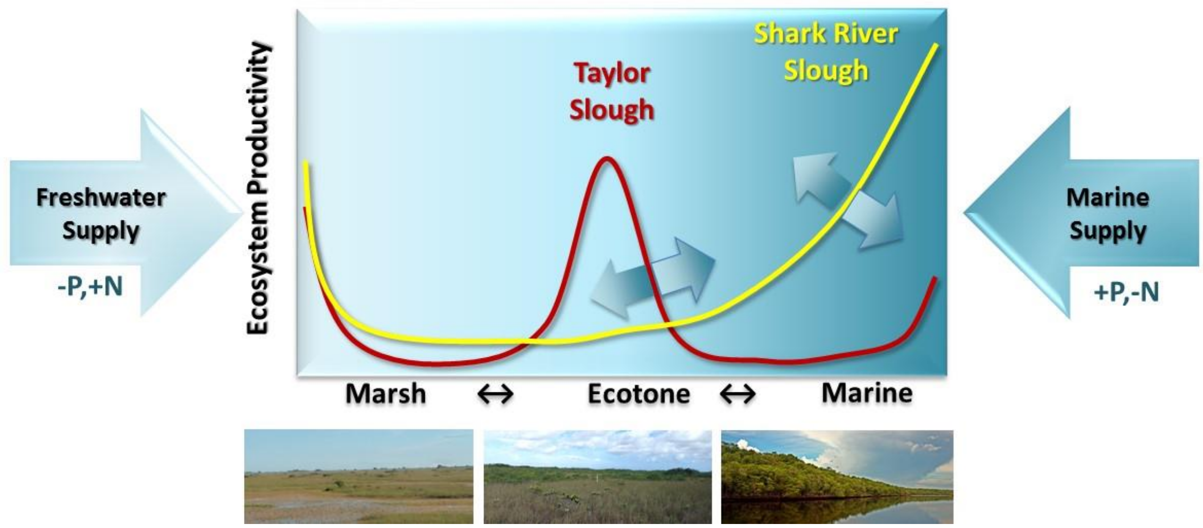


Figure 2. A simplified version of the FCE predictions for how ecosystem productivity will change along the coastal gradient from freshwater marsh, through the oligohaline ecotone and into shallow marine environments in Shark River Slough and Taylor Slough under a shifting balance of fresh and marine water supplies driven by water management and sea level rise, respectively. The red and yellow lines depict relative productivity patterns currently observed in the two sloughs, and arrows represent the movement of the productivity peak in time and space caused by daily, seasonal and inter-annual variability in the balance. Each of the FCE working groups uses a similar model to express past, current and expected changes along the fresh-ecotone-marine gradient.

Early FCE research demonstrated how Everglades estuaries are functionally upside-down relative to the classic estuary model, receiving limiting nutrients from seawater as opposed to typical coastal marshes that receive nutrients from upstream sources (Childers 2006). In FCE II (2006-2012), we used this upside-down model to anticipate how freshwater restoration would affect ecological processes across the marsh-ecotone-marine gradient. Delays in restoration increased ecotone sensitivity to marine influences (Saha et al. 2011) and underscored the importance of trans-disciplinary research to understand, and influence, the hydro-political context of ecosystem restoration. Adopting a social-ecological perspective for FCE science has been powerful and rewarding, revealing how urban residents respond to and influence changes in wildland habitat in unexpected ways that can both promote and delay restoration (Ogden 2008).

Current Research: In FCE III, we further expanded our trans-disciplinary research examining how freshwater flow restoration interacts with the presses and pulses of climate variability, particularly sea level rise (SLR) and storms, to shape this productivity gradient. Restoration delays are increasing saltwater and P intrusion into the oligohaline ecotone (Lagomasino et al. 2014a), promoting transgression of mangroves to the interior (Saha et al. 2011). Interactions with freshwater use and supply in the South Florida Urban Gradient (see Fig. 1) mechanistically link human and biophysical domains across spatial and temporal scales. FCE III activities are addressing four main themes: (1) to evaluate the source of socio-political conflicts over **water** distribution, and how solutions that improve inflows to the Everglades reduce or delay the effects of SLR on estuarine conditions in the coastal zone; (2) to determine how the balance of fresh and marine water supplies to the oligohaline ecotone will control the rates and pathways of **carbon** (C) sequestration, storage, and export by influencing P availability, water residence time, and salinity; (3) to characterize spatial-temporal patterns in ecosystem sensitivity to, and **legacies** of, modifications of freshwater delivery to the Everglades that are driven by climate variability and land-use change, and; (4) to develop future **scenarios** of freshwater distribution and use that maximize the human-environmental sustainability in regions like south Florida that face SLR (Fig. 3). *This hydropolitical context for our research is couched in contemporary social-ecological theory examining the roots of transformation of novel ecosystems.* These thematic goals are met through dedicated long-term research in four core working groups – **biogeochemical cycling, primary production, organic matter and trophic dynamics**. Our research approach couples long-term measurements and multi-scale experiments along the Everglades gradient with socio-political research in the South Florida Urban Gradient to understand the drivers of change (Fig. 3). All of our research contributes to and is informed by an very large array of integrative modeling efforts dedicated to understanding processes of change and predicting consequences of decisions.

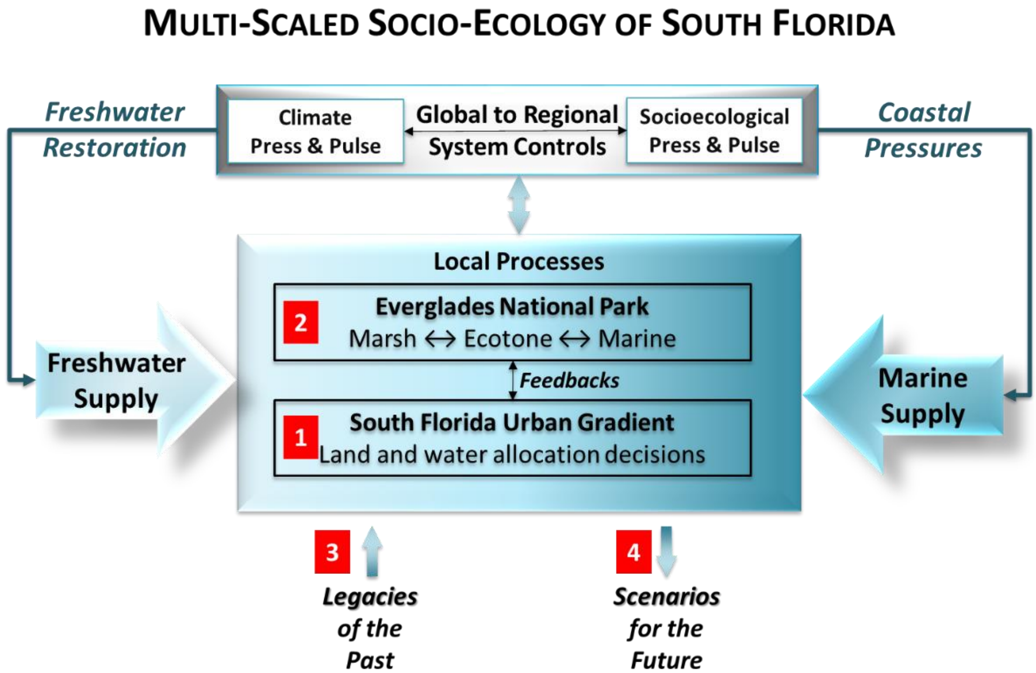


Figure 3. A simplified version of the FCE III Conceptual Model showing how all thematic research is tied to understanding the causes and consequences of changes in the balance of freshwater and marine supplies to the urban-wildland ecosystem of South Florida.

Program Organization: The FCE III program is led by PI Evelyn Gaiser, and Co-PIs Mike Heithaus, Rudolf Jaffé, John Kominoski, Rene Price. Scientific, administrative and budgetary decisions are made according to the FCE Guidelines for Program Administration & Management with democratic decision-making through an Internal Executive Committee comprised of leads representing each of the four working groups and cross-cutting themes, and from key agency partners (Fig. 4). Group interactions, cross-group synthesis and idea incubation occurs through working group meetings and FCE All Scientists Meetings. Two external advisors provide guidance (currently K. McGlathery – VCR LTER, C. Hopkinson – PIE LTER).

Personnel and Key Partners: The FCE III program currently has 65 collaborators and 88 students from 30 institutions. FCE co-produces science for knowledge and management through involving agency scientists (particularly Everglades Foundation, ENP and South Florida Water Management District) directly in scientific studies and program management.

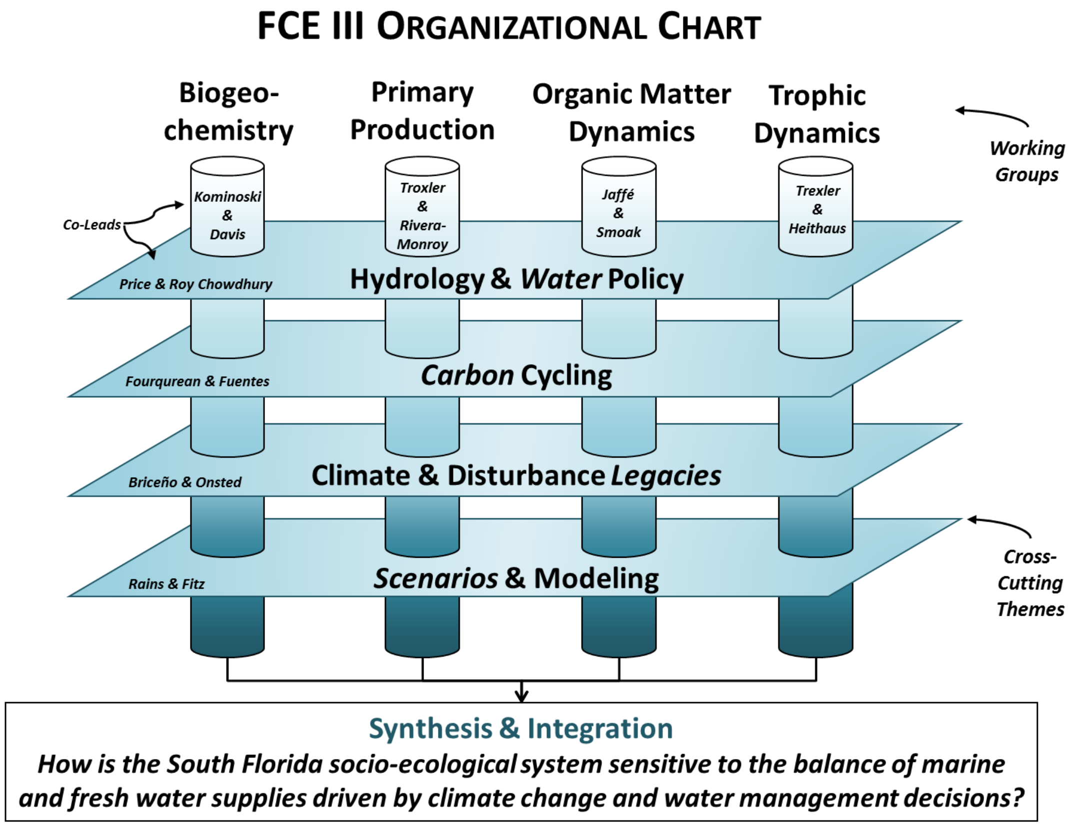


Figure 4. Schematic of FCE III scientific program organization, showing the 4 Working Groups as "pillars" and the 4 Cross-Cutting Themes as "platforms" that link the pillars to address a key question about the sustainability of the FCE. The entire structure rests on an underlying template that includes information management and dissemination, education and outreach, and integration through site-based, Network-level, and international synthesis activities.

Progress: Below we report progress in the last 2.5 years relative to our four working groups and four cross-cutting themes. We do not intend for this to be a comprehensive report but rather a snapshot of progress toward integrative goals with supporting examples. We have been steadily progressing toward the goals of our FCE III proposal and have made particular strides in: (1) quantifying the rates of and uncertainties in SLR projections for our region (Haigh et al. 2014); (2) unraveling the hydropolitical sources of conflict in ecosystem restoration (Schwartz 2014); (3) constraining C budgets and identifying sources of uncertainty across the coastal ecotone at plot-to-landscape scales (Troxler et al. 2013); (4) establishing unprecedented multi-scale experiments to decouple the influence of salinity, nutrients and inundation in coastal C budgets (i.e., Chambers et al. 2014), and; (5) propelling our scenario efforts forward through aggressive and successful leveraged funding efforts (see page 31). We have responded to comments from our 2012 renewal panel by: (1) simplifying our conceptual model in a way that underscores its integrative capacity across our four themes (Fig 3); (2) clarifying the theoretical context for our research within each of four working groups, particularly addressing non-linear system dynamics expected under novel socio-ecological conditions; (3) re-organizing working group leadership (see following sections) to ensure socio-ecological thematic integration; and, (4) ramping up our understanding of food web dynamics through new experiments and collaborative research across LTER sites.

II. WORKING GROUP PROGRESS

A. <u>Biogeochemical Cycling</u> <u>(Leads: J. Kominoski & S. Davis)</u>
***Central question* – How does the balance of fresh and marine water supply to the oligohaline ecotone influence microbially-mediated C, N & P cycling in soils and water?**

History & Justification - FCE research has established that variation in fresh and marine water supplies controls the availability of the limiting nutrient, P, along gradients in SRS and TS/Ph drainages and Florida Bay (Childers et al. 2006a; Fig. 2). Marine supplies, enriched in P, fluctuate seasonally and with storms and SLR to influence C cycling in the coastal ecotone (Smith et al. 2009; Barr et al. 2010; Castañeda-Moya et al. 2010). In Florida Bay, P control on microbial production is modulated by the bioavailability of DOM (Boyer et al. 2006) that is supplied from mangrove and seagrass sources (Jaffé et al. 2004). Increases in salinity and P concentrations from storms, demonstrated with long-term data and anticipated SLR (Saha et al. 2012), likely affect both estuarine and wetland C storage by altering microbial C utilization (Fig. 5). FCE III research is focused on coupling long-term data with experiments to determine how variability in P supply interacts with C source, salinity and inundation in a subsidy-stress theoretical framework to understand biogeochemical controls on C dynamics in the ecotone.

***Hypothesis 1* – The balance of fresh and marine water supplies influences microbially-mediated C and nutrient cycling in wetland soils through interacting effects on P availability, salinity, and water residence time, culminating in gains or losses in C storage.** Long-term data suggest that the magnitude of response of wetland C to both salinity and P will vary along the estuarine gradient based on prior (legacy) exposure (Castañeda-Moya et al. 2010), requiring explicit mechanistic experiments to decouple the drivers of C shifts along each part of the coastal gradient (freshwater, oligohaline, marine). Controlled tests of increased salinity and P in mesocosms show acute (P effect) and extended (salinity effect) increases in C flux from mangrove peat soils (Chambers et al. 2014). Increased salinity and P increased soil porewater total phosphorus (TP), which was more readily taken up by mangrove plants and periphyton than soil bacteria. Greater utilization of added P by mangrove plants and periphyton than soil microbes resulted in higher daytime than nighttime soil C flux, indicating net C losses (Fig. 5). We are exploring causes for C loss in detail to understand controls on peat collapse (abrupt loss of organic soils) observed in coastal areas exposed to novel sources of marine water. We continue to test long-term effects of salinity exposure on C storage in freshwater and oligohaline marsh plants and soils and have begun mesocosm studies of interactive effects of salinity and P on macrophyte, algal, and microbial subsidy-stress responses that influence net ecosystem C storage.

***Hypothesis 2* – The balance of marine and freshwater supplies of dissolved organic C (DOC) to Everglades estuaries will determine bioavailability for bacterioplankton and the microbial loop.** Bacterial communities in the Everglades vary along the coastal gradient in salinity, P supply and C sources (Ikenaga et al. 2010). In Florida Bay, bacterial production is regulated by the bioavailability of DOC (Boyer et al. 2006) and the abundance of P (Guevara et al. 2014), both of which are influenced by environmental gradients in geochemistry and marine-freshwater exchanges. Bacteria receiving P from the Gulf of Mexico do not respond to additional P supplies while P-limited communities further from these sources utilize excess P to more rapidly degrade DOC (Guevara et al. 2014). Increases in marine supply of P and C to estuaries are predicted with storms and SLR, potentially reducing the spatiotemporal variation in (and enhancing rates of) C use by the microbial loop in Florida Bay. Bacterial productivity is more influenced by local DOC, whereas primary productivity is more evenly distributed throughout the estuary, suggesting that heterotrophic bacterial productivity in Florida Bay is relatively uncoupled from primary productivity. We are beginning similar studies in the ecotone to understand how bacterial productivity and enzymatic activity is influenced by soil organic matter quality and nutrient availability.

***Next steps* –** We will couple biogeochemical and microbial responses from experimental manipulations of salinity, inundation and P in sawgrass and mangrove systems with long-term nutrient concentration and microbial composition data to improve predictions of how the marine-freshwater source balance influences the C balance in the ecotone. We will use experimental outcomes to improve biogeochemical predictions of the Everglades Landscape Model under fixed SLR and Everglades restoration scenarios. Carbon flux data from experiments are being incorporated into the dynamic C budget for the freshwater marsh and marsh-mangrove ecotone.

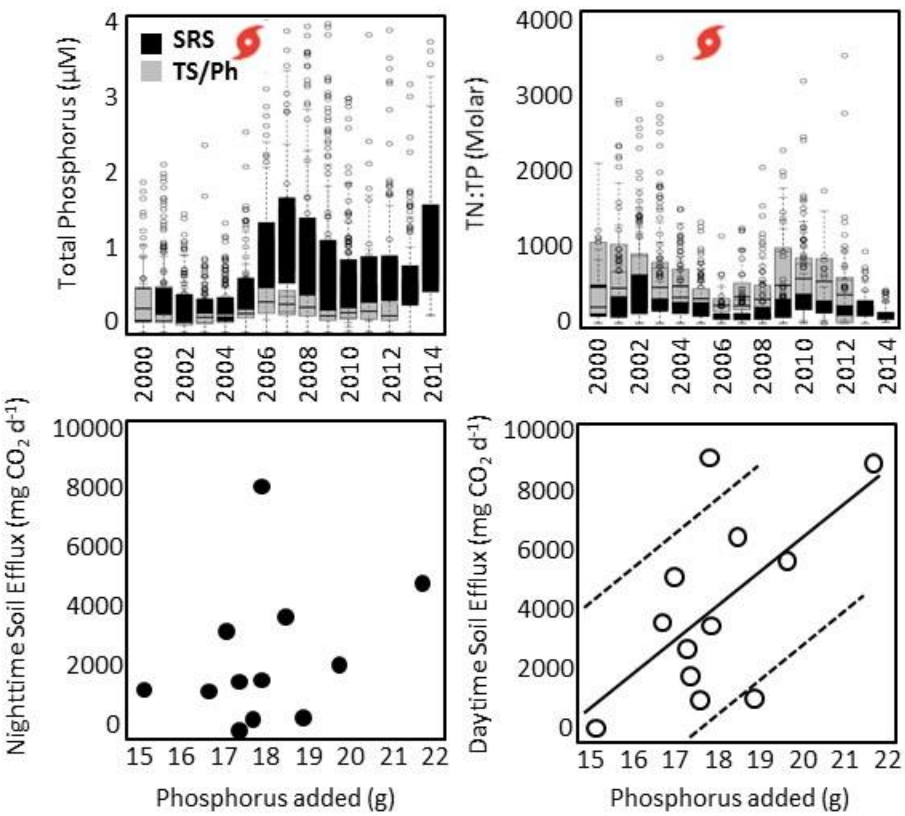


Figure 5. *Top panels:* Long-term patterns of water column total phosphorus (TP) and total nitrogen (TN)-to-TP ratio in the estuarine ecotone of Shark River Slough (SRS) and Taylor Slough/Panhandle (TS/Ph). Red hurricane symbol denotes the impact of Hurricane Wilma (October 2005) that delivered sediment P from the Gulf of Mexico to coastal and ecotone ecosystems, that eventually leached back into the surface waters from interior wetlands, reducing surface water N:P in the estuarine ecotone. *Bottom panels:* Simulating storm-driven effects of P loading on C loss in mangrove peat soils. Lower nighttime versus daytime carbon efflux (mg CO_2-C m^{-2} d^{-1}) from mangrove peat soils in wetland mesocosms with added P. Storm-driven increases in TP may increase soil C loss by enhancing autotrophic over heterotrophic respiration rates. Taken together, both figures indicate spatiotemporal as well as compartment-specific variation in availability of and response to P in the FCE.

B. <u>Primary Production</u> <u>(Leads: T. Troxler & V. Rivera-Monroy)</u>
***Central question* – How does the balance of fresh and marine water supply to the ecotone influence the composition, distribution, and productivity of primary producers?**

***History & Justification* -** Analysis of FCE long-term data generated two key discoveries: (1) within the SRS basin, sawgrass, and periphyton net primary productivity (NPP) do not differ significantly among sites, but mangrove NPP is highest at sites nearest to the Gulf of Mexico; and, (2) within the TS/Ph basin, productivity of sawgrass and periphyton peaks in the upper estuarine ecotone (Ewe et al. 2006). We attribute these striking differences in patterns of NPP not only to the stress of P-limitation throughout the gradient, but also to variation in inundation times and salinity across FCE freshwater marsh and mangrove communities (Childers et al. 2006b; Schedlbauer et al. 2010; Castañeda-Moya et al. 2011, 2013). Long-term FCE research has revealed important connections between primary productivity and P availability, salinity, and water residence time, and motivated FCE III research to examine the influence of drivers of salinity, P availability and water residence time (Cardona-Olarte et al. 2006). In particular, we are inquiring whether the striking spatial patterns observed throughout the Everglades are analogues to potential temporal trajectories as marine exposures increase at accelerated rates.

Hypothesis 1 – **The balance of fresh and marine water supplies regulates primary producer composition and productivity through interacting effects on P availability, salinity, and water residence time.** Effects of SLR on coastal wetland productivity depend partly on local factors such as the rates and history of exposure to saltwater encroachment, and the ability of species to adapt to changing inundation, salinity, and nutrient availability. In the oligohaline ecotone, our long-term data suggest an increasing effect of salinity as a primary driver of productivity and a strong correlation between freshwater discharge and ecotone salinity (Troxler et al. 2014), illustrating how upstream water diversion can amplify the effects of SLR (Michot et al. 2011). Increased P associated with marine water delivery may also alleviate the effects of extended residence time and salinity on primary productivity or water-use efficiency (Childers et al. 2006b; Ewe et al. 2007; Mancera-Pineda et al. 2009; Lovelock et al. 2011). In FCE III, we developed new experiments to examine how drivers of salinity, inundation and P underlie changes in sawgrass NPP, periphyton NPP and composition, litter decomposition and net ecosystem exchange observed between transects and in long-term data (Gaiser et al. 2012, 2014; Troxler et al. 2014). In particular, we are trying to understand how and why primary production interacts with potential peat soil collapse under conditions of increasing marine exposure to salt, P and longer inundation times.

Hypothesis 2 – **Landscape patterns of plant composition and production express legacies of fresh and marine water supplies to the ecotone.** Understanding the relationship between hydrologic variables (including water level, hydroperiod and salinity) and plant community structure and production will improve predictions of wetland responses to freshwater restoration, changing precipitation patterns, and SLR in the southern coastal Everglades. FCE III research is determining the effects of salinity and P on plant abundance and composition across the salinity ecotone in a press-pulse framework. We have analyzed trajectories of changes in C production and storage following Hurricane Wilma (2005) across species and sites to understand how differences in exposure and resilience influence recovery. We found that this storm resulted in a net loss of 1-2 Mg C ha^{-1} y^{-1} of leaf C, which represents 60-70% of the total C input from litterfall (Fig. 6), most of which was flushed out of the forest through subsequent tidal exchange.

These findings are the first quantitative report of mangrove forest resilience in neotropical coastal regions linking mangrove total litterfall and species-specific leaf contribution to litterfall after hurricane disturbance. We also use long-term monitoring of sawgrass NPP and spike rush density to assess the effects of local water management actions to restore the Everglades and differentiate cyclic climate effects from directed management activities (Troxler et al. 2014). Algal community-level responses also provide metrics of change in nutrient supply and hydrology associated with the changing balance of freshwater and marine supplies, especially those reflecting ecosystem patchiness (i.e., spatial beta diversity and turnover) (Bramburger et al. 2013; Lee et al. 2013; Gaiser et al. 2014; Gaiser et al. 2015a).

Next steps **–** We will complete field and mesocosm experiments addressing the effects of salinity, inundation and P on primary production in freshwater and oligohaline marshes, and use these data to improve our dynamic C budget. These data are also being incorporated into the Everglades Landscape Model to improve projections of consequences of water management and SLR scenarios to primary production and composition. We are also completing the first generation of coastal ecotone landscape vegetation maps that will improve our interpretation of the impact of disturbance legacies on potential future trajectories of ecosystem productivity and community dynamics across the FCE landscape.

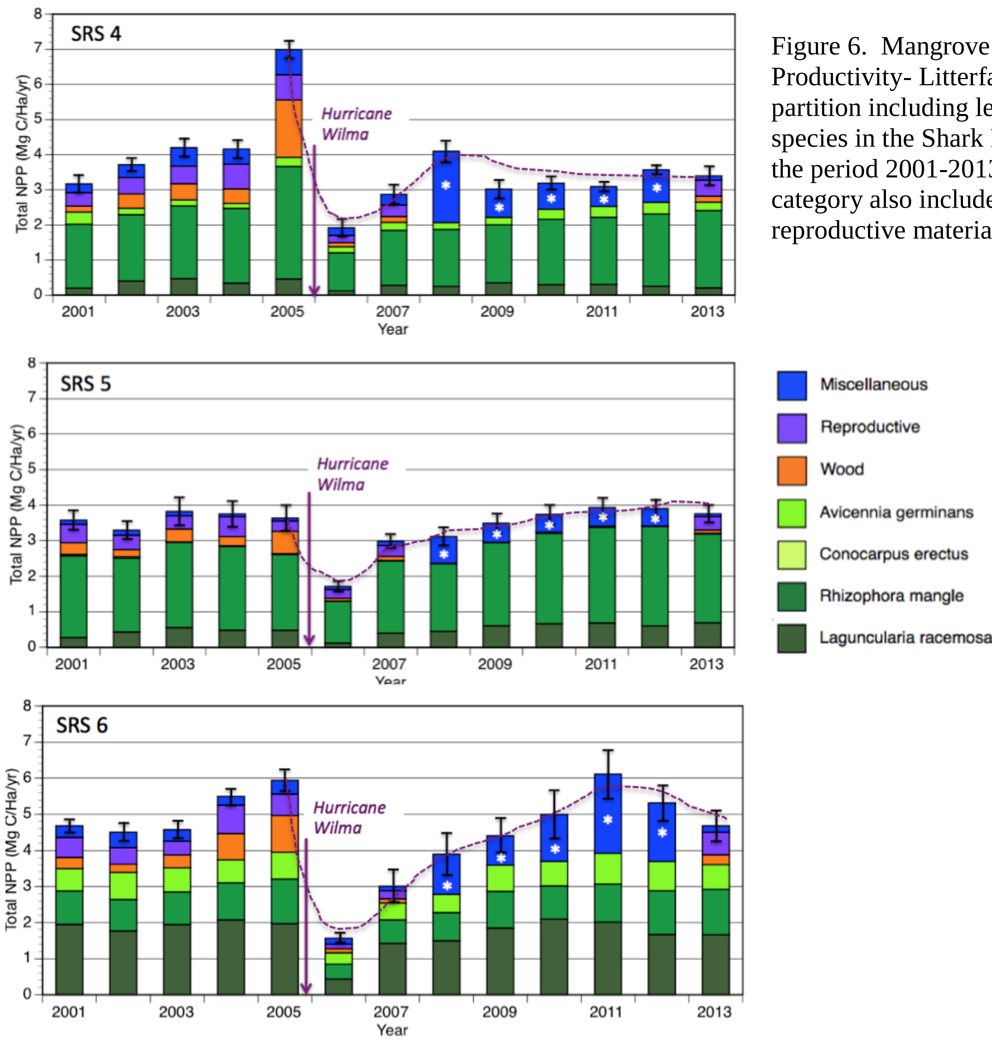


Figure 6. Mangrove forest Net Primary Productivity- Litterfall (NPP_{LF}) and partition including leaf contribution per species in the Shark River estuary during the period 2001-2013. (*Miscellaneous category also includes the wood and reproductive material from 2008-2012).

C. Organic Matter Dynamics (Leads: R. Jaffé & D. Smoak)
***Central question* – How do surface water residence times, P availability, and salinity interact to affect OM quality, abiotic and biotic processing, and exchange between freshwater, ecotone, and marine environments?**

History & Justification - FCE research characterizing OM in coastal ecosystems has improved our ability to track the source and fate of C across system boundaries. We have characterized DOM using a variety of analytical approaches (Lu et al. 2003; Jaffé et al. 2004; Maie et al. 2005; Yamashita et al. 2010; Maie et al. 2012; Chen et al. 2013), but the rates of exchange and transformations need to be quantified to complete a C budget for the FCE estuaries. To this end, we have gained significant insights into DOM photo- and bio-reactivity (Chen and Jaffé, 2014) and into photo-reactivity of POM (Pisani et al. 2011; Shank et al. 2011). However, the drivers of fluxes of DOC, POC, DIC (including CO_2) and contribution to the C budget are yet to be fully evaluated. The primary objectives thus include the quantification of OM and DIC fluxes in FCE marshes and estuaries in order that these can be combined with terrestrial surface-atmosphere and surface-groundwater C fluxes to complete our C budget.

***Hypothesis 1* – Water source and residence time influence the relative contribution and quality of OM from marshes, mangroves, and the marine system to FCE estuaries.** Hydrology and primary producer sources have been identified as critical in the spatial and temporal distribution and quality of OM (Chen et al. 2013; Pisani et al. 2013). We have recently performed the most detailed, unprecedented DOM characterizations applied to wetland samples, using high field 2D nuclear magnetic resonance spectroscopy and ultra-high resolution mass spectrometry. A comparison between DOM samples from long and short hydroperiod sites from three different wetlands (Everglades, Pantanal, and Okavango Delta) showed a clear hydroperiod effect. In Florida Bay, variability in DOM source and composition was driven by seagrass production during the early summer, shifting to a stronger terrestrial source control by late summer when freshwater discharge from the Everglades peaks (Maie et al. 2012). Based on this seasonal (and spatial) pattern, end-member modeling was applied to assess DOM source strengths on spatial and temporal scales, suggesting that seagrass OM sources could exceed 70% of the DOC inputs during the dry season in the central bay, compared to only ca. 30% during the wet season in the northeastern bay (Ya et al. 2014). Similarly, spatial and temporal variations in DOM and POM quality were determined along salinity gradients in the mangrove ecotone, and quantified using a combination of optical properties (fluorescence; Cawley et al. 2013) and molecular biomarker end-member mixing (He et al. 2014). The contribution of mangrove-derived OM was significant, but largely more important to the POC compared to the DOC pool. DIC quality was influenced by respired mangrove-derived C.

***Hypothesis 2* – Variability in water source and residence time control the rates of DOC, POC, and DIC (CO_2) transport in and export from water and soils.** FCE research established that CO_2 fluxes at the soil-water interface may constitute a significant component of C budgets. Significant variability in soil CO_2 fluxes within and among estuarine sites was observed, with locations rich in pneumatophores contributing the largest average flux. Tidal inundation and salinity contributed to significant variation in soil CO_2 flux and lower flux to the atmosphere, with inundation reducing soil CO_2 flux but increasing its concentrations in surface water. Tidal pumping was determined to export significant amounts of both DOC and POC to the main river channel. Cawley et al. (2013) reported that up to 20% of the DOC in the Everglades mangrove rivers may be mangrove-derived, peaking during the wet season, but also implying that most (>80%) of the riverine export of DOC is derived from freshwater marshes. In contrast, the great majority of the POC in these river-dominated estuaries is mangrove derived, followed by a marine source (during tidal exchange) with the Everglades freshwater end-member providing less than 10% (He et al. 2014). A comparison between DOC and POC quality, based on optical properties, agreed with these quantitative assessments, showing a clear uncoupling between these two parameters (Ya 2014).

Next steps – We have begun determining monthly DOC fluxes in the estuary using channel flux models (Fig. 7) and the collection of high resolution data of DOM and associated water quality parameters through multiple tidal cycles and during different seasons to better understand the climatic drivers associated with riverine C export. We will further expand the CO_2 flux measurements from soils, surface waters and vegetation debris with the recent acquisition of additional sensors. We have also started our efforts to better define the 'protein-like' fluorescence in both DOM and POM, as a means to assess relative contributions of actual proteinaceous materials vs. tannins and related polyphenols (Ya 2014; Timko et al. 2014; Romera-Castillo and Jaffé 2014) in the estuarine zone. These activities are critical to constraining source assessments and reactivity of OM in our system, in order to complete our dynamic C budget for the estuary and parameterize predictive landscape models.

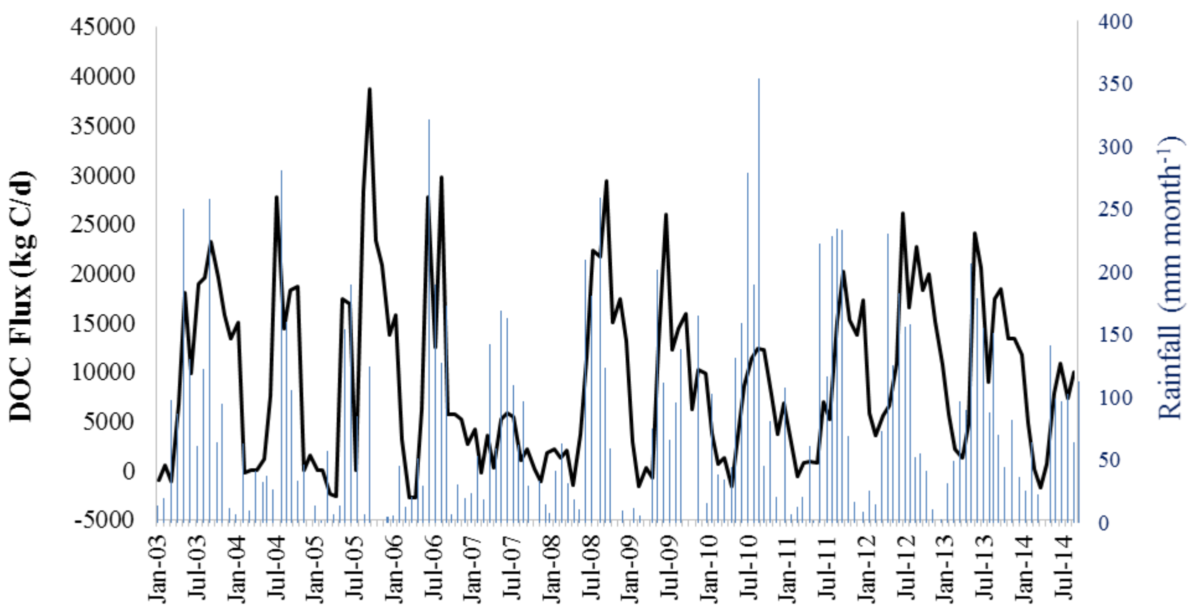


Fig. 7. Monthly flux of DOC at SRS 5 with rainfall (from nearby Flamingo meteorological station) showing seasonal and long-term fluctuations in C outflow from the estuary, underscoring the importance of quantifying flux and source throughout the watershed as important component of C budgets. Fluxes show a significant lag from rainfall, and the peak in Fall 2005 reflects significant outflow after the storm surge associated with H. Wilma.

D. Trophic Dynamics and Community Structure (Leads: M. Heithaus & J. Trexler)
Central question **– How will SLR interact with changes in freshwater inflows to modify detrital food webs and the spatial scale of consumer-mediated habitat linkages?**

History & Justification - Long-term studies of consumers from the freshwater to estuarine gradient have provided insights into the impact of changing hydrological drivers from the marine and freshwater ends of the oligohaline zone on system-wide productivity, structure, and function. For example, studies of alligators (Rosenblatt et al. 2011) and bull sharks (Heithaus et al. 2009; Matich et al. 2011; Matich and Heithaus 2014) have demonstrated the roles of large-bodied and highly mobile consumers in shaping community dynamics within estuarine ecosystems and how these roles might vary among individuals in response to environmental conditions. To determine food web structure, we are using stable isotopic (Williams and Trexler 2006; Sargeant et al. 2010) and fatty acid profiles (Belicka et al. 2012), which have documented a strong dependency on detritus and the microbial loop across the Everglades gradient. This dependency changes with nutrient availability through increases in edibility of algae driven by phosphorus-induced compositional transitions, with green algae and diatoms being more edible than cyanobacteria that dominate native periphyton (Sargeant et al. 2011; Trexler et al. 2015). Food web structure is, therefore, a reflection of variation in individual consumer behaviors driven by water source, and food quality, largely controlled by water quality.

Hypothesis 1 – **Freshwater delivery influences the importance of detritus to freshwater marsh and mangrove estuary food webs.** We hypothesized that detritivory is an important contributor to the energy flow of Everglades food webs and that P availability controls the relative contribution of autotrophic and detrital energy routes. To dissect the influence of water flow and quality on food web function, we created an enclosure experiment using 1-m^3 cages stocked with experimental food-web fragments to evaluate links between algal composition and consumer food assimilation. In preparation for that experiment, we conducted a laboratory diet switching study on three species of consumers to document the turn-over time for fatty acid markers in their tissues. This work tests hypotheses about the role of associational resistance of periphyton constituents in limiting energy flow from the mat to aquatic grazers and omnivores.

Hypothesis 2 – **Variability in freshwater inflows will interact with SLR to modify trophic interactions and the spatial scale of consumer-mediated habitat links.** FCE long-term consumer community structure and biomass data are being used to understand how the freshwater and estuarine fish community responds to hydroclimatic variation. Recently, two climatic extremes impacted the Everglades: a 2010 cold front (the most severe since 1927), followed by a decadal drought in 2011. The cold front reduced the abundance of tropical euryhaline fishes, such as the economically-important snook, while the 2011 drought reduced the abundance of temperate freshwater species, such as largemouth bass, due to reduced habitat connectivity to freshwater marshes (Boucek and Rehage 2014). Long-term and experimental data were used to develop a simulation model relating hydrology to selected aquatic primary consumers (small fish, shrimp and crayfish; Trexler and Goss 2009) to evaluate a collection of future climate scenarios. Climate change scenarios that reduce freshwater flow to the estuary have a strong negative impact on the abundance of species relative to baseline expectations (Catano et al. 2014), which has ramifications for the upper food web. In contrast, SLR simulations affected only a small portion of the FCE by lengthening hydroperiods, which generally increased aquatic productivity; however, the brackish fish communities that are favored by such conditions are known to sustain less biomass than the freshwater fish communities. This could negatively affect wading birds and larger commuting consumers such as alligators and sharks that rely on these small fish communities as a source of food (Matich and Heithaus 2014; Fig. 8).

Next steps – We have begun experimental analyses of how resource gradients affect the relative role of microbial and autotrophic contributions to food webs through the use of manipulative experiments and molecular markers of food assimilation. We will continue to extend our studies of large predator movements and trophic interactions relative to environmental variation to gain further insights into physical drivers of these interactions. We will extend our studies to include areas upstream of the ecotone where experimental changes in water flow will help us predict how larger-scale ecosystem restoration will influence the spatiotemporal dynamics of consumer-mediated ecosystem linkages. We also will initiate experimental studies of the impacts of top predators on the behavior and effectiveness of herbivores and omnivores, and how these are likely to change with environmental perturbations.

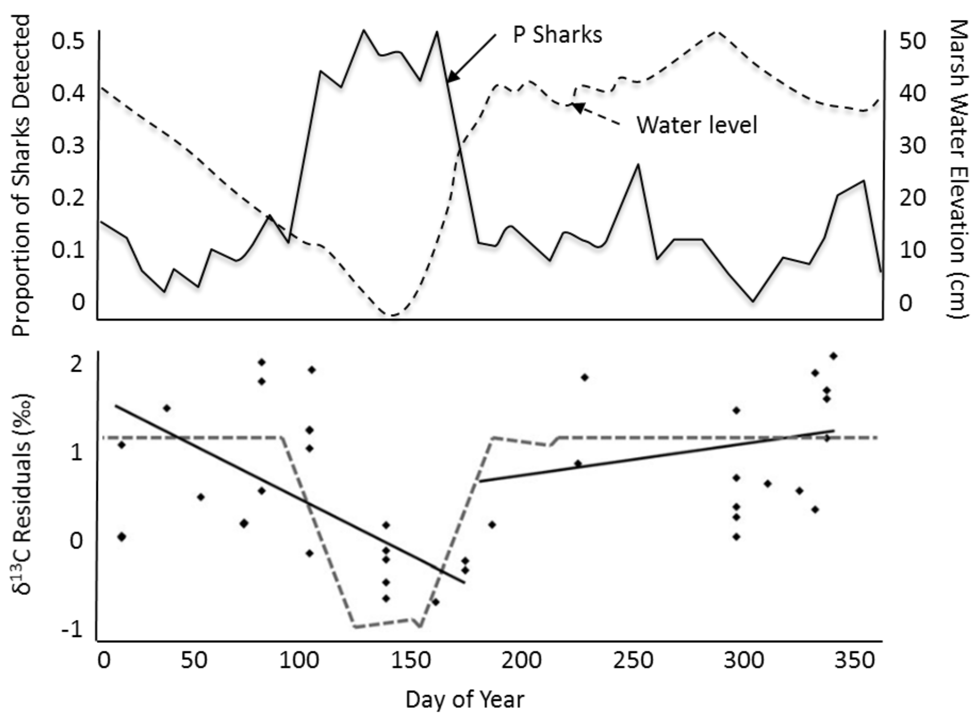


Figure 8. Upper panel shows the proportion of sharks detected by receivers per day (dark line) and water depth (dashed line) upstream of SRS 5. Lower panel shows temporal variation in $\delta^{13}C$ residuals predicted by a piecewise function (black line) and predicted change in difference between plasma and blood $\delta^{13}C$ for a model based on marine + estuarine prey→ estuarine + freshwater prey. Isotope data suggest sharks increase the proportion of marsh prey in their diets during the dry season, and movement data show that bull sharks increase their use of areas adjacent to freshwater marshes during this time. Annual variability in hydrology and planned changes in Everglades water management, therefore, may affect the importance of marsh taxa in the diets of bull sharks during the dry season. From Matich and Heithaus (2014).

III. CROSS-CUTTING THEME PROGRESS

A. <u>Hydrology and Water Policy</u> <u>(Leads: R. Price & R. Roy Chowdhury)</u>
***Central question* – How do climate change and SLR interact with water management practices to control hydrologic conditions in the oligohaline ecotone?**

History & Justification - Previously, we have shown pronounced sensitivity of the flat Everglades landscape to SLR and storms, exacerbated by continued diversion of freshwater into canals (Saha et al. 2011, 2012; Barr et al. 2009; Gaiser et al. 2012; Moses et al. 2012; Wachnicka et al. 2012a). Brackish groundwater discharge driven by seawater intrusion was found to be an important contributor of water, salt, and nutrients to both SRS and TS, thereby stimulating an ecosystem response in the oligohaline ecotone (Simard et al. 2006; Herbert et al. 2009; Zapata-Rios and Price 2012; Koch et al. 2012). The delays in Everglades restoration experienced during FCE II underscored the importance of understanding the role of water in the sociopolitical environment of South Florida (Hollander 2008; Roy Chowdhury et al. 2011; Ogden 2011). With implementation of water restoration projects, we wanted to explore in FCE III how projects that re-establish water flow to southern estuaries interact with SLR and climatic patterns in controlling the ecohydrological conditions of the oligohaline ecotone.

Hypothesis 1 – **Variable inflows from upstream sources, SLR, and storm surge interact to alter surface water residence time, salinity, and groundwater intrusion in the oligohaline ecotone.** Analysis of long-term water budgets and water levels in both SRS and TS has determined that additional inputs of fresh water into the system are not observable at the oligohaline ecotone, and that groundwater salinity there continues to increase (Sullivan et al. 2014a; Sandoval 2013; Fig. 9). Changes in water delivery from canal discharge to retention basins in northern TS resulted in enhanced groundwater seepage out of ENP and decreased surface water flow to the ecotone (Sullivan et al. 2014b). With the decrease in surface water flow, evapotranspiration (ET) and rainfall were the dominant variables affecting water residence time in the TS ecotone, while water chemistry was influenced by ET, rainfall, and inputs from Florida Bay and groundwater discharge (Sandoval 2013). We predict that an acceleration in the rate of SLR, above what has been observed in the past 100 years, would be discernible by 2030 (Haigh et al. 2014). Marine source water continues to influence long-term water chemistry in the oligohaline ecotone, which correlates with mangrove spectral reflectance measurements made at both leaf and canopy scales (Lagomasino et al. 2014a). Disturbances in mangroves, particularly from hurricanes, result in decreases in spectral reflectance measurements and greater variability in ET rates across the mangrove ecotone (Lagomasino et al. 2014b, 2015). In addition, the use of Interferometric Synthetic Aperture Radar (InSAR) in the more tidally influenced SRS ecotone has determined that a tidal flushing zone extends 2-3 km from the sides and 3-4 km inland from the ends of tidal channels (Kim et al. 2013; Wdowinski et al. 2013; Hong and Wdowinski, 2014a,b; Brisco et al. 2014).

Hypothesis 2 – **Stakeholder uncertainties over SLR will increase conflicts over Everglades restoration implementation and will affect freshwater delivery to the oligohaline ecotone.** Our socio-political research has determined that stakeholder conflicts over land and water in the context of Everglades restoration not only significantly hamper restoration progress, they have led to the creation of an "oppositional" culture and identity in southern Florida (Garvoille 2013). In addition to stakeholder opposition, other key obstacles to restoration include political institutions including a savings clause that prohibits reducing permitted levels of water supply or flood protection for existing users (Schwartz 2014). In the lower watershed, zoning policies are the key drivers of land use conversions, and this finding has improved predictions of the rate and pattern of contemporary land use change and impact on the Everglades (Onsted and Chowdhury 2014). Yet, diverse groups of stakeholders also interact in collaborative ways to shape the future of this common resource. FCE research in the upper watershed (Everglades Agricultural Area - EAA) probes how institutional arrangements, especially monitoring and sanctioning, shape the participation of agricultural stakeholders in EAA around water, soil, and fertilizer best management practices; these have resulted in sustained reduction of P loads to the Everglades, resulting in water quality improvements (Daroub et al. 2011), which demonstrates the importance of trans-disciplinary research involving stakeholders early on in the research and decision process. Ultimately, ecosystem restoration may be impossible without challenging water-supply and flood-protection entitlements or accounting for farmers' and residents' decision-making rationales and environmental attitudes (Polsky et al 2014; Groffman et al 2014).

Next steps – The timing of brackish groundwater discharge is important for ecosystem function in the oligohaline ecotone, and future research will determine which hydrological forcings have the greatest influence on the timing of groundwater discharge. We will collect detailed ground based data needed for the development, calibration, and validation of the hydrodynamic model designed to simulate particle tracking and estimate residence times in the tidal domain of SRS. Additional geochemical modeling of P in peat sediments from the oligohaline ecotone will be conducted to understand the effect of groundwater discharge on salinity and nutrient concentrations. The effects of additional water restoration efforts on water delivery to and water quality in the mangrove ecotones of FCE and coastal karstic estuaries will continue to be investigated. In particular, we are advancing the understanding of how water management decisions and their socio-ecological drivers are related to dynamic freshwater flows and marine pressures in the Everglades and similarly functioning karstic coastal wetlands.

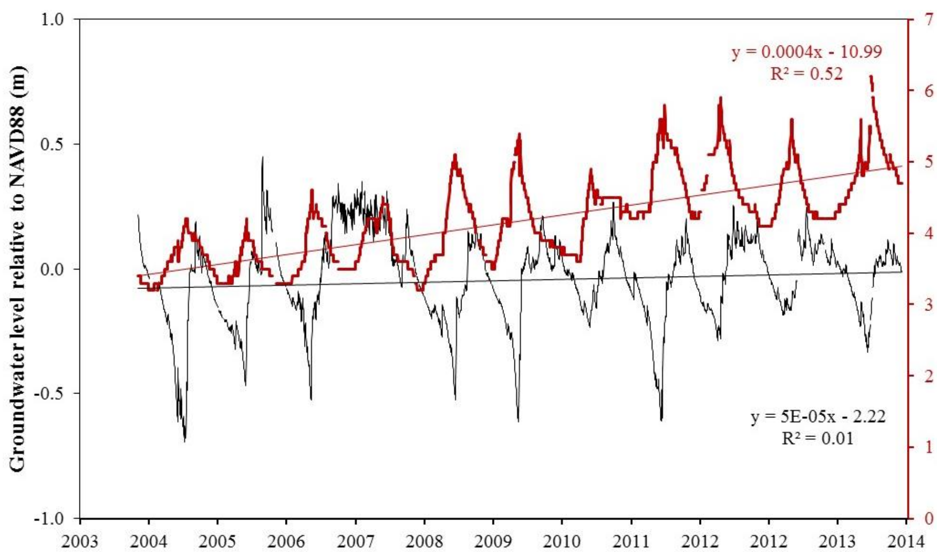


Figure 9. Long-term changes in salinity (red) in the Taylor Slough ecotone resulting from reduced freshwater flows and increasing landward groundwater discharge into the ecotone. Salinity increases are related to water surface water residence time, with seasonal pulses representing the dry season when the amount of surface water and its residence time in the Taylor Slough watershed is lowest (Sandoval 2013).

B. Carbon Cycling (Leads: J. Fourqurean & J. Fuentes)
***Central question* – How do changing freshwater inflows, tidal and storm cycles, and climate patterns affect the magnitude, rates, and pathways of C sequestration, loss, storage, and transport across the land-water continuum?**

History & Justification - A fundamental goal of FCE C cycling research is to identify the drivers and scales of variance of the C budget along the coastal gradient. We measure net ecosystem-atmosphere CO_2 exchange (NEE) and energy balance at marsh, mangrove and seagrass sites along with direct measurements of NPP and OM accumulation from marker horizon-sediment elevation tables and paleoecological studies. Long-term NEE, NPP and remotely sensed data suggest that inter-annual variability in the coastal C balance is largely associated with pulse dynamics of storm disturbance (and cold fronts), tidal cycles, and groundwater dynamics (Zhang et al. 2008; Whelan et al. 2009; Barr et al. 2011; Castañeda-Moya et al. 2011) that influence the key drivers of production - nutrients, salinity, and inundation (Twilley and Rivera-Monroy 2009). Attempts to balance C budgets find that a significant fraction of atmospheric CO_2 uptake is not accounted for in NPP estimates (Barr et al. 2010, 2011), with large uncertainties in the transport of DIC and DOC by tidal advection and loss from mineralization and air-water CO_2 efflux (Duarte et al. 2005; Bouillon et al. 2007, 2008a; Miyajima et al. 2009). Long-term measures of NEE and C burial in mangrove forests and seagrass meadows suggest that C burial ("blue carbon") rivals that of tropical forests (Barr et al. 2011; Fourqurean et al. 2012a,b) at levels relevant to climate mitigation strategies (Pendleton et al. 2012).

***Hypothesis 1* - Temporal variability in C uptake, storage, and transport in the mangrove ecotone reflects the pulsed dynamics of marine water, nutrient, and sediment supplies driven by tides and storms, and freshwater supply driven by seasonal rainfall and water management.** We integrated existing C cycle measurements and developed a framework for deriving the net ecosystem C balance (NECB) for freshwater marsh, mangrove forests and seagrass meadows (Troxler et al. 2013). In the marsh, flux data suggest the freshwater system is CO_2 neutral and a small source of CH_4, at rates intrinsically controlled by hydrology (Jimenez et al. 2012, Malone et al. 2013). Persistent reduction in hydroperiod has resulted in a shift from slough to ridge vegetation dominance (Saunders et al. 2006; Saunders et al. 2014), suggesting changes in hydrology can alter both the C storage capacity and composition of freshwater marshes (Malone et al. 2013). In the mangrove estuaries, we are resolving identified uncertainties of DIC fluxes through direct measures and resolving differences in NECB calculated via flux-tower, biometric information and approximations from C burial rates (Fig. 10). Analyses suggest that annual changes in forest biomass become less important as the integration time increases. Soil data from the mangrove forest at SRS 6 indicate that the 10-year C burial rate is about 225 g C m^{-2} yr^{-1} but the 100-year average is approximately 123 g C m^{-2} yr^{-1} (Breithaupt et al. 2014). When the 100-year temporal scales are used as a proxy for the mangrove forest C balance then the long-term fraction of NECB to –NEE represents approximately 13%. This result is important as it estimates the average yield of –NEE into NECB and can therefore be employed to project soil C accumulation, and, possibly, future states and sustainability of mangrove forests because their survival necessitates sediment accretion rates that keep pace with SLR. In seagrass meadows, we are comparing C burial rates between sites altered by 30 years of nutrient fertilization by roosting birds to our unenriched LTER sites. Differences in composition driven by nutrient fertilization are expected to influence C burial rate, encouraging a species-specific quantification of blue carbon stocks to inform climate change mitigation efforts.

Hypothesis 2 **- Landscape patterns in C fluxes reveal legacies of exposure of the marsh, mangrove, and seagrass ecosystems to long-term changes in the balance of fresh and marine water supplies.** We are conducting landscape-scale remote sensing studies to capture variability in the freshwater-marine balance caused by tidal channel exposure. Fine-scale vegetation data are explored in conjunction with salinity and biomass data to detect how changing patterns of freshwater and marine supply influence landscape C stocks. Using Leica-ScanStation-C10 Terrestrial Laser Scanner, we have also developed new, non-destructive methods to assess whole forest aboveground C stocks of mangrove sites in SRS (Feliciano et al. 2014). Across the ecosystem we are working toward synthesizing dynamic, spatially-explicit, and mechanistically-supported C budgets for the marsh, mangrove and seagrass ecosystems in order to drive simulation models to quantify how the C balance, and associated services (e.g., storm buffering, C sequestration) respond to, and mitigate, changes in water delivery, nutrient fluxes, and pressures of SLR.

Next steps – We will continue investigating controls on the magnitude of –NEE throughout the system to complete our quantitative C data synthesis begun in Troxler et al. (2013), including the dwarf mangrove forest at TS/Ph 7 where we have a new tower. The research is crucial as CO_2 fixation from the atmosphere represents the first step (or input) required for accumulating C as expressed in the NECB. To create dynamic budgets, we will integrate results from ongoing experiments addressing the effect of salinity, P and inundation on the C balance. We will also investigate biological and physical processes that convert biomass (as harvested from the atmosphere in –NEE) into soil C using numerical biophysical and geochemical models. These synthesis activities will be facilitated by a post-doc allocated to this working group during 2015-2016 funded by ENP and FIU.

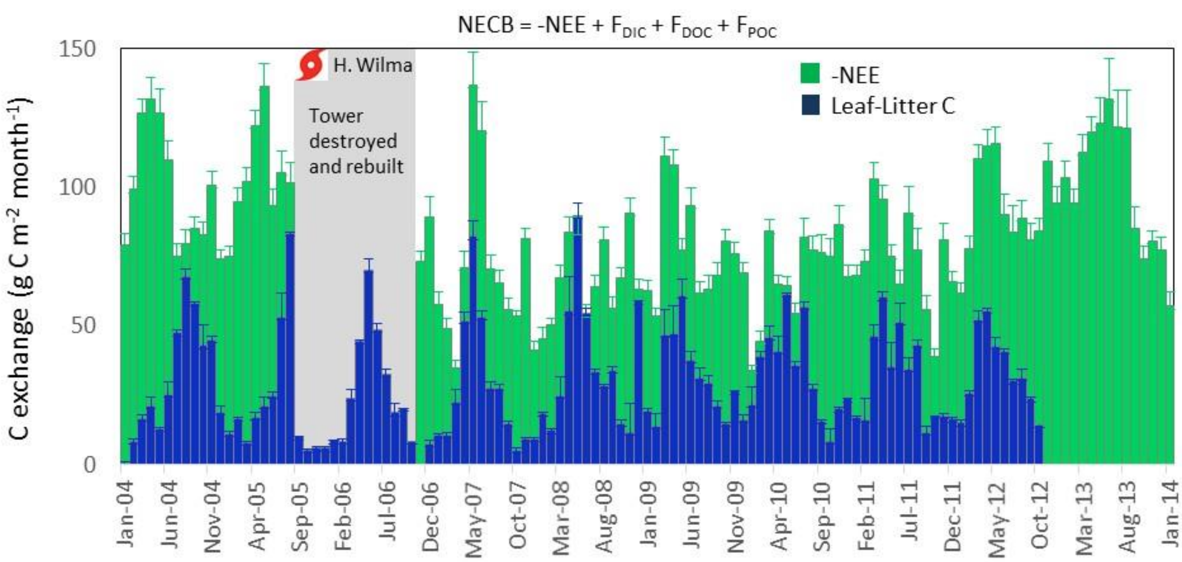


Figure10. Mangrove forest monthly net ecosystem exchange (-NEE, green bars) and leaf litter fall (blue bars) at the Shark River Slough (SRS6) flux tower site. These results illustrate the C assimilation capacity of mangrove forests, the state of the recovery, and resilience of the ecosystem following the disturbance created by hurricane Wilma in October 2005. The –NEE data also illustrate the response of the mangrove forest ecosystem to the extreme events associated with climate variability.

C. Climate and Disturbance Legacies (Leads: H. Briceño & J. Onsted)
Central question – **How have legacies of wetland conversion to urban and agricultural land uses and resulting shifts in water demand/management across the Everglades watershed changed the sensitivity of the coastal zone to freshwater restoration in the face of SLR?**

History & Justification - Our goal is to understand the legacies of regional climate and land-use change on the eco-hydrodynamics of the Everglades oligohaline ecotone. Intersecting patterns of land and water reflect drivers and responses in both ecological and social contexts would add a trans-disciplinary value to previous research from FCE II that revealed the extent of coupling between social and ecological patterns and processes. As underscored in the FCE III Conceptual Model (Fig. 3), water supply and source are the fundamental link between global and local drivers, in turn subjected to socio-ecological pressures. Hence, there is a need for scrutinizing long-term datasets to determine causes and magnitudes of variability in fresh and marine water supplies and their impacts on the ecotone, especially when observational datasets show how spatio-temporal patterns of nutrient fluxes and productivity track both long-term changes in climate and land-use (presses) and shorter-term disturbances due to water management and storms (pulses) (Briceño and Boyer 2010; Castañeda-Moya et al. 2010).

Hypothesis 1 – **Changes in land-use and water allocation decisions in the South Florida Urban Gradient have hydrodynamic consequences in the Everglades landscape that explain observed changes in the oligohaline ecotone.** The amount of water delivered to the ecotone determines its spatial location, and those deliveries, in turn, are determined locally by human demand, whether for agriculture or residential use. Understanding the connection, therefore, between land use and water consumption lends insight into changes in the ecotone. For example, conversion of agricultural land to developed uses almost always decreases water demand, while conversion of row and field crops to nurseries increases it (Pokharel 2014). We have advanced our understanding of the dynamics of urban growth in Miami, and specifically, the efficacy of zoning as a policy mechanism to control and direct such growth (Onsted and Roy Chowdhury 2014), while testing a novel methodology for integrating zoning information into a cellular automaton urban growth model, SLEUTH. We compared metrics of fit with empirical land use change under four distinct zoning scenarios and found that scenarios integrating zoning information for areas facing the highest growth pressures generates the best model fit with empirical data. We conclude that zoning information, when utilized appropriately, improves model performance and is particularly relevant for landscape change in urban and peri-urban areas. We can, therefore, qualitatively assess what kinds of impacts zoning has on land use change and quantify the impact probabilities of resistance to development. As perception informs policy, we are improving our understanding of the social construction of landscapes (Garvoille 2013; Varela-Margolles and Onsted 2014), while developing, in cross-site collaboration, cutting edge categorization techniques to better understand land use change across all LTER sites. We are scaling these approaches to examine thresholds of land use change and impacts on freshwater allocation that result in nutrient and salinity changes in the ecotone, after Briceño et al. (2014).

Hypothesis 2 – **Legacies of changing freshwater inflows to the oligohaline ecotone have influenced sensitivity to the balance of fresh and marine water supplies across the landscape.** FCE is using long-term observational and paleoecological data to address how continually changing exogenous drivers (i.e., climate change, economic policies) interact with internal dynamics to produce existing social, hydrological, and biological patterns. Effects of water delivery decisions on the ecotone are superimposed upon changes caused by seasonal and multi-decadal cycles and punctuated storm events (Briceño and Boyer 2010; Wachnicka et al. 2012). Resolving the influence of these cycles and events has enabled us to tools for forecasting effects of decisions on salinity and water quality in the ecotone. This work follows on the examination of FCE long-term biogeochemical and hydrological datasets by Briceño et al. (2014) showing increased salinity and P at the mouth of Taylor Slough related to reduced freshwater discharge from upstream. Our long-term studies of legacies of water delivery to the ecotone suggest that TP concentrations are more discharge-driven (Fig. 11), while TN is more variable and potentially derived from different sources along the glow path from the freshwater Everglades marshes to Florida Bay.

Next Steps – Ongoing analyses connecting land-use and hydrologic changes to ecotone water chemistry should improve our understanding of how changes in freshwater delivery – driven by policy decisions and climate - impact the key drivers of productivity in the ecotone. To that end, we are incorporating additional policy and jurisdictional considerations into land use change models to improve land use change projections and resultant consequences to water delivery. As land use also affects water quality current research is also focusing on correlating these phenomena using water quality data found in the canals feeding the central Everglades. Climatological studies are using long-term precipitation and water table measurements to construct scenarios of critical rain rates and SLR values, defined as values that, when reached, can be expected to cause abrupt changes in nutrient levels through groundwater discharge, thus causing biogeochemical regime change in FCE.

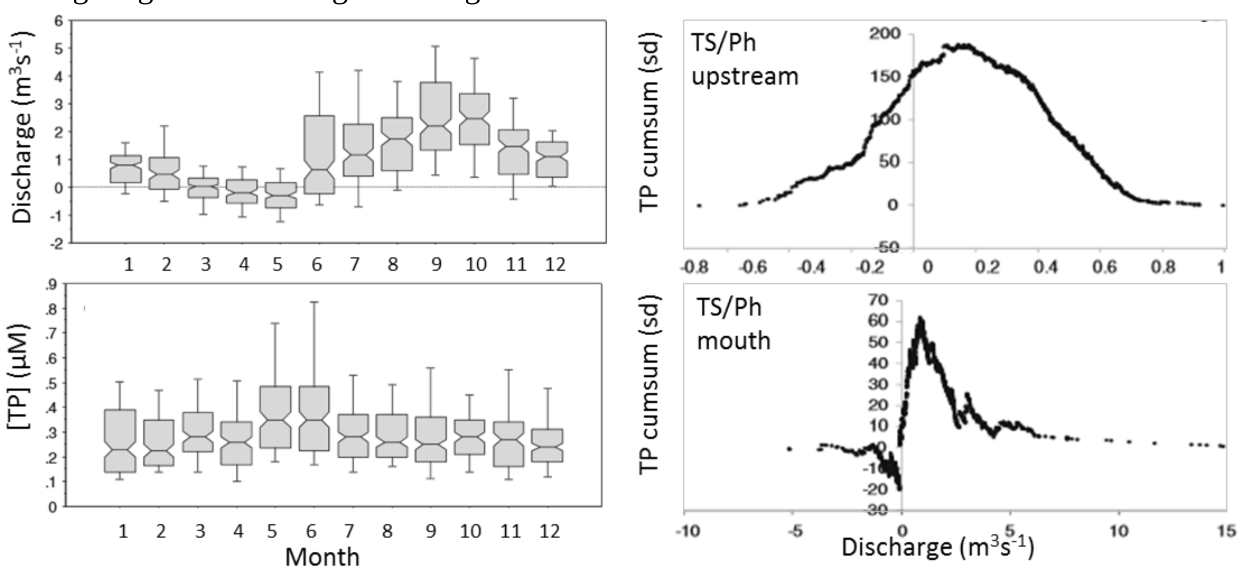


Figure 11. *Left panels:* Box and whisker plots of daily discharge (m^3s^{-1}) and tri-daily TP (μM) by month at Taylor River mouth during the period of FCE record, showing significant seasonal and interannual variance. *Right panels*: Standardized cumulative sum (cumsum (sd)) charts plotting the cumulative sum of standardized deviations of the time-series grand mean of TP concentrations at upstream sites and mouth of Taylor River, against monthly discharge. Both stations display non-linear responses to discharge. Peak-shaped inflexions highlight largest changes from above-average to below-average values, while v-shaped inflexions indicate the opposite. These findings indicate strong negative connections between freshwater flows from upstream and estuary TP concentrations, and suggest that reductions in freshwater flow will allow surface and subsurface flows of marine water, enriched in TP, to elevate concentrations at the mouth and interior of Taylor Slough. From Briceño et al. (2014).

D. Scenarios and Modeling (Leads: M. Rains, C. Fitz)
***Central question* – What scenario of water distribution and climate change will maximize socio-economic and environmental sustainability of a future FCE?**

History & Justification - Our research is focused on three key priorities driven by a history of rigorous multi-scale modeling activities in the Everglades: developing and adopting specific hydro-climatic and social scenarios to drive modeling efforts; understanding ecotone nutrient dynamics under different hydro-climatic scenarios; and testing hypotheses and visualizing landscape-scale dynamics under different scenarios. The FCE program is particularly well-suited for a scenarios framework (i.e., Biggs et al. 2007; Thompson et al. 2012) because of the vulnerability of the socio-ecological system to variability in both freshwater supply and marine pressures driven by water management and marine pressures. Water quantity and quality play important roles in many aspects of FCE ecology, including nutrient availability (Price et al. 2010), primary productivity (Gaiser et al. 2011; Rivera-Monroy et al. 2011), and sediment accumulation (Smith et al. 2009). Therefore, hydrologic modeling underlies most of our ecosystem modeling efforts and the work is highly collaborative, leveraging ongoing complex modeling efforts in which FCE scientists are intimately engaged.

Hypothesis 1 – **Scenarios that maximize freshwater inflow to the Everglades will sustain distinctive biophysical features and dynamics of the oligohaline ecotone in the face of climate change.** Over the past several years, FCE scientists participated in workshops with colleagues at Florida Atlantic University and several government agencies involved multi-stakeholder workshops to develop plausible scenarios of future climate change and SLR in south Florida. As part of this effort, the South Florida Water Management Model (SFWMM) was run under a variety of such future scenarios (Obeysekera et al. 2014). Daily flows through water control structures from those SFWMM runs drove the managed flows of the Everglades Landscape Model (ELM), which explicitly integrates dynamic flux equations of hydrology, nutrients, plants, and soils (Fitz et al. 2011; Fitz and Paudel 2012). The 36-year Baseline future run assumed 2010 initial conditions, to which two future scenarios were compared: (a) a 10% *decrease* in precipitation, a 7% increase in potential ET, and a 50-cm rise in sea level and (b) a 10% *increase* in precipitation, a 7% increase in potential ET, and a 50-cm rise in sea level. In general, the decreased rainfall scenario had ecologically-significant decreases in surface-water depths in the freshwater marshes, while the increased rainfall scenario had marginal increases in surface-water depths in the freshwater marshes. SLR caused the oligohaline ecotone to move ~15 km inland, with a nearly 25% increase in marine-influenced landscape area (Fig. 12). Details of the FCE models and results (e.g., surface-water depths, salinity, P concentrations) are available at http://www.ecolandmod.com/projects/ELM_FCE and are being used across working groups to derive biological response surfaces. Our next step is to combine these with a suite of restoration options being determined through long-term collaborations with stakeholders and agency partners.

Hypothesis 2 – **Scenarios that maximize the sustainability of ecosystem services provided by the marsh-mangrove ecotone will also improve freshwater sustainability in the South Florida Urban Gradient.** As part of the Synthesis of Everglades Research and Ecosystem Services (SERES) project collaboration, five restoration scenarios were compared to evaluate the effects of incremental water storage and the removal of levees and canals on the restoration of hydrology and ecology in the Everglades. A range of hydrological, ecological, and economic models/analyses were used in a trans-disciplinary assessment of the scenarios, compared to the existing Congressionally-approved Comprehensive Everglades Restoration Plan. The SFWMM simulated regional managed depths and flows throughout the Everglades and adjoining agricultural and urban regions, with model outputs used to drive the other models and analyses. Increased surface-water storage in above-ground reservoirs in the EAA provided a viable means to further improve the hydro-ecology throughout most of the Everglades and Florida Bay. For example, one scenario result generally showed increased peat accretion rates (ELM-simulated; Fitz et al. 2011; Fitz and Paudel 2012), increased periphyton edibility (PERIMOD-simulated; Gaiser et al. 2015a), improved small fish abundance (model described in Trexler and Goss 2009), and increased economic benefits/ecosystem services relative to the baseline CERP reported by Mather Economics (2011). The complete analyses are available in draft form (SERES 2014; the ELM results are available at http://www.ecolandmod.com/projects/ELMreg500SERES/). A workshop this year explored the mechanisms to extend FCE collaborations with the NSF-funded South Florida Water, Sustainability, and Climate (SFWSC) project, in order to explicitly integrate urban land use changes with changing water demands and Everglades hydrology.

Next steps – Work toward developing and adopting scenarios to drive modeling efforts will continue, with efforts focused on developing widespread consensus on scenarios used by multiple groups in south Florida, including the SFWSC project, the Everglades Foundation, the SFWMD, and the US Army Corps of Engineers. The ELM is currently calibrated-validated with 1981-2000 data. Future work will include recalibration-revalidation using more recent data, with an emphasis on assimilating long-term FCE data, especially tidal propagation (e.g., Wdowinski et al. 2013), sawgrass-mangrove productivity and succession (e.g., Rivera-Monroy et al. 2011), and freshwater periphyton productivity (e.g., Gaiser et al. 2011, 2015a).

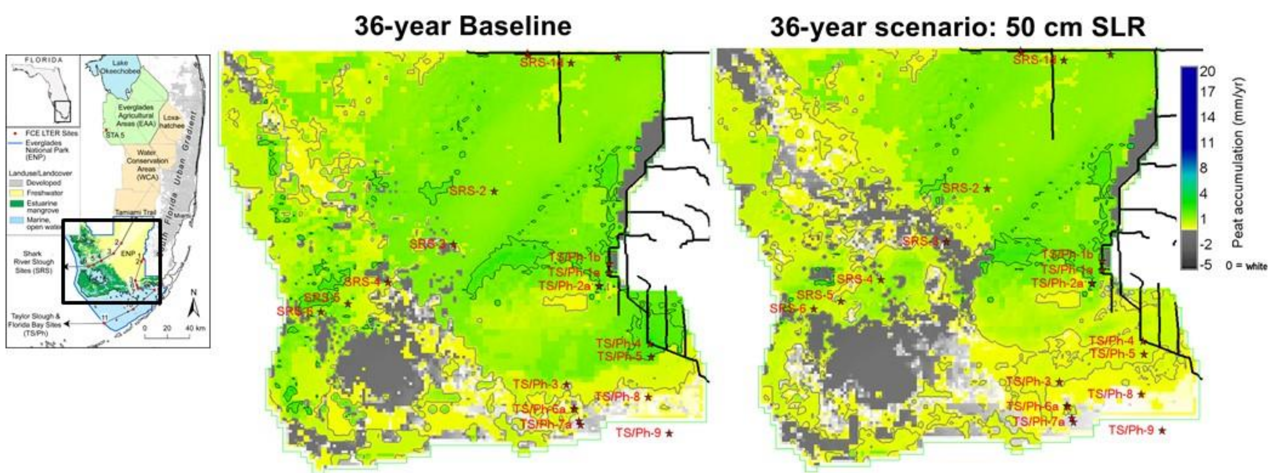


Figure 12: The FCE program is using the Everglades Landscape Model (ELM) to determine how restoration decisions will interact with sea level rise to influence the position of the oligohaline ecotone in the coastal Everglades. These maps portray the difference in peat accumulation rates between baseline conditions (left map) and an example scenario of only an increased sea level (right map), indicating widespread peat collapse may occur in the Everglades without substantial restoration of freshwater flows.

IV. BROADER IMPACTS AND PROGRAMMATIC ACTIVITIES

A. Education and Outreach (Leads: N. Oehm, S. Dailey)

The FCE III Education & Outreach program addresses the goals outlined in the *2011 Strategic and Implementation Plan.* Key constituents include: (1) K-12 students through Research Experience for Secondary Students (RESSt) and Research Assistantships for High School Students (RAHSS) programs, (2) teachers through Research Experience for Teacher (RET) programs, (3) undergraduate students through Research Experience for Undergraduates (REU) programs, and (4) citizens and policy-makers through a variety of activities in local to global communities.

K-12 Programs – So far in FCE III, we have reached 7,258 elementary, 4,686 middle school, 33,582 high school, and 1,800 educators through internet broadcasts, Skype, and live auditorium presentations. K-12 education is partly fostered through a partnership with the Deering Estate, which resulted in a recent collaboration with in a My Community, Our Earth (MyCOE) project with the Association of American Geographers. MyCOE leveraged $31,000 that was used to introduce 872 majority-minority students at Felix Varela Senior High School about the use of GIS/GPS technologies. A subset of 75 students were supervised by RETs in 41 mapping projects, concluding with an Our Earth GIS Day to reach a broader sector of the community. Subsequently, the U.S. Department of State selected 3 FCE students for a workshop on GeoTechnologies for Climate Change and the Environment, and enabled several students to attend a workshop in Bolivia to further this training. Our RAHSS program has enabled 24 high school students from 9 schools to be formally mentored by 15 FCE scientists and graduate students. Examples of successful RAHSS students include: Jamie Odzer, who received nine awards including 3rd Place at the Intel International Science and Engineering Fair for studies of macroinvertebrates; Cindy Saenz, who received two awards for studies on the bioavailability of leachates in SRS; Sara Osorio, who received three awards including the highest rating and 3rd Place in Environmental Science at the State Science and Engineering Fair of Florida for studies of diatom assemblages along a salinity gradient; and Felipe Tamayo who is studying fitness of native fishes and, together with Sara, presented research results at the Ft. Lauderdale Museum of Discovery and Science. We are also proud of Chris Sanchez who published his RAHSS research in the *Journal of Paleolimnology* and went on to conduct comparative research at the Central Arizona-Phoenix LTER REU program.

Undergraduate Education - FCE III researchers incorporated discoveries into 102 reported formal courses reaching 1,714 students. Researchers have provided over 204 semester units of undergraduate mentoring to more than 92 undergraduates in 27 labs. In addition, FCE provides two formal REUs each year including: Julio Pachon of Cornell University who studied the effects of P addition on soil C loss and presented results at several regional and national scientific meetings, and Rachel Johnson of University of Virginia who worked on a project to determine the causes for peat collapse in the coastal ecotone and is now conducting collaborative research at the Virginia Coastal Reserve LTER as a graduate student.

Teacher Training - RET Teresa Casal, Jennifer Tisthammer (Director of Deering Estate) and coordinator N. Oehm traveled to the Jornada LTER where they received training to implement the FCE-Deering Everglades DataJam. Teresa and RETs Catherine Laroche, Jennifer Gambale, and Terri Reyes coordinated 60 of their students from Felix Varela Senior High School to produce 18 DataJam posters that were exhibited at the 2015 FCE ASM. We have submitted a collaborative proposal with Deering Estate to secure additional funding for support in expanding the DataJam. RETs Lisa Giles and Paul Rehage worked closely with REUs and researchers to produce high school lessons, and RET Teresa Casal is using teaching pre-service teachers to use FCE datasets at the School of Education at Miami Dade College.

***Graduate Student Group* –** The FCE graduate program includes over 75 students and is led by a multi-institutional executive board. They meet more than monthly in informal and formal settings to advance collaborative research, communicate science to the public, and socialize. They coordinate the FCE Blog "*Wading through Research*" and manage much of our social media. Graduate students also coordinate seminar series and broadcast relevant lectures via a USTREAM channel they established for FCE. They host visiting research groups, including a group of 20 undergraduate students from Concordia College in Spring 2014.

***Community Outreach* –** Outreach to policy-makers and the public is a core part of FCE science and is discussed throughout this report. FCE scientists continue to provide research and results reported to decision makers for use in shaping policy as panelists for the Everglades Foundation and the Environmental Protection Agency and through reports to the South Florida Water Management District and the South Florida Ecosystem Restoration Task Force. In addition to participating in scientific advisory roles across state and federal agencies, FCE researchers have participated in more than 85 events where they have served as panelists, organized reports, chaired committees, organized/hosted events, conducted trainings, tabled events, and served as judges. More formal outreach activities include our LTEArt program, which has engaged the Tropical Botanic Artists in six exhibits of Marine Macroalgae: Hidden Colors of the Sea and four exhibits of In Deep with Diatoms, and partnered with Xavier Cortada on the Reclamation Project (part of LTER Ecological Reflections) and Native Flags. We have created videos about our research through partnerships with filmmaker, Richard Kern, resulting in *Surviving the Everglades* and presentations of *Encounters in Excellence* to over 50,000 K-12 students annually in Miami Dade County Public Schools. The FCE Citizen Science program consists of two major initiatives: (1) Predator Tracker, which allows patrons of the Living in the Everglades exhibit at the Ft. Lauderdale Museum of Discovery and Science and website visitors to track Everglades predators such as alligators and bull sharks (discussed in the half-hour episode *Coastal Carnivores* as part of the PBS series *Changing Seas*); and, (2) the Coastal Angler Science Team CAST, a collaboration between anglers and researchers as a means for understanding how changes in the Everglades impact coastal fisheries.

***Communication* -** FCE research has been highlighted through several media outlets including the Wall Street Journal, Miami Herald, Science, All Things Considered and Radiolab on National Public Radio, Florida Wildlife Corridor Expedition on Public Broadcasting in Jacksonville, West Palm Beach, and Miami along with an episode of Coastal Carnivores and the National Geographic Website. To date, FCE has 57 YouTube posts, 7 television broadcasts, 2 Kern films, 3 radio broadcasts, 29 periodicals, 107 blog entries, 5 websites, and our quarterly FCE newsletter, *"News from the Sloughs."*

B. Cross-site and Network Activities

The ability of the FCE program to advance theory on the dynamics of social-ecological systems while also informing and learning from the decision-making process has been largely cultivated through partnerships. Partnerships within the U.S. LTER Network were instrumental in developing a framework for long-term information collection and synthesis that embraces studies of the critical human dimension of ecosystem transformation (Collins et al. 2011). Network collaborations influenced the direction of FCE's programmatic evolution through the exchange of ideas and involvement of researchers with perspectives from the humanities to the physical sciences. In turn, the reliance of the FCE program on partnerships between academic and agency scientists to understand and influence transformation of this expansive but human-dominated ecosystem has enabled it to serve as a model of successful conveyance of research into policy-making (i.e., Sullivan et al. 2014b). Finally, FCE researchers have participated widely in international LTER research and leadership, primarily because some of our most globally threatened and vulnerable coastlines are in the nearby and similarly structured tropical environments (Gaiser et al. 2012, 2015b). By comparing properties of the Everglades with other subtropical and tropical wetlands, we have challenged ideas of novelty while revealing properties of ecosystems at the ends of gradients that are often ignored. We have also provided insights from and encouragement for long-term collaborative studies that inform resource management in similarly threatened coastal wetlands.

Network Partnerships and Cross-Site Coastal Research – FCE researchers have advanced network research in the five core areas of LTER and also in the human dimensions arena. In particular, FCE scientists are leading cross-site efforts to understand atmosphere-biosphere exchanges of C through: (1) quantifying C biomass across coastal sites by relating standing stocks to remotely sensed data; (2) participating in proposal efforts involving other coastal LTER sites; (3) organizing synthesis efforts at the 2014 and 2015 Science Council meetings directed at synthesis of primary productivity; and, (4) participating in and leading cross-site workshops and educational activities, including coastal LTER C sessions at the 2015 American Society of Limnology and Oceanography and North American Carbon Program meetings, and two special sessions on the drivers of coastal C storage and loss at the 2015 Meeting of the Ecological Society of America (ESA). Specific outcomes of the special session will lead to cross-site products comparing effects of salinity on C in salt and freshwater coastal marshes (GCE LTER's SaltEx project in Georgia, Timberlake Restoration project in North Carolina, long-term experiments in South Carolina), as well as C storage/loss patterns among marsh-mangrove vegetation regime shifts in response to SLR and temperature increases along the Gulf (Texas) and Atlantic (Florida) coasts. Co-PI Kominoski will present network-level synthesis of some of this work at the 2015 NSF LTER Mini-Symposium. In addition, R. Boucek and J. Rehage (FCE), and L. Deegan, J. Nelson, M. Mather, and H. Golden (PIE LTER) are hosting sessions at ESA and the National Meeting of the American Fisheries Society to synthesize work on disturbance effects on consumer mediated habitat linkages, and about how abnormal spawning behaviors in iteroparous fishes influence stock recruitment relationships and stock assessments of exploited fishes. Both sessions will generate peer reviewed manuscripts. Our organic matter dynamics research continues to engage aquatic LTER sites nationally and globally to determine sources and fate of C. In particular, cross-site studies (KNZ, BNZ, ARC, MWT, LUQ, CWT, HBR LTERs) of dissolved black C, which accounts for up to 20% of DOC in the Everglades, confirmed the ubiquity of this material (Jaffé et al. 2012), and suggested that it is derived from long-term degradation of charred materials (Ding et al. 2013; Ding et al. 2014a) and an enhanced input of anthropogenic combustion-derived DBC in remote locations (Ding et al. 2014b). FCE's ongoing collaborations with other urban LTER sites have advanced our understanding of the ecological and social dynamics of urbanization (Polsky et al. 2014) as well producing key methodological contributions to multi-scalar research (Roy Chowdhury et al. 2011).

International Discoveries and ILTER Leadership – FCE research continues to find expanded context and relevance through comparative research in other karstic ecosystems and in the subtropics and tropics. International collaborations are strong and growing and, for this reason, FCE researchers have taken leadership roles in the ILTER Network: collaborator Troxler is now the U.S. ILTER representative and PI Evelyn Gaiser led the 2013 ILTER integrative activities at the 2013 NSF mini-symposium, resulting in a special 2015 issue of the journal *Ecosphere*. An FCE-led contribution (Gaiser et al. 2015b) reviews how long-term, comparative, international research has provided perspective on iconic features of the Everglades that have, in turn, informed general ecosystem paradigms. In particular, research in other karstic ecosystems from the Caribbean to Australia, and shorter-term studies across other contrasting wetlands, have shed light on distinctive and puzzling aspects such as the "upside-down estuary" and "productivity paradox" discovered in FCE research. These studies suggest that coastal wetlands on carbonate platforms have: (1) hydrological and biogeochemical properties that reflect "hidden" sources of groundwater and nutrients (Fig. 13), (2) productive benthic algal communities that present a low-quality food to aquatic consumers that encourages (3) highly diversified feeding strategies within and among populations, and (4) extensive and productive seagrass meadows and mangrove forests that promote strong cultural dependencies on the ecosystem services they provide. The contribution of international research to each of these general ecological topics is discussed with a particular goal of encouraging informed decision-making in threatened wetlands across the globe (Camacho-Ibar and Rivera-Monroy 2014).

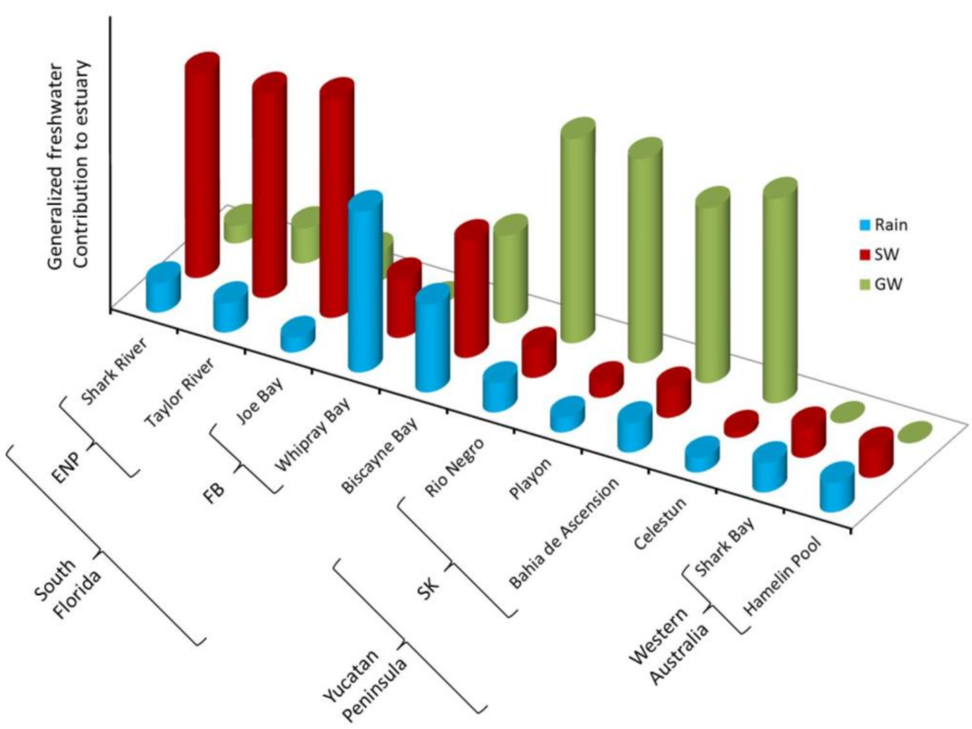


Figure 13. FCE has led research to explore the propensity for coastal karstic systems to be hydrologically and bio-geochemically "upside-down." We have completed full water budgets for comparative karst wetlands to determine contributions from rainfall (Rain), surface water flow (SW) and groundwater recharge (GW) to estuaries in south Florida, Yucatan Peninsula, and Western Australia. (Source: Gaiser et al. 2015b).

C. Information Management (Leads: L. Powell, M. Rugge)

Objectives

The FCE LTER Information Management System (IMS) provides a centralized network of information and data related to the coastal Everglades ecosystem. Given the potentially important role that the FCE LTER program may play in Everglades restoration, a key objective is to increase public and private awareness of our Everglades research activities. The FCE IMS Group has established IMS level protocols and services for data collection, quality assurance, data organization, data archive, data access, and data distribution to facilitate our scientific work and to ensure the integrity of the information and databases resulting from the research. A detailed accounting of the FCE IMS scope, system design and its support for science is found online under our research tab at http://fcelter.fiu.edu/research/information_management/ and the formal FCE Data Management Policy is posted at http://fcelter.fiu.edu/data/DataMgmt.pdf.

Information Technology Resources, Security & Data Protection

The FCE IMS Group consists of one full-time Information Manager, Linda Powell, and one full-time Project Manager, Mike Rugge. Overlap between the IMS group's critical tasks allows collaboration on computer system administration issues and with the FCE webserver and Oracle11g Database design issues, content and implementations.

The FCE IMS group manages three virtual Linux servers, two virtual Windows servers, one physical Linux server and two desktop workstations for a total storage capacity of 3.253 Terabytes. FCE site data, databases and project information are housed on a suite of virtual servers maintained by the Florida International University's Division of Information Technology: two Oracle 11g database servers (production & development), two web servers (production & development) and a FCE FTP server. The dedicated development virtual servers for both the Oracle 11g database and the FCE website are extremely beneficial to the IMS group because changes made to these systems can be tested without having to worry about interrupting service or corrupting existing system setups. All FCE physical servers and workstations undergo continual updates and patches to their operating systems and have dynamic firewalls. Database and flat file integrity are maintained through access passwords and user privileges and roles. A full discussion of the FCE Disaster Recovery plan is at http://fcelter.fiu.edu/research/information_management/index.htm?section=ims_security.

The virtual server environment, coupled with the FCE physical computers, allow for more storage that enables the FCE IMS to receive, handle, analyze and deliver high-resolution data at the FCE site level and permits the FCE program comprehensive and timely contributors of sensor data and metadata to the LTER Network Information System (NIS).

FCE III Website and Data Archives

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 to a wide variety of information ranging from the FCE LTER project overview to links to additional research-related websites and online data downloads. The FCE IMS group has incorporated several LTER working group initiatives to improve standardization of data search and access from across the LTER sites through the adoption of controlled vocabularies and common interface features. The FCE web site ''Data' Section is unique to most other LTER sites in that it acts as a portal to three major data categories: 1) FCE Data Products, 2) LTER Network Data and 3) Outside Agency Related Everglades Data. Users can easily select a data category of interest and are taken to a new page containing pertinent links found under that category. The FCE Data Products page has 7 major subcategories such as core research data, signature datasets and climate data. Users are given a 'FCE Sampling Attribute' subcategory where they can search by a sampling attribute and the return results will include sites, datasets and projects associated with that sampling attribute. FCE publications are updated frequently and are searchable on-line by querying on any combination of date, author, keyword, and publication type. Presentations are listed on the FCE website, and in some cases, users may view a presentation via a document link. Limited GIS and raster data are available for download via our Everglades interactive map application and the GIS Data and Maps page.

All of the FCE LTER core data and metadata files from individual research studies are stored in a hierarchical flat file directory system. FCE project information and minimal research data metadata are stored in an Oracle 11g database that drives the FCE web site. Core research 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. The FCE program is now in full compliance with the LTER PASTA system as all FCE program data, with the exception of 17 'restricted' dissertation research data sets, have been uploaded into the LTER Network PASTA system. The FCE IMS contains 143 datasets, of which a total of 126 are also publicly available online at http://fcelter.fiu.edu/data/FCE/.

All FCE personnel have access to our password protected Intranet site. Researchers can easily compile their personal FCE information by selecting the menu choice 'Your Information' whereby all pertinent contact information, publication, presentation, leveraged funding, dataset and project description results are reported online. Users can also browse the intranet site for downloadables like the FCE project information form and important FCE documents such at the ENP Sampling Permits, the FCE III proposal and the LTER network Planning Grant and Strategic Planning Process presentation.

FCE III Future Initiatives

A nearly completed (Winter 2014) web-based data processing visualization tool will allow researchers to rapidly visualize complex data streams and to efficiently process and annotate data directly from the FCE Core Research Data web page.

D. Synthesis and Integration (Leads: D. Childers, E. Gaiser, L. Ogden)

The FCE III program is making progress advancing theory on the dynamics of coastal socio-ecological systems through thematic integration that cross-cuts core working group research. We are resolving sources of uncertainty in projections of change in key drivers, including the SLR rate (Haigh et al. 2014) and the cultural and institutional causes for progress (or delays) in the freshwater restoration process (Schwartz 2014). The setting of our research in novel ecosystem theoretical framework has been rewarding because it postulates that external agents of change will result in unanticipated non-linear changes in a context driven by historical socio-ecological patterns and constraints. An example of this captured by our LTER is the collapse of peat soils in patches throughout the ecotone. We suspect that the pattern of peat collapse is a product of the long-term "press" of SLR, which is prolonging inundation and increasing salinity and P exposure in near-ecotone freshwater marshes, and the "pulse" of storm activity that offset this collapse through delivery of mineral soils from the coast. Because peat collapse may be a positive feedback to saltwater intrusion into the Biscayne Aquifer that supplies most of Florida's freshwater, it is a key uncertainty in models of ecosystem response to SLR, and has become a focus for FCE manipulative studies in both mesocosm and field experiments.

The FCE is committed to synthesis of science to guide restoration policy and the advancement of ecological theory. Restoration policy is guided by biennial reports to the U.S. Congress on the progress of Everglades Restoration (Fig. 14). FCE long-term data and experiments are used to derive ecological targets for restoration, and deviation from those targets are assessed annually (using model adjustments that account for "natural" hydro-climatic variance). Deviations are compiled into robust signals (using a red-yellow-green "stoplight" system to denote baseline, caution and failure) that can be easily understood by water managers and policy makers.

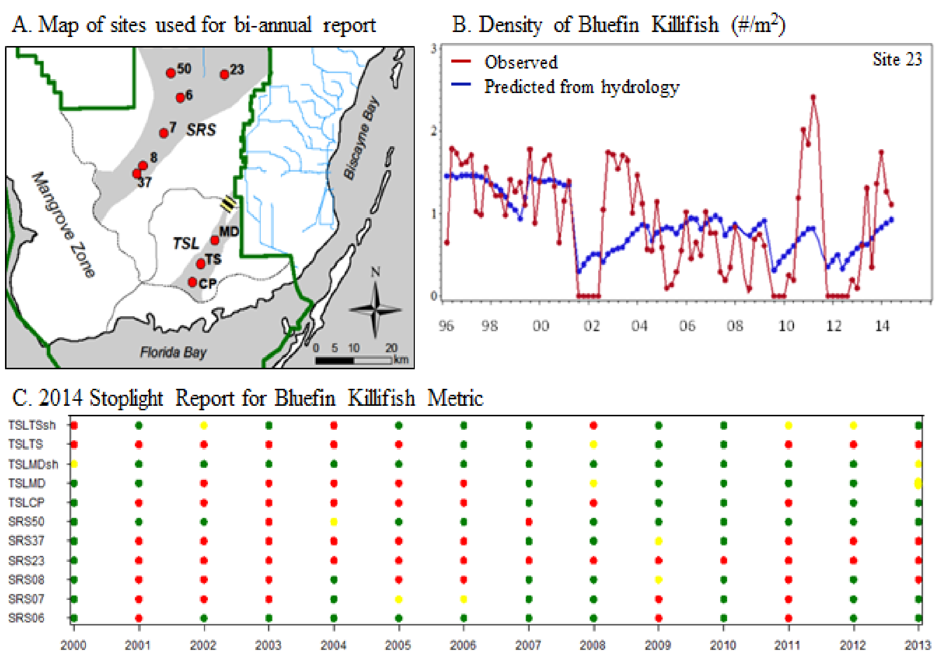


Figure 14. An example of LTER contributions to the Report to the US Congress (http://www.sfrestore.org/) A. Long-term data from the FCE SRS and TS/Ph transects are used to develop performance measures. B. Time-series data from each site are compared to targets derived from a model based on rainfall (from Trexler and Goss 2009). C. Report card indicating compliance with targets (green), deviation requiring attention (yellow), and deviation indicating failure to meet management goals (red).

The FCE program has also driven synthesis through the production of several integrative special issues. A 2014 *Wetlands* special issue explores how water management may have unintended consequences of stimulating P enrichment (Sullivan et al. 2014b), a key conflict in Everglades restoration. We will complete two special issues of *Ecosphere* in 2015: the first reflects on how international LTER informs science of the U.S. LTER Network, and the second examines effects of cold fronts on subtropical wetland ecology. In addition, FCE is producing a synthesis volume of *Restoration Ecology* that summarizes our project *Synthesis of Everglades Restoration and Ecosystem Services.* By co-producing science reliant on academic and agency scientists partnerships, the FCE program is informing general ecological theory, while serving as a model of successful conveyance of research into policy-making in Florida and threatened coastal wetlands elsewhere (Gaiser et al. 2015b).

A key component of our FCE III synthesis efforts is the writing of our contribution to the LTER Network Synthesis Series. Our book, entitled - *The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape*, is being edited by Dan Childers, Evelyn Gaiser, and Laura Ogden. Our publisher, Oxford University Press, anticipates completion by Fall 2015. We held several organizational and writing workshops in Miami since October 2013, have late drafts of all nine chapters in hand. The chapters and their lead authors are:

Preface and Chapter 1: *Introduction* (D. Childers, E. Gaiser, & L. Ogden)
Chapter 2: *The Everglades as an Icon* (L. Ogden & J. Trexler)
Chapter 3: *Water, Sustainability, and Survival* (R. Price & K. Schwartz)
Chapter 4: *Fragmentation, Connectivity, and Teleconnections: Legacies and Future Implications* (J. Kominoski, J. Rehage & B. Anderson)
Chapter 5: *The Life of P: A Shifting Water Quality Paradigm in the Karstic Everglades* (J. Cattelino, G. Noe, V. Rivera-Monroy, K. Schwartz & J. Wozniak)
Chapter 6: *Carbon Cycling and Related Cycles at a Multitude of Scales* (J. Boyer, J. Fuentes, R. Jaffé, G. Starr, & T. Troxler)
Chapter 7: *Exogenous Drivers: What has Disturbance Taught Us?* (E. Castañeda & S. Davis)
Chapter 8: *Back to the Future* (F. Sklar)
Chapter 9: *Re-imagining Ecology through an Everglades Lens* (E. Gaiser, D. Childers & L. Ogden)

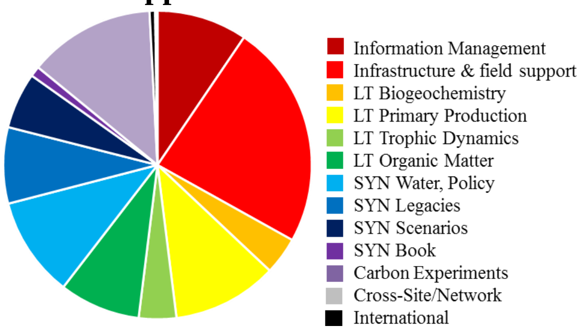
This book makes important contributions to our understanding of wetlands, urban ecology, and climate change, as well as the role of science in Everglades restoration efforts. Specifically, it:

- Presents an approach to understanding the ecology of the Everglades that incorporates social science and urban ecology;
- Uses long-term data to investigate the interactions among trajectories of change, including water management, restoration efforts, and SLR;
- Contributes to our understanding of ecological disturbance in the context of a managed ecosystem;
- Unravels ecological paradoxes present in the “upside down” estuaries of the Coastal Everglades, and;
- Demonstrates the ways in which science supports one of the largest restoration programs in the world.

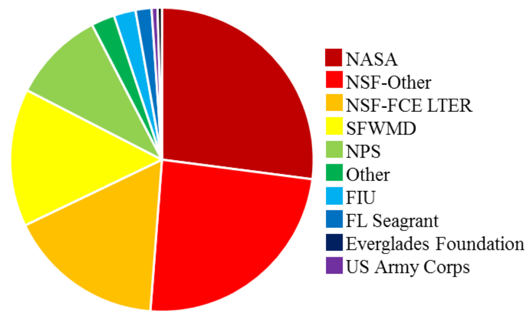
E. Funding and Publication Overview

Leveraged Funding: FCE agency scientists are critical to the function of the program, so it is difficult to accurately quantify the "leveraged support" because some FCE activities (including some data collection, analysis, modeling) are conditions of agency collaborators' employment. Between 2013-2015, the program received $2,940,000 from NSF for the core award and $14,693,224 in leveraged funding to FCE collaborators (Fig. 15). The breakdown of the core award and leveraged funding is:

NSF core support for FCE LTER



Sources of leverage funding 2013-15



Topical breakdown of leveraged funding

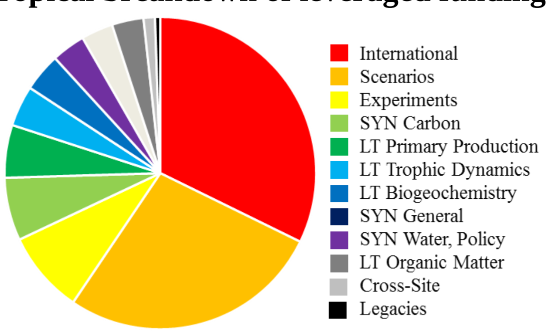


Figure 15. FCE core funding is heavily allocated toward field support and operations, including long-term (LT) data collection and experiments within working groups and synthesis (SYN) through cross-cutting themes. Some key leveraged projects include funding from ENP and the U.S. Army Corps of Engineers that sustains and supplements our routine landscape-scale biophysical sampling, funding from Florida Sea Grant in support of our experimental work on causes for peat collapse associated with SLR, funding from NASA that has extended our international socio-ecological work in mangrove forests of the Caribbean, and special funding for modeling and scenarios research from an NSF WSC project dedicated to hydro-economic scenarios and an Everglades Foundation project dedicated to synthesis of ecosystem services.

Publication Overview: FCE III has generated 138 publications, including highly cited papers in *Science*, *Nature Communication*, *Frontiers*; 6 MS theses and 12 PhD dissertations; 9 book chapters; 3 special issues published (*Wetlands*, *Journal of Paleolimnology*, *Ecosphere*) (Fig. 16).

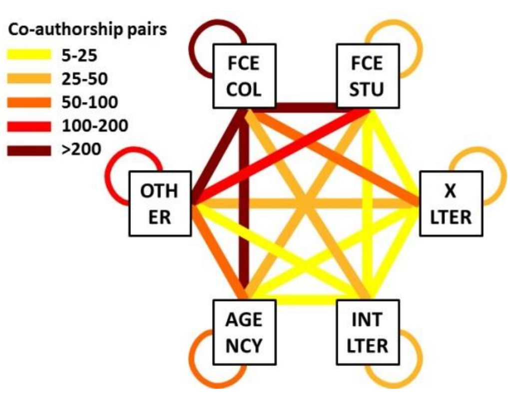


Figure 16. Diagram depicts collaborative linkages through publication by FCE collaborators (FCE COL), students (FCE STU), agency scientists, scientists at other LTER sites (X LTER), international LTER collaborators (INT LTER) and others. Line color indicates the number of pairings across the 635 co-authors of the 138 publications from 2013-2015 (FCE III). Compared to FCE I and II, the program reports an increase in the proportion of international co-authorships representing our collaborative research in the subtropics.

F. Literature Cited

All cited publications are available at http://fcelter.fiu.edu/publications/. This report also referenced the following publications from other research:

Camacho-Ibar, V.F., and V.H. Rivera-Monroy. 2014. Coastal Lagoons and Estuaries in Mexico: Processes and Vulnerability. Estuaries and Coasts 37: 1313-1318.

Daroub, S. H., S. Van Horn, T. A. Lang, and O. A. Diaz. 2011. Best Management Practices and Long-Term Water Quality Trends in the Everglades Agricultural Area. Critical Reviews in Environmental Science and Technology 41 (S1):608–632.

Pendleton, L. and others 2012. Estimating global "Blue Carbon" emissions from conversion and degradation of vegetated coastal ecosystems. Plos One **7**.

SERES Final Report. 2014. Synthesis of Everglades Research and Ecosystem Services Project: An Analysis of Five Options for Restoring the Everglades Ecosystem. Draft Final Report Submitted to Everglades National Park.

Schwartz, K. The anti-politics of biopolitical disaster on Florida's coasts. Western Political Science Association, Seattle, Washington, April 2-4, 2014.