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# FCE III Year Three Annual Report for NSF Award DEB-1237517

Evelyn E. Gaiser

*Florida International University, gaisere@fiu.edu*

Michael R. Heithaus

*Florida International University, heithaus@fiu.edu*

Rudolf Jaffe

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

John Kominoski

*Department of Biological Sciences, Florida International University, jkominos@fiu.edu*

René M. Price

*Florida International University, pricer@fiu.edu*

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FCE III YEAR THREE ANNUAL REPORT  
FOR NSF AWARD DEB-1237517

FLORIDA COASTAL EVERGLADES LTER  
Florida International University

Reporting Period: 12/01/2014 – 11/30/2015  
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Principal Investigators

Evelyn Gaiser

Michael Heithaus

Rudolf Jaffé

John Kominoski

René Price

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## Accomplishments

### Major goals of the project

The goal of the Florida Coastal Everglades Long Term Ecological Research (FCE LTER) program is to conduct long-term studies to understand how climate change and resource management decisions interact with biological processes to modify coastal landscapes. Our focus is on the oligohaline ecotone of the Florida Everglades, integrating marine and freshwater influences. Long-term data show that the ecotone is highly sensitive to increasing marine pressures, driven over longer-time scales by sea level rise (SLR), and shorter-time scales by storms and tidal exchanges. Freshwater flow, controlled by climate variation and upstream allocation decisions, interacts with marine pressures to affect the ecotone. FCE is in its third phase of research (FCE III), focused on linking the long-term dynamics in the ecotone of two major drainages, Shark River Slough (SRS) and the Taylor Slough/Panhandle (TS/Ph), to the balance of these two primary water sources.

The overarching goals of this reporting year included: (1) continue collection and analysis of long-term datasets to address long-term dynamics of the oligohaline ecotone relative to changes in fresh and marine water supplies, (2) improve understanding of the socioecological and hydrological politics of freshwater restoration in the face of SLR, (3) continue laboratory, mesocosm, and ecosystem- and landscape-scale experiments manipulating salinity, P and inundation, (4) conduct data-model synthesis linking climate and disturbance legacies to future projections, (5) complete FCE synthesis book chapters for submission to publisher and initiate new data-model synthesis activities, (6) continue updates of FCE data to the Network Information System (PASTA), (7) integrate core findings through LTER network-wide collaborations, (8) advance education (FCE Schoolyard) and outreach activities through expanded partnerships directed toward goals of the Strategic Implementation Plan for LTER.

FCE III research is conducted within the context of four major working groups (WG): *Biogeochemical Cycling*, *Primary Production*, *Organic Matter (OM) Dynamics*, and *Trophic Dynamics*. Integration is accomplished through four Cross-Cutting Themes (CCT): *Hydrology and Water Policies*, *Carbon (C) Cycling*, *Climate and Disturbance Legacies*, and *Modeling and Scenarios*. Further synthesis is being driven by our contributions to a holistic synthesis book to be completed in the coming months. Here, we report progress integrating across each of these categories relative to the goals set in our proposal and organized in a new way that address interests of our mid-term review team. Specifically, we break down our activities, goals and results into four categories: *long-term system dynamics*, *hydropolitics and SLR*, *experimental integration*, and *legacies and scenarios of change*.

## Major Activities

**Long-term data collection and analysis:** Field and laboratory data collections have continued as planned without interruption. Several field instrumental upgrades and expansions were made possible through the recent LTER supplemental funding. These include replacements of sensors for existing flux towers, instrumentation of a new flux tower, a suite of dissolved oxygen sensors to understand aquatic metabolic contributions to C budgets, and expanded sensors for determining the patterns and drivers of predator behavior in the ecotone in response to changing freshwater flow, among others. Integration of long-term hydrological, biogeochemical, and primary production data are ongoing to determine how the balance of fresh and marine water supplies regulates plant composition and primary productivity through interacting effects on phosphorus (P) availability, salinity, and water residence time. We also continue landscape-scale studies to determine how plant composition and primary productivity express legacies of fresh and marine water supplies to the ecotone. One key question motivated by our long-term data is the fate of C exposed to seasonal and interannual variability in water supplies. We continue studies of the chemistry, transport, and fate of P and C across the ecotone, with an emphasis on identifying the source of P supporting high primary productivity in the ecotone and the residence time of C passing through the ecotone. We have combined monthly DOC data for the past 14 years, and established relationships among hydrological, climatic and biochemical parameters. We also completed measurements of soil accretion rates over the last 100 years within the mangrove forests, and examined macronutrient stoichiometry and biomass C pools along gradients of soil P availability. To determine how variability in freshwater inflows interacts with SLR modify the spatial scale of consumer-mediated habitat links we extended long-term studies of teleost communities, bull sharks, alligators, and bottlenose dolphins through acoustic telemetry and animal-borne cameras (alligators only). We also initiated a synthetic analysis of trophic interactions and habitat use of large predators.

**Hydropolitics and Sea Level Rise:** FCE made major strides in addressing the science and politics of Everglades restoration in the face of SLR in the past year. The FCE leadership was able to discuss the source of conflicts surrounding Everglades restoration, and possible scientifically backed solutions to them, in direct conversations with United States President Barack Obama, Director of the White House Office of Science, Technology and Policy, John Holdren, former Vice President Al Gore, and former Senator Bob Graham. Scientific advancements informing these discussions included data from continuous hydrological and geochemical monitoring of SLR rates in the Everglades from ground-based and satellite observations, and projections of SLR and rainfall downscaled from IPCC models. Specific products included a completed M.S. thesis on the hydrologic controls of groundwater discharge and a Ph.D. dissertation on the fate of groundwater P supplies under SLR, and related publications. Hydropolitical research included 1) investigations of policymaking and advocacy settings, archival research, and interviews with government agencies, the Miccosukee Indian Tribe and other stakeholder groups; 2) performing interviews with farmers, agricultural researchers, and state and federal government officials involved in the water management regulations and institutional dynamics under the Everglades Forever Act; and 3) setting up hydrodynamic models to determine water flow patterns related to urban growth and climate change scenarios. This research and progress enabled FIU to form a Sea Level Solutions Center

that will enable FCE to expand social and environmental research on SLR effects, mitigation and adaptation in South Florida and similar coastal environments.

**Experiment Integration:** FCE investigators and graduate students, have been meeting together on a monthly basis to exchange progress on mesocosm and field experiments testing ecosystem-level responses to SLR and saltwater intrusion in coastal wetlands. This includes quarterly meetings with agency collaborators to plan and implement salinity  $\times$  inundation and salinity  $\times$  P mesocosm and field (salinity only) experiments, involving freshwater and brackish soils and plant-soil peats. These experiments are modeled after experiments in 2011 (Chambers et al. 2014) and 2013, using mangrove soils and plant-soil peats, and P dosing experiments (SFWMD). An all-hands meeting to assess mesocosm and field results to-date was held in May 2015 at FIU. Students presented data from field and mesocosm experiments that began in fall 2014. Data from the 2013 experiment have been analyzed and presented at scientific conferences. Troxler and Kominoski trained two REU students involving research that tested 1) wetland plant physiological responses to salinity and P, and 2) threshold responses of soil microbial communities to subsidy-stress gradients in salinity and P. To assess how freshwater delivery influences the importance of detritus to freshwater marsh and mangrove estuarine food webs, we conducted separate laboratory and field experiments extending studies that used fatty acid and stable isotopic analyses to document the relative contribution of microbial production, driven primarily by bacterial metabolism of detritus from periphyton and algal production, to invertebrates and fishes. The team was successful in obtaining another three years of funding from Florida Sea Grant to supplement this research, and five FCE graduate students submitted proposals to the 2015 Everglades Foundation Fellowship Program based on these experiments.

**Legacies and Scenarios:** We hypothesized that changes in land-use and water allocation in the FCE, and changes in freshwater inflows have hydrodynamic consequences in the Everglades landscape that explain changes in the oligohaline ecotone. This year's progress included: a) committing to data-model synthesis across teams in order to better understand P fluxes driven by water source changes; b) land-use change analysis and forecasting using new techniques and models; c) time series analysis to detect long-term changes in salinity, nutrients, and rainfall relative to land-use change, water quality regulations, and climate teleconnections; d) developing a paleoclimate chronology from several tree species; and, e) linking shifts in ecosystem CO<sub>2</sub> exchange rates and ground-based productivity measurements to climate and land-use changes across freshwater marsh and mangrove ecosystems. We have advanced our scenarios framework to constrain FCE-wide modeling efforts, with the goal of 3-4 plausible scenarios of climate, SLR, ecosystem restoration (e.g., water delivery to Everglades), and regional water demand (e.g., demand for water that might otherwise be delivered to the Everglades). We are using a landscape-scale ecological model to visualize outcomes under plausible scenarios, with a dual emphasis on hypothesis testing and serving the needs of the regional planning and policy-making community. Fourth, we are opportunistically providing support to the broader FCE modeling community by serving as a clearinghouse for FCE modeling information.

### Specific Objectives

**Long-term data collection and analysis:** Our central objective is to determine how the balance of fresh and marine water supplies influence P availability and salinity to change C

sequestration, storage and export in coastal wetlands. Specifically, biogeochemical cycling researchers focused this year on investigating how pulses of salinity and P associated with seasonal variability and storm surges influence C losses from freshwater wetlands. Coordinated research on primary productivity is determining how hydrological and biogeochemical changes are playing out in terms of sawgrass productivity, algal community dynamics, and mangrove growth within FCE plots and at landscape scales using series of remotely sensed imagery, particularly this year focusing on sub-transect research along our ecotone transition zone. Mangrove studies are also focusing on the long-term trajectories of change and biophysical feedbacks to natural disturbances such as Hurricane Wilma (2005) and a distinct cold snap in January 2010. This year we also aimed to address the dynamics of particulate and dissolved C in space and time by assessing the fate of drivers of downstream DOC export and the source strengths of DOC at the mouth of the estuary. To contribute to our C budget analysis, we also aimed to determine long-term accretion rates in mangrove estuaries, and relate them to SLR and gradients of nutrient availability to lead toward dynamic C models. Related research on consumers is addressing how these detrital resources contribute to diets of freshwater and marine small fish and large predators, and how water balance influences their ability to transport this energy across freshwater marsh-ecotone-estuary boundaries. In particular, we aimed to increase our tracking of the movement of top predators in marsh habitats where freshwater flow is being experimentally manipulated, and to address the impacts of extreme events (cold snaps, droughts) on these movements and feeding behaviors. We also aimed to meet with other coastal LTER sites and work within international working groups to conduct integrative research on the interactions of consumers with the fate of coastal blue C under climate change. Longline sampling of juvenile bull sharks in the Shark River Estuary have continued in Tarpon Bay, where continuous data is available since 2006 and >80% of sharks have been caught during the project. Data suggest the population is still recovering from the 2010 cold snap with less overlap in spatial distribution among smaller and larger juvenile sharks. However projections suggest the population may exhibit structure and behavior similar to 2006-2009 within the next 1-3 years (i.e. summer 2016-summer 2018). Our findings suggest a slower recovery (6-8 years) than predicted based on bull shark life history (3-5 years), which may have altered their role(s) within the ecosystem. We plan to continue monitoring the bull shark population within the estuary using longline sampling, stable isotope analysis, and acoustic telemetry, as well as use data to explore more relationships with other predators within the ecosystem and annual and seasonal fluctuations in environmental conditions.

Long-term data have provided us with insights into how changes in freshwater delivery, SLR, and climate disturbance will affect Everglades food webs. Our laboratory studies suggested that biomarkers must be used with caution in field settings due to differential growth rates on different diets. With this knowledge, we will be able to assess changes in detrital contributions to marsh food webs across variable environmental conditions. Studies of large predators in the marsh (Paros et al. in review), across the ecotone, and in the estuary (e.g. Matich and Heithaus 2015), have elucidated how environmental conditions – including extreme disturbance events - can have a large impact on population sizes and movements. For example, snook and bull sharks were heavily impacted by a large cold snap and populations – as were abundances of snook prey – and have taken years to return to pre-disturbance conditions (e.g. Matich and Heithaus 2014, Boucek and Rehage 2014; Fig. 1,2).

**Hydropolitics and Sea Level Rise:** Our studies on SLR rates this year included developing a better understanding of how climate change and SLR interact with water management practices to control hydrologic conditions in the oligohaline ecotone. We also have been working on evaluating how stakeholder uncertainties over SLR will increase conflicts over Everglades restoration implementation and will affect freshwater delivery to the oligohaline ecotone.

**Experiment Integration:** The goals of our experimental research were to continue mesocosm (salinity  $\times$  inundation and salinity  $\times$  P) and field (salinity) experiments with freshwater and brackish soils and plant-soil peats. We wanted to complete analyses of data from 2013 (soil microbial community data forthcoming) and 2015 REU projects, and begin writing manuscripts for publication. We also planned to integrate results from our field mesocosm experiments on the response of *Cladium* NEE to increased salinity in freshwater and brackish water marshes. We planned to continue team to coordinate logistics of laboratory and field research, as well as begin analyzing data from the salinity  $\times$  inundation and salinity  $\times$  P experiments. Simultaneously, we planned laboratory and field studies to assess the dynamics of how fatty acids and stable isotopes are assimilated in representative Everglades consumers to determine detrital contributions to diets of consumers and how these vary with freshwater inputs.

**Legacies and Scenarios:** Overall goals are to determine the relationship between land-use change and ecosystem variability, which in turn requires a prior understanding of the drivers of land-use change. We seek to better forecast the future impact of climate change, SLR and Everglades restoration on the ecosystem by better understanding the impact of past rainfall and water deliveries on the biogeochemistry of Everglades National Park. To create a baseline from which to better link landscape structure, connectedness, and boundaries with land-water management dynamics, we plan to continue studies that examine paleoclimatological data, CO<sub>2</sub> exchange rates, vegetation dynamics, and fluctuations in sea surface temperatures. We also continue to explore the human dimensions of ecosystem transformation by examining: a) institutions of landscape change; b) institutions of water management; and c) geographic patterns of restoration support amongst the South Florida population. We have linked these retrospective and long-term studies to our synthesis efforts by proceeding on three modeling fronts: defining scenarios to constrain modeling efforts; conducting analyses to support modeling efforts; and conducting modeling efforts. Specifically, we have continued to collaborate with FCE and non-FCE scientists to develop consensus climate-change and land-use scenarios for use in modeling efforts throughout South Florida; we are completing laboratory experiments to better understand and constrain P budgets by better understanding the adsorption-desorption of P from the underlying soils and bedrock, with findings to be used in geochemical modeling exercises focused on the effects of salt-water intrusion on key adsorption-desorption mechanisms; we are constructing, calibrating, and validating a hydrodynamic model to be used to better understand suspended and dissolved particle residence times in the FCE; and we have been using the Everglades Landscape Model (ELM v2.8.6) to model the effects of enhanced fresh-water inflow and SLR on ecosystem properties in the greater Everglades.



## Significant results

**Long-term data collection and analysis:** Long-term studies to determine links between saltwater encroachment and P availability showed that brackish groundwater discharge to the ecotone of Taylor Slough was positively correlated with higher freshwater heads in the upper reaches of Taylor Slough (Fig. 3) but had the greatest influence on surface water chemistry during the dry season (Linden 2015). Lab experiments confirm these sources, finding that more P is desorbed from bedrock exposed to saltwater in the freshwater-mangrove ecotone than in the freshwater marsh or marine bay environments (Fig. 4; Flower et al., 2015; Fig. 5). Total exchangeable P in bedrock is low so spikes in SRP are only evident following contact with higher-salinity waters, suggesting effects of saltwater intrusion are short-lived (Fig. 6). Patterns in DOC sources and fluxes also show strong seasonal control, with marine supplies from seagrass communities being lowest in the wet season and fluxed being controlled by rainfall and managed freshwater inflow. Ground and surface water sources of salinity and nutrients are reducing the biomass of ecotone periphyton mats by dissolving particulate inorganic C (Fig. 7) and changing composition to non-mat forming species.

The profound biogeochemical and mangrove production effects of Hurricane Wilma in 2005 are subsiding, faster at downstream than upstream sites (i.e., SRS-4 is still recovering; Fig. 8). Fast recovery of shade-intolerant *R. mangle* is explained by increased light availability, and ability to sustain higher growth and establishment rates in the surge-fertilized soils. In addition, the January 2010 cold snap defoliated the forest in February ( $37.36 \text{ g C m}^{-2} \text{ mo}^{-1}$ , SRS-6), double the pre-Wilma (2001-2004) monthly average litterfall C input (Fig. 9). Despite the sudden impact of this disturbance, all sites recovered quickly by the following month (March). There was considerable variation in taxon-specific and ecosystem-level N:P ratios among the sites. *R. mangle* foliar N:P ratios followed local environmental gradients (Castañeda-Moya et al. 2013) (Fig. 10), reflecting the limiting condition in Taylor Ridge, while root N:P ratios were highly variable (Castañeda-Moya et al. 2011). Carbon stocks in aboveground biomass of Shark River decreased from upstream to downstream locations (Jerath et al. in review). All Taylor River mangrove C stocks were considerably lower than Shark River mangroves (Rovai et al. in review). We compared accretion rates with the sea level tide gauge record at Key West, FL, finding that accretion rates match (within error) the relatively modest average SLR over the most recent 50 and 100-year periods for most of the system (Breithaupt et al., 2014; Smoak et al., 2013).

Long-term data have provided us with insights into how changes in freshwater delivery, SLR, and climate disturbance will affect Everglades food webs. Laboratory studies suggested that biomarkers must be used with caution in field settings due to differential growth rates on different diets. We are now able to assess changes in detrital contributions to marsh food webs across variable environmental conditions. Studies of large predators in the marsh (Paros et al. in review), across the ecotone, and in the estuary (e.g. Matich and Heithaus 2015), have elucidated how environmental conditions – including extreme disturbance events – can have a large impact on population sizes and movements. For example, snook and bull sharks were heavily impacted by a large cold snap and populations – as were abundances of snook prey – and have taken years

to return to pre-disturbance conditions (e.g. Matich and Heithaus 2014, Boucek and Rehage 2014; Figs. 1 and 2).

**Hydropolitics and Sea Level Rise:** The obstacle to the Comprehensive Everglades Restoration Plan (CERP) is sociopolitical: redesigning a massive mid-century flood-control system without altering political-economic relations. Restoration planners embraced risky/untested technologies that ultimately were undermined by environmental constraints (Schwartz 2014; Schwartz in preparation). CERP water quality targets have reduced P levels from hundreds of parts per billion (ppb) in the 1980s to less than 40 ppb in 2014, research on and monitoring of Best Management Practices, training partnerships between agricultural researchers and farmers, and SFWMD enforcement. Ecosystem restoration may ultimately require adjusting flood-protection and water-supply entitlements, acquiring more land, and accounting for farmers' and residents' decision-making rationales and environmental attitudes, especially toward SLR (Polsky et al 2014; Groffman et al 2014). We have redoubled our efforts to address the implications of SLR for Everglades restoration through numerous submitted proposals and new engagements through the FIU Sea Level Solutions Center.

**Integrated Experiments:** Through a combination of field and mesocosm experiments initiated in 2014, we evaluated the effects of: 1) salinity  $\times$  inundation on porewater nutrients and microbial extracellular enzyme activities (EEAs) in sawgrass peat soils (mesocosm), and 2) salinity on porewater nutrients and microbial EEAs associated with decomposing sawgrass roots in brackish and freshwater wetlands (field). Elevated salinity (mesocosm) had no effect on porewater nutrients (Fig. 11). Cellulase (not alkaline phosphatase) activities in ambient, exposed soils were similar to those in elevated, submerged soils, suggesting an interaction between salinity and inundation that may be enzyme-specific (Fig. 12). Increases in P with seawater salinity subsidize soil microbial C processing. Salinity (field) consistently had minimal effects on porewater nutrient concentrations in freshwater wetlands (Fig. 13) and decreased soil EEAs associated with decomposing sawgrass roots in surface (0-10 cm depth) and subsurface soils (10-20 cm, 20-30 cm depth) in both wetland types (Figs. 14, 15). Without increased P, salinity is a stress to soil microbial communities in both freshwater and brackish wetland soils. Field and chamber studies suggest that salinity exposure did not affect wet season net ecosystem exchange (NEE) in freshwater (FW) or brackish water (BW) marsh sites, and both were a net C sink despite significant soil porewater changes. However, after the onset of the dry season when water levels receded below the soil surface, the BW marsh became a net C source and this effect was amplified with increased salinity (Fig. 16).

**Legacies and Scenarios:** Linkages of climate and disturbance legacies to long-term dynamics in the ecotone highlight the importance of resolving long-term trajectories of land-use change and climate signals as drivers of change in ground and surface water discharge and nutrient transport data. Burgman and Jang (2015) improved climate input data substantially, finding differences among the sensitivity, seasonality, and amplitude of three different state of the art atmospheric circulation models. This is important as we determine relationships between productivity and key climate drivers including cyclical teleconnections (Fig. 17) and pulse events (Malone et al., 2014; Malone et al., 2015). We also participated in a workshop convened to improve the downscaling of precipitation forecasts. Statistical models linking runoff to land uses predicted NO<sub>x</sub>-N concentrations much more successfully than P concentrations, and to a certain

extent, NH<sub>3</sub>-N concentrations (Londono, 2015). We modeled FCE outcomes for draft scenarios with rainfall  $\pm 10\%$  and ET +7%. Surface-water depths would be expected to decrease or increase in response to the decreased or increased rainfall scenarios, respectively. Regardless, SLR of 50 cm could cause the oligohaline ecotone to move as much as 15 km inland, with a nearly 25% increase in landscape area that is marine-influenced (Fig. 18).

## Key outcomes or Other achievements

Here we provide a bulleted list of outcomes and achievements organized across these same themes:

### Long-term Dynamics:

- Phosphorus has the greatest capacity to desorb from ecotone sediments when exposed to brackish groundwater as compared to fresh groundwater or seawater.
- Higher freshwater head levels upstream of the ecotone in Taylor Slough drives greater groundwater discharge along the ecotone, but the groundwater discharge has the largest impact on surface water chemistry during the dry season when surface water levels are low.
- Salinity and P increases associated with saltwater encroachment reduce periphyton production of inorganic C.
- Increased freshwater delivery from water management projects is increasing similarity in sawgrass production across upstream freshwater sites.
- Sawgrass marsh NEE responds differently to salinity in the wet and dry season, with increased CO<sub>2</sub> emission in the dry season.
- Upstream marshes are recovering more slowly from the effects of Hurricane Wilma than downstream marshes that are frequently inundated by tide.
- Seagrass contributions to the DOC pool in Florida Bay are strongly seasonal and spatially driven, but are clearly dominating throughout most of the bay.
- Long-term DOC fluxes are primarily explained by variations in water inflow (management), rainfall and salinity (tides)
- Accretion rates have not kept pace with the substantially higher SLR in the last decade. Locations that are not keeping pace with SLR over any of the three time scales are located in the ecotone region most susceptible to enhanced organic C mineralization.
- Ranges in N:P ratios of *R. mangle* foliage and local differences in plant composition in our FCE sites indicate that both regional geomorphic settings and basin-scale (km<sup>2</sup>) variability may mask latitudinal trends in changing nutrient availability and plant composition. Similarly, our results show that taxon-dependent nutrient allocation needs to be partitioned when evaluating global trends in mangrove nutrient composition due to local scale (ha) environmental controls on species diversity within any latitude.
- Extreme climate events, like droughts and cold snaps, play an important role in both community dynamics and population densities and structures of top predators. Recovery from disturbances may take multiple years.
- Large predators from the estuary to the marsh appear to show considerable variation in movement patterns in response to environmental change. This variation within taxa may be important in ecosystem dynamics.

### **Hydropolitics and Sea Level Rise:**

- One of the primary obstacles to implementing hydrologic restoration projects and delivering additional fresh water to the oligohaline ecotone is the state's failure to acquire sufficient land or to confront entrenched flood-protection and water-supply guarantees, combined with the technical challenges of large-scale water storage and conveyance in SE Florida.
- Compliance with regulations throughout the Everglades Agricultural Area would provide a clear incentive for farmers to reduce P, thereby reduce uncertainty and increase confidence in how management actions will secure P reductions, while allowing farms to remain financially viable.
- FIU established a Sea Level Solutions Center and is working with local municipalities and citizens to understand and solve problems related to sustainability of South Florida under SLR, including through Everglades Restoration.

### **Integrated Experiments:**

- Completed laboratory experiments on P adsorption-desorption behavior in soils and bedrock. In general, P adsorption-desorption are strongly dependent upon water chemistry, especially salinity, and both increased fresh-water inflow and salt-water intrusion would be expected to change P adsorption-desorption and therefore P availability in the oligohaline ecotone (Figs. 5 and 6). One paper is in review, and two other papers are nearly drafted.
- Results from mesocosm and field experiments were presented at FIU's Biology Research Symposium, FCE's All-Scientists, FCE's Mid-Term Review, Ecological Society of America (ESA), LTER All-Scientists, and the American Geophysical Union Meetings.
- Completed soil-only salinity  $\times$  inundation experiment. Initiated salinity  $\times$  inundation and salinity  $\times$  P mesocosm experiments with live plant-soil experimental units from extracted brackish and freshwater cores.
- Kominoski and Troxler trained two REU students (Kristina Morales, Mary Grace Thibault) in summer 2015 and supported staff for field and mesocosm experiments.
- Submitted four graduate student proposals to the Everglades Foundation Fellowship Program to fund complementary research to be carried out in conjunction with FCE III mesocosm and field experiments.
- Laboratory analyses and field studies show that fatty acid analysis can be used to track the relative contribution of detritus through Everglades food webs.

### **Legacies and Scenarios:**

- Land use characterization is a better predictor of TN concentrations in nearby canals than TP concentrations (Londono, 2015)
- Atmospheric circulation models suggest that SST forcing in the middle latitudes may contribute more than previously thought. (Burgman and Jang, 2015)
- Everglades water levels are important for ecosystem exposure to extreme events and changes in hydrology and climate may result in significant shifts in species distributions with climate change. (Malone et al., 2015)
- Continued to collaborate with other scientists, managers, and decision-makers to develop scenarios to integrate modeling efforts throughout South Florida.
- [http://www.ecolandmod.com/projects/ELM\\_FCE](http://www.ecolandmod.com/projects/ELM_FCE)

- Continued to collaborate with other scientists on conducting bathymetric surveys of the lower Shark and Harney River systems (Fig. 19), and began using these data in conjunction with long-term water-level and salinity data and more recently acquired tracer (Ho et al. 2009), LiDAR (Feliciano et al. 2014), and InSAR (Hong et al. 2015) data to construct, calibrate, and validate a hydrodynamic model of flow and transport in the oligohaline ecotone of lower Shark River Slough (Fig. 20).

## Opportunities for training and professional development

FCE provides training and professional development through a variety of courses, targeted, but not exclusive to LTER personnel. In Fall 2015, Drs. Evelyn Gaiser and Tiffany Troxler helped to coordinate and deliver content for a distributed LTER readings course entitled “*Sea level rise and saline intrusion into coastal habitats*”. Focusing on the challenges associated rising sea levels to both natural and human communities, this interdisciplinary course provided a unique opportunity to learn from several experts with varying perspectives. Distributed across several universities, the course content was delivered live, over the internet, complete with a chat function, and the ability “raise your hand” to ask questions.

Dr. Evelyn Gaiser previously offered “Readings in Long-Term Ecological Research” class during the Spring 2015 semester and was designed specifically as professional development for FCE graduate students to keep up with LTER science and prepare for the 2015 FCE LTER mid-term review. The purpose of the course was students to:

- Become more engaged in FCE LTER science which will enable them to put their own projects in a larger context
- Contribute to the future of the FCE LTER program and creatively influence science directions
- Improve their skills in communicating through the poster medium
- Improve their skills pitching their science to the public
- Improve their understanding of the Everglades
- Gain a greater appreciation for long-term science and will more likely make LTER part of their futures
- Gain a greater appreciation for multi-disciplinary, collaborative science and include collaborative elements in their theses and dissertations
- Improve their ability to critically evaluate science
- Enhance their academic careers through a sense of belonging to a supportive network of colleagues and friends

Dr. John Kominoski has offered two courses for FCE students during the 2014-2015 academic year. During the Fall of 2014, 13 graduate students enrolled in *Communicating Science* where students learned how to improve the accuracy, brevity, and clarity of their writing. Students were provided mentoring in:

- The preparation, revision, and drafting of a thesis or dissertation, for submitting drafts to their committee
- Become a better reviewer to your peers
- Accept and thrive from professional criticism

- Enhance writing ability and creativity
- Strategize for a successful career in science

In another course, Dr. Kominoski instructed 4 graduate students enrolled in his Spring 2015 *Ecosystem Ecology in the Greater Everglades Landscape* class. Over the course of the semester, students were introduced to the distinct, yet hydrologically connected ecosystems of the Greater Everglades. The course included

- Three, 1-2 day, weekend field trips focusing on each of three locations along the North-South landscape gradient with field sample collection, laboratory processing, and data analyses in the:
  - Northern Everglades Ecosystems (Archbold Biological Station) assessing how community assembly changes with disturbance and affect aspects of ecosystem functioning.
  - Central Everglades Ecosystems (Water Conservation Area – 3A) assessing how plant density, light, and organic matter availability influence various aspects of ecosystem metabolism.
  - Southern Everglades (Everglades National Park) & Florida Bay Ecosystems (Florida Bay Interagency Science Center) assessing how basic ecosystem subsidy-stress models can be used to inform autotrophic and heterotrophic response pathways to P and salinity exposure at multiple spatial scales.
- Two, half-day data analysis and interpretation components held at the mid-term and end of the semester.

In addition to the courses offered by FCE scientists, FIU and FCE partners at the *Patricia and Phillip Frost Museum of Science* have offered the [Science Communication Fellows Program \(SCFP\)](#) to our scientists. A member of the NSF-supported Portal to the Public Network ([PopNet](#)), the *SCFP* is modeled after the program that originated Pacific Science Center in Seattle, Washington.

With the stated goal of “connecting public audiences to current science in their own communities, through direct interactions with local science, technology, engineering and mathematics researchers and experts”, the three day *SCFP* professional development workshop bridges the gap between researchers and the public by providing a forum to strengthen and practice their science communication skills.

FCE graduate student, Nick Schulte, was the first participant in the Fall 2014 cohort of *SCFP* where he was directly mentored by museum experts who the experience and necessary tools for translating their research into a hands-on, table top demo to showcases their work in a format that is easily consumed by a broad and diverse audience.

This fall, another *SCFP* is being offered exclusively for FIU, including FCE, personnel. FCE’s Education and Outreach Coordinator plans to apply and if accepted, he plans to share the information with other FCE colleagues.

Nicholas Oehm, FCE Education and Outreach Coordinator and Co-Chair of the

LTER Education and Outreach Committee (EOC), also coordinated monthly EOC conference calls on the first Wednesday of each month. These monthly calls devoted the majority of time towards professional development highlighting existing program or timely discussion topics for developing new initiatives. In 2014, ten LTER EOC representatives delivered eight professional development presentations highlighting: four LTER citizen science programs; two EOC Subcommittees; and two Site Education EO initiatives. The talks included:

- *Flowering phenology of native Vaccinium species and non-native Melilotus albus: Building resilience to invasion through citizen science*. January 2014. Elena Sparrow (BNZ) and PhD candidate Katie Villano Spellman (BNZ)
- *LTER EOC Higher Ed Working Group Projects and Status Report*, March 2014. Clarisse Hart (HVF) & Art Schwartzchild (VCR)
- *Professional Development Subcommittee Highlights*, April 2014. Scott Simon (SBC)
- *Data Jam*, June 2014. Stephanie Bestelmeyer (JRN)
- *Geraniumania*, August 2014. Mary Spivey (CDR)
- *The First Virtual Symposium LUQ LTER Schoolyard Program and La Escuela del Bosque, New Mexico*, September 2014. Kim Eichhorst (SEV), Steve McGee (LUQ), and Noelia Rodriguez (LUQ)
- *CAST: Coastal Angler Science Team*, October 2014. Ross Boucek (FCE-GRAD)
- *Learning progressions for environmental science teaching*, December 2014. Alan Berkowitz (BES)

FCE graduate student, Ross Boucek, was a regular participant and this information is being used in working with FCE personnel to enhance and improve the Education and Outreach program.

FCE researcher, Jeff Onstead, completed Plotly training while on sabbatical at Cal State Channel Islands. An online data visualization tool, Plotly provides online graphing, analytics and statistics tools for individual or collaborative use that could be use with online or distributed LTER classes.

## Communicating results to communities of interest

FCE III results were disseminated to a broad range communities that are typically not aware of these results through a variety of education and outreach initiatives by addressing the goals and objectives outlined in the *2011 Strategic and Implementation Plan: LTER Research and Education*. Our programs deliver FCE EO to each of our key constituents and under-represented groups in our community including: K-12 students, teachers and administrators; undergraduate and graduate students; professors; policy makers; and citizens.

The hallmark of the FCE education programming is our Research Experience Program (REP). FCE III has continued to offer both formal and informal mentoring to students in grades K-20+, pre- and professional service teachers, community college and university faculty.

### **K-12**

The FCE K-12 program works with K-12 students in the classroom and our research laboratories. Over the last year, FCE related presentations have been delivered to 5,511

elementary, 2,991 middle school, 37,125 high school, 818 undergraduates, 85 graduate students, and 80 educators through internet broadcasts, Skype, and researcher presentations.

During the 2014-2015 school year, 33,870 high school students learned about FCE's Coastal Angler Science Team (CAST) citizen science project through our partner Richard S. Kern with *Encounters in Excellence* program. The action-packed film *Surviving the Everglades* was seen by students in 134 digitally projected presentations, personally narrated by Mr. Kern at 53 Miami Dade County Public Schools (MDCPS) where students are given the opportunity to interact with the filmmaker in a post-program question and answer session.

Some of the *Surviving the Everglades* footage will be developed into 3-5 minute videos and posted to the companion website *OdysseyEarth*, a multi-media website designed to complement and expand the Encounters in Excellence program. The first video [Electrofishing and Citizen Science](#) has already been posted on OdysseyEarth.com and highlights FCE's *Coastal Angler Science Team* citizen science program and researcher Dr. Jennifer Rehage.

### **Professional and Pre-Service Teachers**

FCE III has continued to work closely in mentoring K-12 teachers. In September 2013, RET Teresa Casal, Jennifer Tisthammer (Director of Deering Estate) and the EO Coordinator traveled to the Jornada (JRN) LTER where they received support in developing and implementing the FCE-Deering Everglades DataJam. As a follow up in 2014, Teresa, Catherine Laroche, Jennifer Gambale, and Terri Reyes used residual RET funds to coordinate 60 of their students from Felix Varela Senior High School to produce 18 DataJam posters that were exhibited at the 2015 ASM. Jennifer Tisthammer and her staff have submitted additional proposals to secure additional funding to support the expansion of the DataJam.

### **Outreach**

FCE III continues to provide service and outreach to our broader community.

Dr. Evelyn Gaiser has been invited to discuss FCE research with President Obama and his Science Advisor John Holdren, while Dr. Steve Davis has provided at least 12 briefings to local, state, national and international policy makers regarding Everglades restoration issues. Some of Dr. Davis' briefs include: US Congressional staffers, former Senator Mel Martinez; Miami Dade County Commissioner Daniella Levine-Cava, US Congresswoman Kay Tranger (TX); US Congressman Curt Clawson (FL), and a group of European Policymakers. He and others have also provided briefings to 16 community groups such as: Coral Gables Rotary Club; Northern Trust of Broward County; EU International Visitor Leadership Program; FL Bankers Association; and Palm Beach Women's Club.

FCE research and results are continuously 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. Our scientists are regularly invited panelists—over 20 researchers have participated in more than 85 events including: National Council for Science and Environment Climate Summit in Washington, DC (2015); Biscayne Bay Regional Restoration Coordination Team; 15<sup>th</sup> National Conference and Global Forum on Science, Policy, and the Environment; and Socio-ecological Vulnerability and Resilience in Miami-Dade.



Scientists have disseminated their research results to other segments of the community through 10 different training programs. In a week-long professional development workshop, 15 AP Environmental Science teachers learned about tropical botany at the National Tropical Botanic Garden, at the Kampong in Miami. In another workshop, teachers in Orlando were trained on the use of *Predators of Shark River* curriculum, while the Trophic Dynamics Working Group has offered a PIT tagging techniques and Oregon RFID autonomous antenna system operations workshop at Florida Atlantic University.

Working through our partners, our scientists engage in the community as judges in competitions and through tabling at large events. Our scientists regularly judge the South Florida Regional Science and Engineering Fair, Sarasota Senior High School Science Fair, the Fairchild Environmental Challenge, and also serve on the Miami Dade County Public School's Intel International Science and Engineering Fair selection committee.

As regular participants in events such as the *Annual Deering Seafood Festival* and ZooMiami's *Party for the Planet*, over 19,000 guests (>10,000 and 9,445, respectively) pass by our tables where children can learn about FCE research through educational activities such as the Marine Macroalgae Mobile Lab and the Coastal Angler Science Team mark and recapture, simulated "Fishing Tournament". Other smaller events include, *Miami Underwater Festival* at the Miami Museum of Science, and *Family Science Nights* in the Florida Keys.

### **FCE and the Humanities**

The ongoing relationship between FCE researchers and the Tropical Botanic Artists have resulted in an additional four exhibitions of [In Deep with Diatoms \(2014\)](#). In February 2015, the *Diatoms* were exhibited alongside several ceramic diatom sculptures by FCE Partner, Eco Artist Xavier Cortada at *The Patricia and Phillip Frost [Art] Museum*. The Frost hosted an opening reception and panel discussion, "Using Science to Create Art" facilitated by Cortada and included TBA's Pauline Goldsmith, both FCE's Dr. Evelyn Gaiser and Nicholas Oehm.

*Diatoms* were also displayed at the 2014 LTER Science Council meeting at Konza Prairie LTER and additional shows are currently being planned. TBA's new exhibit *Tamiami Trail: In the beginning portraits of plants found along the historic Tamiami Trail* was launched at the National Tropical Botanic Garden's Kampong—additional exhibitions are currently being planned.

### **Citizen Science**

The FCE Citizen Science program consists of two major initiatives: [Predator Tracker](#) and [CAST](#). Introduced in as part of the [Living in the Everglades](#) exhibit at the [Ft. Lauderdale Museum of Discovery and Science](#). Predator Tracker allows museum patrons and website visitors to track Everglades predators such as alligators and bull sharks over the internet through Predator Tracker (<http://tracking.fiu.edu>) or by purchasing the *Alligators of Shark River* in the Apple App Store. The research is also discussed in the episode *Coastal Carnivores* (26 min) as part of the PBS series *Changing Seas*.

In 2013, FCE added the [CAST: Coastal Anglers Science Team](#) program which has been developed as a collaboration between anglers and researchers as a means for understanding how changes in the Everglades impact coastal fisheries.

### **Communication**

FCE research continues to make the headlines with a variety of international, national, and local media outlets. Drs. Mike Heithaus and Jennifer Rehage, along with FCE graduate student were recently highlighted for their work in May 2015 in *Ocean Mysteries with Jeff Corwin—The Predators of Shark River*. In another effort, Dr. Len Scinto was interviewed about adaptation strategies being used in Miami and Biscayne Bay by *1.5 STAY ALIVE*. Intended to increase international awareness on the effects of climate change, the program is currently posted on the 1.5 Stay Alive channel on YouTube and the final product is scheduled for release in Germany.

FCE research is regularly discussed in the media and has been covered by BBC, CNN, NBC Miami, Univision, ABC, WEXL, WPBT2, and highlighted on NPR. Several periodicals have published 27 news articles on FCE researchers including the *Kuwait Times*, *Washington Post*, *PR Newswire*, *Miami Herald*, *Keys News*, *The Beacon*, *Cultural Anthropology*, *American Heritage*, *Outside Magazine*, *Slate Magazine*, *Soundings Magazine*, *FIU News*, and *FIU Alumni Association News*. Additional coverage has been distributed through the internet on 6 websites including: Florida Fish and Wildlife Conservation Commission (FWC); Woodrow Wilson Institute's New Security Beat; Odyssey Earth; Soil Science Society of America; and interviewed by Vrij Nederland (Netherlands)

Social media outlets, such as our YouTube channel, have grown to include a total of 43 videos with the addition of 24 in 2014. FCE's Wading Through the Research Blog (<http://floridacoastaleverglades.blogspot.com>) continues to be maintained by the graduate student group with 80 total posts, 11 during 2014 and an additional 10 to date in 2015. Dr. Michael Heithaus' Lab Group maintains the FCE-based Heithaus Lab (<http://heithauslab.blogspot.com>) with a total of 35 posts with 7 during 2014-2015. Facebook continues to serve primarily as an internal means of social networking to maintain interactions between FCE members based at FIU and our collaborating and partner institutions with near weekly posts.

### **Plans to accomplish goals during the next reporting period**

**Long-term Dynamics:** We will continue to address how the presses and pulses in the balance of fresh and marine water delivery influence hydrology, biogeochemistry, productivity and consumer dynamics along the coastal gradient. Hydrological and geochemical monitoring will continue using ground-based measurements. Density-dependent flow modeling will be initiated to determine restoration efforts on the water delivery to and the water quality in the mangrove ecotone. Specifically, we are completing studies on how salinity, hydrology and P are changing sawgrass, periphyton and mangrove NPP across space and time. We are using remotely sensed data to determine how well our FCE research sites enable larger-scaling of our NPP and NEE measurements, and will coordinate these results with those from our flux towers, including a new tower in the dwarf mangrove zone at TS/Ph7. Vegetation class percent cover will be used to estimate biomass, relying on pre-existing and/or literature data for estimates of vegetation class biomass per unit area. For mangrove sites, this information will be used to establish a regional

conceptual model of mangrove species succession and resilience that are triggered by different disturbances operating at different temporal and spatial scales in the Everglades mangrove ecotone region. We plan to continue to develop a model to predict effects of CERP and SLR scenarios on DOC exports through the Shark River estuary. FCE-wide assessment of environmental/biogeochemical drivers controlling DOM composition (optical properties) will be performed on a 12-year (monthly sample) dataset. We will determine organic C, N, and P accumulation rates in soils and foliage.

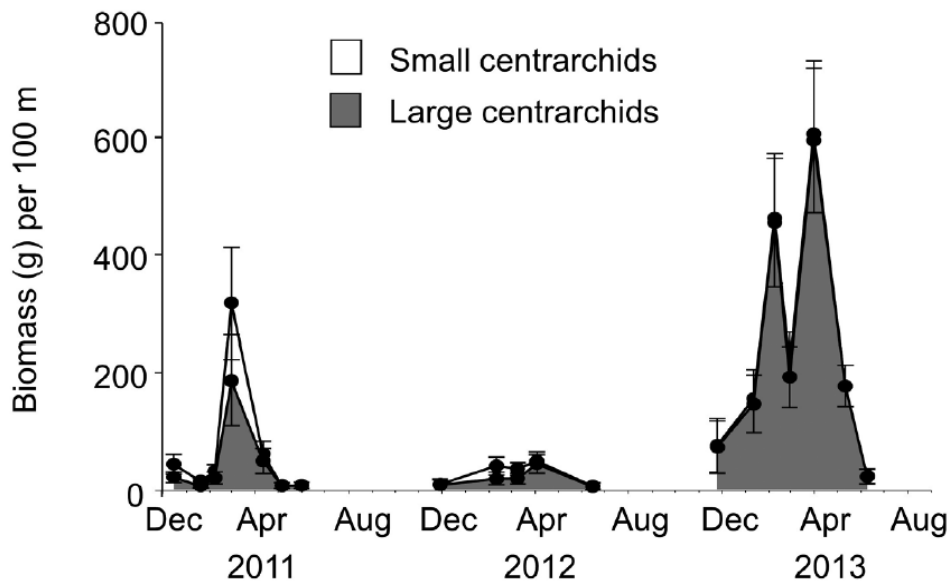
**Hydropolitics and Sea Level Rise:** The Soil and Water Assessment Tool (SWAT) will be used to simulate hydrological flow components over built (canal) and topographic drainage features across the complex South Florida Urbanization Gradient (SFUG) under land-use change and climate change scenarios. Qualitative as well as quantitative analyses will continue to investigate the social-political dimensions of Everglades restoration, and results will be compiled into journal articles as well as a monograph.

**Integrated Experiments:** We will complete analysis of summer 2013 experimental data and begin data analysis for the first year of salinity  $\times$  inundation and salinity  $\times$  P experiments. We will continue to mentor REU students and analyze data from the 2015 REU projects. We will present results at the 2016 FIU Biology Research Symposium, 2016 FCE All-Scientists Meeting, and 2016 ESA Meeting and will submit manuscripts for publication from the 2013 experiment. We will initiate and maintain salinity and salinity  $\times$  P mesocosm and field experiments. We will also use the information gleaned from laboratory studies to conduct field sampling and experimental studies to determine the contributions of detritus to marsh food webs and how these change with variation in community structure and environmental conditions. We also plan to establish enclosure experiments to determine how top predators – and their movements affect community dynamics. Long-term datasets in the marsh, ecotone, and estuary will be extended and we will conduct syntheses to more fully explore the food web structure in the estuarine zone.

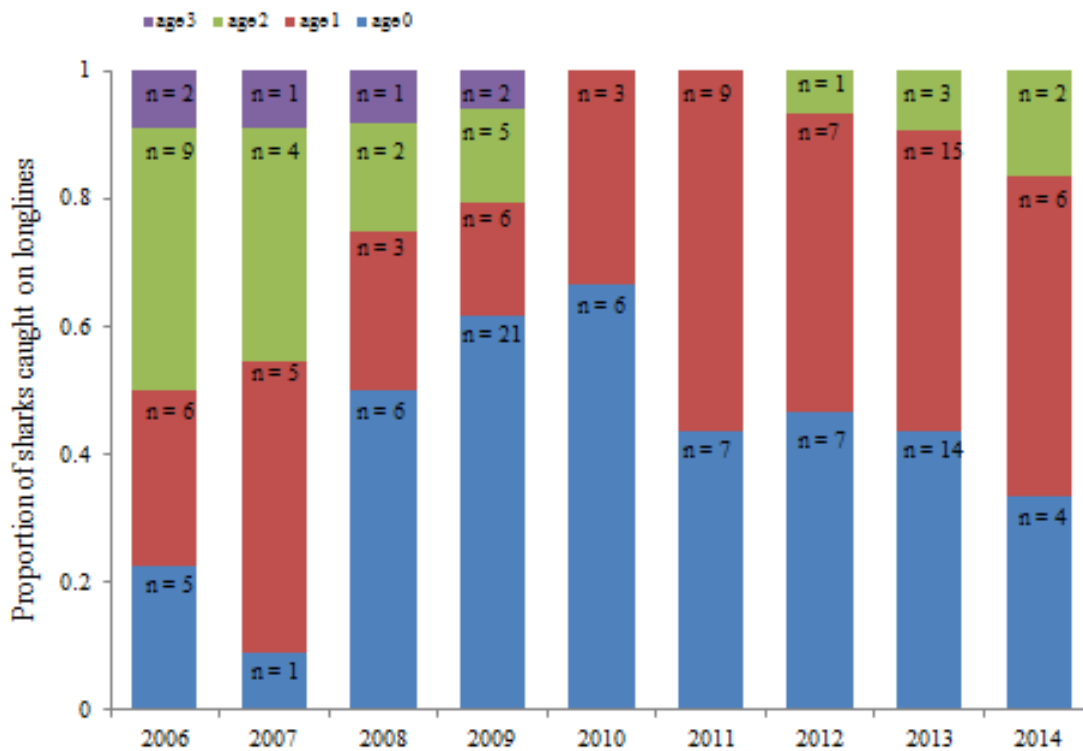
**Climate and Disturbance Legacies:** We are developing land-use change scenarios for our modeling efforts and have already begun to incorporate the Urban Development Boundary as well as different planning districts and jurisdictions to create more regulatory heterogeneity. We will also append water demand forecasts to the various land-use change forecasts, within the context of SLR and freshwater flows. Taking the analysis we have already completed, we intend to publish a series of papers connecting a) salinity with rainfall; b) salinity with nutrients; and c) groundwater with nutrients. We will continue to work on building a bridge across disciplines in order to better understand the complex connections and feedbacks among land use, water use, and ecosystem patterns and processes. We had planned on having the scenarios defined by early 2015, but were delayed by unanticipated difficulties in the dynamic downscaling of rainfall data, with the largest errors associated with the reproduction of the convective storms that dominate summer rainfall. We now expect the dynamically downscaled rainfall data to be available in late 2015 or early 2016. We have largely completed our laboratory experiments on P adsorption-desorption, and plan to soon move on to geochemical modeling exercises focused on the effects of salt-water intrusion on key P adsorption-desorption mechanisms. We will soon finish bathymetric data collection and will then move on to expanding the hydrodynamic model domain and modeling particle residence times under baseline and scenarios conditions. Last, we

continue to make improvements to the ELM code but otherwise remain ready to simulate key performance metrics and visualize outcomes once the scenarios framework is established.

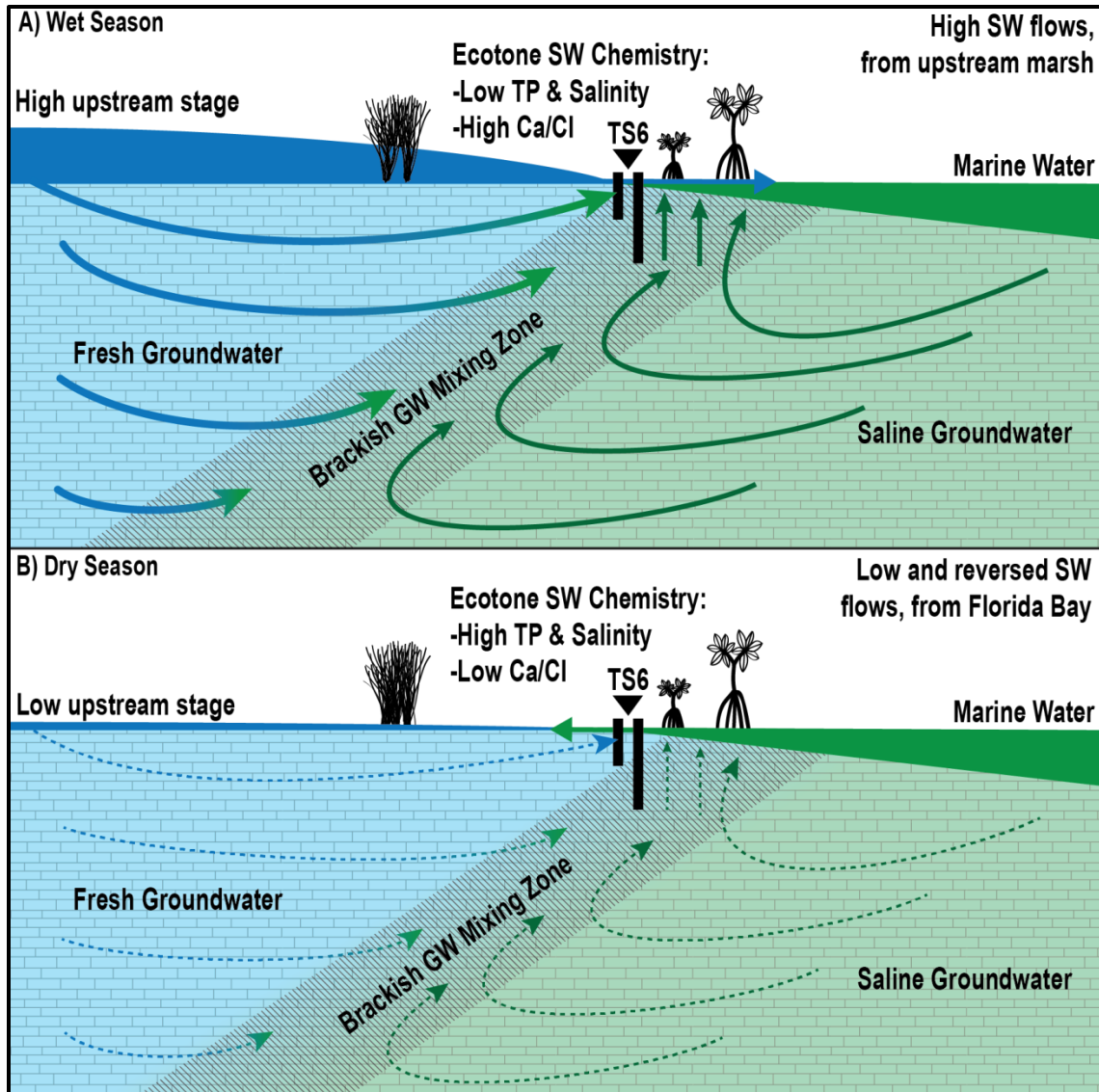
## Figures and Tables



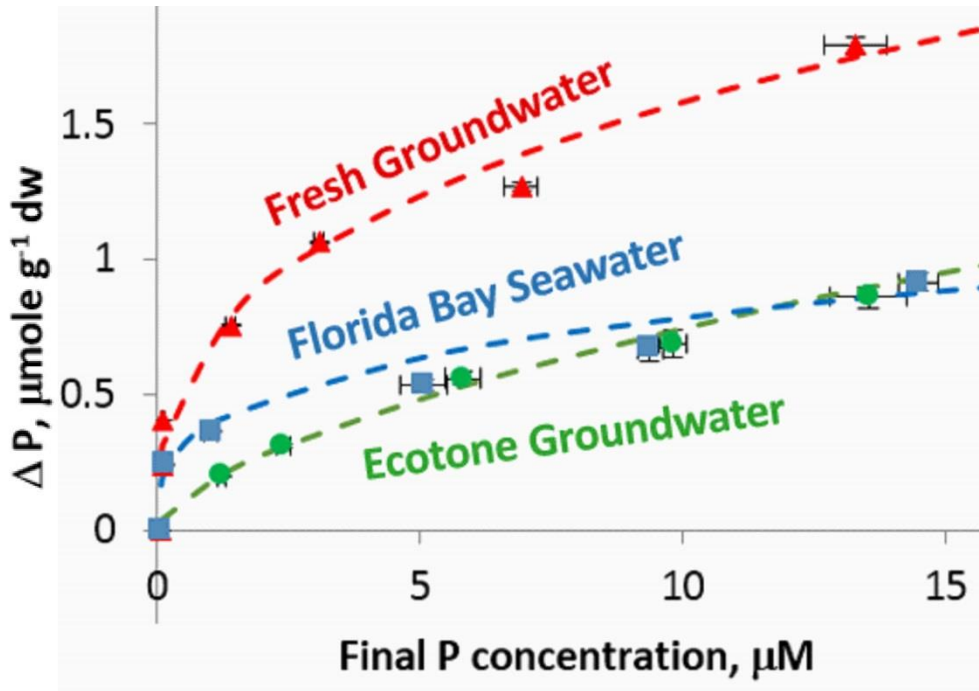
**Figure 1.** Variation in floodplain biomass entering the coastal river partitioned by early-spawned centrarchids (gray area under the curve)



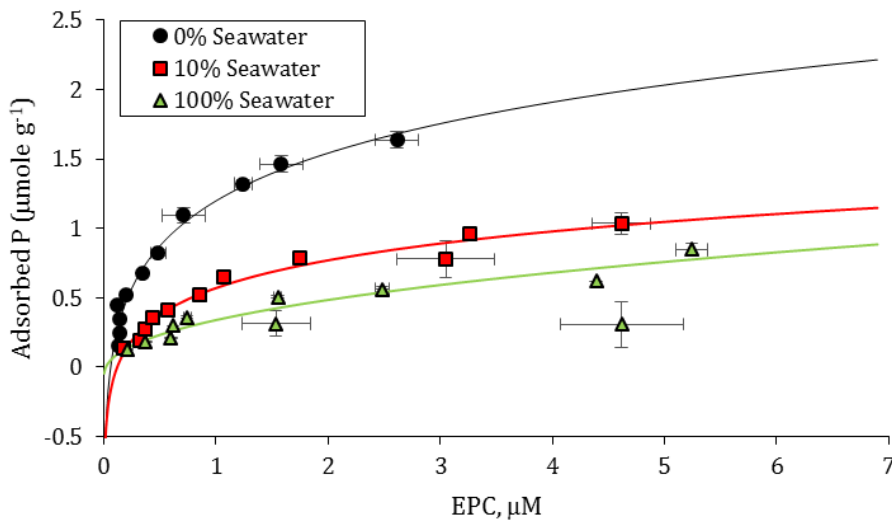
**Figure 2.** Changes in age structure of bull sharks in response to 2010 cold snap.



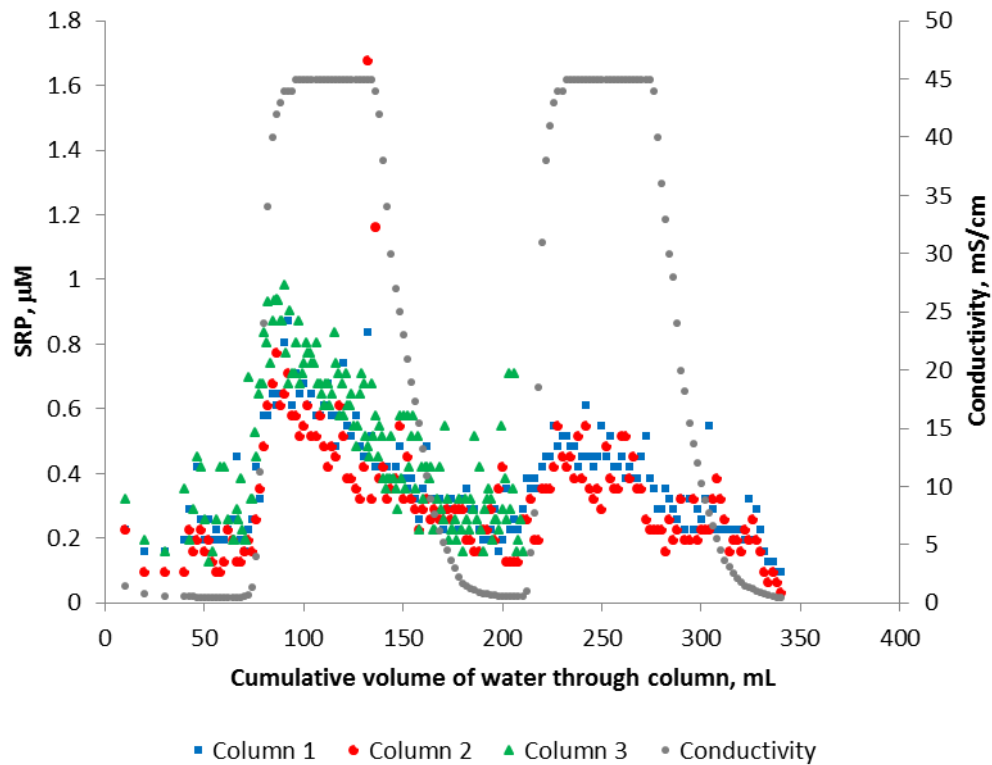
**Figure 3.** A) Higher upstream surface water (SW) stages during the wet season lead to a greater potential for groundwater (GW) discharge and greater flow from fresh sources (blue) through the ecotone, with lower TP, lower salinities, and higher Ca/Cl ratios in ecotone SW. B) Lower upstream SW stages during the dry season lead to a lesser potential for GW discharge and low to reversed SW saline flow from Florida Bay (green) into the ecotone, with higher TP, higher salinities, and lower Ca/Cl ratios in ecotone SW. GW wells at TS6 are denoted by black vertical lines. Fresh water observed in the shallow well at TS6 during the dry season may be related to the lower potential for upward movement of saltier water from deeper in the mixing zone, allowing fresh aquifer water to migrate to that well. Vertical dimensions are greatly exaggerated.



**Figure 4.** The amount of  $\text{HPO}_4^{2-}$  adsorbed onto ecotone sediment from Taylor Slough ( $\text{DP}_{\text{sed}}$ ) normalized to the mass of sediment dry weight sediment ( $\text{mmole g}^{-1} \text{ dw}$ ) versus the final concentration of  $\text{HPO}_4^{2-}$  in three solutions: fresh groundwater, Florida Bay surface water and ecotone groundwater. The Taylor Slough sediment has the lowest capacity for adsorption of  $\text{HPO}_4^{2-}$  when exposed to ecotone groundwater.

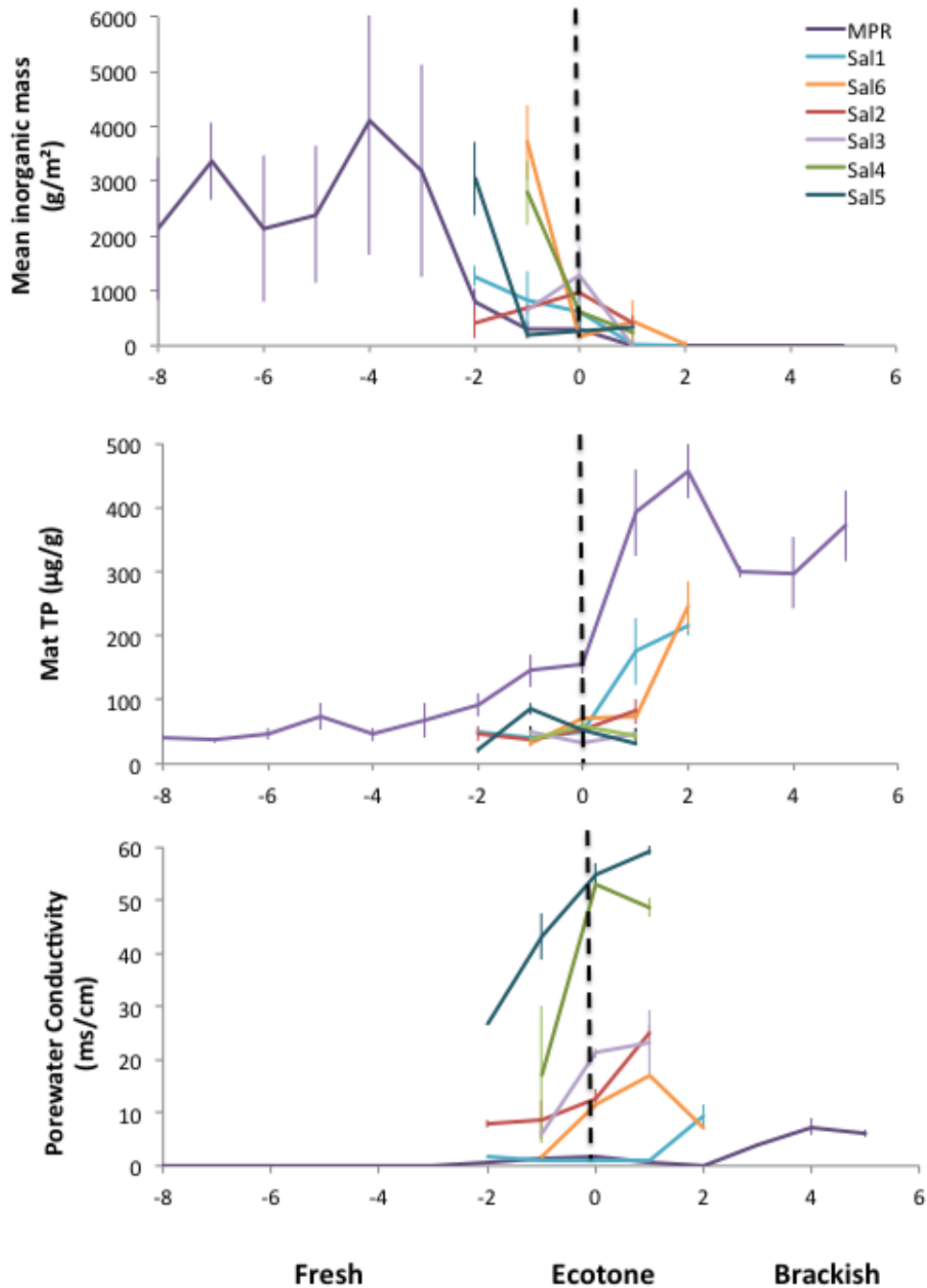


**Figure 5.** Adsorption of SRP to bedrock is greatest when in contact with fresh Everglades groundwater (i.e., 0% Seawater) and least when in contact with saline Florida Bay seawater i.e., 100% Seawater).

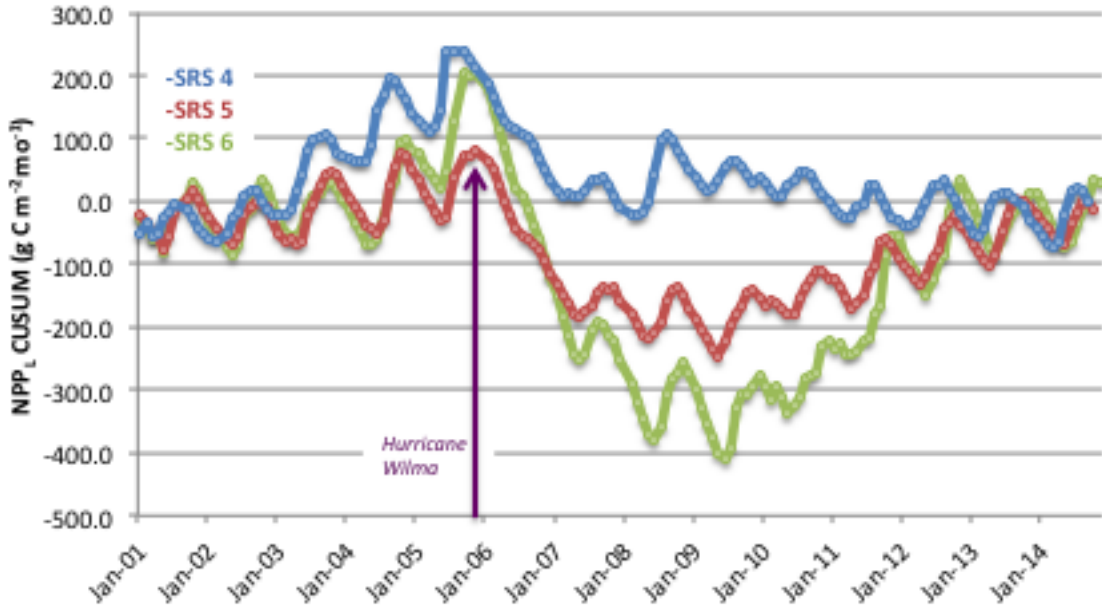


**Figure 6.** When bedrock is put in contact with saline, Florida Bay seawater, there is an ephemeral spike in SRP. However, SRP declines rapidly thereafter because there is little total SRP adsorbed to the bedrock. Results are from three separate column experiments.

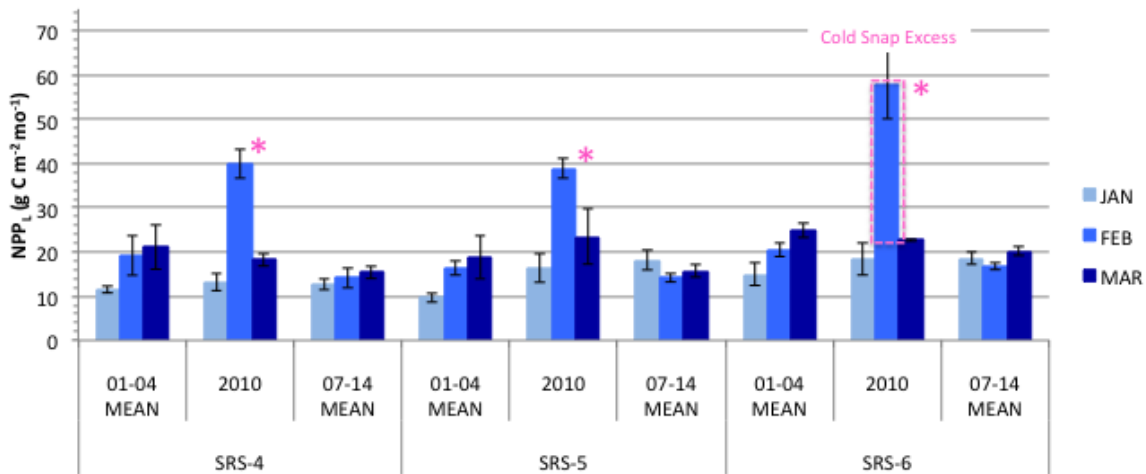




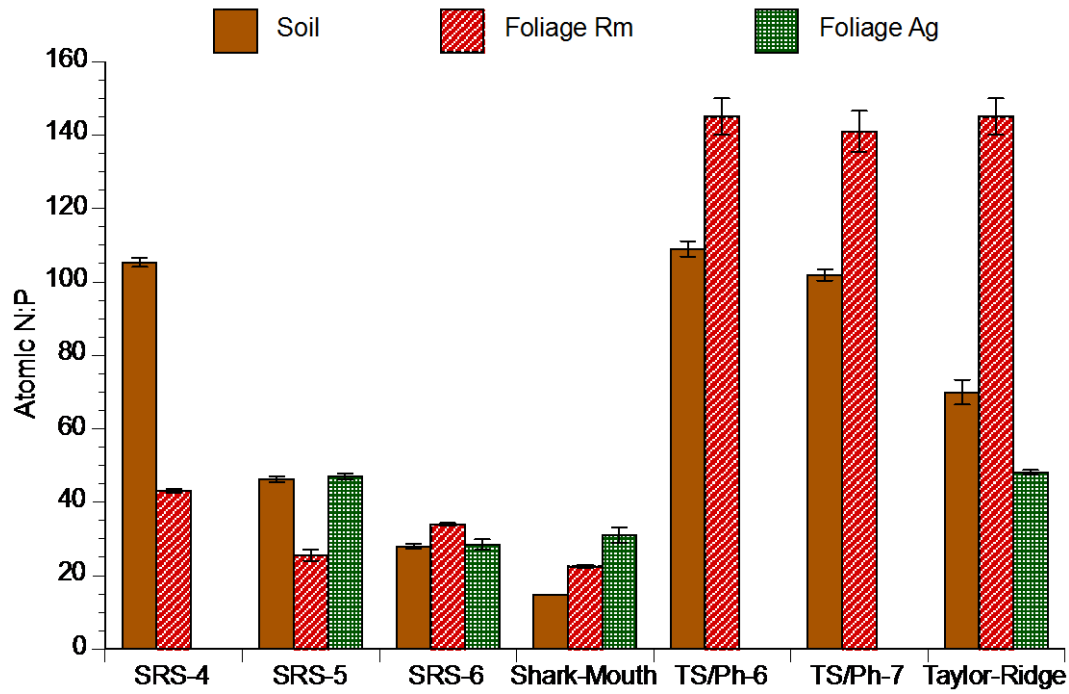
**Figure 7.** Changes in periphyton inorganic mass, total phosphorus (TP) content and porewater conductivity along FCE transects from freshwater to ecotone to brackish marshes.



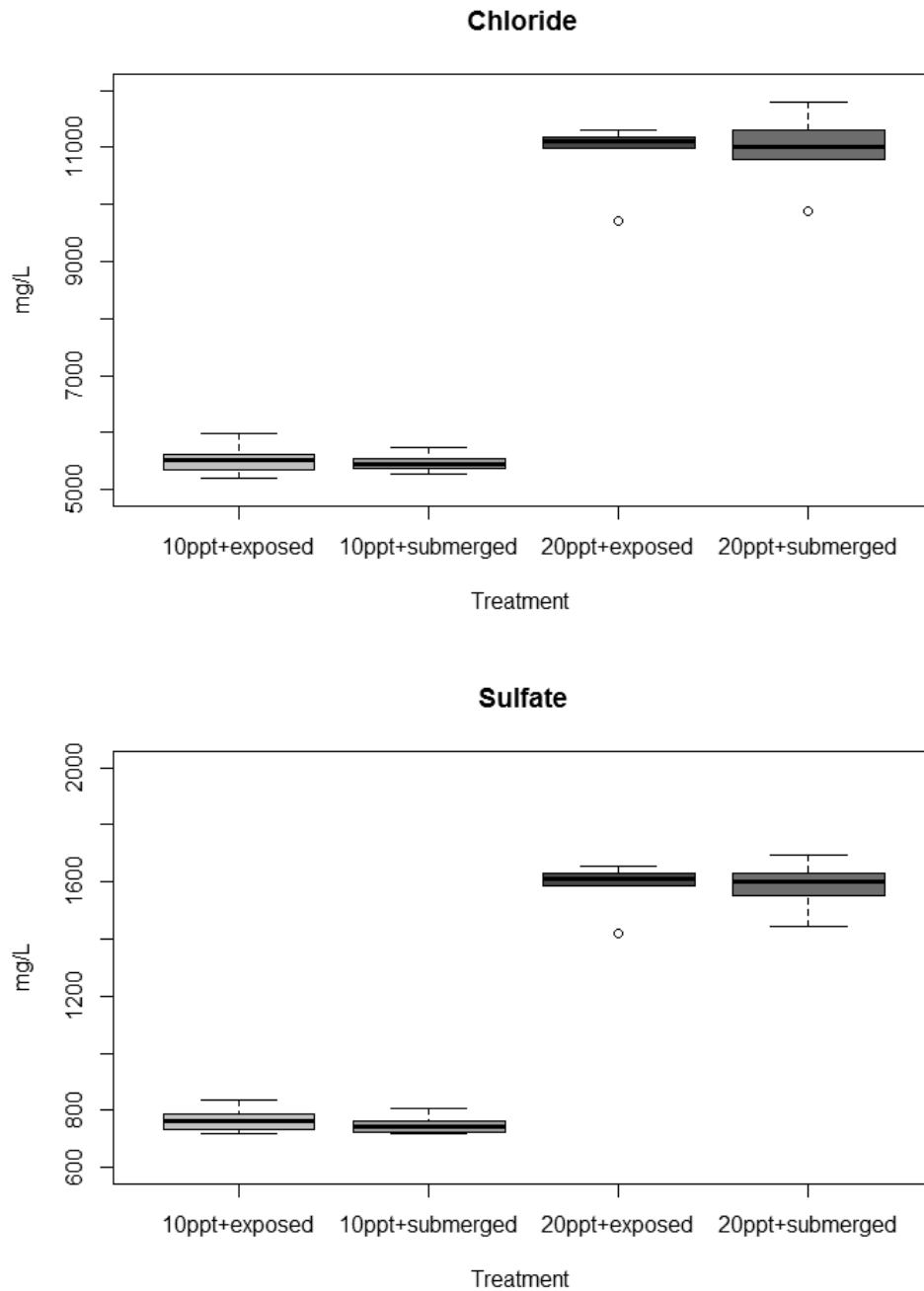
**Figure 8.** Long-term  $NPP_L$  ( $g\ C\ m^{-2}\ mo^{-1}$ ) for SRS sites presented in a cumulative sum graph (CUSUM,  $g\ C\ m^{-2}\ mo^{-1}$ ). The negative slope following **Hurricane Wilma** indicates below average  $NPP_L$  during that period. **SRS-5** and **SRS-6** begin recovery by January 2007, while **SRS-4** is still recovering.



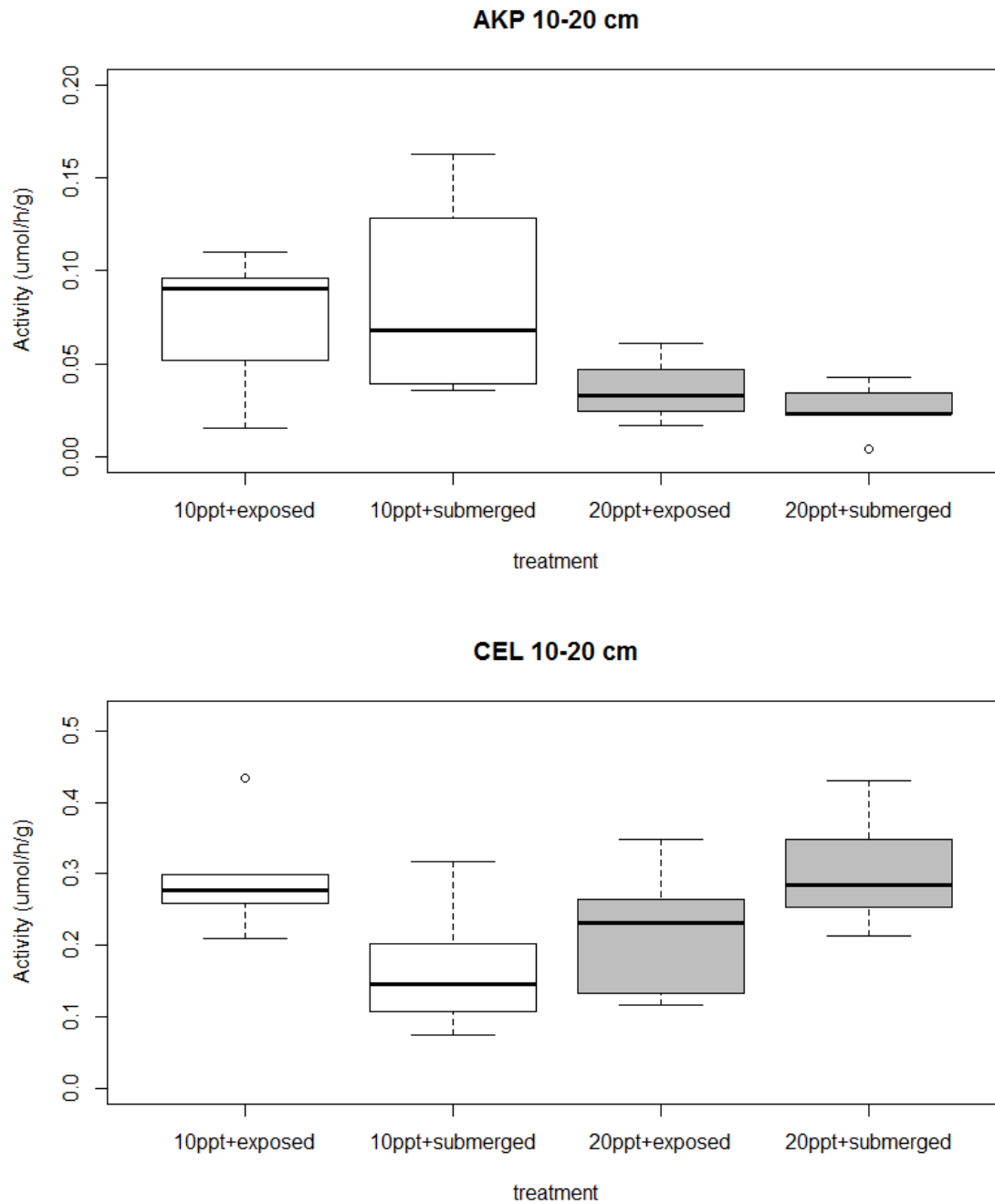
**Figure 9.** Comparison of  $NPP_L$  ( $g\ C\ m^{-2}\ mo^{-1}$ ) for January, February, and March 2001-2004 and 2007-2014 means following the January 2010 cold snap (\*). **Cold snap excess** defoliation was estimated as  $37.36\ g\ C\ m^{-2}\ mo^{-1}$  in February 2010 in SRS-6.



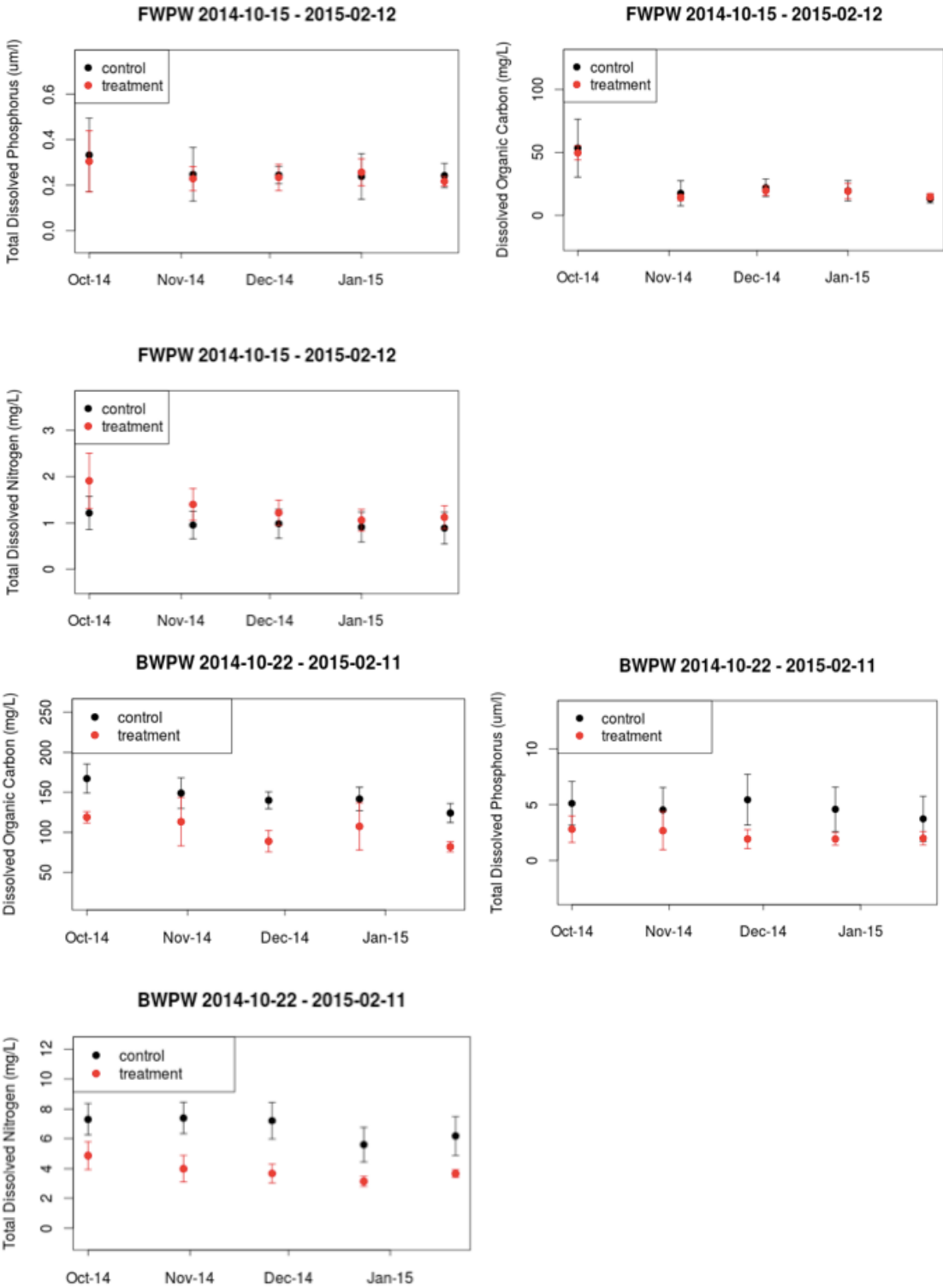
**Figure 10.** N:P stoichiometry of soil and foliage of *Avicennia germinans* (Ag) and *Rhizophora mangle* (Rm) in FCE Mangrove sites (means  $\pm$  se). Note that *Avicennia germinans* is not present in SRS-4 or in Taylor River wetlands located in sloughs (TS/Ph-7 and TS/Ph-6).



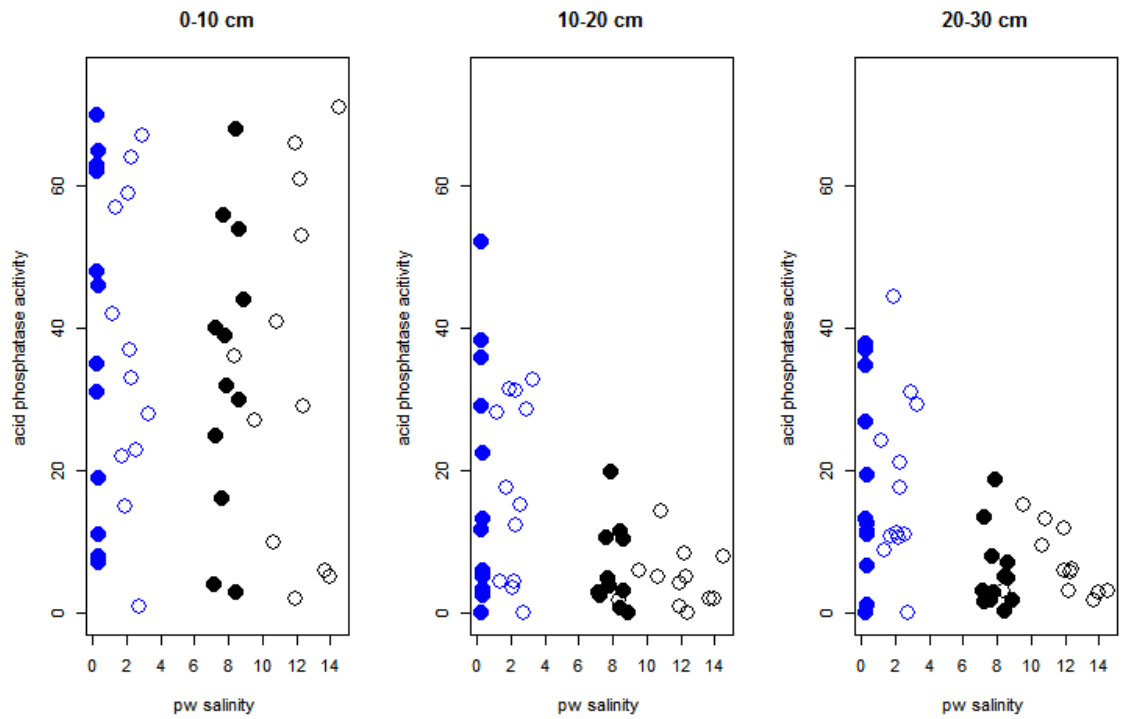
**Figure 11.** Porewater chloride and sulfate concentrations from submerged and exposed brackish water sawgrass peat soils exposed to ambient (10 ppt) and elevated (20 ppt) seawater salinity in wetland mesocosms. Seawater salinity increased chloride and sulfate concentrations ( $P < 0.05$ ), but inundation and exposure had no effect on porewater nutrient concentrations ( $P > 0.05$ ). Data for porewater carbon, nitrogen, and phosphorus are forthcoming. Current experiments are addressing soil biogeochemical responses to salinity and inundation using live plant-soil experimental units.



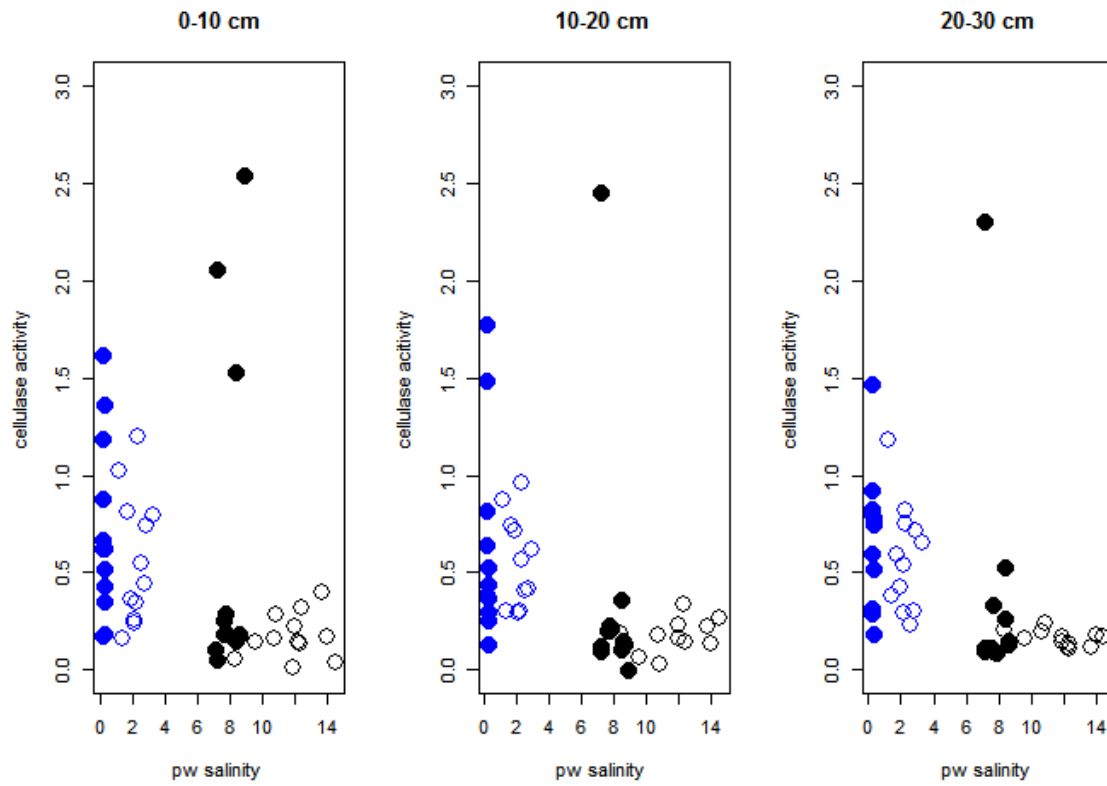
**Figure 12.** Subsurface (10-20 cm depth) microbial extracellular enzyme activities (EEAs) from submerged and exposed brackish water sawgrass peat soils exposed to ambient (10 ppt) and elevated (20 ppt) seawater salinity in wetland mesocosms. Elevated seawater salinity decreased alkaline phosphatase activities and increased cellulase activities ( $P < 0.05$ ). Exposed soils had higher cellulase activities than inundated soils under ambient salinity ( $P < 0.05$ ).



**Figure 13.** Effects of increased porewater salinity (+ 10 ppt above ambient) on porewater nutrient concentrations in field manipulations in freshwater and brackish water sawgrass peat wetlands. Increased salinity in freshwater wetlands consistently had moderate stimulatory (total dissolved nitrogen, TDN) or no effect on porewater nutrient concentrations (total dissolved phosphorus, TDP; dissolved organic carbon, DOC). In contrast, increased salinity in brackish wetlands consistently reduced porewater nutrient concentrations.

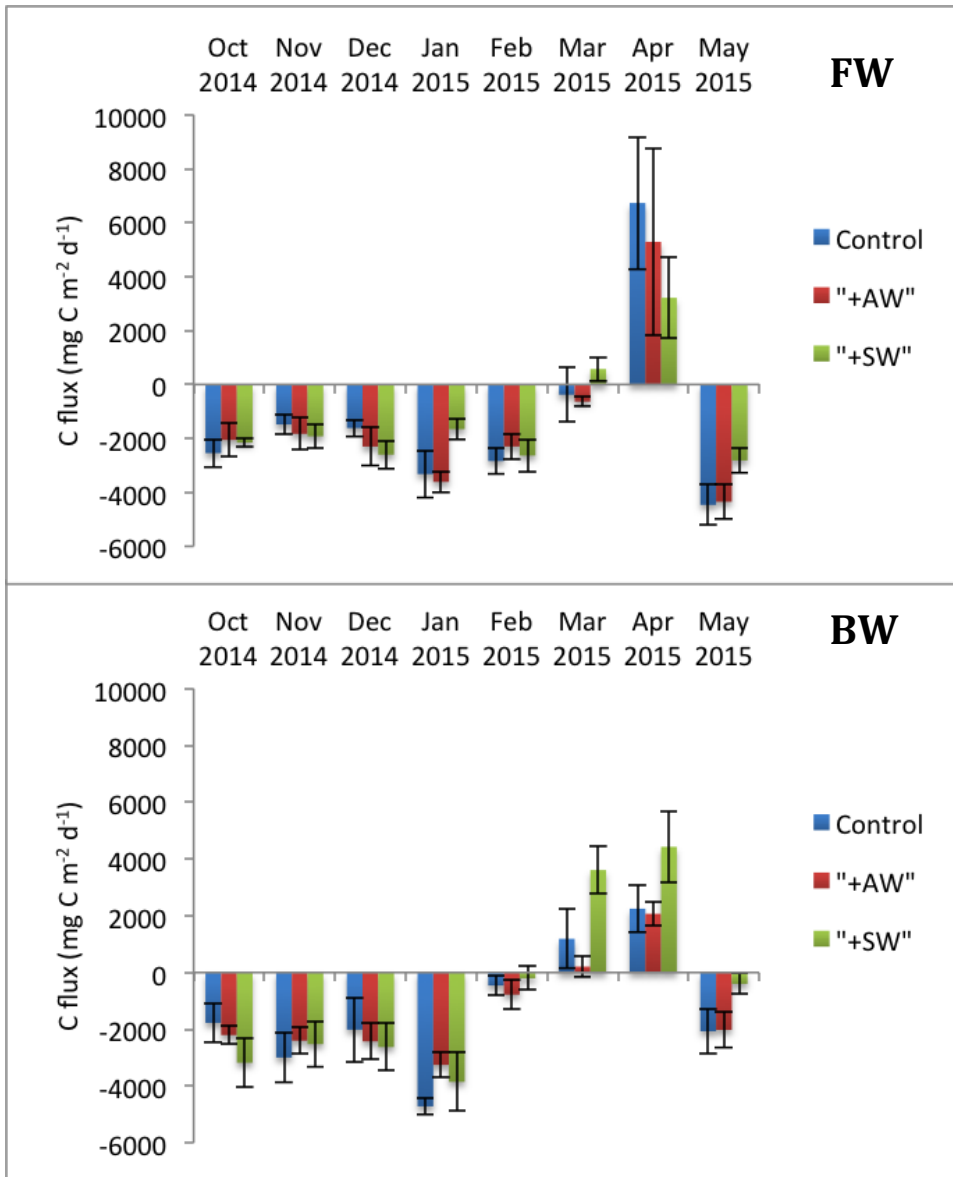


**Figure 14.** Increased porewater salinity in field manipulations in brackish water (black symbols) and freshwater (blue symbols) sawgrass peat wetland decreased acid phosphatase activities on decomposing sawgrass roots in subsurface (10-20 and 20-30 cm depth) soils. Open symbols represent fine and filled symbols coarse roots.

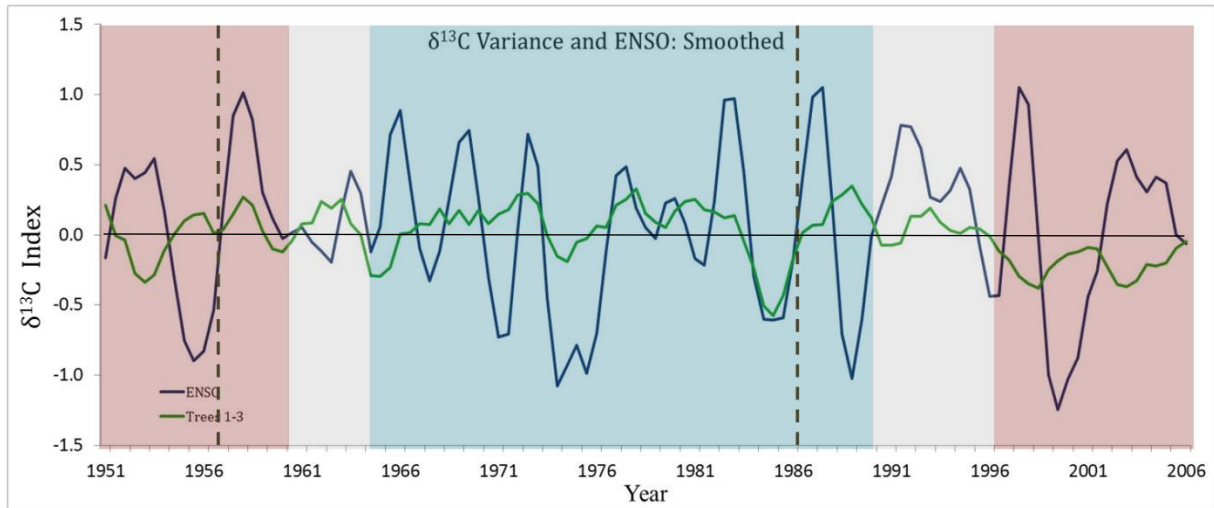


**Figure 15.** Increased porewater salinity in field manipulations in brackish water (black symbols) and freshwater (blue symbols) peat wetland soils decreased cellulase activities on decomposing sawgrass roots in surface (0-10 cm depth) and subsurface (10-20 and 20-30 cm depth) soils. Open symbols represent fine and filled symbols coarse roots.

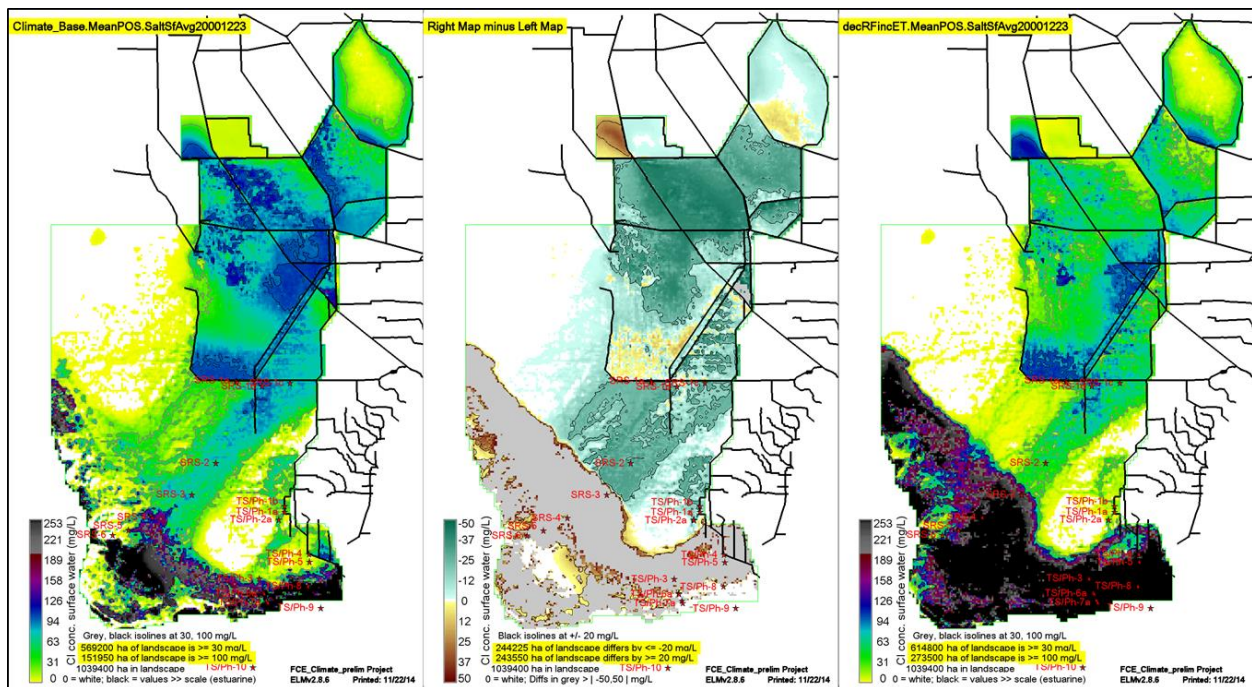




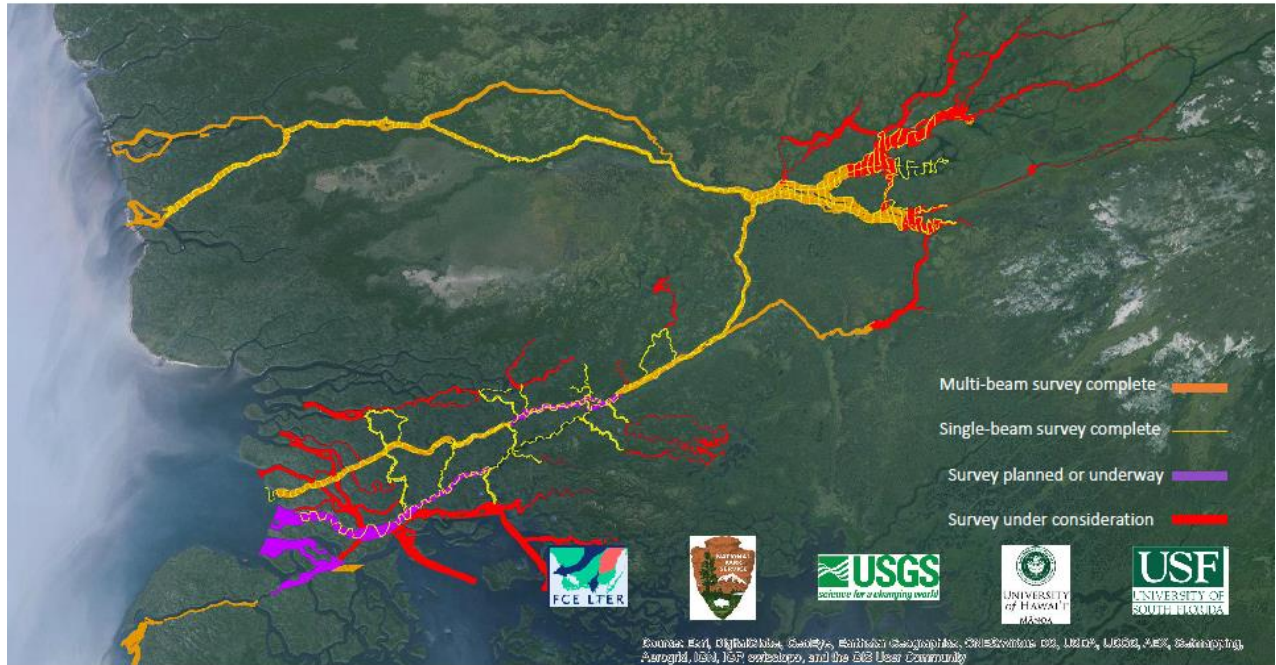
**Figure 16.** Net ecosystem exchange (NEE) measured as carbon (C) flux in freshwater (FW) and brackish water (BW) marsh sites of the field chamber experiment. Both marshes were a source of C to the atmosphere in the dry season and this effect was amplified with increased salinity in the brackish marsh. AW= ambient water, SW=saltwater



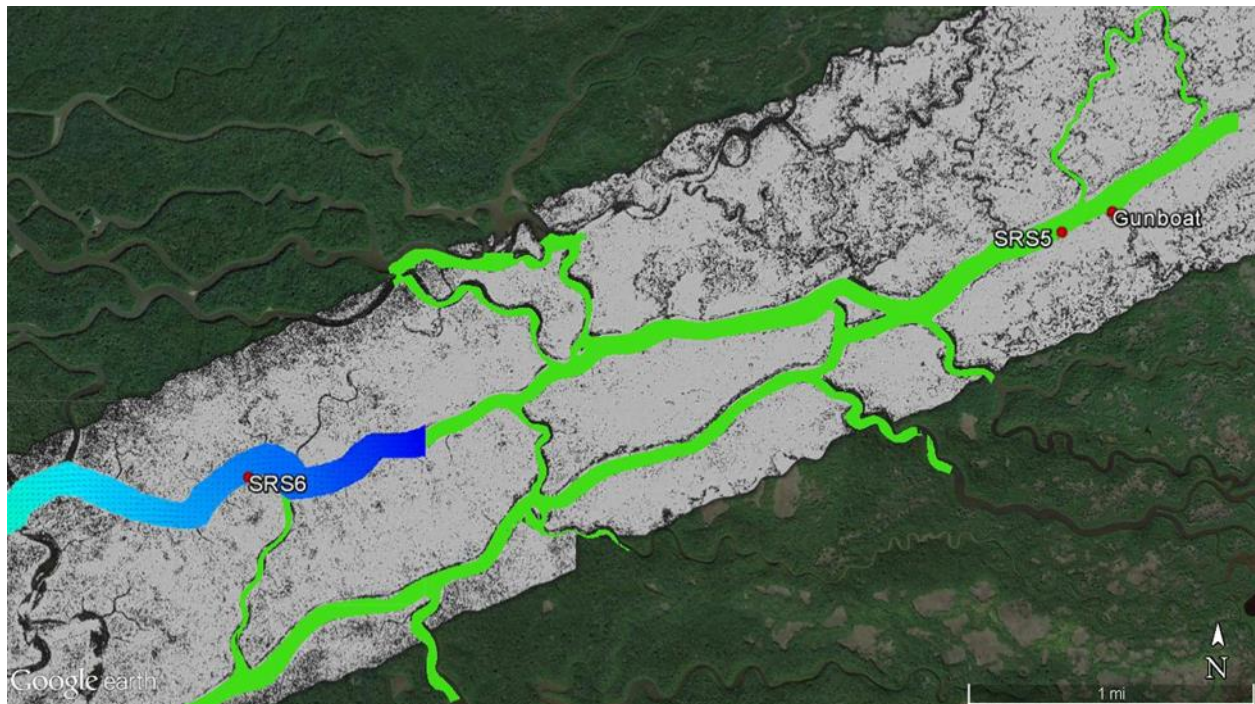
**Figure 17.**  $\delta^{13}\text{C}$  index for *Pinus elliottii* trees vs ENSO 3.4 (1950-2006). The green line is the average carbon isotope variance for three of the four trees in this study. The blue line is the sea surface temperature variation for ENSO region 3.4. The red and blue boxes represent the warm and cool phases, respectively, of the AMO. During the cool phase of the AMO, the  $\delta^{13}\text{C}$  index trends with ENSO; however, the trends show an opposite relationship during the warm phases. The transitions occur about five years before the shift in AMO phase (dashed lines). – **From Rebenack et al. (in progress).**



**Figure 18.** Example performance measure of the mean chloride (Cl) concentrations in the baseline scenario (left map), the -10% rainfall, +7% ET, and 50-cm sea-level rise scenario (right map), and the difference between the two scenarios (middle map).



**Figure 19.** Completed bathymetry surveys are shown in orange (multi-beam) and yellow (single-beam). Currently planned multi-beam surveys are highlighted in purple and survey areas under consideration are highlighted in red.



**Figure 20.** Planned model domain (green), current model domain (blue), LIDAR swath (grey), and long-term monitoring stations at SRS5, SRS6, and Gunboat Island (USGS 252230081021300)

## Products

## Publications

### Journal

- Aldwaik, S., J. Onsted, R.G. Pontius, Jr. (2015). Behavior-based aggregation of land categories for temporal change analysis. *International Journal of Applied Earth Observation and Geoinformation*. 35: 229-238. DOI: [dx.doi.org/10.1016](https://doi.org/10.1016)
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## Thesis/Dissertation

### Ph.D. Dissertations

- Feliciano, Emanuelle A. 2015. Multi-scale Remote Sensing Assessments of Forested Wetlands: Applications to Everglades National Park. University of Miami.
- He, Ding. 2014. Application of Biomarkers and Compound Specific Stable Isotopes for the Assessment of Hydrology as a Driver of Organic Matter Dynamics in the Everglades Ecosystem. (2014). Florida International University.
- Mahmoudi, Mehrnoosh. 2014. Numerical Modeling of the Effects of Hydrologic Conditions and Sediment Transport on Geomorphic Patterns in Wetlands. Florida International University.
- Mic, Dumitrita Suzana. 2015. Producing Collaboration Through Community-Level Processes of Climate Change and Water Management Planning. Florida International University.
- Nodine, Emily. 2014. Evidence of climate variability and tropical cyclone activity from diatom assemblage dynamics in coastal southwest Florida. Florida International University.
- Ya, Chao. 2014. Sources, Fate and Transformation of Organic Matter in Wetlands and Estuaries. Florida International University.

### Master's Theses

- Kiger, Amber. 2015. Changing Bacterial Growth Efficiencies across a Natural Nutrient Gradient in an Oligotrophic Estuary. Florida International University.
- Lee, Jessica A. 2015. Drying times: Integrating citizen science to examine survival of Florida Largemouth Bass in a coastal refuge habitat. Florida International University.
- Linden, Edward. Hydrologic Controls of Coastal Groundwater Discharge in Southern Taylor Slough, Everglades National Park, Florida. (2015). Florida International University.

### Undergraduate Honors Thesis

- Valeria A. Paz. 2015. Using stable isotopes to investigate trophic interactions of bottlenose dolphins (*Tursiops truncatus*) in the Florida Coastal Everglades. Florida International University.

## Websites

### ***Florida Coastal Everglades LTER Program Website***

<http://fcelter.fiu.edu/>

The Florida Coastal Everglades LTER Program Website provides information about FCE research, data, publications, personnel, education & outreach activities, and the FCE Student Organization.

### ***Coastal Angler Science Team (CAST) Website***

<http://cast.fiu.edu/>

The Coastal Angler Science Team (CAST) Website, created by FCE graduate student Jessica Lee, provides information about how researchers and anglers are working together to collect data on important recreational fish species in Rookery Branch and Tarpon Bay in the Everglades and invites anglers to participate in this project.

### ***Predator Tracker***

<http://tracking.fiu.edu/>

The Predator Tracker website has information about the Predator Tracker application and a link to download the application. Predator Tracker is a stand alone application based on a kiosk at the Museum of Discovery and Science in Ft. Lauderdale. The application allows one to learn how researchers at Florida International University track and study big predators in the Shark River Estuary in Everglades National Park and explore their predator tracking data.

### ***Wading Through Research***

<http://floridacoastaleverglades.blogspot.com/>

A blog created by FCE graduate students which focuses on the experiences of graduate students conducting research in the Everglades.

## Other products

### ***Databases***

The FCE Information Management System contains 173 datasets, of which a total of 151 are also publicly available online at <http://fcelter.fiu.edu/data/FCE/>. Datasets include climate, consumer, primary production, water quality, soils, and microbial data as well as other types of data.

The Legacies team has acquired and rendered EDEN Water depth rasters so that they can be used in GIS.

## Other publications

[K.Z.S. Schwartz \(2015\). \*Big Money, Big Politics, and Big Infrastructure: Florida's saga illustrates climate change's deep challenges.\* Blog post for New Security Beat, March 31, 2015.](#)

## Participants & Other Collaborating Organizations

### Participants\*

\*People who worked at least 1 person month on the project

<b>Name</b>	<b>Most Senior Project Role</b>
Gaiser, Evelyn	PD/PI
Heithaus, Michael	Co PD/PI
Jaffe, Rudolf	Co PD/PI
Kominoski, John	Co PD/PI
Price, Rene	Co PD/PI
Briceno, Henry	Faculty
Childers, Daniel	Faculty
Collado-Vides, Ligia	Faculty
Fuentes, Jose	Faculty
Oberbauer, Steve	Faculty
Oehm, Nick	Faculty
Onsted, Jeff	Faculty
Rains, Mark	Faculty
Rehage, Jennifer	Faculty
Rivera-Monroy, Victor	Faculty

<b>Name</b>	<b>Most Senior Project Role</b>
Roy Chowdhury, Rinku	Faculty
Schwartz, Katrina	Faculty
Smoak, Joseph	Faculty
Starr, Gregory	Faculty
Troxler, Tiffany	Faculty
Wdowinski, Shimon	Faculty
Cummings, Justin	Postdoctoral (scholar, fellow or other postdoctoral position)
Romera-Castillo, Cristina	Postdoctoral (scholar, fellow or other postdoctoral position)
Torres, Maria	Postdoctoral (scholar, fellow or other postdoctoral position)
Dailey, Susan	Other Professional
Fitz, Carl	Other Professional
Powell, Linda	Other Professional
Rugge, Michael	Other Professional
Hines, Adam	Technician
Tobias, Franco	Technician
Travieso, Rafael	Technician
Barr, Jordan	Staff Scientist (doctoral level)



<b>Name</b>	<b>Most Senior Project Role</b>
Castaneda, Edward	Staff Scientist (doctoral level)
Davis, Stephen	Staff Scientist (doctoral level)
Frankovich, Tom	Staff Scientist (doctoral level)
Pisani, Oliva	Staff Scientist (doctoral level)
Boucek, Ross	Graduate Student (research assistant)
Clasen, Hunter	Graduate Student (research assistant)
Danielson, Tess	Graduate Student (research assistant)
Feliciano, Emanuelle	Graduate Student (research assistant)
He, Ding	Graduate Student (research assistant)
Mic, Dumitrita	Graduate Student (research assistant)
Regier, Peter	Graduate Student (research assistant)
Wagner, Sasha	Graduate Student (research assistant)
Williams, Asher	Graduate Student (research assistant)
Ya, Chao	Graduate Student (research assistant)
Fuenmayor, Maria	Undergraduate Student
Soto, Stephanie	Undergraduate Student
Fourqurean, Virginia	Research Experience for Undergraduates (REU) Participant

<b>Name</b>	<b>Most Senior Project Role</b>
Khan, Abid	Research Experience for Undergraduates (REU) Participant
Morales, Kristina	Research Experience for Undergraduates (REU) Participant
Thibault, Mary	Research Experience for Undergraduates (REU) Participant

### Partner Organizations

<b>Name</b>	<b>Location</b>
College of William & Mary	Williamsburg, Virginia
Dartmouth College	Hanover, New Hampshire
Encounters in Excellence, Inc.	Miami, Florida
Everglades Foundation	Palmetto Bay, Florida
Everglades National Park	Homestead, Florida
Florida Atlantic University	Boca Raton, Florida
Florida Gulf Coast University	Fort Meyers, Florida
Florida State University	Tallahassee, Florida
Indiana University	Bloomington, Indiana
Louisiana State University	Baton Rouge, Louisiana
Miami-Dade County Public Schools	Miami-Dade County, Florida
National Aeronautics and Space Administration	Pasadena, California
National Audubon Society - Tavernier Science Center	Tavernier, Florida

<b>Name</b>	<b>Location</b>
National Oceanic and Atmospheric Administration - AOML	Miami, Florida
National Park Service - South Florida/Caribbean Network	Palmetto Bay, Florida
Pacific Northwest National Laboratory	Richland, Washington
Plymouth State University	Plymouth, New Hampshire
Sam Houston State University	Huntsville, Texas
South Florida Water Management District	West Palm Beach, Florida
The Deering Estate	Miami, Florida
The Pennsylvania State University	University Park, Pennsylvania
University of Alabama	Tuscaloosa, Alabama
University of California, Berkeley	Berkeley, California
University of California, Los Angeles	Los Angeles, California
University of Central Florida	Orlando, Florida
University of Florida	Gainesville, Florida
University of Georgia	Athens, Georgia
University of Hawaii at Manoa	Honolulu, Hawaii
University of Miami	Coral Gables, Florida
University of South Florida	Tampa, Florida
University of South Florida St. Petersburg	St. Petersburg, Florida
USGS	Reston, Virginia
Yale University	New Haven, Connecticut

Name	Location
Zoological Society of Florida	Miami, Florida

## Impacts

### Impact on the development of the principal discipline(s)

Work currently performed in the FCE mangrove ecotone has served well to emphasize the importance of long-term research to understand complex functional and structural processes influence by natural and human disturbances not only in the neotropics, but also in other tropical and subtropical latitudes around the world. Mangrove restoration is currently one of the most active management strategies to recuperate mangrove areas around the world. Our current work in the FCE has been used in the design and operation of mangrove restoration projects currently underway in the Yucatan Peninsula, Mexico. This includes an increased understanding of groundwater flow dynamics and groundwater-surface water interactions in wetlands and along coastlines. The work to associate other impacts (water demand, water quality, etc.) with land use change along coasts exposed to sea level rise is a crucial step for geographers and the work we are doing is helping to achieve this.

Evelyn Gaiser served as Co-Editor for special issues focused on FCE LTER in the *Journal of Paleolimnology, Wetlands, and Ecosphere*. She served as Co-Editor for a special issue focused on FCE LTER and International LTER in *Ecosphere*.

### Impact on other disciplines

The FCE approach (natural and human systems) has been beneficial to expand and participate in other similar projects in different Gulf of Mexico coastal settings (deltas). We have use the knowledge and conceptual framework in the implementation of large-scale wetlands restoration projects potential benefits and impacts. For example Rivera-Monroy (collaborator) is currently participating in the CNH: Coupled Natural-Human Dynamics in a Vulnerable Coastal System project (NSF-1212112).

Steve Davis participated in the Modified Water Deliveries (G-3273 Constraint Relaxation/S-356 Field Test and S-357N Operational Strategy) Planning Process. This is part of a \$500 million Everglades restoration project that pre-dates the CERP and will help to deliver more freshwater to Northeast Shark River Slough. He also helped influence the initiation of a study to determine factors (e.g., rainfall, operations, other restoration projects, and sea level rise) contributing to claims of flooding (high groundwater levels) made by some South Dade farmers in the summer of 2013.

Evelyn Gaiser served as a contributor for Indicators of Everglades Restoration, South Florida Ecosystem Restoration Task Force and a collaborator for Synthesis of Everglades Research and Ecosystem Services, Everglades Foundation.

Jennifer Rehage was an invited panelist at the Everglades Coalition meeting in Key Largo, FL in January 2015 and presented at the RECOVER meeting at the South Florida Water Management District in January 2015.

## **Impact on the development of human resources**

### **Undergraduates**

FCE invests heavily in STEM human resource development through programs that target undergraduates and pre-service teachers, and provides training to professional service teachers in developing new educational materials. The FCE Research Experience Program is the cornerstone for engagement with undergraduates, graduates, and teachers and provides a range of opportunities for research, teaching and mentoring in science. Over the last year, FCE scientists have provided 66 semester units (SU) of undergraduate mentoring to 40 undergraduates, in 17 FCE labs at 9 different institutions in the US and Mexico. A 93% majority (n=62) of students mentored are traditionally underrepresented in STEM, including 72% female (n=48) and at least 75% (n=50) are considered ethnic minorities. At least 56% of the 66 SU can be identified as returning students and suggests their mentoring is both a positive and valuable experience. This figure is likely a conservative estimate, as it does not account for graduating students or students with work or academic conflicts.

FCE scientists continue to integrate and disseminate research results through the educational materials used in their courses. Fourteen researchers report discussing FCE research with over 1,403 K-20 students (520 K-12; 818 undergraduates, 65 graduate students), distributed in 29 classes, across 7 institutions in the US (5), Italy, and Colombia.

FCE researchers mentored four REUs during 2015. Kristina Morales REU project in Dr. John Kominoski's lab included collected weekly soil redox measurements in freshwater sawgrass wetland mesocosms exposed to stress (salinity) and subsidy (phosphorus) manipulations. In addition, Kristina conducted independent mesocosm experiments, testing gradients of salinity and phosphorus on microbial functioning and carbon loss in freshwater peat soils. Dr. Tiffany Troxler mentored Mary Thibault during the summer of 2015. Mary developed measurements to understand the ecophysiological response of sawgrass to inundation and salinity variation.

Virginia Fourqurean, an REU student in Dr. Jennifer Rehage's lab, investigated the relationships between bass, snook and alligator condition. She presented a poster of her research results entitled "Using large predator fish body condition to predict alligator body condition in response to hydrologic seasonality in the Florida Coastal Everglades" at the LTER All Scientists Meeting in September 2015. Abid Khan also worked with Dr. Jennifer Rehage and Ross Boucek. His project examined the link between hydrology, body size and the spawning movements of common snook in the Shark River.

### **Professional and Pre-Service Teachers**

Providing opportunities that expose practitioners, teachers, young people and the community to science and technology is essential for human resource development in STEM. Throughout FCE III, scientists have continued to mentor K-12 teachers. In 2014, Teresa, Catherine Laroche, Jennifer Gambale, and Terri Reyes used residual RET funds to coordinate 60 of their students from Felix Varela Senior High School to produce 18 DataJam posters using FCE datasets. These DataJam posters were then exhibited at the 2015 ASM.

In June 2015, FCE and the National Tropical Botanic Garden offered a summer institute in *Conservation Biology and Ethnobotany for Environmental Science Curriculum* as professional development for local Advanced Placement Environmental Science, Biology, and Human Geography teachers. The week-long institute was facilitated by FCE Education & Outreach staff and included a day in the Everglades with Dr. John Kominoski. In an email forwarded by the MDCPS Director of Advanced Academics, teacher Ken Arrison wrote, “This PD was phenomenal. By far the best PD I have ever been to.” Plans are currently under way to provide a similar workshop in June 2016.

Investing in pre-service teachers is an ongoing effort at FCE. Former RET, Teresa Casal, continues to discuss FCE research in courses she teaches in the School of Education at Miami Dade College. More recently, FCE began working with the STEM Transformation Institute through its FIUteach program. Following the high fidelity model designed by the UTeach Institute, FIUteach recruits and mentors STEM majors into the program which allows them to simultaneously earn their undergraduate STEM degree and subject area teaching license. The FIUteach program invests in STEM human resource development by improving the quality of STEM education of students chosen to become K-12 teachers and for those that go on to continue their scientific training in graduate school.

FCE is currently and will continue to support the FIUteach program by providing internships with its scientists and training some of its students to discuss FCE research at informal science education venues like the Miami Museum of Science, ZooMiami, and the Charles Deering Estate at Cutler. In the spring of 2016, FIUteach students will begin enrolling in a Research Methods class where FCE scientists are likely to serve as mentors in some of their semester-long research projects.

### **Impact on information resources that form infrastructure**

The FCE Information Management (IM) team (L. Powell and M. Ruge) completed a physical hardware restructure and system information migration onto a series of virtual servers housed on Florida International University Division of Information Technology’s (UTS) equipment. Work this year on improving its network-wide standardization has facilitated the use of site data in synthesis projects. The following contributions were made to the LTER network by the FCE IMS information manager: 1) information management member of a NSF 2015 mid-term review team for LTER site, 2) Chair of the LTER IM Unit Registry working group, 3) member of the IM Data Package Reporting working group, 4) workgroup session organizer for upcoming LTER ASM meeting in Estes Park, Colorado for session entitled “*An Exploration into LTER Big Data: Challenges and Solutions Related to Storing, Managing and Delivering High Resolution Data*”,

5) attendance at the 2015 Information Management Committee annual meeting in Estes Park, Colorado and 6) FCE IMS data contributions to ClimDB, SiteDB, All Site Bibliography, PersonnelDB and the LTER PASTA system.

The FCE LTER program continues to support and contribute to its information management system (IMS) during the FCE III (2015):

- Submitted ALL FCE program data, 156 data sets, into the LTER PASTA system.
- Completed and implemented a custom web-based application to facilitate exploration, manipulation, and annotation of long-term ecological data signals. Users are able to graph FCE data directly from the FCE website without having to download and reformat those data.

### ***IT Infrastructure***

The FCE information management system (IMS) Web server, Oracle 11g database and FTP server are loaded on five (5) virtual servers housed Florida International University Division of Information Technology's (UTS) equipment. The FCE III Disaster Recovery Plan call for data to be backed up offsite at the Northwest Florida Regional Data Center (NWRDC) located on the campus of Florida State University in Tallahassee, Florida. Thus allowing the FCE website and Oracle 11g database to be continually available throughout disaster events such as hardware failures and hurricanes.

### ***FCE III Website and Data Archives***

The FCE web site provides outstanding support for site and network science. The site's homepage (<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 IM Team has incorporated several LTER working group initiatives to improve standardization of data search and access across LTER sites through adoption of controlled vocabularies and common interface features. A web-based data visualization tool allows researchers to rapidly visualize complex data streams and to efficiently process and annotate data. A quarterly researcher newsletter call "News from the Sloughs" ([http://fcelter.fiu.edu/about\\_us/news/](http://fcelter.fiu.edu/about_us/news/)) is available on the FCE website, bringing interesting research articles and FCE highlights to the FCE group.

All 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 drive the FCE website. This hybrid system (flat file and database) gives FCE researchers, network scientists and the general public an option to download complete original data files submitted by FCE scientists in addition to downloading queried data from the Oracle 11g database. Core data are made available to the public within two years of data collection and are accessible on-line in accordance with the FCE Data Management Policy and LTER Data Access Policy.

The FCE IM team lends its expertise to site and network researchers when necessary by providing application support (Excel2EML), assistance with metadata entry, data submissions, individual project database design, collaborations on GIS Work and research graphics.

***Key Outcomes***

All of the FCE LTER core data and metadata files (156 datasets) have been submitted to the LTER PASTA system (<https://portal.lternet.edu/nis/browseServlet?searchValue=FCE>) and are available via the FCE website at <http://fcelter.fiu.edu/data/core/>.

***Goals***

Add enhancements to the existing FCE research data metadata to 1) better clarify the core datasets that are emerging as key, long-term data sets central to the FCE program, 2) work with FCE researchers to quantify uncertainty/error in existing data sets and include this information in the data abstracts and dataset metadata and 3) add publication information and/or 'related' data information to existing metadata. Upgrades will be made to the FCE data visualization tool that include graphs that have variable from MULTIPLE datasets, the ability to download a 'subset' of data as shown on the graph and more distinct color schemes for the graph background and plot points and lines.