Florida Coastal Everglades LTER

FCE III Final Report

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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 understand how climate change and resource management decisions interact with biophysical processes to modify coastal landscapes. Changes in drivers of freshwater or marine endmembers of karstic coastal ecosystems – with strong biotic feedbacks of geomorphology, hydrology, and ecosystem processes – shift the dominance of landscape patterns that determine carbon sequestration and food webs dynamics. We have observed rapid intrusion of salt water and associated limiting nutrients (phosphorus) into brackish and freshwater ecosystems driven by increased rates of sea-level rise (Dessu et al. 2018). Experimental studies are revealing the mechanisms by which saltwater intrusion into freshwater and brackish wetlands drives rapid loss of stored carbon (Wilson et al. 2018; Charles et al. 2019; Servais et al. 2020). However, we now have evidence of changes in ecological process attributed to restoration projects implemented over the last few years. Observed increases in pulsed delivery of fresh and marine water to this sensitive ecosystem via water management and climate change provides a landscape-scale template for testing theories of how pulse dynamics may maintain ecosystems in a developing state, reducing vulnerability to the accelerating press driven by climate change (sea-level rise).

FCE III research was organized around four goals to reveal the social-ecological drivers and consequences of a shifting balance of fresh and marine water supplies to coastal ecosystems (Fig. 1): (1) **Water** - assessing how climate change, particularly accelerating sea-level rise, interacts with political conflicts over freshwater distribution; (2) **Ecosystem Dynamics** - determining how the balance of fresh and marine water supplies control ecosystem structure and functions through the dynamics of **biogeochemistry**, **organic matter**, **primary producers**, **consumers**, and the rates and pathways of **carbon** sequestration; (3) **Legacies** - characterizing spatiotemporal patterns of ecosystem sensitivity to, and legacies of, past climate variability and land/water-use change, and; (4) **Scenarios** - modeling how future policy scenarios of freshwater distribution may reduce vulnerability to rapid climate change.

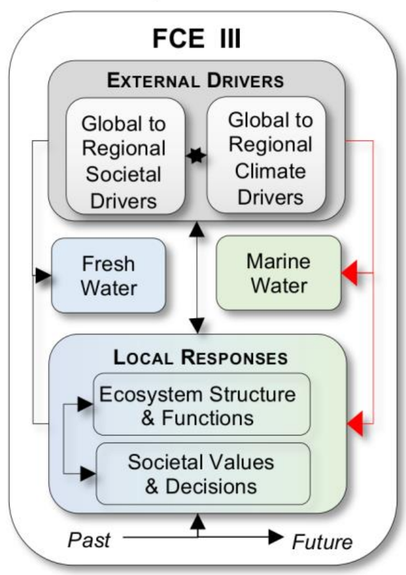

Figure 1. Conceptual Framework Guiding FCE III Research

We addressed these goals through continued biophysical data collection along the Shark River Slough (SRS) and Taylor Slough/Panhandle transects in Everglades National Park with a focus on dynamics in the oligohaline ecotone, while we expanded our socio-hydrological research to extend beyond the boundaries of the Park. We expanded our cross-system eddy flux tower network, adding a site in the dwarf mangrove forest (TS/Ph-7) and seagrass ecosystem of Florida Bay (TS/Ph-9). Experimental research focused on mesocosm-scale manipulations of P concentration and salinity, to examine responses on spatiotemporal scales that can guide interpretation of responses to the landscape-level experiment provided by Everglades restoration. We focused synthesis efforts on scenario-driven modeling and the production of our synthesis book (Childers et al. 2019).

Major Activities

Water: We maintained continuous measurements of groundwater and surface water levels, temperature, salinity, and chemistry in the oligohaline ecotone of both sloughs. Rainfall and ET from meteorological stations were combined with surface water inflows, outflows, and water levels measured across ENP into a water balance. Wetland Interferometric Synthetic Aperture Radar was used to provide high spatial-resolution water level change maps over a greater region of the oligohaline ecotone of SRS by comparing pixel-by-pixel observations over time. Using a multi-methodological approach, we interviewed local residents, recreationalists, and resource managers and analyzed archival data and restoration planning documents to understand the management (institutional) and local perspectives that create connections and disconnections of water inflow structures and eventually to the oligohaline ecotone.

Ecosystem Dynamics: We produced an integrated carbon budget continuous estimates of net ecosystem exchange from our flux towers, regular above and belowground net primary productivity values, organic matter accretion from sediment elevation and paleoecological studies, dissolved inorganic carbon fluxes across the land-water-air continuum, and measurements of dissolved and particulate carbon tidal fluxes (Troxler et al. 2013). This framework was newly applied in the dwarf mangrove system in TS/Ph, and comparisons between the SRS and TS/Ph datasets will enable rigorous tests of this hypothesis. We coordinated a large-scale initiative to determine landscape variability in the patterns and controls on carbon budget components, including the expansion of our eddy flux network to include a tower in the dwarf mangrove forest of TS/Ph-7 and underwater O_2-based gas flux in Florida Bay. We used the framework described above to calculate and cross-validate carbon cycling measurements from plot-based and tower-based methods.

- **Biogeochemistry:** We used a suite of controlled experiments at our mesocosm facility to understand how P, salinity, and water residence time and depth affect microbially-mediated carbon and nutrient cycling along the TS/Ph and SRS transects. Four treatments were assigned across 24 mesocosms, including salinity and P controls, and salinity-enhanced, P-enhanced, and combined salinity and P treatments. We measured treatment effects on soil CO_2 and CH_4 efflux (continuous), bacterial production, redox conditions, total and dissolved nitrogen (N), P, organic carbon concentrations, and the optical properties of water (weekly), soil bulk density, total C, N and phosphorus concentrations, microbial activity and composition (by molecular fingerprinting), and leaf and root decomposition rates (Wilson et al. 2018a, Charles et al. 2019, Servais et al. 2020). We examined bacterial productivity along FCE transects relative to biogeochemical drivers (Kominoski et al. 2020, Lee et al., unpublished data).

- **Primary Producers:** We assessed the effects of salinity, water residence time, and P availability on productivity of sawgrass, mangrove saplings, and periphyton in collaboration with biogeochemical cycling studies in the mesocosm experiment described above. We quantified changes in aboveground and belowground biomass and net primary production of sawgrass and mangroves using an allometric approach and root in-growth cores, respectively, and of periphyton net primary production using artificial substrates (Wilson et al. 2019, Mazzei et al. 2020). Changes in abiotic drivers including leaf and periphyton P, N and C, porewater salinity, hydrogen sulfide, and soil redox potential were assessed (Servais et al. 2020).

- **Organic Matter:** We assessed estuarine organic matter inputs, mixing, and transport dynamics along salinity transects in each estuary in the wet and dry season (Regier & Jaffe 2016). We determined dissolved organic matter quality and exchange dynamics between ground and surface water in Shark River, Taylor River, and Florida Bay (Regier et al. 2016). In addition to molecular-level characterizations, stable carbon isotope determinations of dissolved organic and inorganic and particulate organic carbon provided carbon source identification and degradation dynamics (Ya et al.

2015). Organic matter degradation rates were measured in laboratory photo- and biodegradation incubations of samples from estuarine transects taken during the wet and dry seasons.

- **Consumers:** We conducted experiments in Everglades wetlands to determine how energy-flow pathways are changed by freshwater delivery, particularly if the delivery is associated with P-enrichment. We manipulated nutrients and key consumers using established in-situ field enclosures to test how freshwater sources and predator behaviors control markers of food assimilation (stable isotopes of C and N, fatty acids), delineating predictions based on the presence of key microbial energy-flow routes in oligotrophic Everglades wetlands that are changed when P is enriched (Abbey-Lee et al. 2013). Our second line of work evaluated microbial energy flow into estuarine food webs, relying on movement studies to identify wide ranging estuarine consumers that travel between marshes, the ecotone, and downstream marine areas. After identifying foraging and "refuging" sites where consumers feed and travel to, we evaluated isotopic and fatty acid signatures of detritus, algae, macroinvertebrates, and mesoconsumers in an effort to delineate linkages to the wide-ranging top predators (i.e., alligators and large fish) (Eggenberger et al. 2019). To determine variability in potential contributions of top predators to community dynamics and nutrient cycling, we maintained quarterly sampling of bull shark abundance and bi-annual sampling of alligator abundance, diets, and body condition in the ecotone region in relation to freshwater flow, salinity, dissolved oxygen and nutrient concentrations, and other continuous FCE data (Rosenblatt et al. 2015; Matich et al. 2017).

Legacies: We extended our land-use change work to the full Everglades landscape, analyzing the past four decades of landscape change across the urban, suburban, and exurban/agricultural gradients using aerial photographs and multi-resolution satellite platforms (GeoEye, Landsat, MODIS) (Onsted & Chowdhury 2014). We generated remote-sensing based vegetation indices to explore drivers of directional, cyclical, and stochastic change on salinity, nutrient concentrations, and carbon storage. Statistical analyses and modeling were used to test relationships among indices of land cover, landscape structure, and climate-hydrological indicators at varied spatial scales to investigate boundary dynamics and neighborhood effects.

Scenarios: We coordinated meetings of science experts and stakeholders to balance the interplay between tightly- and loosely- linked scenarios, creating common (transdisciplinary) storylines while allowing full independence to discipline-specific modelers, and formulating bridges to encourage cross-discipline or cross-scale comparisons. We identified a manageable number of plausible timelines and climatic and water management conditions to drive interactive socio-ecological models. These model domains range from site-specific (points) to spatially extensive models (>10,000 km^2) with temporal domains ranging from weeks to decades (Flower et al. 2017a). Model outcomes were visualized using GIS-based mapping tools (including video) developed through our public-private partnerships and used to evaluate the economic consequences of scenario options to ecosystem services, including freshwater supply, flood protection, and fish and wading bird abundances (as they apply to recreational use) (Wetzel et al. 2017).

Specific Objectives

Water: Objectives were to determine how climate change and sea-level rise interact with water management practices to control hydrologic conditions in the oligohaline ecotone. We expected that climate processes of rainfall and evapotranspiration along with sea-level rise would continue to be the dominant drivers of water availability across the Everglades landscape, but that the balance between regional water demand and restoration efforts will fine tune the position of the oligohaline ecotone, and its surface and groundwater quality. We also planned to examine the social, institutional, and economic processes that have produced current hydrologic disconnections within the broader watershed and its ultimate impact on the oligohaline ecotone.

Ecosystem Dynamics: Objectives were to determine how changing freshwater inflows, tidal and storm cycles, and climate patterns affect the magnitude, rates, and pathways of carbon sequestration, loss, storage, and transport across the land-water continuum. We planned to integrate carbon transport and loss processes into FCE carbon budgets, expecting to find that the temporal variability in the carbon balance along the FCE transect will reflect the seasonally-adjusted plant eco-physiological and ecosystem respiratory responses to the variable influences of marine and freshwater supplies defined by changes in surface and pore-water conductivity, water residence time, and tidal energy. We also expected that landscape-scale patterns of change in the carbon balance will be determined by the mitigating or magnifying effects of water management and rainfall variability on the impacts of sea-level rise.

- **Biogeochemistry:** Objectives were to determine how the balance of fresh and marine water supply to the oligohaline ecotone influence microbially-mediated carbon and nutrient cycling in soils and water. We expected that factors that increase salinity and phosphorus supply from marine sources would increase microbially-mediated rates of carbon efflux and transport, but only if water depth and residence time remain unchanged. We also expected that bacterial growth efficiency will: 1) increase with bioavailability of dissolved organic carbon determined by its source; 2) increase with additions of inorganic phosphorus relative to organic phosphorus; and 3) be related to changes in salinity, independent of changes in dissolved organic carbon source.

- **Primary Producers:** Objectives were to determine how the balance of fresh and marine water supply to the oligohaline ecotone influence the composition, distribution, and productivity of primary producers. We expect that marine delivery of phosphorus and salinity will be amplified under scenarios where freshwater delivery is not restored, resulting in mangrove transgression and decline in sawgrass aboveground net primary production in the oligohaline ecotone. By examining large-scale patterns of plant community composition and production in light of large-scale changes in hydro-dynamics, we hoped to reveal the relevance of the results of mechanistic studies to interpreting and predicting long-term and landscape-scale dynamics in the Everglades ecotone.

- **Organic Matter:** Objectives were to determine how surface water residence times, phosphorus availability, and salinity interact to affect organic matter quality, abiotic and biotic processing, and exchange between freshwater, ecotone, and marine environments. We expected an increased importance of marine supplies of organic matter to the ecotone, particularly from the groundwater, when freshwater delivery is depressed, and increased processing to more refractory forms when water residence time is extended. We also expected that carbon fluxes from water and soils will be determined by the magnitude of hydrodynamic pulses (tides, freshwater flows, storms) and the rates of organic matter degradation driven by longer-term changes in the balance of water sources.

- **Consumers:** Objectives were to determine how sea-level rise will interact with changes in freshwater inflows to modify detrital food webs and the spatial scale of consumer-mediated habitat linkages. We expected that the freshwater inputs would enhance the importance of microbial loops and detritus in the food webs of Everglades freshwater marshes and mangrove estuaries, as long as inputs are not enriched in phosphorus. Behavioral sensitivity to seasonal changes in habitat access and suitability caused us to expect that the strength and direction of consumer subsidies to the ecotone would also shift with changes in the balance of freshwater and marine water supplies to the ecotone.

Legacies: Objectives were to determine how the legacies of wetland conversion to urban and agricultural land uses and resulting shifts in water demand/management across the Everglades watershed have changed the sensitivity of the coastal zone to freshwater restoration in the face of sea-level rise. We hypothesized that periods and locations of land-use and/or climate-driven changes in available freshwater correlate (perhaps with lags, step-functions or nonlinearities) with the migration of the oligohaline ecotone along the TS/Ph and SRS transects. We expected that legacies of changing freshwater inflows to the oligohaline ecotone have influenced sensitivity to the balance of fresh and marine water supplies across the landscape.

Scenarios: Objectives were to determine what scenario of water distribution and climate change will maximize socio-economic and environmental sustainability of a future FCE. We hypothesized that 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. We also anticipated that 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.

Significant Results

Water: Sea level rose 3x faster than the prior decade (Haigh et al. 2014; Fig. 2) and is highest in the wet season (Dessu et al. 2018). Wet-season rainfall increased by 29 cm between 1995-2016 (Abiy et al. 2019b). Freshwater inflows currently only account for 9-19% of annual water budgets (Sandoval et al. 2016), but new upstream infrastructure (bridges, retention structures) is increasing water levels in freshwater marshes. Agricultural best management practices are reducing water use (Yoder 2019), required to meet the demands of a growing population (Onsted & Roy Chowdhury 2014; Aldwaik et al. 2015). Everglades restoration is now allowing P inflows to meet the mandated maximum of 10 µg TP L^{-1} (Rivera-Monroy et al. 2019a). The 2017 authorization of a structures to store and clean water will provide more seasonal freshwater pulses to the FCE, reducing saltwater intrusion into the marsh-mangrove ecotone (Dessu et al. 2018) and the region's freshwater supply, the Biscayne Aquifer (Blanco et al. 2013).

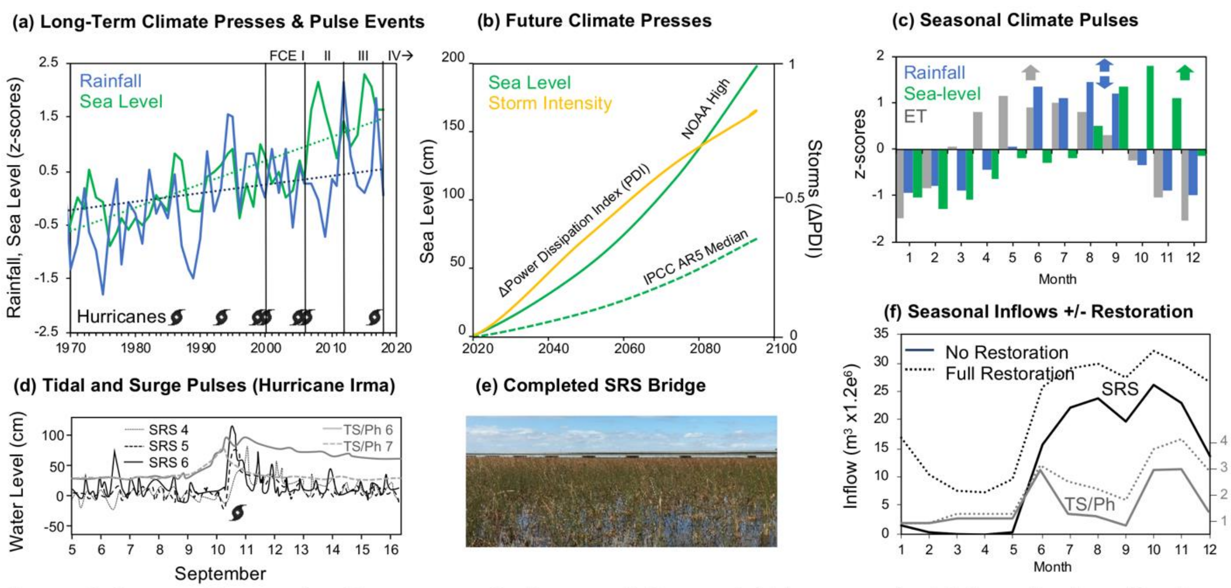

FIGURE 2. CLIMATE DRIVERS AND PROJECTIONS OF PRESSES & PULSES. (a) Mean annual rainfall, sea level, and hurricanes (hurricane symbol) over the past 50 years; (b) projections for sea-level and storm intensity; (c) seasonality in mean rainfall, sea-level, and evapotranspiration (ET) (arrows indicate direction of projected change); (d) changes in water level in SRS and TS/Ph with passage of Hurricane Irma (Sept 2017); (e) a completed SRS bridge - one of many projects restoring freshwater pulses to FCE; (f) modeled monthly inflows to 1.5 km^2 subregions of SRS and TS/Ph for a year with average rainfall (1982) using the Everglades Landscape Model without (base) and with full restoration (*note scale difference for TS/Ph on right y-axis*).

Ecosystem Dynamics: Experiments have shown a reduction in sawgrass root production with salt exposure that shifts peat marshes from carbon sinks to sources (Wilson et al. 2018a; Servais et al. 2019), resulting in losses of soil elevation and carbon stocks (Charles et al. 2019) – analogous to the spatially patchy and abrupt collapse of peat soils observed on the FCE landscape and elsewhere (Tully et al. 2019). Subsidy-stress experiments, designed to decouple the influences of P and salinity, suggest that plants exposed to saltwater can increase CO_2 uptake in the presence of increased P (Fig. 3). Long-term data from our freshwater marsh eddy flux towers illustrate how seasonal inundation duration determines whether marshes are a carbon source or sink, controlled mainly by ecosystem respiration (Malone et al. 2013; Zhao et al. 2019). The formation and dissolution of carbonate minerals that comprise the inorganic fraction of FCE soils have implications for the net ecosystem carbon balance (Howard et al. 2018).

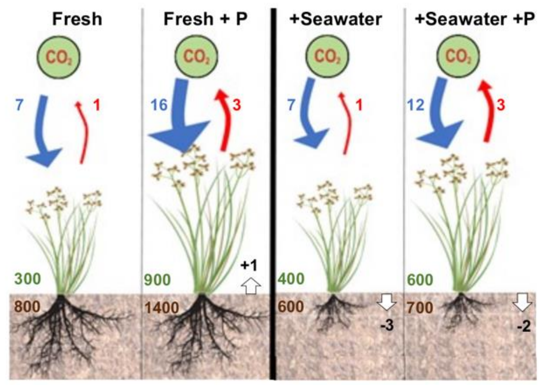

Figure 3. Freshwater Marsh Response to Saltwater Intrusion from manipulations of phosphorus (+ 15 µmol P d^{-1}) and seawater (9 ppt NaCl). Responses include changes in carbon dioxide flux (*blue and red arrows*, µmol CO_2 m^2 s^{-1}), biomass of above and belowground vegetation (*green and brown numbers*, respectively, in g m^{-2}, respectively) and soil elevation gain or loss (*arrows*, in cm).

- **Biogeochemistry**: During the dry season and extended droughts, TP is concentrated in marsh surface water (Davis et al. 2018). Where marshes dry completely, organic matter mineralization drives P release after reflooding (Sola et al. 2018). Downstream, wet-season surface water TP and DOC concentrations vary with the extent of tidal and storm-driven marine supplies (Figs. 4, 5), while in the dry season, groundwater intrusion through limestone mobilizes P to the root zone (Flower et al. 2017b,c). These marine pulses leave legacies in soils and water that influence long-term plant and microbial productivity and composition (Mckay et al. 2017; Castañeda-Moya et al. 2020; Kominoski et al. 2020).

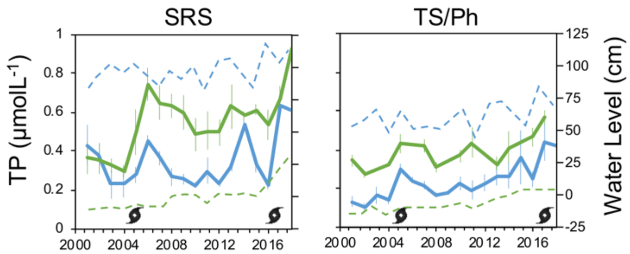

Figure 4. Pulse events and Total Phosphorus (TP) Legacies. Annual mean (+/- standard error) of water TP (*lines*) and water depth (*dashed lines*) in *mangrove* estuaries and *freshwater* marshes, showing resource legacies of storm surge (🌀) pulses in 2005 and 2017, especially in tidal SRS.

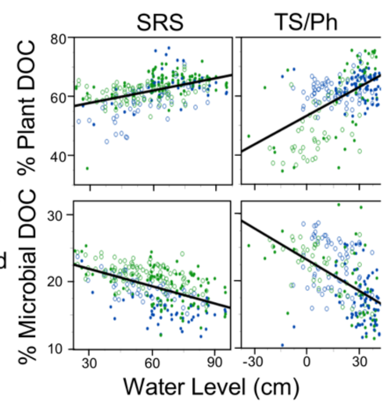

Figure 5. Dissolved Organic Carbon (DOC) from plant and microbial sources in the *mangrove* estuary and *freshwater* marsh in wet (filled circles) and dry (open circles) seasons (2004-2014).

- **Primary Producers:** In freshwater marshes, sawgrass productivity is equal to that of periphyton mats (Marazzi & Gaiser 2018), which are abruptly lost upon exposure to TP exceeding 10 µg L^{-1} (Gaiser et al. 2015a). Where freshwater restoration is increasing wet-season water depth, we are observing dominance transitions from sawgrass to a deeper-water slough species (*Eleocharis cellulosa*). In the marsh-mangrove ecotone, rapid declines in periphyton biomass and sawgrass productivity are occurring where salinity exceeds 5-10 and 10-20 ppt, respectively (Fig. 6; Troxler et al. 2014; Mazzei & Gaiser 2018). Declines in sawgrass productivity are less pronounced where plant roots can access P desorbed or dissolved from saltwater-exposed carbonate sediments or rock (Liu et al. 2014; Flower et al. 2017b). Mangrove forests are also stimulated by P but stressed by salt, such that every 10 ppt increase in salinity results in a 5% decline in production (Barr et al. 2013; Castañeda-Moya et al. 2013).

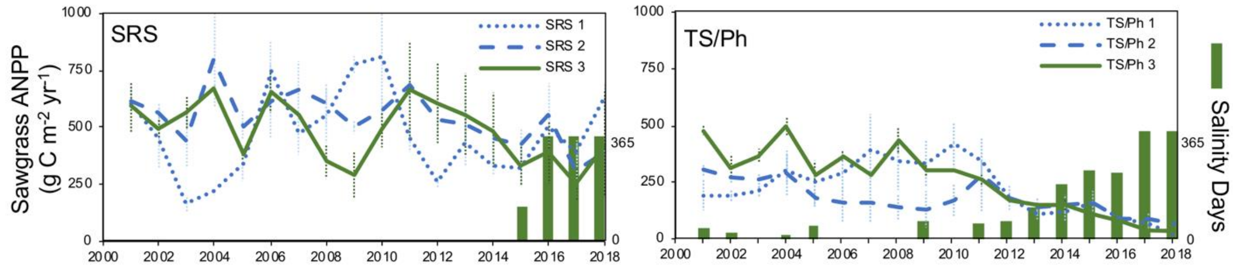

FIGURE 6. FRESHWATER MARSH PRODUCTIVITY. Long-term trends in the number of days with measurable salinity at SRS 3 and TS/Ph 3 (*green bars*), and trends in mean (± standard error) of sawgrass (*Cladium jamaicense*) Annual Net Primary Productivity (ANPP) at freshwater SRS and TS/Ph sites (*blue lines*), with significant negative relationship to salinity days at SRS 3 and TS/Ph 3 (*green lines*) [recent declines at TS/Ph 1 and 2 are related to water level increases from freshwater restoration].

- **Organic Matter:** We have been at the forefront of advancing methodologies for tracing the sources and fate of DOC in aquatic ecosystems (Jaffé et al. 2014), showing that most DOC in tidal rivers is freshwater-derived and is decreasing over time with the loss of upstream carbon sources due to decades of drying and oxidation (Cawley et al. 2014; Regier et al. 2016). Only ~10% of the mangrove-derived carbon is transported by tidal drainages in organic (mainly particulate) form (Regier & Jaffé 2016; Chen & Jaffé 2016), while the rest is transported downstream as dissolved inorganic carbon (Troxler et al. 2015).
- **Consumers**: In freshwater marshes, periphyton mats are the primary source of carbon for consumers (Williams & Trexler 2006; Belicka et al. 2012). The degree of P limitation is negatively correlated with edibility of the autotrophic bacteria in periphyton, which is positively correlated with mesoconsumer density and biomass (Sargeant et al. 2011; Trexler et al. 2015). At the coast, sharks, alligators, and piscivorous fishes show a strong reliance on marsh prey production, which is regulated by the severity of marsh drying (Boucek & Rehage 2013; Boucek et al. 2016a). This prey subsidy is a strong driver of consumer distribution, as consumers move from marine to freshwater marsh ecosystems tracking seasonally-displaced marsh prey (Matich & Heithaus 2014; Griffin et al. 2018), partitioning resources and space differently among individuals and taxa (Rosenblatt et al. 2015; Matich et al. 2017). Along with freshwater marsh prey pulses, extreme events (cold spells, hurricanes, droughts) drive long-term prey and consumer abundances (Boucek & Rehage 2014, Boucek et al. 2016b) and movements (Boucek et al. 2017; Strickland et al. 2019; Massie et al. 2019; Fig. 7).

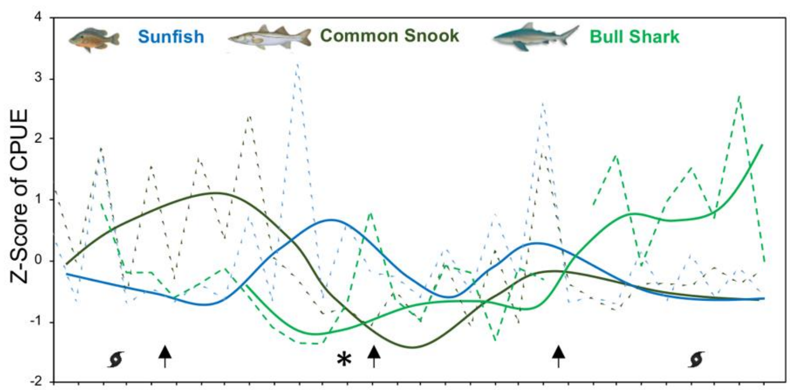

FIGURE 7. SEASONAL CATCH PER UNIT EFFORT (CPUE) of dominant large estuarine consumers (Common Snook and Bull Sharks) and their freshwater prey (*Lepomis* sunfishes) which pulse into SRS, with LOESS curves (a locally estimated regression approach) overlaid to illustrate long-term trends. Values are averaged across wet (Jun-Dec) and dry (Jan-May) seasons. Hurricanes (🌀), droughts (↑), and cold snaps (*) are determinants of both prey and consumer abundance.

Legacies: Florida Bay shows high rates of net primary productivity, but burial rates of autochthonous inorganic mineral carbon are 4-10× higher than burial rates of organic carbon (Howard et al. 2018). The pace of interior-ward movement of SRS mangroves over the last century is linked to the historic rate of sea-level rise (Yao & Liu 2017; Fig. 8), but decadal accretion rates (-1.5-4.7 mm y^{-1}) of TS/Ph scrub mangroves are much lower than the current local sea-level rise rate (9 mm y^{-1}). Sites with the highest accretion rates (SRS mouth) contained 5 cm of inorganic carbon from Hurricane Wilma (Oct. 2005) and 4 cm from Hurricane Irma (Sept. 2017) equivalent to 50 and 40 years of organic carbon accretion, respectively (Breithaupt et al. 2019). These mineral storm deposits contained double the P content of mangrove peat soils (Castañeda-Moya et al. 2020), which is gradually sequestered into plant biomass and leached out of soils and pulsed upstream with tides (Davis et al. 2019; Kominoski et al. 2020). This P subsidy induced rapid (<5 years) forest recovery in areas where canopy defoliation was >90% (Danielson et al. 2017). As leaf turnover recovered over time, foliar residence time decreased to pre-Wilma values – a relationship that could be used as a proxy of canopy recovery and resilience in studies across mangrove ecotypes and coastal settings (Rivera-Monroy et al. 2019b).

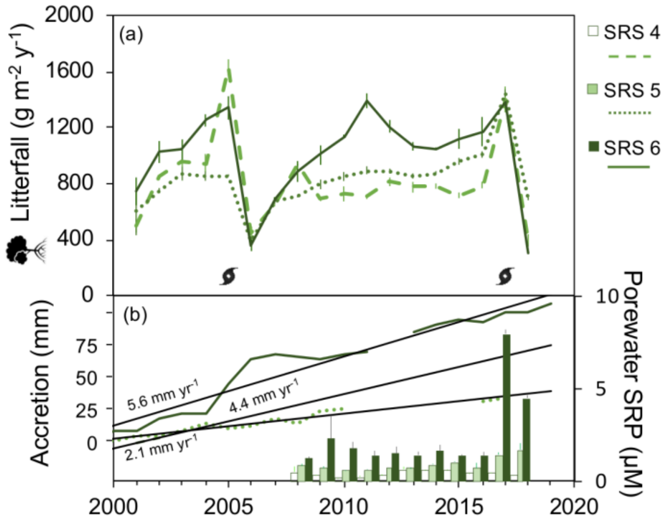

FIGURE 8. MANGROVE PRODUCTION AND ACCRETION REFLECT STORM-SURGE RESOURCE PULSES FROM HURRICANES (🌀) WILMA (2005) AND IRMA (2017). (a) Annual mean litterfall (with standard errors) show defoliation and rapid regrowth, fueled by pulses of (b) porewater soluble reactive phosphorus (SRP - *bars with standard errors*) from P-rich sediments delivered from the Gulf of Mexico that also increased accretion rates (black *lines with slope of linear regression*).

Scenarios: We modeled ecosystem responses to sea-level rise (0.5 m) interacting with climate change (+1.5 ºC, +7% evapotranspiration, and ±10% rainfall), predicting that mangrove forests would migrate up to 15 km inland and freshwater habitat area would decrease by more than 25% by 2060 (Flower et al. 2017a). Increased rainfall provided significant benefits to the salinity regime (Fig. 9), providing a more gradual adjustment for at-risk flora and fauna – a benefit that, when coupled with freshwater restoration, increase the capacity for mangrove establishment and forest development to the interior (Flower et al. 2019). This work has allowed key stakeholders to recognize that coastal ecosystems contain large stores of carbon in vegetation and soils of significant value ($2-3.4 billion in social cost of mangrove wetlands; Jerath et al. 2016; Wetzel et al. 2017) that are at risk of being released to the atmosphere with excessive salinity, extreme drought, and nutrient enrichment (Fourqurean et al. 2012a,b; Breithaupt et al. 2014; Suárez-Abelanda et al. 2014).

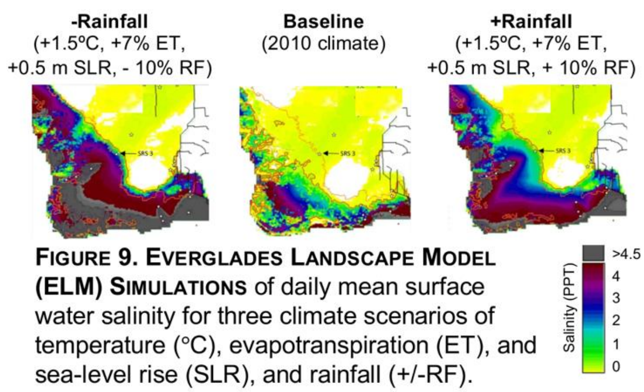

FIGURE 9. EVERGLADES LANDSCAPE MODEL (ELM) SIMULATIONS of daily mean surface water salinity for three climate scenarios of temperature (°C), evapotranspiration (ET), and sea-level rise (SLR), and rainfall (+/-RF).

Key outcomes or Other achievements

During FCE III (2013-2018), we produced 348 works that acknowledge FCE, consisting of 272 journal articles, 1 book, 25 book chapters, 5 thematic issues of journals, 32 dissertations, and 18 theses. We published 7 papers in broad, high-impact journals (impact factor >10, e.g., Science, Nature, PNAS). Extramural funding leveraged for FCE research averaged 7 times the NSF base. We developed and continued 176 data packages that are searchable by LTER core area, fully compatible with the LTER Network Information System, and discoverable on the LTER Environmental Data Initiative (EDI) data portal and DataOne (see Data Management Plan for details). Major outcomes include:

Water: By coupling long-term hydrologic and social science studies, FCE research has quantified the rates and pathways of accelerated saltwater intrusion in coastal wetlands, while also identifying successful pathways toward resolving restoration conflicts and achieving optimal scenarios for water quantity, flow, and quality. Studies of the drivers of climate variability continue to underscore the importance of global-atmospheric interactions beyond the FCE boundaries.

Ecosystem Dynamics: Saltwater intrusion is increasing salinity and P in the marsh-mangrove ecotone, reducing sawgrass production but increasing connectivity of marine and freshwater food webs. Freshwater marshes exposed to salt can experience abrupt losses of vegetation and stored carbon – a pattern that may be reversed with freshwater restoration. The shifting balance of fresh and marine water supplies drives spatiotemporal variability in net ecosystem carbon balance along a freshwater-marine gradient through its influence on P, salinity, and duration of inundation (Troxler et al. 2013). Variability in the magnitude of fresh and marine water delivery along the FCE gradients drives dynamics of water biogeochemistry and organic matter (Davis et al. 2018; Kominoski et al. 2020). Our studies of primary producers have quantified how spatiotemporal variability in marine and freshwater supplies control patterns and trends in composition, distribution, biomass, and net primary productivity of coastal vegetation (Herbert & Fourqurean 2009; Troxler et al. 2014; Danielson et al. 2017; Marazzi et al. 2019). Our research on consumers has shown how salinity, P availability, and inundation change the role of detritus in food webs, the strength of trophic interactions, and the spatial scale of consumer-mediated habitat linkages (Fig. 10).

Legacies: The FCE paired transect design has enabled robust documentation of how disturbance legacies determine ecosystem trajectories and suggest that vulnerability to saltwater intrusion in coastal wetlands may be reduced by freshwater and marine pulses. Our paleoecological research shows that tidal and storm-driven marine P subsidies have fueled the long-term inland migration of mangroves, offsetting negative effects of saltwater intrusion on organic carbon burial over the last century (Breithaupt et al. 2012).

Scenarios: Taking advantage of episodic "natural" disturbances and experiments, we are parameterizing models to evaluate the limits of primary producers to the stressor of saltwater intrusion, constructing new models for relating drivers to responses, evaluating ecosystem resilience and recovery trajectories to disturbances, and informing scenarios that are helping us to project the future of the FCE.

In summary, the Everglades is a complex social-ecological system with emergent properties resulting from a long history of conflicts over water use, reduced freshwater inflows, and increased sea-level rise and storms (Gaiser et al. 2015b; Childers et al. 2019). Saltwater intrusion has caused abrupt release of CO_2 from marshes to the atmosphere via collapse of peat soils. In the absence of sufficient fresh water, catastrophic losses of soil elevation will hinder the landward migration of mangroves by reducing seedling establishment in deeper, sulfide-rich water (Chambers et al. 2016; Troxler et al. 2019). A consequence of soil elevation loss is reduced social-ecological resilience to sea-level rise and decreased ecosystem service values. Freshwater restoration now provides a manipulation at an unprecedented scale to determine whether the return of freshwater pulses interacts with increasing marine resource pulsing to reverse these trends and preserve core ecological features of coastal wetland ecosystems that enhance their ability to persist as sea-level rise accelerates.

Opportunities for training and professional development

FCE has a very active education and outreach program that promotes the professional development of the majority-minority populations of FIU and our K-12 schools. Our Schoolyard program focuses primarily on Miami-Dade County Public Schools by engaging a diverse population of pre-professional-service teachers in Science, Technology, Engineering, and Math (STEM) disciplines, and our community partners to increase Everglades literacy. Since 2013, our scientists have mentored 179 K-12 students and 4 teachers in our Research Experience Program. Teachers generate Data Nuggets available online and in use within and outside the State of Florida. We provided professional development to 114 teachers from 70 schools, delivered 73 K-12 presentations, and high school students have presented 17 posters receiving 42 awards (26 local, 12 state, 1 national, and 3 international). Our children's book has been placed in 488 K-8 schools and 50 public libraries, and our Predator Tracker and Alligators of Shark River apps are used globally. Since 2013, 247 undergraduates from 26 universities in 9 U.S. states and 3 other countries have worked with FCE researchers. This program was formalized in 2019 through an NSF Research Experiences for Undergraduates (REU) site grant at FIU focused on coastal ecosystems. FCE graduate students have always been very active participants in the FCE and LTER Network (see Romolini et al. 2013). They co-produce science as a result of mentoring by both academic and agency scientists and are engaged in all aspects of the FCE program, including writing proposals and leading authorship of 53% of our publications, mentoring undergraduate and high school students, and engaging in public participatory science projects.

Communicating results to communities of interest

Since 2013, 92 FCE researchers have participated in over 700 media events that include 32 local, national and international news agencies. Our findings have been shared with the public through Miami's Frost Science Museum, the Ft. Lauderdale Museum of Discovery and Science, coverage in 51 television/radio segments (including episodes of Changing Sea, Shark Week, and Ocean Mysteries), our Diatom of the Month blog that is now managed internationally, and over 337 outreach events and more than 189 public presentations. Our collaboration with the Tropical Botanic Artists has led to 24 art exhibitions with over 80 paintings displayed at 14 venues across South Florida and three national exhibits. During the COP21 Paris Talks in 2015, FCE Artist in Residence, Xavier Cortada launched the first annual exhibit at Art Basel Miami consisting of discussions addressing sea-level rise, global climate change, and biodiversity loss and featuring works created at FCE, H.J. Andrews, and Hubbard Brook LTERs. FCE scientists also express data through music with three compositions available on YouTube.

Products

Publications

Books

Childers, D.L., E.E. Gaiser, and L.A. Ogden. 2019. The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

Book Chapters

Childers, D.L., E.E. Gaiser, and L.A. Ogden. 2019. Chapter 1, in Childers, D.L., E.E. Gaiser and L.A. Ogden (eds.) The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

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Davis, S.E., E. Castañeda-Moya, R. Boucek, R.M. Chambers, L. Collado-Vides, H.C. Fitz, J.D. Fuentes, E.E. Gaiser, M.R. Heithaus, J.S. Rehage, V.H. Rivera-Monroy, J.P. Sah, F.H. Sklar, and T. Troxler. 2019. Chapter 7: Exogenous Drivers - What has Disturbance Taught Us?, in Childers, D.L., E.E. Gaiser and L.A. Ogden (eds.) The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

Gaiser, E.E., L.A. Ogden, D.L. Childers, and C. Hopkinson. 2019. Chapter 9: Re-Imagining Ecology through an Everglades Lens, in Childers, D.L., E.E. Gaiser and L.A. Ogden (eds.) The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

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Ogden, L.A., J.C. Trexler, D.L. Childers, E.E. Gaiser, and K.Z.S. Schwartz. 2019. Chapter 2: The Everglades as Icon, in Childers, D.L., E.E. Gaiser and L.A. Ogden (eds.) The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

Price, R.M., K.Z.S. Schwartz, W.T. Anderson, R. Boucek, H.O. Briceno, M.I. Cook, H.C. Fitz, M.R. Heithaus, J. Onsted, J.S. Rehage, V.H. Rivera-Monroy, R. Roy Chowdhury, and A.K. Saha. 2019. Chapter 3: Water, Sustainability, and Survival, in Childers, D.L., E.E. Gaiser and L.A. Ogden (eds.) The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

Rivera-Monroy, V.H., J. Cattelino, J. Wozniak, K.Z.S. Schwartz, G.B. Noe, E. Castañeda-Moya, G. Koch, J.N. Boyer, and S.E. Davis. 2019. Chapter 5: The Life of P: A Biogeochemical and Sociopolitical Challenge in the Everglades, in Childers, D.L., E.E. Gaiser and L.A. Ogden (eds.) The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Oxford University Press.

Sklar, F.H., J.F. Meeder, T. Troxler, T.W. Dreschel, S.E. Davis, and P.L. Ruiz. 2019. Chapter 16 - The Everglades: At the Forefront of Transition, pp. 277-292 in Wolanski, E., J.W. Day, M. Elliott and R. Ramachandran (eds.) Coasts and Estuaries: The Future. Elsevier.

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Troxler, T., G. Starr, J.N. Boyer, J.D. Fuentes, R. Jaffe, S.L. Malone, J.G. Barr, S.E. Davis, L. Collado-Vides, J.L. Breithaupt, A.K. Saha, R.M. Chambers, C.J. Madden, J.M. Smoak, J.W. Fourqurean, G. Koch, J. Kominoski, L.J. Scinto, S. Oberbauer, V.H. Rivera-Monroy, E. Castañeda-Moya, N.O. Schulte, S.P. Charles, J.H. Richards, D.T. Rudnick, and K.R.T. Whelan. 2019. Chapter 6: Carbon Cycles in the Florida Coastal Everglades Social-Ecological System across Scales, in Childers, D.L.,

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Journal Articles

All publications referenced in this report are available in the References section as well as the NSF publication repository.

Dissertations and Theses

Master's Theses

Eggenberger, Cody. 2019. Coupling telemetry and stable isotope techniques to unravel movement: Snook habitat use across variable nutrient environments. Master's thesis, Florida International University.

Massa, Eric. 2019. Effects of phosphorous on benthic diatom assemblage network structure. Master's thesis, Florida International University.

Ontkos, Alex. 2018. Habitat use of three abundant predatory fish species in the freshwater marshes of the Florida Everglades. Master's thesis, Florida International University.

Tasci, Yasemin. 2019. Modeled affinity constants for phosphorus adsorption and desorption due to saltwater intrusion. Master's thesis, University of South Florida.

Websites

Florida Coastal Everglades LTER Program Website

https://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 176 datasets which are archived in the Environmental Data Initiative's (EDI) data repository (https://portal.edirepository.org). Datasets are publicly available on FCE LTER's website (https://fce-lter.fiu.edu/data/core/), too. Datasets include climate, consumer, primary production, water quality, soils, and microbial data as well as other types of data. A table of FCE LTER datasets in the EDI Data Repository is included in the Appendix of this report.

Participants & Other Collaborating Organizations

Group photo from the 2019 FCE LTER All Scientists Meeting

Participants

Name	Most Senior Project Role
Gaiser, Evelyn	PD/PI
Heithaus, Michael	Co PD/PI
Jaffe, Rudolf	Co PD/PI
Kominoski, John	Co PD/PI
Price, Rene	Co PD/PI
Burgman, Robert	Faculty
Castaneda, Edward	Faculty
Flower, Hilary	Faculty
Fourqurean, James	Faculty
Grove, Kevin	Faculty
Kiszka, Jeremy	Faculty
Malone, Sparkle	Faculty

Name	Most Senior Project Role
Martens-Habbena, Willm	Faculty
Nelson, James	Faculty
Oehm, Nick	Faculty
Rehage, Jennifer	Faculty
Stingl, Ulrich	Faculty
Trexler, Joel	Faculty
Troxler, Tiffany	Faculty
Wdowinski, Shimon	Faculty
Dessu, Shimelis	Postdoctoral
Duran, Alain	Postdoctoral
Laas, Peeter	Postdoctoral
Liao, Heming	Postdoctoral
Mercado Molina, Alex	Postdoctoral
Rezek, Ryan	Postdoctoral
Santos, Rolando	Postdoctoral
Van Dam, Bryce	Postdoctoral
Wakefield, Stephanie	Postdoctoral
Zeller, Mary	Postdoctoral
Castellanos, Emily	Other Professional
Rugge, Michael	Other Professional
Bond, Charles	Technician
Burgos, Sofia	Technician
Chakrabarti, Seemanti	Technician
Cordoba, Nicole	Technician
Gastrich, Kirk	Technician
Stumpf, Sandro	Technician
Tobias, Franco	Technician
Travieso, Rafael	Technician
Viadero, Natasha	Technician
Wilson, Sara	Technician
Fitz, Carl	Staff Scientist (doctoral level)

Name	Most Senior Project Role
Vanderbilt, Kristin	Staff Scientist (doctoral level)
Bernardo, Melissa	Graduate Student
Bonnema, Erica	Graduate Student
Briggs, Kristin	Graduate Student
Castillo, Nicholas	Graduate Student
Chavez, Selena	Graduate Student
Eggenberger, Cody	Graduate Student
Emery, Meredith	Graduate Student
Flood, Peter	Graduate Student
Garcia, Laura	Graduate Student
James, Ryan	Graduate Student
Lopes, Christian	Graduate Student
Massa, Eric	Graduate Student
Massie, Jordan	Graduate Student
Ontkos, Alex	Graduate Student
Paz, Valeria	Graduate Student
Rodemann, Jonathan	Graduate Student
Sanchez, Jessica	Graduate Student
Shannon, Thomas	Graduate Student
Smith, Matt	Graduate Student
Stansbury, Kaitlin	Graduate Student
Strickland, Nicole	Graduate Student
Strickland, Bradley	Graduate Student
Sullivan, Kristy	Graduate Student
Ugarelli, Kelly	Graduate Student
Zhang, Boya	Graduate Student
Gonzalez, Jeffrey	Undergraduate Student
Horminga, Samantha	Undergraduate Student
Infante, Maria	Undergraduate Student
Jonas, Ariana	Undergraduate Student
Samara, Yamilla	Undergraduate Student

Name	Most Senior Project Role
Schinbeckler, Rachel	Undergraduate Student
Sisco, Sarah	Undergraduate Student
Contreras, Andreina	Research Experience for Undergraduates (REU) Participant
Linenfelser, Joshua	Research Experience for Undergraduates (REU) Participant

Partner Organizations

Name	Location
Clark University	Worcester, Massachusetts
College of William & Mary	Williamsburg, Virginia
Dartmouth College	Hanover, New Hampshire
Eckerd College	St. Petersburg, Florida
EcoLandMod, Inc	Fort Pierce, Florida
Encounters in Excellence, Inc.	Miami, Florida
Everglades Foundation	Palmetto Bay, Florida
Everglades National Park	Homestead, 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
NASA Goddard Space Flight Center	Greenbelt, Maryland
National Audubon Society - Tavernier Science Center	Tavernier, Florida
National Park Service - South Florida/Caribbean Network Inventory	Palmetto Bay, Florida
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
Tulane University	New Orleans, Louisiana
U.S. Geological Survey	Reston, Virginia

Name	**Location**
University of Alabama	Tuscaloosa, Alabama
University of California, Los Angeles	Los Angeles, California
University of Central Florida	Orlando, Florida
University of Florida	Gainesville, Florida
University of Hawaii at Manoa	Honolulu, Hawaii
University of Louisiana at Lafayette	Lafayette, Louisiana
University of South Carolina	Columbia, South Carolina
University of South Florida	Tampa, Florida
University of South Florida St. Petersburg	St. Petersburg, Florida

Impacts

Impact on the development of the principal disciplines

Collaborations within and outside of FCE generate synthesis products, including our contribution to the Oxford University Press LTER book series: “The Coastal Everglades: The Dynamics of Social-Ecological Transformations in the South Florida Landscape” (Childers et al. 2019), chapters in other synthesis books (DeLaune et al. 2013; Entry et al. 2015; Batzer & Boix 2016; Willig & Walker 2016), and cross-site syntheses of ecosystem development and disturbance theory (Kominoski et al. 2018; Gaiser et al. 2020). We continue to mobilize cross-LTER site comparisons, including studies of global black carbon distribution (Khan et al. 2017), sea-level rise vulnerability (Tully et al. 2019), roles of apex predator movements (Rosenblatt et al. 2013; Boucek & Morley 2019), changes in seagrass carbon stocks (Christiaen et al. 2014; Arias-Ortiz et al. 2017), global mangrove biogeochemistry and productivity across geomorphological settings (Twilley et al. 2019; Ribeiro et al. 2019), and drivers of mangrove resilience (Farfán et al. 2014; Roy Chowdhury et al. 2017). Our international collaborations remain a strong pillar for synthesis and include comparative works on subtropical wetlands (Gaiser et al. 2015a; Marazzi et al. 2017; Rivera-Monroy et al. 2017), the role of wetlands in the global carbon cycle (Barr et al. 2014), and global information exchange (Vanderbilt & Gaiser 2017; Vanderbilt et al. 2017). FCE researchers are active in LTER Network leadership including serving on 7 committees (contributing heavily to Information Management– see Wheeler et al. 2017).

Impact on other disciplines

The FCE has built on US LTER Network collaborations to expand understanding of social-ecological resilience to extremes events through the Urban Resilience to Extremes Sustainability Research Network. By engaging municipal leaders, private industry, and public stakeholders with ecologists, social scientists, architects, and engineers, we are informing the technological, ecological, and social context for resilient solutions. The FCE has also engaged journalists in development of media to improve public literacy and advocacy for resilient adaptation to sea-level rise.

Impact on the development of human resources

FCE is based in Miami at FIU, the nation’s largest majority-minority-serving (64% Hispanic; n = 37,272) and the fourth largest U.S. university (n = 58,063). FCE excels at serving this community by introducing students to ecological science and the effects of human activities in the Earth’s biosphere. We focus on recruitment of underrepresented groups into our research experience programs, resulting in a majority of FCE undergraduate students identifying as underrepresented groups (49% Hispanic; 4% non-Hispanic Black, and 65% female). Similarly, a total of 66% of the 179 students and 165 teachers working with FCE scientists are from underrepresented groups (60% Hispanic).

Impact on physical resources that form infrastructure

The FCE LTER program supports a biophysical research platform at 14 locations in Everglades National Park used by 88 collaborators, 83 graduate students, and 17 staff from 27 academic institutions and agencies. The platform includes ISCO autosampling devices and dataloggers (all sites), field laptops, weather stations, flow meters, water level recorders, acoustic animal tracking devices, five eddy covariance towers, and associated solar power, power storage, and data retrieval/storage systems. The FCE LTER program has also enabled access to Everglades National Park resources, including the mesocosm facility used for outdoor salinity, inundation and phosphorus addition experiments. The program also enables data storage on three virtual Linux servers, three virtual Windows servers, and two desktop workstations.

Impact on institutional resources that form infrastructure

The FCE LTER leverages 57 additional projects funded by other sources, with a ratio of total leverage to NSF base funding of 7:1. More than 95% of our leveraged funding comes from NSF-funded projects, the U.S. Department of Interior (National Park Service), the U.S. Army Corps of Engineers, the South Florida Water Management District, the National Aeronautics and Space Administration, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and Florida Sea Grant. Some of these projects support additional research at FCE LTER sites while others help us contextualize our findings spatially at additional sites we call 'satellite sites.'

Impact on information resources that form infrastructure

The mission of the FCE LTER Information Management System (FCE IMS) is to provide easily accessible, high quality, well-documented datasets to support research, outreach, and education at the FCE LTER and in the broader community. FCE currently has 176 datasets archived in the Environmental Data Initiative's (EDI) data repository, forty-four of which are ongoing and contain ten or more years of data. During FCEIV, the FCE IM Team (Kristin Vanderbilt, Information Manager (IM); Mike Rugge, Program Manager & GIS/Programming Specialist) updated these datasets, responded to changing LTER Network recommendations and scientist needs, and made improvements to the FCE IMS to facilitate efficient management and discovery of FCE LTER information products.

FCE IMS Responds to New LTER Network Recommendations and Researcher Needs
FCE continues to update existing long-term data sets within two years of data collection per the LTER Data Access Policy and NSF Data Sharing Policy. New long-term, experimental, or short-term datasets supported by the FCE grant are archived in the same timely fashion. Dataset contributors include FCE scientists, government or NGO researchers, and graduate students. Most FCE datasets are publicly accessible as soon as they are archived, and as of 2018 these datasets are released under the CC-BY 2.0 license as recommended by the LTER Executive Committee. The main exception to this policy regards graduate student data, which can be embargoed for up to five years while the student has exclusive use of the data.

A core LTER IM activity is generating Ecological Metadata Language (EML) to submit with data to the Environmental Data Initiative repository. During FCEIV, a second method for generating Ecological Metadata Language (EML) was adopted at FCE to address new needs. Researchers have traditionally submitted metadata to the IM using a Microsoft Excel template which is then converted into EML 2.1 using a perl program (XLSX2EML.pl) maintained by M. Rugge. This approach works well for datasets with a single data table, but it cannot accommodate data packages that include multiple entities (such as a series of related data tables, data processing code, or protocols). Such data packages are becoming more common as scientists embrace principles of open science and reproducibility. To satisfy researchers with multi-entity data packages to archive, FCE has adopted the EMLAssemblyline R package written by EDI (Smith 2020). The EMLAssemblyline is an R package developed by EDI for generating EML that is itself based on the R EML package (Boettiger & Jones 2020). Both methods, FCE's MS Excel template and EMLAssemblyline, produce EML 2.1 that complies with the *EML Best Practices Recommendations* (EDI 2017). Both will also soon be updated to yield EML 2.2.

Making FCE Information Products Easier to Find and Manage
New FCE Website: FCE LTER met a major IM milestone described in the 2018 proposal when a new FCE website was launched in late 2019. The old FCE website was hand-coded and laborious to maintain. The new website takes advantage of Cascade, the content management system used by FIU, to make

website updates easier. While the Project Manager did most website updates himself on the old website, migrating the website into Cascade enables other FCE staff to have permissions to sections of the website in order to update their own content. The information on the new website has been refreshed and reorganized for ease of navigation with input from PIs, staff, and students. Cascade facilitates integration with social media, newsfeeds, and offers website search functionality. The new website significantly improves on the old one by being mobile device friendly and resolving to a size appropriate to the device on which it is being viewed.

Unfortunately, Cascade does not support dynamic web pages, such as the popular custom query interfaces to data, bibliography, and personnel databases found on the old FCE website. M. Rugge therefore used the Foundation Framework, a responsive front-end software framework for web design, to produce a template mimicking the Cascade FCE website. He re-wrote all the query scripts on the old website in PHP in order to replace near-obsolete Embperl scripts. He preserved the many options from the old website for filtering datasets, publications, personnel and photographs for ease of discovery, while offering the new look and feel of the Cascade website. The dynamic part of the FCE website is served via an Apache webserver that is managed by the Project Manager on a Linux virtual machine, while the Cascade part of the website is served by FIU Communications. This new, hybrid FCE website has improved the experience of web visitors seeking data or information about the FCE LTER. As an added bonus, the website also has the look and feel of other websites managed by FIU's College of Arts and Sciences (CASE).

New FCE Data Catalog: FCE has updated its approach to generating and querying the FCE website's Data Catalog. The new method takes advantage of RESTful web services provided by EDI's PASTA+ data repository software. Previously, the FCE IM had submitted EML documents to the EDI Data Repository and then captured a subset of that metadata in a local Oracle database to drive the FCE Data Catalog. Maintaining two copies of the metadata, one in the EDI repository and the other local, was inefficient. With the new system, the IM submits EML to the EDI Data Repository as before, but then the EDI Repository becomes the source of metadata to populate the FCE Data Catalog. Further, PASTA+'s Solr repository can be queried from the FCE website to discover FCE datasets based on metadata stored in keywords, author, and title EML fields. This new approach for generating and querying the FCE Data Catalog expedites updates of FCE datasets.

The new FCE Data Catalog improves over the old catalog because EDI's web services allow the retrieval and display of the DOI associated with each dataset citation on the new FCE website. Having complete dataset citations on the FCE website will make it easier for FCE scientists to cite the datasets they use. As more FCE scientists include dataset citations in the papers they author, the better FCE LTER will be able to track data usage in the future.

Impact on technology transfer

The FCE LTER Information Management System (IMS) provides publicly accessible data not only for this project but also for the additional 57 leveraged projects, either through the Environmental Data Initiative or through our "Related Data" link on our FCE data portal. The FCE IMS team trains researchers and students, as they design and conduct their research projects, about data collection, documentation and organization best practices. The information manager presentations to the FCE LTER Graduate Student Association so that the students understand how to submit data and metadata, as well as their obligation to do so. The information manager is also available to provide input on data management plans for any proposal written by FCE researchers. Recently, she co-organized sessions at the 2018 LTER All Scientist Meeting and 2019 International LTER (ILTER) Open Science Meeting that included invited ontology experts and discussion of future semantic developments for the US LTER. Long involved with the ILTER Network, she was co-editor of an Ecosphere special issue about the ILTER (Vanderbilt & Gaiser 2017) and has contributed to ILTER research (Dick et al. 2018). She has also co-authored several publications on information management (Gries et al. 2018, Vanderbilt & Blankman 2017, Vanderbilt et al. 2017, Wheeler et al. 2017). She is presently the Associate Editor for Data Science for the journal Ecological Informatics. In her role with EDI, she trains new LTER IMs and is the liaison between EDI and the Information Management Executive Committee. FCE Project Manager M. Rugge has developed tools that others in the LTER Network and at EDI have used. He created an XSLT stylesheet that renders EML metadata in a human readable format. It is used on the FCE website and EDI has implemented it in the EDI Data Portal. He wrote the FCE’s Perl XLXS2EML program for generating EML metadata from an MS Excel metadata template. He updates this program when necessary to comply with new EML versions and recommendations. This tool is openly available on the FCE website and via the LTER Network’s github repository.

Impact on society beyond science and technology

FCE is dedicated to the continued co-production of knowledge as a direct conduit of FCE findings to resource managers, decision-makers, and other stakeholders (Gaiser et al. 2019). In collaboration with the Everglades Foundation, we have provided over 138 briefings and 72 tours to local, state, national and international lawmakers, non-governmental organizations, and community partners. FCE scientists have testified to the U.S. House of Representatives and the European Union Parliament, counseled the Intergovernmental Panel on Climate Change and the National Academy of Science Independent Review of Everglades Research, and discussed the relevance of findings to resource decisions with former President Barack Obama, former Senator Robert Graham, the Florida Congressional Delegation and their staffs, and former White House Science Advisor Dr. John Holdren. We also engage with decision makers to translate science into restoration policy (i.e., Wetzel et al. 2017).

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Appendix: List of FCE LTER Data Sets

The FCE LTER program has contributed 176 datasets to the EDI Data Repository. The Citation column contains dataset title, publication date, creators, and Digital Object Identifier (DOI). Temporal coverage of the dataset and relevant LTER Core Research Areas (PP = primary production, PS = population dynamics and trophic structure, OM = organic matter accumulation or utilization, IM = inorganic inputs and movements of nutrients through the ecosystem, DP = patterns and frequency of disturbances, LU = land use and land cover change, HE = human-environment interactions) are also shown.

Citation	Temporal Coverage	Core Areas
National Climatic Data Center (NCDC) NOAA. 2020. NOAA Daily Surface Meteorologic Data at NCDC Everglades Station (ID-082850)(FCE LTER), South Florida from February 1924 to 2017 ver 17. Environmental Data Initiative. https://doi.org/10.6073/pasta/705982cd2283522fd897664bbd65aef2.	1924-02-01 - 2017-12-31	DP
National Climatic Data Center (NCDC) NOAA. 2020. NOAA Daily Surface Meteorologic Data at NCDC Flamingo Ranger Station (ID-083020) (FCE), South Florida from January 1951 to Present ver 15. Environmental Data Initiative. https://doi.org/10.6073/pasta/7fed0a47b285b6be06030fa4108e56aa.	1951-01-01 - 2019-11-30	DP
National Climatic Data Center (NCDC) NOAA. 2020. NOAA Daily Surface Meteorologic Data at NCDC Miami International Airport Station (ID-085663)(FCE LTER), South Florida from January 1948 to Present ver 18. Environmental Data Initiative. https://doi.org/10.6073/pasta/c96d8d437d62bff1ff7cc61bc7dad09d.	1948-01-01 - 2020-02-18	DP
National Climatic Data Center (NCDC) NOAA. 2020. NOAA Daily Surface Meteorologic Data at NCDC Royal Palm Ranger Station (ID-087760)(FCE LTER), South Florida from May 1949 to Present ver 14. Environmental Data Initiative. https://doi.org/10.6073/pasta/19d4d4031f389ea62faa65c0f0f7342f.	1949-05-01 - 2020-02-05	DP
National Climatic Data Center (NCDC) NOAA. 2013. NOAA Daily Surface Meteorologic Data at NCDC Tavernier Station (ID-088841)(FCE), South Florida from June 1936 to May 2009 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/dd507279ead6dab518823bdcafec8071.	1936-06-01 - 2009-05-31	DP
Briceno, H. 2018. Surface Water Quality Monitoring Data collected in South Florida Coastal Waters (FCE) from June 1989 to Present ver 8. Environmental Data Initiative. https://doi.org/10.6073/pasta/15a68e643d4c359a8c62efe1099b508f.	1989-06-27 - 2017-10-26	IM
Briceno, H. 2020. Microbial Sampling from Shark River Slough and Taylor Slough, Everglades National Park, South Florida (FCE LTER) from January 2001 to Present ver 8. Environmental Data Initiative. https://doi.org/10.6073/pasta/73e3a958c9d7b1eeaf55fa41b4815b6d.	2001-01-01 - 2018-05-01	PP
Heithaus, M., P. Matich, and A. Rosenblatt. 2019. Large consumer isotope values, Shark River Slough, Everglades National Park (FCE LTER), May 2005 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/0fb149ced55edb32c282deb234caab56.	2005-05-11 - 2018-07-18	PS

Citation	Temporal Coverage	Core Areas
Heithaus, M., P. Matich, and A. Rosenblatt. 2019. Temperatures,salinities, and dissolved oxygen levels in the Shark River Slough, Everglades National Park (FCE LTER) , from May 2005 to May 2014 ver 7. Environmental Data Initiative. https://doi.org/10.6073/pasta/79e8ef59e5b93b2ff59321e0a93118ae.	2005-05-11 - 2014-05-18	IM
Center for Operational Oceanographic Products and Services (CO-OPS). 2019. NOAA Monthly Mean Sea Level Summary Data for the Key West, Florida, Water Level Station (FCE) (NOAA/NOS Co-OPS ID 8724580) from 01-Jan-1913 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/566f715b925fdf8d9d96c17d7f7c992f.	1913-01-01 - 2019-05-01	DP
Gaiser, E. and L. Scinto. 2014. Biogeochemical data collected from Northeast Shark Slough, Everglades National Park (FCE) from September 2006 to Present ver 7. Environmental Data Initiative. https://doi.org/10.6073/pasta/ee08228027fd32182996ce39cfde7e22.	2006-09-11 - 2008-09-18	OM
Anderson, W. 2013. Pond Cypress C-111 Basin, Everglades (FCE), South Florida Dendroisotope Data from 1970 to 2000 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/9e929b1d4c7ab02e3afd12652391f3a3.	1970-01-01 - 2000-12-31	PP
Trexler, J. 2016. Consumer Stocks: Fish, Vegetation, and other Non-physical Data from Everglades National Park (FCE), South Florida from February 2000 to April 2005 ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/354b4b6ac638551cc947a9e83e17805d.	2000-02-01 - 2005-04-01	PS
Trexler, J. 2016. Consumer Stocks: Physical Data from Everglades National Park (FCE), South Florida from February 1996 to April 2008 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/bc7e38fe4b8f5f976f1adb9e6395a8f8.	1996-02-07 - 2008-04-10	PS
Trexler, J. 2013. Consumer Stocks: Fish Biomass from Everglades National Park (FCE), South Florida from February 2000 to April 2005 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/b0e2ae3fb140447717b8dd9fdc3f4ac5.	2000-02-01 - 2005-04-01	PS
Trexler, J. 2013. Consumer Stocks: Fish Biomass from Everglades National Park (FCE), South Florida from February 1996 to March 2000 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/4c6f16f6825cc77204ef76f21e86b75a.	1996-02-01 - 2000-03-01	PS
Trexler, J. 2016. Consumer Stocks: Wet weights from Everglades National Park (FCE), South Florida from March 2003 to April 2008 ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/7ff817fdf10aac0ad84a64acd6ca1c95.	2003-03-31 - 2008-04-10	PS
Price, R. 2019. Rainfall Stable Isotopes collected at Florida International University-MMC (FCE LTER), Miami Florida, from October 2007 to Present ver 6. Environmental Data Initiative. https://doi.org/10.6073/pasta/adbd8a51eeb4b76bdbbf40a5db30d210.	2007-10-22 - 2019-05-07	IM
Boyer, J. and S. Dailey. 2013. Overnight Shark River Surveys from Shark River Slough, Everglades National Park (FCE), South Florida from October 2001 to March 2002 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/8b6e429fb37dbeaeaa22f962af725a42.	2001-10-01 - 2002-03-12	OM, IM

Citation	Temporal Coverage	Core Areas
Gaiser, E. and D. Childers. 2019. Water Quality Data (Porewater) from the Shark River Slough, Everglades National Park (FCE), from January 2001 to Present ver 11. Environmental Data Initiative. https://doi.org/10.6073/pasta/8000a852fabf49599a2da8055fd044f8.	2001-01-01 - 2019-01-01	IM
Gaiser, E. and D. Childers. 2019. Sawgrass Above and Below Ground Total Nitrogen and Total Carbon from the Shark River Slough, Everglades National Park (FCE), from September 2002 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/f183f7ef316e0ede14bf0b8d80c36a41.	2002-09-01 - 2019-03-01	PP
Gaiser, E. and D. Childers. 2019. Sawgrass Above and Below Ground Total Phosphorus from the Shark River Slough, Everglades National Park (FCE), from September 2002 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/26ae26f77da4f6ef86c0f5f781ce1b51.	2002-09-01 - 2019-03-01	IM
Gaiser, E. and D. Childers. 2019. Water Quality Data (Extensive) from the Shark River Slough, Everglades National Park (FCE), from October 2000 to Present ver 12. Environmental Data Initiative. https://doi.org/10.6073/pasta/3edb21eb7cd4f3681a17292e17700378.	2000-10-31 - 2018-12-31	IM
Gaiser, E. and D. Childers. 2019. Water Quality Data (Grab Samples) from the Shark River Slough, Everglades National Park (FCE), from May 2001 to Present ver 12. Environmental Data Initiative. https://doi.org/10.6073/pasta/8e8dc6a2b1a47c48ed4a951d2c4838fa.	2001-05-23 - 2018-12-07	IM
Troxler, T. 2019. Water Quality Data (Extensive) from the Taylor Slough, Everglades National Park (FCE LTER), from April 1996 to Present ver 11. Environmental Data Initiative. https://doi.org/10.6073/pasta/5e32731a74634d39ad19b3b6334307e2.	1996-04-07 - 2018-12-29	IM
Troxler, T. and D. Childers. 2019. Water Quality Data (Grab Samples) from the Taylor Slough, Everglades National Park (FCE), from May 2001 to Present ver 9. Environmental Data Initiative. https://doi.org/10.6073/pasta/d36baf5e9fa98559ced5901f4f6c38c5.	2001-05-30 - 2018-11-29	IM
Troxler, T. and D. Childers. 2019. Water Quality Data (Extensive) from the Taylor Slough, just outside Everglades National Park (FCE), from August 1998 to December 2006 ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/986977091d9ff18aac52ea1c4886e64b.	1998-08-19 - 2006-12-03	IM
Troxler, T. and D. Childers. 2015. Water Quality Data (Grab Samples) from the Taylor Slough, just outside Everglades National Park (FCE), for August 1998 to November 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/cd96927a753e84af3d9d2a07b02fa322.	1998-08-11 - 2006-11-15	IM
Troxler, T. and D. Childers. 2015. Water Quality Data (Porewater) from the Taylor Slough, just outside Everglades National Park (FCE), from August 1998 to October 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/1c4f9019e3dc4306b17a067f455430ad.	1998-08-01 - 2006-10-01	IM
Troxler, T. 2019. Water Quality Data (Extensive) from the Taylor Slough, Everglades National Park (FCE), South Florida from July 1999 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/c485d6cd55dfaed28ea8d9985816a63d.	1999-07-29 - 2018-12-31	IM

Citation	Temporal Coverage	Core Areas
Troxler, T. 2019. Water Quality Data (Grab Samples) from the Taylor Slough, Everglades National Park (FCE LTER), South Florida from September 1999 to Present ver 9. Environmental Data Initiative. https://doi.org/10.6073/pasta/a27bee7be093db941365ab224c339b09.	1999-09-13 - 2018-12-27	IM
Troxler, T. and D. Childers. 2015. Water Quality Data (Porewater) from the Taylor Slough, Everglades National Park (FCE), South Florida from September 1999 to December 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/d4e923e473d693cce2a896d82348e112.	1999-09-01 - 2006-12-01	IM
Troxler, T. and D. Childers. 2019. Sawgrass Above and Below Ground Total Phosphorus from the Taylor Slough, Everglades National Park (FCE LTER), South Florida for March 2002 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/50874ba7600fb71e1449cab6683e528c.	2002-03-01 - 2019-04-01	IM, PP
Troxler, T. and D. Childers. 2019. Sawgrass Above and Below Ground Total Nitrogen and Total Carbon from the Taylor Slough, Everglades National Park (FCE LTER), South Florida for March 2002 to Present ver 8. Environmental Data Initiative. https://doi.org/10.6073/pasta/1236a3a431500ef619f5ad277ebbd650.	2002-03-01 - 2019-05-01	IM, PP
Gaiser, E. and D. Childers. 2019. Sawgrass above ground biomass from the Shark River Slough, Everglades National Park (FCE), South Florida from November 2000 to Present ver 5. Environmental Data Initiative. https://doi.org/10.6073/pasta/2d4ef632fe268a3dda19cbb59214f0f1.	2000-11-01 - 2019-01-01	PP
Troxler, T. and D. Childers. 2015. Sawgrass above ground biomass from the Taylor Slough, just outside Everglades National Park (FCE), South Florida from October 1997 to December 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/e6640b978d38e54d88f2231ebc7db92d.	1997-10-01 - 2006-12-01	PP
Troxler, T. and D. Childers. 2020. Sawgrass above ground biomass from the Taylor Slough, Everglades National Park (FCE LTER), South Florida from August 1999 to Present ver 8. Environmental Data Initiative. https://doi.org/10.6073/pasta/75ba1cbaaf6bd2f600c63b26e4075820.	1999-08-01 - 2019-01-01	PP
Troxler, T. and D. Childers. 2015. Periphyton Net Primary Productivity and Respiration Rates from the Taylor Slough, just outside Everglades National Park (FCE), South Florida from December 1998 to December 2004 ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/6cd7783c4871eaf3527ab177deacd035.	1998-12-08 - 2004-12-15	PP
Troxler, T. and D. Childers. 2015. Soil Physical Data from the Shark River Slough, Everglades National Park (FCE), from November 2000 to January 2007 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/903576c777c0b7dc6bf87cd86f9fbc05.	2000-11-01 - 2007-01-01	IM
Troxler, T. and D. Childers. 2015. Soil Physical Data from the Taylor Slough, just outside Everglades National Park (FCE), from October 1998 to October 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/81e0fc75f420c948340b17715a4d78a5.	1998-10-01 - 2006-10-01	IM

Citation	Temporal Coverage	Core Areas
Troxler, T. and D. Childers. 2015. Soil Physical Data from the Taylor Slough, within Everglades National Park (FCE), from September 1999 to November 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/ac54452865f50d6ca972a4c196522e4f.	1999-09-01 - 2006-11-01	IM
Troxler, T. and D. Childers. 2015. Soil Characteristic and Nutrient Data from the Taylor Slough, within Everglades National Park (FCE), from March 2002 to April 2004 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/6040a745baed01378e215c8070d0126d.	2002-03-01 - 2004-04-01	IM
Price, R. and D. Childers. 2019. Precipitation from the Shark River Slough, Everglades National Park (FCE), South Florida from November 2000 to Present ver 12. Environmental Data Initiative. https://doi.org/10.6073/pasta/bce2f88a472a486704f26da265308da0.	2000-11-15 - 2018-12-31	DP
Troxler, T. and D. Childers. 2015. Water Levels from the Taylor Slough, Everglades National Park (FCE), South Florida from April 1996 to Present ver 6. Environmental Data Initiative. https://doi.org/10.6073/pasta/c6f897f83cf418015657eab9bcc4a6b4.	1996-04-07 - 2012-09-30	DP
Childers, D. and R. Price. 2019. Water Levels from the Shark River Slough, Everglades National Park (FCE), South Florida from October 2000 to Present ver 11. Environmental Data Initiative. https://doi.org/10.6073/pasta/8fdf7ed68053f30b92cc0ba91f2c7f4c.	2000-10-29 - 2018-12-31	DP
Troxler, T. and D. Childers. 2015. Precipitation from the Taylor Slough, just outside Everglades National Park (FCE), South Florida from August 2000 to December 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/6581a4898452afd4bc1f6665b44aeb4f.	2000-08-31 - 2006-12-19	DP
Troxler, T. and D. Childers. 2015. Water Levels from the Taylor Slough, just outside the Everglades National Park (FCE), South Florida from October 1997 to December 2006 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/2bb421d19f71704ed7476ca128bacb72.	1997-10-29 - 2006-12-31	DP
Troxler, T. and D. Childers. 2020. Precipitation from the Taylor Slough, Everglades National Park (FCE LTER), South Florida from July 2000 to Present ver 8. Environmental Data Initiative. https://doi.org/10.6073/pasta/7bd9a996223de17e9dc1eb48eb9a4a61.	2000-07-11 - 2018-12-31	DP
Troxler, T. and D. Childers. 2020. Water Levels from the Taylor Slough, Everglades National Park (FCE), South Florida from August 1999 to Present ver 9. Environmental Data Initiative. https://doi.org/10.6073/pasta/5d308344e7340f90723dd4cd2e61f61f.	1999-08-04 - 2018-12-31	DP
Jaffe, R. 2013. Monthly monitoring of Fluorescence, UV, Humic and non-Humic Carbon, Carbohydrates, and DOC for Shark River Slough, Taylor Slough, and Florida Bay, Everglades National Park (FCE) for January 2002 to Present ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/09d51db8543d43cb6f8f4e21f9630611.	2002-01-01 - 2004-08-01	OM
Jaffe, R. 2013. Examination of protein-like fluorophores in chromophoric dissolved organic matter (CDOM) in a wetland and coastal environment for the wet and dry seasons of the years 2002 and 2003 (FCE) ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/6d2e26bc8c8cd2322981d22a095ab968.	2002-03-01 - 2003-10-01	OM

Citation	Temporal Coverage	Core Areas
Jaffe, R. 2013. Monthly monitoring fluorescence data for Florida Bay, Ten Thousand Islands, and Whitewater Bay, in southwest coast of Everglades National Park (FCE) for February 2001 to December 2002 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/1bb7981116c89e6f414964b0a113b294.	2001-02-20 - 2002-12-17	OM
Jaffe, R. 2013. Quantitative and qualitative aspects of dissolved organic carbon leached from plant biomass in Taylor Slough, Shark River and Florida Bay (FCE) for samples collected in July 2004 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/22916d1d52d8a756020b8c7537b1bd87.	2004-07-22 - 2004-08-22	OM
Jaffe, R. 2013. Chemical characteristics of dissolved organic matter in an oligotrophic subtropical wetland/estuary ecosystem, Everglades National Park (FCE), South Florida from December 2001 to January 2002 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/76696c297746734756f827ec748eb20f.	2001-12-06 - 2002-01-28	OM
Jaffe, R. 2013. Physical and microbial processing of dissolved organic nitrogen (DON) (Salinity Experiment) along an oligotrophic marsh/mangrove/estuary ecotone (Taylor Slough and Florida Bay) for August 2003 in Everglades National Park (FCE), South Florida, USA ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/07272b339cff887abca38b8676789a56.	2003-08-04 - 2003-08-04	OM
Jaffe, R. 2013. Physical and microbial processing of dissolved organic nitrogen (DON) (Photodegradation Experiment) along an oligotrophic marsh/mangrove/estuary ecotone (Taylor Slough and Florida Bay) for August 2003 in Everglades National Park (FCE), South Florida, USA ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/da883a9edecd3c2a2be661531b16a780.	2003-08-04 - 2003-08-04	OM
Jaffe, R. 2013. Characterization of dissloved organic nitrogen in an oligotrophic subtropical coastal ecosystem (Taylor Slough and Shark River Slough) for December 2001 in Everglades National Park (FCE), South Florida, USA ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/cc9f23891b8bb977eaf5d7eb6f76005f.	2001-12-01 - 2001-12-01	OM
Gaiser, E. 2020. Periphyton Productivity from the Shark River Slough and Taylor Slough, Everglades National Park (FCE LTER), from October 2001 to Present ver 10. Environmental Data Initiative. https://doi.org/10.6073/pasta/7f39fae51cdbf902b73020bddeb8a3a0.	2001-10-30 - 2018-10-15	PP
Gaiser, E. 2014. Macrophyte count data collected from Northeast Shark Slough, Everglades National Park (FCE) from September 2006 to Present ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/effd9e98134913af21b670febebd6233.	2006-09-11 - 2008-09-17	PP, PS
Gaiser, E. 2014. Periphyton data collected from Northeast Shark Slough, Everglades National Park (FCE) from September 2006 to Present ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/03e9d26feab9b1eb156477057aa587b7.	2006-09-11 - 2008-09-17	PP, PS
Gaiser, E. 2020. Periphyton Accumulation Rates from Shark River Slough, Taylor Slough and Florida Bay, Everglades National Park (FCE LTER) from January 2001 to Present ver 11. Environmental Data Initiative. https://doi.org/10.6073/pasta/b5b4d8388cd2a415eeac9fc50a6743d8.	2001-01-06 - 2018-10-29	PP, PS

Citation	Temporal Coverage	Core Areas
Gaiser, E. 2020. Periphyton Biomass Accumulation from the Shark River and Taylor Sloughs, Everglades National Park (FCE), from January 2003 to Present ver 9. Environmental Data Initiative. https://doi.org/10.6073/pasta/edd4ed44a9b3428eb516b87e54e836cd.	2003-01-06 - 2018-10-15	PP
Collado-Vides, L. 2019. Macroalgae Production in Florida Bay (FCE), South Florida from May 2007 to Present ver 8. Environmental Data Initiative. https://doi.org/10.6073/pasta/e49e256a8b8d4842b68894721107ab16.	2007-05-07 - 2019-01-10	PP
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Citation	Temporal Coverage	Core Areas
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Price, R. 2013. Water flow velocity data, Shark River Slough (SRS) near Frog City, south of US 41, Everglades National Park (FCE) from October 2006 to Present ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/eb350d627455e94f0566adea2a7c65e8.	2006-10-09 - 2009-07-13	IM
Price, R. 2019. Water flow velocity data, Shark River Slough (SRS) near Gumbo Limbo Island, Everglades National Park (FCE) from October 2003 to Present ver 9. Environmental Data Initiative. https://doi.org/10.6073/pasta/bdc327b2f493cfd4f51e3820fcbe4a0c.	2003-09-10 - 2018-12-18	IM
Price, R. 2013. Water flow velocity data, Shark River Slough (SRS) near Satinleaf Island, Everglades National Park (FCE) from July 2003 to Present ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/c63a5d588755fa961bcd0dfc041e6d19.	2003-07-09 - 2005-12-16	IM
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Rosenblatt, A. 2013. Water Temperature measured at Shark River, Everglades National Park (FCE) from July 2007 to June 2011 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/a50dd41d188c25bc122deee65c2c73a9.	2007-07-01 - 2011-06-04	DP
Barr, J., J. Fuentes, and J. Zieman. 2013. Radiation measurements at Key Largo Ranger Station, South Florida (FCE) for July 2001 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/7682f3f1180f6048716b39531328a0b4.	2001-07-11 - 2001-07-20	DP

Citation	Temporal Coverage	Core Areas
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Barr, J., J. Fuentes, and J. Zieman. 2013. Mangrove leaf physiological response to local climate at Key Largo, Watson River Chickee, Taylor Slough, and Little Rabbit Key, South Florida (FCE) from July 2001 to August 2001 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/7390d5ffed6b06f0b881a8942a53e880.	2001-07-19 - 2001-08-13	PP
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Barr, J., J. Fuentes, and J. Zieman. 2013. Flux measurements from the SRS-6 Tower, Shark River Slough, Everglades National Park, South Florida (FCE) from January 2004 to August 2005 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/aec87311dc582fde9adf4a11a198e0aa.	2004-01-01 - 2005-08-31	PP
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Frankovich, T. 2013. Seagrass Epiphyte Accumulation: Epiphyte Loads on Thalassia testudinum in Rabbit Key Basin, Florida Bay (FCE) from March 2000 to April 2001 ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/5aadc198730a74b48ae27b6c1e11f3a8.	2000-03-27 - 2001-04-19	PP
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Citation	Temporal Coverage	Core Areas
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McIvor, C. 2015. Global Climate Change Impacts on the Vegetation and Fauna of Mangrove Forested Ecosystems in Florida (FCE): Nekton Mass from March 2000 to April 2004 ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/beb355c2f21efc3653f888709cf49637.	2000-03-10 - 2004-04-07	PS
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Heithaus, M. and P. Matich. 2019. Large shark catches (Drumline), water temperatures, salinities, dissolved oxygen levels, and stable isotope values in the Shark River Slough, Everglades National Park (FCE LTER) from May 2009 to May 2011 ver 6. Environmental Data Initiative. https://doi.org/10.6073/pasta/f8b5c0585e41ab48f07faf79c380043c.	2009-05-13 - 2011-05-14	PS

Citation	Temporal Coverage	Core Areas
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Onsted, J. 2015. FCE Redlands 1994 Land Use, Miami-Dade County, South Florida ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/1d696e0668ed238469adeaed24dd7bc1.	1994-01-01 - 1994-12-31	LU
Onsted, J. 2014. FCE Redlands 1998 Land Use, Miami-Dade County, South Florida ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/ab8e1dea7bc33019195125750934 60fc.	1998-01-01 - 1998-12-31	LU
Onsted, J. 2014. FCE Redlands 1998 Roads, Miami-Dade County, South Florida ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/f5831e56dffab52a99bbe8a1a2563b1d.	1998-01-01 - 1998-12-31	LU
Onsted, J. 2014. FCE Redlands 2006 Land Use, Miami-Dade County, South Florida ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/b7e35d8321a2db2138748b869993dacd.	2006-01-01 - 2006-12-31	LU
Onsted, J. 2014. FCE Redlands 2006 Roads, Miami-Dade County, South Florida ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/c1e2b4bdf4d5a1ad441e69b7417cdfab.	2006-01-01 - 2006-12-31	LU
Onsted, J. 2014. FCE Redlands Flood Zones, Miami-Dade County, South Florida ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/54138174a44f11a0000279a7e480b632.	-	LU
Onsted, J. 2014. FCE Redlands 2001 Land Use, Miami-Dade County, South Florida ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/b1c64a9c7c616829ace724de8d41785b.	2001-01-01 - 2001-12-31	LU
Onsted, J. 2014. FCE Redlands 2008 Slope Mosaic, Miami-Dade County, South Florida ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/f0c0fcaaca44b472112745262c372628.	2008-01-01 - 2008-01-01	LU
Onsted, J. 2014. FCE Redlands 2001 Zoning, Miami-Dade County, South Florida ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/e6e6563f64ae6d6aa4cb07b294f1ec95.	2001-01-01 - 2001-12-31	LU
Onsted, J. 2014. FCE Redlands 1994 Land Use, Miami-Dade County, South Florida ver 2. Environmental Data Initiative. https://doi.org/10.6073/pasta/e7856aad78610c7c365cf620f47a5ef5.	1994-01-01 - 1994-12-31	LU
Heithaus, M. and R. Nowicki. 2019. Percent cover, species richness, and canopy height data of seagrass communities in Shark Bay, Western Australia, with accompanying abiotic data, from October 2012 to July 2013 ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/29ed91e46b4a898129f8b03c3500abbd.	2012-10-20 - 2013-07-14	PS

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Heithaus, M. and J. Thomson. 2019. Capture data for sharks caught in standardized drumline fishing in Shark Bay, Western Australia, with accompanying abiotic data, from February 2008 to July 2014. ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/b4c39439f21d56d0c87b00c59073cf89.	2008-02-26 - 2014-07-04	PS
Heithaus, M. and J. Thomson. 2019. Capture data for sharks caught in standardized drumline fishing in Shark Bay, Western Australia, with accompanying abiotic data, from January 2012 to April 2014. ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/225c82aa5925cee430a8c7a6a44e8d85.	2012-01-13 - 2014-04-11	PS
Heithaus, M. and R. Nowicki. 2019. Count data of air-breathing fauna from visual transect surveys including water temperature, time, sea and weather conditions in Shark Bay Marine Park, Western Australia from February 2008 to July 2014 ver 5. Environmental Data Initiative. https://doi.org/10.6073/pasta/e91ff5368ab0dfc412678170f8a0d1a6.	2008-02-25 - 2014-07-21	PS
Heithaus, M. and J. Thomson. 2019. Marine turtles captured during haphazard at-sea surveys in Shark Bay, Australia from February 2008 to December 2013 ver 4. Environmental Data Initiative. https://doi.org/10.6073/pasta/7696e20214fbf84f25d664ff7dc8050c.	2008-02-26 - 2013-12-14	PS
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Citation	Temporal Coverage	Core Areas
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