FLORIDA COASTAL EVERGLADES LTER
FCE IV YEAR THREE ANNUAL REPORT
FOR NSF AWARD DEB-1832229

RETs Beatriz Guimarães, Lacey Simpson, and Cristina Whelan (left to right) in Deering's Cutler Slough
Photo: Nicholas Oehm

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Table of Contents

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 biophysical processes to modify ecosystem trajectories of coastal landscapes. Changes to hydrologic drivers at either the freshwater or marine endmember 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. Experimental studies are revealing the mechanisms by which saltwater intrusion into freshwater and brackish wetlands drives rapid loss of soil elevation and stored carbon. However, we now have evidence of changes in ecological processes attributed to restoration projects implemented over the last few years. Observed increases in pulsed delivery of fresh and marine water via water management and climate change to these sensitive ecosystems 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).

In the past year, we focused on continuing core long-term data collection and thematic research of FCE, while also implementing the research described in our 2020 renewal proposal. We continued to address the central question of how changes in the balance of fresh and marine water supplies influence ecosystem structure and function in coastal karstic ecosystems along our freshwater to marine gradients of two major drainages, Shark River Slough (SRS) and the Taylor Slough/Panhandle (TS/Ph).

We requested a no cost extension to the first FCE IV grant with the goal of completing work that was delayed in 2020 due to COVID, including (1) microbial community research, (2) trophic dynamics research, and (3) our REU and RET programs.

Major Activities

Microbial Communities
We continued our time series to analyze bacterial communities in the water column at all LTER core sites. The results of two sampling points in 2017, as well as monthly sampling during 2019, indicated low seasonality in these communities, and we therefore switched to a quarterly sampling starting in 2020. Additionally, the samples were processed and filtered at FIU since 2020, and not at UF/IFAS in Davie anymore.

We focused on metabolic capabilities of most abundant bacterial groups in the marshes (*Polynucleobacter)* and marine waters (SAR11). *Polynucleobacter* are abundant freshwater bacteria worldwide and SAR11 are the most abundant organisms on Earth. We were able to isolate strains from both groups, sequenced their genomes, and analyzed their abundance in our datasets.

Trophic Dynamics
In the Shark River Slough transect, we have continued our long-term electrofishing-based consumer sampling, our long-line based sampling of Bull Sharks and our acoustic telemetry-based movement tracking and tagging of recreational fish species (e.g.,) Common Snook and Florida Largemouth Bass) and Bull Sharks. And we conducted downloads of the acoustic receivers that store movement data in the field every 4 months.

We collected samples for stable isotope analysis and characterization of our food webs during the dry season of 2021 (March-May). Approximately 500 samples across 9 sites (1 marsh and 3-4 coastal per system) were collected including producers, primary consumers and secondary consumers.

We processed samples collected in 2019 and submitted those for analysis of stable isotopes (C, N, S) at the Washington State University Isotope Lab. A total of 835 samples were processed and submitted.

Specific Objectives

Microbial Communities
Our objectives were to understand biogeochemical patterns of microbial decomposers along salinity and P gradients of SRS and TS/Ph by characterizing assemblages of water-column and benthic microbial communities responses to salinity and P.

Trophic Dynamics
Our objectives were to: (1) continue collection and processing of food web stable isotope samples to identify changes in resource contributions to consumers over seasonal and spatial gradients in salinity and primary productivity across the freshwater-estuarine-marine habitat mosaic, (2) collect abundance and movement data on bull sharks, alligators, and game fish.

Significant Results

Microbial Communities
There are clear changes in the bacterial communities in the water column since 2020 (Figure 1). All samples from before 2020 form a coherent cluster, while samples after 2021 show clustered according to sampling event/season. This trend was similar in Shark River Slough and Taylor Slough, and independent on the habitat (marsh, ecotone, mangrove, coastal).

We were able to identify major microbial players in these ecosystems (Figure 2). Communities in the marshes are dominated by *Betaproteobacteria* (now classified as *Gammaproteobacteria*) of the genus *Polynucleobacter* and other *Betaproteobacteria*. In mangrove-dominated areas, other *Gammaproteobacteria*, and in coastal areas in TS/Ph, *Alphaproteobacteria* dominate. The results of a snapshot of these communities is available as manuscript and will be re-submitted soon (Laas et al.). The manuscript on the time series analysis is on hold until the latest samples have been sequenced and analyzed. Differences between pre-Irma and post-Irma samples were more pronounced in downstream sites at Shark River Slough and Taylor Slough, namely SRS 4-6 and TS/Ph 6, 7, and 9, compared to marsh sites. This is in contrast to the results on DOC composition pre/post Irma.

16S rRNA sequences related to *Polynucleobacter* can amount to nearly 40% of the total community in marsh sites (Figure 3). Our isolates (in blue) are (near) identical in sequence to these abundant sequence groups (amplicon sequencing variants, ASV, in red).

We were able to isolate a strain of SAR11 subgroup III (strain Cody 6) and are currently analyzing its genome. An interesting side note is the presence of marine SAR11 sequences in the marshes, albeit in low abundance (Figure 4). This hasn't been reported before, and we are wondering if this group could be a good bioindicator for saltwater intrusion in the marshes.

Figure 1: Non-metric multi-dimensional scaling (NMDS) plot of microbial communities based on Bray-Curtis dissimilarity matrices of 16S rRNA amplicon data. A) Shark River Slough SRS, B) Taylor Slough TS/Ph sites.

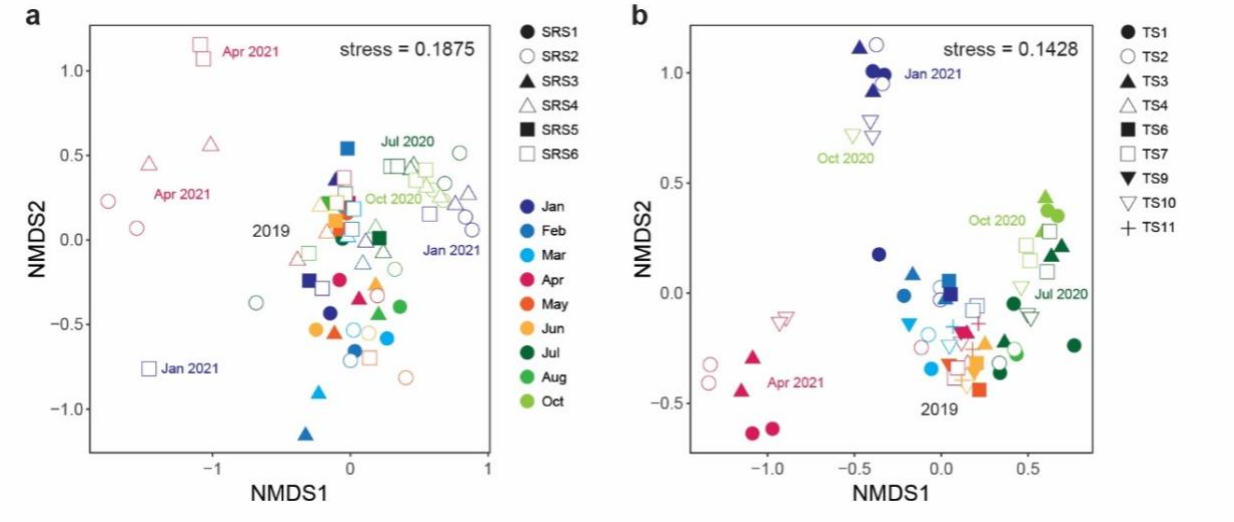


Figure 2: Summary of all 16S rRNA amplicon data from this project. The panels show main bacterial groups (upper panels) and subgroups of *Gammaproteobacteria* (lower panels) for Shark River Slough and Taylor Slough (TS/Ph).

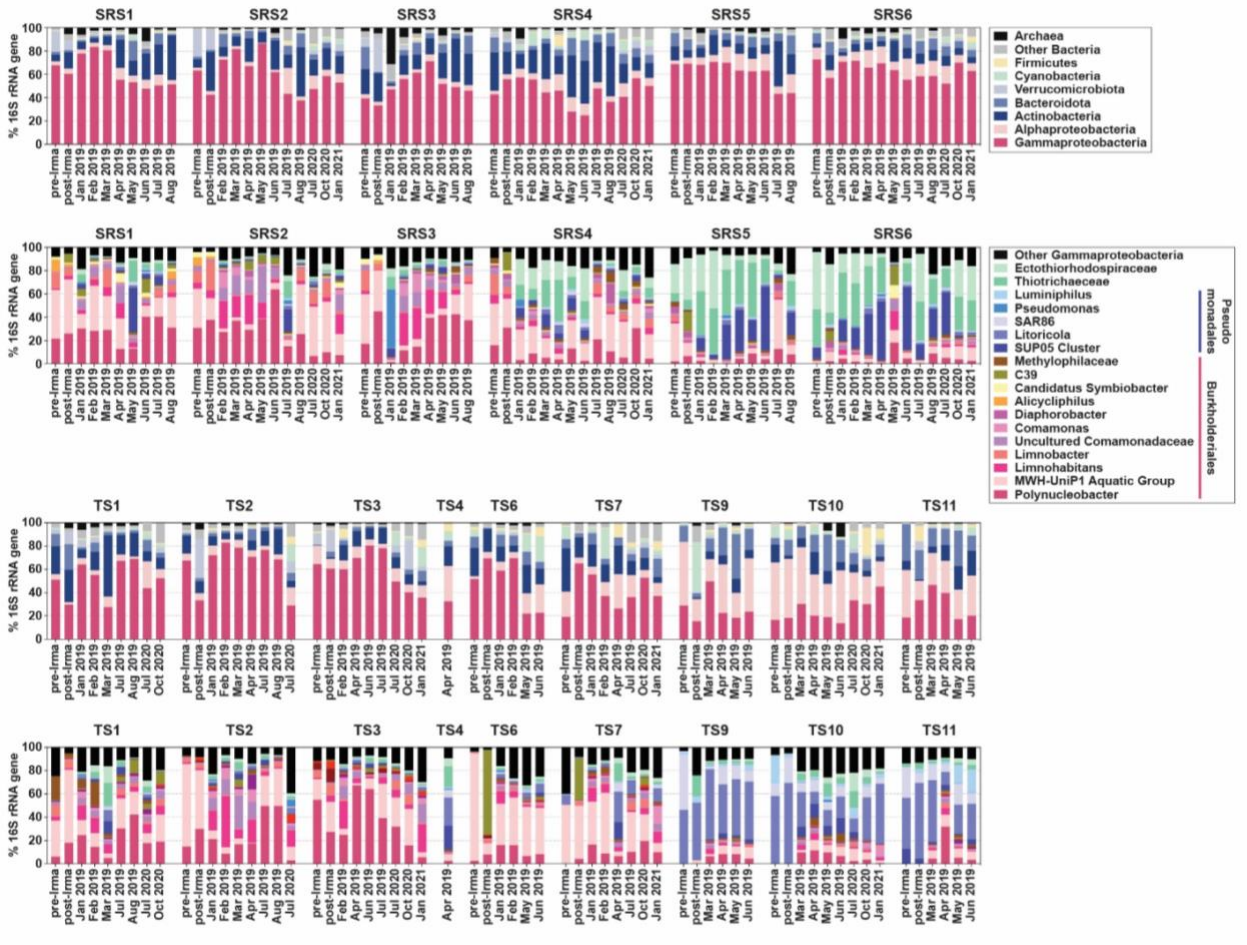


Figure 3: Phylogenetic tree of abundant betaproteobacterial groups (MWH-UniP1-Aquatic Group and *Polynucleobacter*) in the marshes. Sequences in red are from environmental amplicon sequencing (ASV), sequences in blue stem from our isolates. Percentages indicate relative abundance of a given ASV in the database. The insert shows distribution of both groups in the datasets.

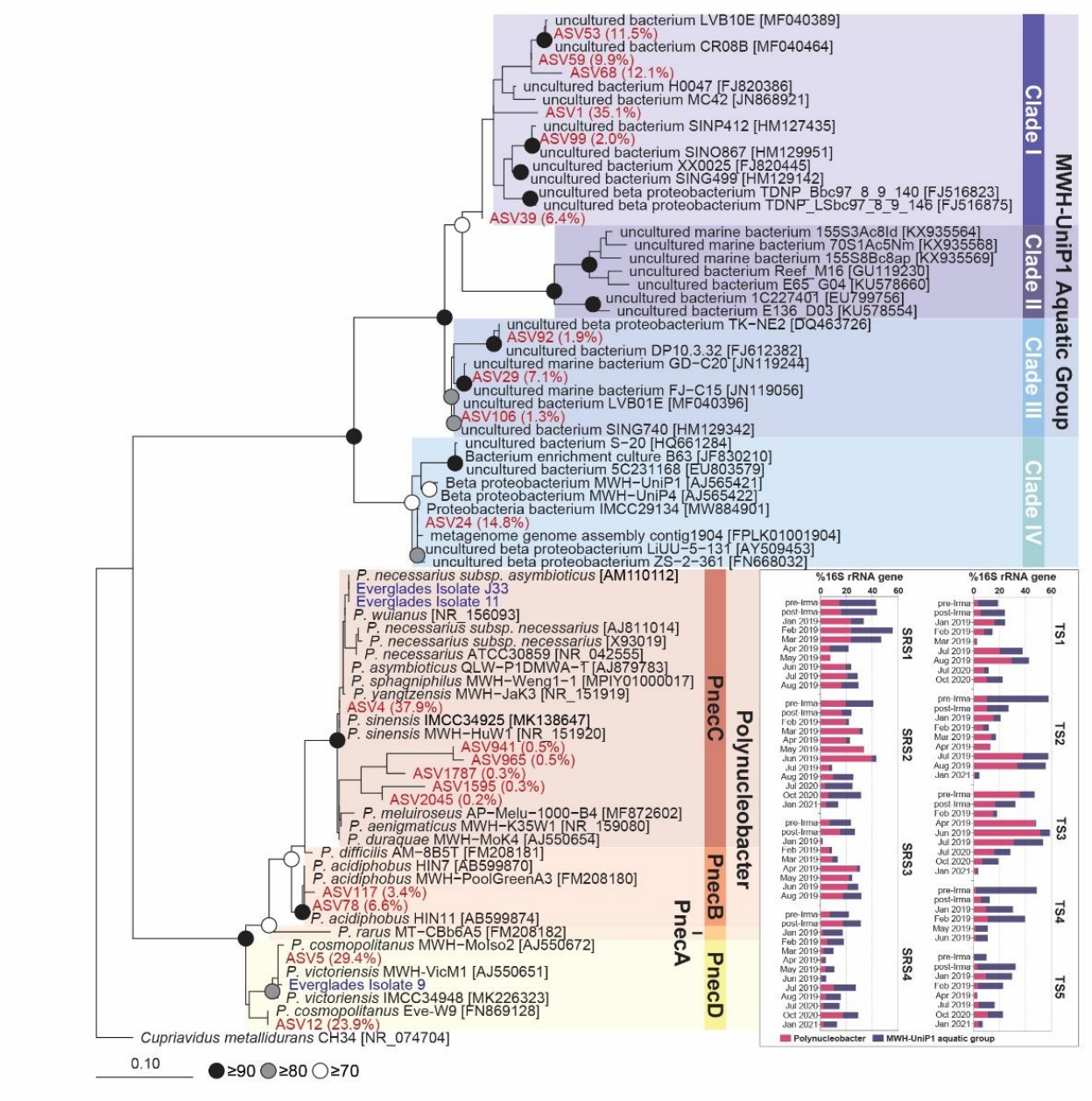
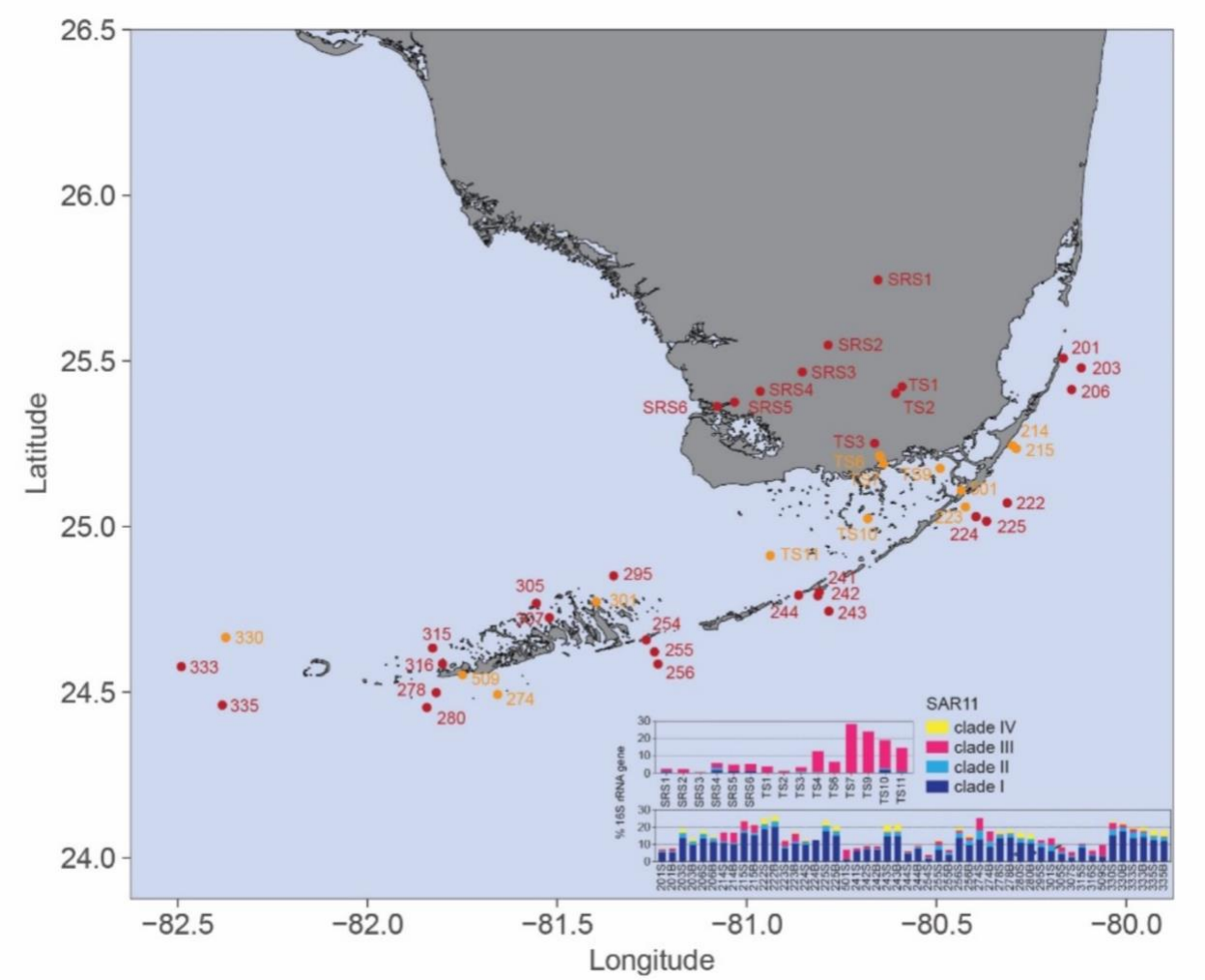


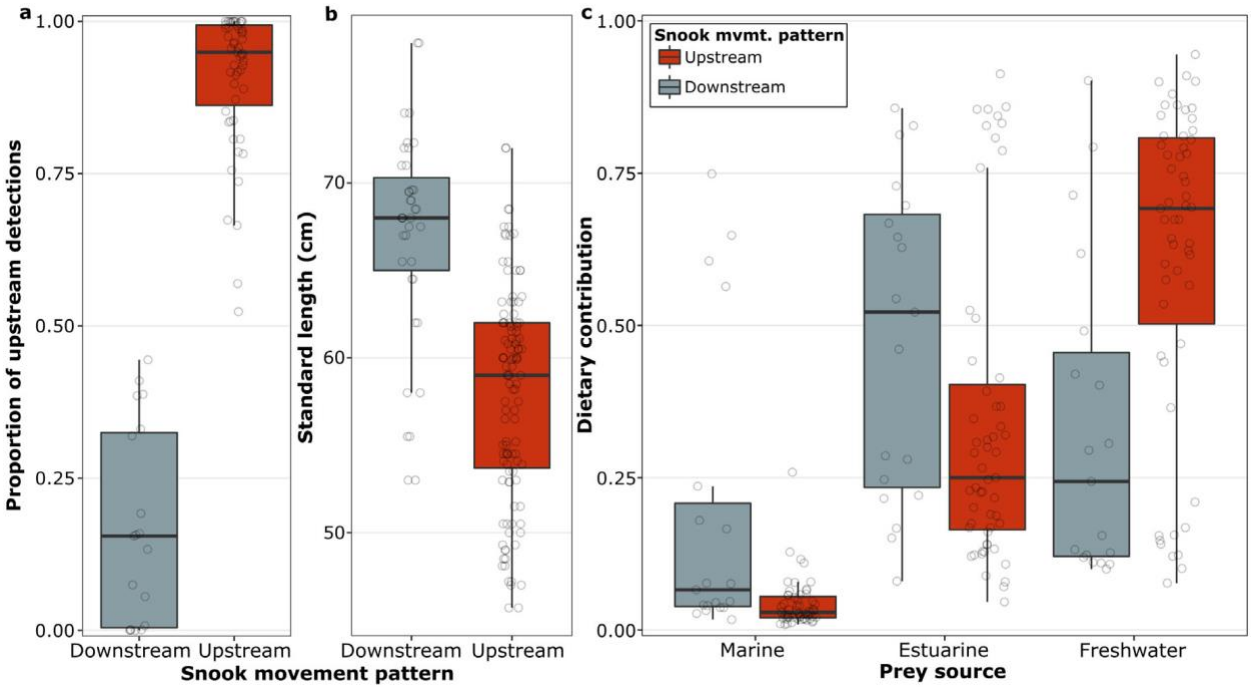
Figure 4: Distribution of SAR11 subgroups in the Florida Coastal Everglades and waters around the Florida Keys based on 16S rRNA amplicon data. SAR11 subgroup III is the most abundant in the FCE sites, accounting for up to 30% of all retrieved sequences in TS7. In more marine waters, this group is replaced by other subgroups, mostly subgroup I. While SAR11 have been studied in pure culture to some extent, most isolates are from subgroups IA and IB.



Trophic Dynamics

We published a study pairing our movement and food web data on Common Snook and showing on snook have varying movement strategies and those movement strategies result on differential resource use (Rezek et al 2020, https://esajournals-onlinelibrary-wiley-com.ezproxy.fiu.edu/doi/pdfdirect/10.1002/ecs2.3305). Snook that spend more time at the headwaters of the Shark River rely more strongly on freshwater resources, while those snook that spend more time downstream, rely more heavily on estuarine and marine resources (Figure 5). These results demonstrate how individual variations in predator movement behavior can mediate the direction and scale of food web subsidies across coastal seascapes.

Figure 5: Boxplots showing the proportion of receiver detections in upstream regions of the Shark River Estuary (a), standard length (b), and estimated prey source dietary contributions (mixing model posterior means) (c) to individuals classified as downstream snook vs. upstream snook based on acoustic telemetry data.



Key outcomes or other achievements

- Differences between pre-Irma and post-Irma microbial community samples were more pronounced in downstream sites at Shark River Slough and Taylor Slough, namely SRS 4-6 and TS/Ph 6, 7, and 9, compared to marsh sites.
- Marine SAR11 sequences were present in the marshes, albeit in low abundance.
- Snook that spend more time at the headwaters of the Shark River rely more strongly on freshwater resources, while those snook that spend more time downstream, rely more heavily on estuarine and marine resources.

Opportunities for training and professional development

Research Experience for Undergraduates (REU)
FCE LTER invests in human resource development through the recruitment and training of undergraduate and graduate students from diverse communities. Each year, our base funding to provides stipend support for two undergraduates that are also included as members of FIU's Coastal Ecosystems REU Site (CE-REU) and are invited to participate in cohort-building, networking opportunities, social events, and weekly field trips.

Originally delayed due to the COVID-19 pandemic, 2019 REU Leslie Toll Roque was mentored by Drs. Valverde-Barrantes and Salazar-Amoretti during the summer of 2021. The results of her study examining the *Salt intrusion effect on endangered South Florida plant species: impacts on growth and reproduction of Chamaecrista lineata var keyensis*, were presented at the 2021 CE-REU Site Symposium. Toll-Roque has continued working with her mentors beyond her REU and has been invited to present her work at the annual FCE All Scientists Meeting.

Research Experience for Teachers (RET)
The FCE Research Experience Programs provides professional development to K-12 teachers through Research Experience for Teacher (RET) fellowships. In the Fall 2019, RET Cristina Whelan and four students from her Research and Experimentation course at BioTECH High School deployed teabags along the spatiotemporal pulse gradient of the Cutler Slough under mentorship of PI Kominoski and the Education and Outreach Coordinator Oehm. Located on the grounds of FCE's Deering Estate partner, this tidal creek has been reconnected to upstream wetlands as a small-scale urban representation of Everglades restoration. The initial samples were collected, analyzed, and the resulting data was presented by the students at the 2020 Southeast Regional Science and Engineering Fair of Florida in their poster *Go With The Flow: Differences In Tea Decomposition In a Restored Wetland*. In the spring of 2020, Whelan's work was postponed due to the COVID-19 pandemic and when she returned in March 2021 found that her original samples had been removed. On April 3, 2021, a request for a new permit was submitted to Miami Dade County Parks and she received a final approved permit on September 2, 2021. In October, Whelan deployed a second set of samples and has scheduled an initial collection for late November.

Communicating results to communities of interest

Leslie Toll Roque presented the results of her REU research examining the Salt intrusion effect on endangered *South Florida plant species: impacts on growth and reproduction of Chamaecrista lineata var keyensis* at the 2021 CE-REU Site Symposium at Florida International University.

Plans to accomplish goals during the next reporting period

The RET program received supplemental funds in the spring of 2021 for two years of the RET program. We requested a no cost extension in the fall of 2021, and we plan to complete the RET work described in the supplemental proposal.

Products

Publications

Book Chapters

Waide, R., and K. Vanderbilt. 2021. Understanding the Fundamental Principles of Ecosystems through a Global Network of Long-Term Ecological Research Sites, in Waide, R. and S.E. Kingsland (eds.) The Challenges of Long-Term Ecological Research: A Historical Analysis. Springer: Cham. DOI: 10.1007/978-3-030-66933-1_16

Journal Articles

Chambers, R.M., A. Gorsky, E. Castañeda-Moya, and V.H. Rivera-Monroy. 2021. Evaluating a steady-state model of soil accretion in Everglades mangroves (Florida, USA). Estuaries and Coasts 44: 1469–1476. DOI: 10.1007/s12237-020-00883-1

Dattamudi, S., S. Chanda, and L.J. Scinto. 2021. Microbial respiration and enzyme activity downstream from a phosphorus source in the Everglades, Florida, USA. Land 10: 696. DOI: 10.3390/land10070696

Dessu, S.B., R. Paudel, R.M. Price, and S.E. Davis. 2021. Using empirical data and modeled scenarios of Everglades restoration to understand changes in coastal vulnerability to sea level rise. Climatic Change 168: 19 (2021). DOI: 10.1007/s10584-021-03231-9

Flower, H., M. Rains, Y. Tasci, J.Z. Zhang, K. Trout, D.B. Lewis, A. Das, and R. Dalton. 2021. Why is calcite a strong phosphorus sink in freshwater? Investigating the adsorption mechanism using batch experiments and surface complexation modeling. Chemosphere 286: 131596. DOI: 10.1016/j.chemosphere.2021.131596s

Gervasi, C.L., R.O. Santos, R. Rezek, W.R. James, R. Boucek, C. Bradshaw, C. Kavanagh, J.K. Osborne, and J.S. Rehage. 2021. Bottom-up conservation: using translational ecology to inform conservation priorities for a recreational fishery. Canadian Journal of Fisheries and Aquatic Sciences DOI: 10.1139/cjfas-2021-0024.

Grove, K., A. Barnett, and S. Cox. 2020. Designing justice? Race and the limits of recognition in greater Miami resilience planning. Geoforum 117: 134-143. DOI:10.1016/j.geoforum.2020.09.014

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Lagomasino, D., T.E. Fatoyinbo, E. Castañeda-Moya, B. Cook, P. Montesano, C.S.R. Neigh, L.A. Corp, L.E. Ott, S. Chavez, and D.C. Morton. 2021. Storm surge and ponding explain mangrove dieback in southwest Florida following Hurricane Irma. Nature Communications 12: 4003 (2021). DOI: 10.1038/s41467-021-24253-y

Lee, D.Y., J. Kominoski, M. Kline, M. Robinson, and S. Roebling. 2021. Saltwater and nutrient legacies reduce net ecosystem carbon storage despite freshwater restoration: insights from experimental wetlands. Restoration Ecology DOI: 10.1111/rec.13524: e13524.

Malone, S.L., J. Zhao, J. Kominoski, G. Starr, C.L. Staudhammer, P.C. Olivas, J.A. Cummings, and S. Oberbauer. 2021. Integrating aquatic metabolism and net ecosystem CO_2 balance in short- and long-hydroperiod subtropical freshwater wetlands. Ecosystems DOI: 10.1007/s10021-021-00672-2.

Medina-Calderon, J.H., J.E. Mancera-Pineda, E. Castañeda-Moya, and V.H. Rivera-Monroy. 2021. Hydroperiod and salinity interactions control mangrove root dynamics in a karstic oceanic island in the Caribbean Sea (San Andres, Colombia). Frontiers in Marine Science 7: 598132. DOI: 10.3389/fmars.2020.598132

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Rovai, A., R.R. Twilley, E. Castañeda-Moya, S.R. Midway, D.A. Friess, C.C. Trettin, J.J. Bukoski, A.E.L. Stovall, P. Pagliosa, A.L. Fonseca, R.A. Mackenzie, A. Aslan, S.D. Sasmito, M. Sillanpaa, T.G. Cole, J. Purbopuspito, M.W. Warren, D. Murdiyarso, W. Mofu, S. Sharma, H.T. Pham, and P. Riul. 2021. Macroecological patterns of forest structure and allometric scaling in mangrove forests. Global Ecology and Biogeography 30: 1000-1013. DOI: 10.1111/geb.13268

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Van Dam, B., M. Zeller, C. Lopes, A. Smyth, M. E. Böttcher, C. Osburn, T. Zimmerman, D. Pröfrock, J. Fourqurean, H. Thomas. 2021. Calcification-driven CO_2 emissions exceed “Blue Carbon” sequestration in a carbonate seagrass meadow. Science Advances 7(51): eabj1372. DOI: 10.1126/sciadv.abj1372

van Zinnicq Bergmann, M.P.M., B.D. Postaire, K.R. Gastrich, M.R. Heithaus, L.A. Hoopes, K. Lyons, Y.P. Papastamatiou, E.V.C. Schneider, B.A. Strickland, B.S. Talwar, D.D. Chapman, and J. Bakker. 2021. Elucidating shark diets with DNA metabarcoding from cloacal swabs. Molecular Ecology Resources 21: 1056-1067. DOI: 10.1111/1755-0998.13315

Zeller, M., B. Van Dam, C. Lopes, and J. Kominoski. 2020. Carbonate-associated organic matter is a putative FDOM source in a subtropical seagrass meadow. Frontiers in Marine Science - Marine Biogeochemistry DOI: 10.3389/fmars.2020.580284.

Conference Papers and Presentations

Ishtiaq, K., L. Lamb-Wotton, E. Swain, and T. Troxler. 2020. Evaluating peatland vulnerability to sea level rise and saltwater intrusion using coupled simulations of coastal transport and soil-plant mechanistic models in the Florida Coastal Everglades. American Geophysical Union Fall Meeting, Virtual, December 10, 2020.

Lamb-Wotton, L., K. Ishtiaq, D. Gann, S.L. Malone, P.C. Olivas, S.E. Davis, D.T. Rudnick, F.H. Sklar, and T. Troxler. 2020. Using fine-scale variation in ecosystem state parameters to evaluate alternate stable states within a salinizing peat marsh in the Florida Coastal Everglades. American Geophysical Union Fall Meeting, Virtual, December 11, 2020.

Malone, S.L., S. Oberbauer, J. Zhao, G. Starr, and C.L. Staudhammer. 2020. Carbon uptake efficiency across wetland ecosystems in the Florida Everglades. American Geophysical Union Fall Meeting, Virtual, December 10, 2020.

Robinson, T., B.A. Rogers, T. Oliver-Cabrera, B. Zhang, S. Kruse, and S. Wdowinski. 2020. Complex relationships between surface deformation, surface topography, and top-of-limestone surface in the covered karst Sandhill Reservation, West-central Florida. American Geophysical Union Fall Meeting, Virtual, December 15, 2020.

Wdowinski, S.. 2020. Direct and indirect wind impacts on coastal sea level along the US Atlantic and Gulf shorelines. American Geophysical Union Fall Meeting, Virtual, December 7, 2020.

Zhang, B., L. Lamb-Wotton, K. Ishtiaq, D. Gann, S. Wdowinski, T. Troxler, and E. Swain. 2020. Space-based monitoring of water depth and soil salinity over collapsing peat marshes using Sentinel-1 SAR amplitude observations. American Geophysical Union Fall Meeting, Virtual, December 11, 2020.

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.

Participants & Other Collaborating Organizations

Participants

Name	Most Senior Project Role
Gaiser, Evelyn	PD/PI
Fourqurean, James	Co PD/PI
Grove, Kevin	Co PD/PI
Kominoski, John	Co PD/PI
Rehage, Jennifer	Co PD/PI
Heithaus, Michael	Faculty
Nelson, James	Faculty
Oehm, Nicholas	Faculty

Name	Most Senior Project Role
Rezek, Ryan	Faculty
Salazar-Amoretti , Diego	Faculty
Santos, Rolando	Faculty
Stingl, Uli	Faculty
Valverde-Barrantes , Oscar	Faculty
Whelan, Cristina	K-12 Teacher
James, W. Ryan	Postdoctoral (scholar, fellow or other postdoctoral position)
Strickland, Bradley	Postdoctoral (scholar, fellow or other postdoctoral position)
Gastrich, Kirk	Other Professional
Trabelsi, Shakira	Other Professional
Castillo, Nicholas	Graduate Student (research assistant)
Eggenberger, Cody	Graduate Student (research assistant)
Flood, Peter	Graduate Student (research assistant)
Garcia, Laura	Graduate Student (research assistant)
Linenfelser, Joshua	Graduate Student (research assistant)
Massie, Jordan	Graduate Student (research assistant)
Paz, Valeria	Graduate Student (research assistant)
Rodemann, Jonathan	Graduate Student (research assistant)
Viadero, Natasha	Graduate Student (research assistant)
Toll Roque, Leslie	Research Experience for Undergraduates (REU) Participant

Collaborating Organizations

Coastal Carolina University
Conway, South Carolina

College of William & Mary
Williamsburg, Virginia

The Deering Estate
Miami, Florida

East Carolina University
Greenville, North Carolina

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 Myers, Florida

Florida State University
Tallahassee, Florida

Georgia Tech
Atlanta, Georgia

Helmholtz-Zentrum Hereon
Geesthacht, Germany

Life University
Marietta, Georgia

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 and Monitoring Program
Palmetto Bay, Florida

National Tropical Botanical Gardens
Coconut Grove, Florida

North Carolina State University
Raleigh, North Carolina

Oak Ridge National Laboratory
Oak Ridge, Tennessee

Oklahoma State University
Stillwater, Oklahoma

The Pennsylvania State University
University Park, Pennsylvania

Sanibel-Captiva Conservation Foundation
Sanibel, Florida

South Florida Water Management District
West Palm Beach, Florida

Tulane University
New Orleans, Louisiana

UNAVCO
Boulder, Colorado

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 St. Petersburg
St. Petersburg, Florida

U.S. Geological Survey
Reston, Virginia

University of South Florida
Tampa, Florida

University of Wisconsin
Madison, Wisconsin