2021 Project Funding

APPLICATION FORM

Project proposals must include:

☑Summary (3-page maximum, format provided)
☑Narrative (format and instructions provided below)
☑Project Timeline and Budget Worksheet (Excel Attachment)

PROJECT SUMMARY

CHNEP 2021 Project Funding

Project Title: Boat Wake Resuspension of Sediment Over Seagrass Beds in Estero Bay, Florida

Lead Organization and Address:

Organization Name: Florida Gulf Coast University Board of Trustees

Organization Address 1: 10501 FGCU Blvd. S, Fort Myers, Fl 33965-6565

Organization Address 2:

Primary Contact within Lead Organization (including position, email, and phone number):

Primary Contact Name: David Fugate

Primary Contact Position: Associate Professor, Department of Marine and Earth Sciences

Primary Contact Email: dfugate@fgcu.edu

Primary Contact Phone: 239.590.7136

Project Partners and Roles (organization names and primary contacts):

First Partner and Primary Contact/Role:

Other Partners and Primary Contacts and Roles (as needed):

Project Objective (50 words or less):

This project will determine the extent to which boat wake driven resuspension is detrimental to water quality over seagrass beds in Estero Bay. The results will be disseminated through a broad spectrum of recipients including local governmental institutions and the general public.

Total Amount Requested: **$48,606**

Matching Contributions Proposed: **$** **Type (in-kind, cash, etc.):**

Proposed Grant Duration (months): 12 months

Permits and Approvals, if needed: No permits required

Description of Needed Permits and Approvals (50 word limit):

Permit Approval Status (50 word limit):

PROJECT NARRATIVE
CHNEP 2021 Project Funding

Project Description:

This project will quantify the impact of boat wakes on water column turbidity above seagrass beds. Direct damage to seagrass beds through propeller scarring is a well-documented threat in the Charlotte Harbor Region (Brown, et al. 2016). However, less research has been done on the indirect effects of sediment resuspension from boat wakes, which is also a serious stressor on seagrasses (Bilkovic, et al. 2017).

In this proposal we will present strong evidence that boat wakes may be detrimental to seagrass health in Estero Bay and propose the methods to confirm and quantify the effect. We hypothesize that boat wakes increase turbidity, the degree to which water loses it transparency due to the presence of suspended particulates. Natural factors, such as tidal currents, terrestrial runoff, and waves caused by diurnal winds and episodic storms, can increase turbidity, as well. Therefore, we will focus on the contribution of boat wakes to turbidity relative to these natural factors, and determine the extent to which remediation efforts, such as expanding no-wake zones or enforcement of no-power boat zones would be beneficial. This project addresses several issues within the Coastal & Heartland National Estuary Partnership (CHNEP) priority actions including supporting a comprehensive water quality assessment strategy, conducting data collection and analyses to support hydrologic restoration, and protecting, restoring, and monitoring estuarine habitats (seagrass beds). It also addresses Congressionally set priority issues such as the loss of seagrass habitats and impacts on water quality.

Seagrass beds provide crucial resources to the estuarine ecosystem. They provide food and habitat for commercially and recreationally important fisheries species, among many other ecosystem functions (Hemminga and Duarte 2000, Worm, et al. 2006). Seagrass beds also help trap and stabilize sediments and provide damping of wave action (Koch, et al. 2006). However, seagrass health in Estero Bay is declining. Monitoring of Estero Bay seagrass through aerial photography by the South Florida Water Management District (SFWMD) shows that in addition to severe propeller scarring there is a decrease in area of continuous seagrass cover and an increase in patchy seagrass cover from 2004 to 2014 (Brown, et al. 2016, Rickards 2018). The Estero Bay Aquatic Preserve (EBAP) has performed in-water transect monitoring of seagrass beds in Estero Bay since 2003. Their data show a significant reduction in mean percent seagrass coverage from 2012 to 2016 compared to earlier years (Fig. 1, Rickards, 2018). Quarterly, bay-wide, in-water surveys from May 2017 – May 2018 found that macroalgal percent cover exceeded seagrass cover, which suggests that the aerial photography surveys might overestimate seagrass coverage (Rickards 2018). Rickards' (2018) analyses also found that seagrass cover was negatively correlated with turbidity in the bay.

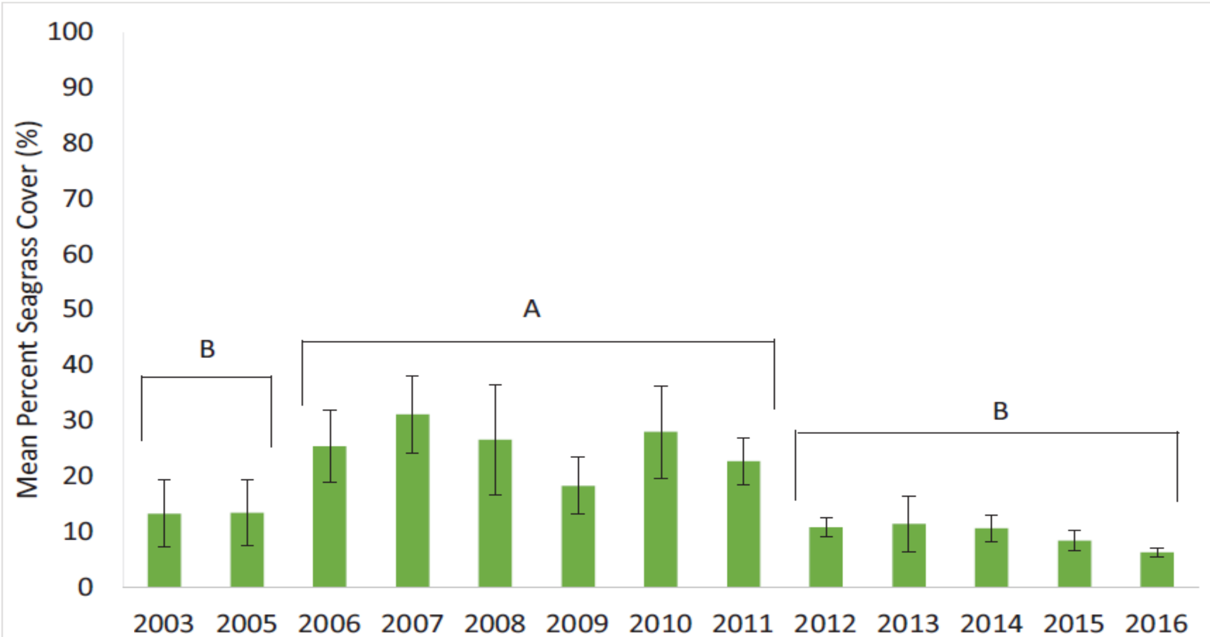

Figure 1 . Mean percent cover of seagrass in quadrats on EBAP transects in Estero Bay from 2003-2016. Letters indicate significantly different groups. 2004 is excluded due to missing data. Error bars depict standard error of the mean (SEM). (adapted from Rickards, 2018)

With increasing residential development, recreational boating has been increasing in Estero Bay. The number of boats registered in southwest Florida doubled between 1980 and 2000 (Madley, Krolic and Sargent 2004). Boat wakes have also been found to be the primary source of resuspension of contaminated sediments near shipping channels (Fugate and Friedrichs 2003). Additionally and most important to this project, recreational boating likely has an indirect effect on seagrass health through resuspension of sediment by boat wakes. Seagrasses require relatively high levels of minimum light irradiation (e.g. Bilkovic et al. 2017). In Charlotte Harbor, seagrasses were found to require 15-30% of solar irradiation, but turbidity in Estero Bay often prevents that much light from penetrating (Rickards 2018, Dixon 2000). Because the Bay is already failing to meet light penetrance targets, small increases in turbidity may have significant effects on seagrass health (Hotaling 2014). Continuous turbidity data acquired by EBAP since 2004 show a fluctuating median turbidity at a station in the southern part of the Bay (Fig. 2a). Further examination of this data show that **median turbidity levels during the weekend are almost always higher than median levels of turbidity during the weekdays** (Fig. 2b). Thirteen out of 15 years of measurement showed a higher turbidity during the weekend. This pattern can be quantified by creating a "weekend index" (Bilkovitch et al., 2017) which is calculated by:

$$weekend\ index = \frac{median\ weekend\ turbidity - median\ weekday\ turbidity}{median\ weekday\ turbidity}$$

where the weekday and weekend median values are obtained by measurements every 15 minutes by EBAP throughout the entire year. So, for example, the overall median of the weekend index of 0.056 means that over the 15 years of data, turbidity during the weekend was typically 5.6% greater than during the weekdays and reached as high as 21.3% in 2016.

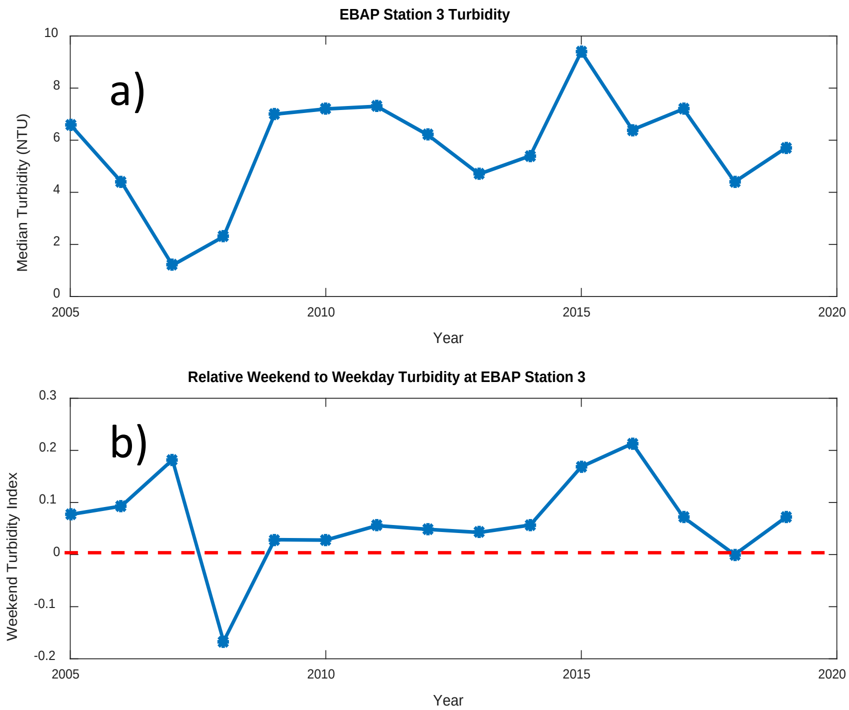

Figure 2: a) Median Turbidity and b) Weekend Turbidity Index. Red dashed line shows equal turbidity on weekdays as on weekend. Positive values show more turbidity on the weekend.

These data and analyses are strong evidence that weekend boating activities are affecting the turbidity in the Bay. However, we cannot extract information directly linking the turbidity to the boat wakes from this data. Nor can we gauge the relative impact of the boat wake driven turbidity to other sources of turbidity and whether it is sufficient to warrant policy changes. Turbidity increases by boat wakes have been found to persist for as long as an hour when there were no currents present, e.g. in Venice Lagoon, Italy (Rapaglia, et al. 2011). However, a study in Massachusetts found that during low tide, resuspension from boat wake reduced light more than 60%, but the sandy sediment settled relatively quickly compared to the finer grain sediments that were resuspended during wind events (Crawford 2002). Koch (2002) also found minimal impact of sediment resuspension by boat wake over a seagrass habitat in the Chesapeake Bay. The EBAP data presented here from the southern part of Estero Bay are from a sensor that is not situated directly within a seagrass patch. It may be that the sandy sediment in unvegetated regions may settle quickly and not be an issue for the seagrass beds. This project will quantify and compare sediment resuspension by boat wakes in both seagrass beds and unvegetated areas. Additionally, seagrass beds in wavy conditions often have a sandy substrate, while those in low energy sites have fine sediments (e.g. Koch, 2006). We will compare the sediment and wave dynamics in a well trafficked site to that of a low boat traffic site. It may be that the sandy seagrass sites are well adapted to boat wakes because their sediment settles rapidly.

Another unresolved question from this data is to what degree natural wind driven waves resuspend sediment compared to boat wakes. Resuspension by waves is a function of wave energy, which itself is a function of the wave height, frequency, and duration. While boat wakes generally have a much larger amplitude than wind waves, they do not last as long. In the study in Massachusetts, diurnal wind waves resuspended more sediment overall than boat wakes (Crawford, 2002). Another uncertainty in this preliminary analysis is that the results may underpredict the effect of boat wakes during the weekends, since statistically, episodic storms are more likely to occur in the 5 days during the week compared to only 2 days of the weekend. This project will also quantify and compare resuspension by boat wakes and wind driven waves.

Outreach

The results of this investigation will be communicated through various channels to inform and educate policy makers and the environmental community. Presentation(s) will be submitted to the CHNEP Watershed Summit and communicated to EBAP who work to design and implement environmental policies in Estero Bay. We will also share our results with the Estero Bay Agency on Bay Management. A Public Service Announcement youtube video will be produced that discusses the importance of turbidity to seagrass beds and how it is affected by public use activities. The results will also be communicated through a presentation at FGCU's Water School Seminar Series. The results will be shared internationally to the scientific and environmental community through publication in a peer reviewed journal. The study will also be discussed in FGCU's Introduction to Physical Oceanography class for Marine Science majors, many of whom go on to have a career in Florida's professional environmental community.

<u>Project Objectives:</u>

This project addresses several issues within the Coastal & Heartland National Estuary Partnership (CHNEP) priority actions including supporting a comprehensive water quality assessment strategy, conducting data collection and analyses to support hydrologic restoration, and protecting, restoring, and monitoring estuarine habitats (seagrass beds). It also addresses Congressionally set priority issues such as the loss of seagrass habitats and impacts on water quality.

The main research objectives of this study focus on seagrass beds in Estero Bay, and are to determine whether remediation efforts, such as expanding no-wake zones or enforcement of no-power boat zones would be beneficial. The specific objectives are:

Quantify and compare the amount of resuspension of sediment by boat wakes over seagrass beds and unvegetated regions.

Quantify and compare the amount of resuspension by wind waves to the amount of resuspension by boat wakes.

Determine changes in the above measurements related to the seagrass growing season.

Determine the variability of sediment resuspension related to changes in spring and neap tides and low and high tides.

Compare the longevity of boat-wake turbidity effects in high-energy areas versus in low-energy areas to determine the potential for seagrass beds to adapt to higher wave energy regimes as sediment composition changes.

Project Approach:

Our approach to investigating these questions will include both intense, short-term, high spatial and temporal resolution transects and longer term monitoring (fortnightly) within the seagrass. Intensive surveys will consist of a transect of instruments that runs from an unvegetated section in or near the channel to within a seagrass bed. Pressure sensors will be located at both ends of the transect and will detect boat wakes and the degree of wave attenuation as the waves travel to the seabed. An additional wave sensor will be positioned at the border of the seagrass bed to allow comparison of wave dissipation across the vegetated and unvegetated region. An example of a time series of wave spectra within a seagrass bed is shown in Figure 3. Wave pressure measurements were made over 2 days in Estero Bay on September 25-27, 2019 in a sparse seagrass bed. Bursts of 2048 measurements were made at 8 Hz for slightly over 4 minutes and a new burst was measured every 15 minutes. Spectral analyses of the data in Matlab show how the dominant frequencies vary and can discern the periods of wind driven waves from waves caused by boat wakes. The spectra with anomalous high wave power density values and lower frequency indicate times of boat wake crossing. Higher frequency waves around 18:00 hours are from afternoon winds. An example time series of pressure (which indicates water elevation) is shown for the spectrum with a high energy around 1500 hours on the second day (Fig. 4). In the time series, you can see the small wind driven waves at the beginning of the burst, followed by a strong boat wake near the end of the burst. For this project, we will co-locate turbidity, light, and acoustic sensors with the wave sensors to quantify exactly how much sediment is suspended and how much light attenuation is caused by boat wakes versus wind driven waves. Optical backscatter sensors (OBS) will be used to measure turbidity, and these values can be calibrated to mass concentrations from bulk water samples. Acoustic instruments will include Sontek 10Hz ADVs and/or Nortek a HR Aquadopp. Acoustic backscatter can be calibrated to the suspended sediment concentrations (e.g. Fugate, 2002) and has the advantage that it can measure at a much higher frequency than traditional OBS instruments so that we can resolve changes in turbidity within the wave period. High frequency sampling light sensors (Li-Cor) will also be deployed at surface and bottom of the water column over the seagrass bed to measure the light attenuation. This general approach of using transects to determine the effect of boat wake on sediment resuspension has been used successfully in other investigations (Bauer et al., 2002; Crawford, 2002; Houser, 2011);

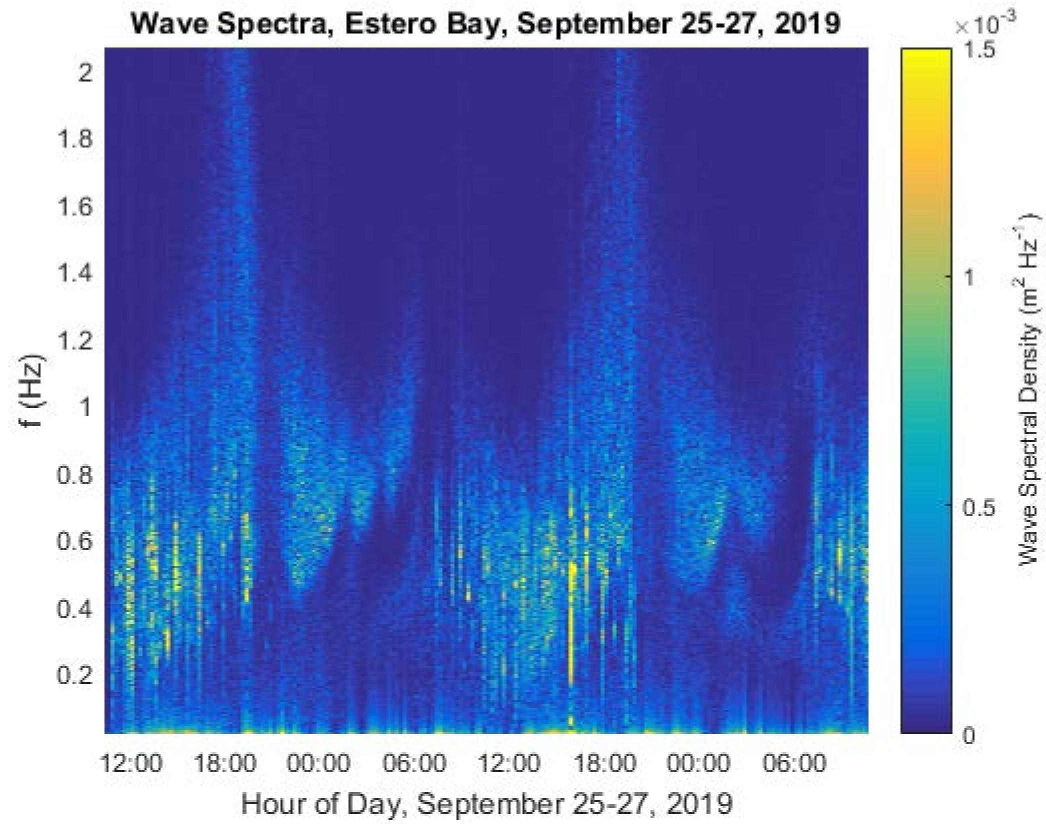

Figure 3. Wave spectra from a seagrass bed in Estero Bay. High spectral densities and lower frequencies show the presence of boat wakes. High frequency waves in the afternoon are caused by wind.

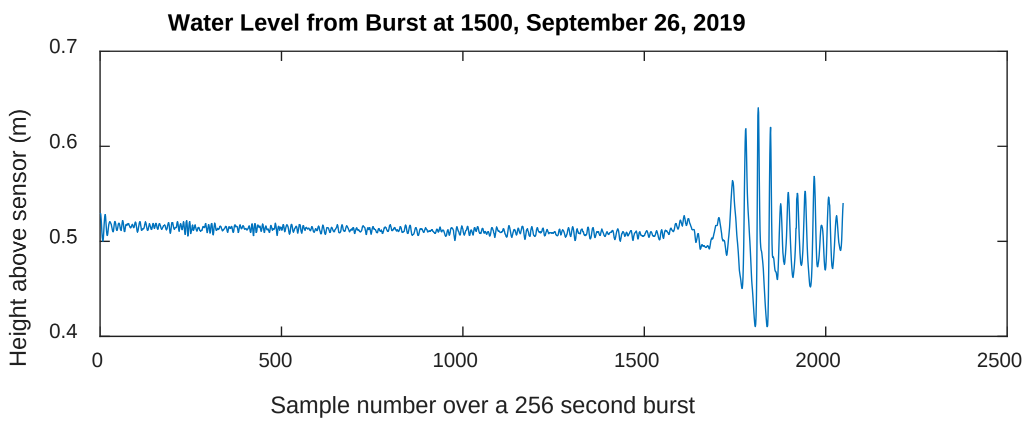

Figure 4. Water level over a seagrass bed in Estero Bay. Water level was sampled at 8 Hz for 256 seconds. The high amplitude waves at the end of the series are boat wakes.

We will perform the transect surveys on a quarterly basis to examine changes as seagrass beds evolve through the season. Two main seagrass bed sites will be established. Each site will include a transect with three stations, the first at an unvegetated region near the channel, the second at an intermediate location at the front edge of the seagrass bed, and a final station inside the seagrass bed. Of the two main seagrass bed sites one will be in an area with relatively high boat traffic and another where there is lower boat traffic. This will help determine whether seagrass beds are able to adapt to the local wave conditions as the median sediment grain size changes. Deployments will be made during slack tides to reduce complications caused by tidal currents and changes in tidal elevation. This sampling scheme will result in 8 intensive transect surveys throughout the year of study.

Ancillary measurements will include grain size analyses of the unvegetated and vegetated sites, and wind speed and direction measurements made from FGCU's weather station at the Vester Marine Lab. Seagrass density and species distribution will be determined at each of the transect surveys using standard quadrat monitoring methods (Douglass, et al. 2020).

Additionally, we will continuously monitor turbidity within the seagrass beds over a fortnightly period at each quarterly deployment to assess the effect of spring and neap tides on turbidity. These measurements will complement the turbidity measurements now being obtained by EBAP in Estero Bay.

If the results indicate that remediation efforts, such as expanding no-wake zones or enforcement of no-power boat zones are warranted, then the implementation of these measures will have long lasting effects by increasing the health of seagrass beds throughout Estero Bay. This project will also strengthen the collaboration between FGCU and EBAP to maintain and improve the environment in Estero Bay.

<u>Outputs/Deliverables:</u>

A total of eight intense high resolution transects will be completed. Two each quarter, one in a high boat traffic area and another in a low boat traffic area. Evidence for this work will be data plots and figures produced in each quarterly report.

A total of eight fortnightly turbidity monitoring events will be completed for each main site and each quarter. Evidence for this work will be data plots and figures produced in each quarterly report.

Quarterly progress reports or meetings with Project Manager

A draft and final report will document to what extent boat wakes increase turbidity over seagrass beds including quantitative measurements and comparisons with natural turbidity levels caused by wind waves and other details discussed in the proposal.

Matlab and / or Excel files archiving the data obtained and made available to any requesting agency such as EBAP.

Budget Narrative:

The main project tasks are the intensive transect measurements and fortnightly monitoring for each of the quarters. The first quarter will require purchase of some equipment, namely 2 wave sensors and 2 LiCor sensors at a cost of $12,000. FGCU will provide other equipment such as 1 wave sensor, and acoustic doppler velocimeter (ADV) or acoustic doppler profiler (ADCP), and YSIs with turbidity sensors, as well as boat fuel and captains. FGCU will provide analysis of seagrass characteristics at each site through Dr. Douglass's pre-existing seagrass monitoring efforts. Each transect will require programming of the instruments, deployment and monitoring in the field, downloading the data from the instruments, data processing and data analysis. The second, third and fourth deployments are estimated at about $7125, for salaries for the PI and graduate student and other miscellaneous expenses such as batteries and instrument construction. The first transect is estimated at a higher cost of $19,125 because of the purchase of the instruments. Evidence for each of these deployments will be provided in the form of data figures and plots in the quarterly report.

A secondary task which cannot be performed until the end of the study is the archiving of the immense amount of data that will be collected. These data will be archived in Matlab format in order to save space, though Excel format can also be produced if desired by CHNEP. The organization of the files and final data processing is estimated at $1,000.

The draft and final report will include the comprehensive analyses of the results of the experiments and recommendations for management policies regarding boat wake resuspension of sediment over seagrass beds, estimated at $7,000.

Project Team:

David Fugate, Ph.D. – Principal Investigator: Dr. Fugate's main field of study is hydrodynamics and sediment transport in coastal regions. He will be overseeing the instrument preparation and field deployments with the assistance of a yet to be determined graduate student. He will also be responsible for the data processing, analyses, data archiving and writing the final report.

David C. Fugate

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Education

B.S., 1983, School of Public Health, University of North Carolina at Chapel Hill, NC, Biostatistics

M.A., 1996, School of Marine Science, Virginia Institute of Marine Science, College of William and Mary, Biological Sciences,

Ph.D., 2002, School of Marine Science, Virginia Institute of Marine Science, College of William and Mary, Physical Sciences, advisor: Carl Friedrichs

Postdoctoral, 2003-2005, Institute of Marine and Coastal Science, Rutgers University, advisor: Robert Chant

Mentoring and Training

Classes: Marine Systems, Scientific Processes, Physical Oceanography, Oceanography, Coastal and Estuarine Sediment dynamics, Marine Science Field Course, Physical and Biological Interactions in Marine Science, Earth Sciences

Advising graduate and undergraduate students at Florida Gulf Coast University

Grants Awarded

2016, subaward from South Florida Water Management District, Co-PI on Settling and Entrainment Properties of STA Particulates, PI Serge Thomas, $121,154

2015, subaward from Environment Protection Agency, Physical Impacts of Seagrass Restoration, $24,751

2009, MRI-R2: Acquisition of a Laboratory Research and Teaching Flume for Estuarine Sediment Bed and Ecological Research and Education, co-PI Mike Parsons, $220,525

2007, South Florida Water Management District, Dynamics of the Estuarine Turbidity Maximum (ETM) in the St Lucie Estuary, $49900

2007, South Florida Water Management District, Dynamics of the Estuarine Turbidity Maximum (ETM) in the Caloosahatchee River, $25550

2007, Charlotte Harbor National Estuarine Program, “Fate of Caloosahatchee River ETM Associated Sediment”, $15000

2006, New Jersey Sea Grant, “Estimation of the fall velocity of suspended sediment in the Passaic R., NJ”, $76,000

Professional Affiliations

American Geophysical Union.
Estuarine Research Federation.

Publications

Fugate, D. C. and Jose, F., 2019, Forces in an Estuary: Tides, Freshwater, and Friction, Oceanography 32 (1), 231-236.

Buzzelli, C., P.H. Doering, Y. Wan, D. Sun, **D. Fugate**, 2014, Modeling ecosystem processes with variable freshwater inflow to the Caloosahatchee River Estuary, southwest Florda. I. Model development, Estuarine, Coastal, and Shelf Science 151, 256-271

Chant, R.J., **Fugate, D.C.** and Garvey, E., 2011, The shaping of an estuarine superfund site: roles of evolving dynamics and geomorphology, *Estuaries and Coasts (34)1,* pp 90-1-5.

Hunt, H.L., **Fugate, D.C.**, and Chant, R.J., 2009. Modeling bedload transport of juvenile bivalves: predicted changes in distribution and scale of postlarval dispersal, *Estuaries and Coasts 32(6),* 1090-1102

Fugate, D.C., and C.T. Friedrichs, 2007, Lateral dynamics and associated transport of sediment in the upper reaches of a partially mixed estuary, Chesapeake Bay, USA, *Continental Shelf Research* 27, 679-698.

Fugate, D.C., R.J. Chant, 2006, Aggregate settling velocity of combined sewage overflow. *Marine Pollution Bulletin* 52, pp 427-432

Fugate, D.C., C.T. Friedrichs, A. Bilgili, 2006, Estimation of Residence Time in a Shallow Back Barrier Lagoon, Hog Island Bay, Virginia, USA., in, Estuarine and Coastal Modeling, Proceedings of the Ninth International Conference, October 31-November 2, 2005, Charleston, SC, ed. Spaulding, ML, American Society of Civil Engineers, 864 pp.

Fugate, D.C., and R.J. Chant, 2005, Near bottom stresses in a small highly stratified estuary, *Journal of Geophysical Research* 110, C03022, doi:10.1029/2004JC002563.

Fugate, D.C., and C.T. Friedrichs, 2003, Controls on Suspended Aggregate Size in Partially Mixed Estuaries, *Estuarine Coastal and Shelf Science, 58,* pp 389-404.

Fugate, D.C., and C.T. Friedrichs, 2002. Determining concentration and fall velocity of estuarine particle populations using ADV, OBS, and LISST. *Continental Shelf Research* 22, pp. 1867-1886.

Lawson, S.E., P.L. Wiberg, K.J. McGlathery and **D. Fugate**, 2007, Wind-driven sediment suspension controls light availability in a shallow coastal lagoon, *Estuaries and Coasts(30)1,* pp 102-112.

Conrad, C.F., **Fugate, D.C.**, Daus, J., Chisholm-Brouse, C.J., Kuehl, S.A., 2007, Assessment of the historical trace metal contamination of sediments in the Elizabeth River, Virginia, *Marine Pollution Bulletin* 54, pp 385-395.

Hunt, H.L., and Maltais, M.J., **Fugate, D.C.,** and Chant, R.J., 2007, Spatial and temporal variability in juvenile bivalve dispersal: effects of sediment transport and flow regime, *Marine Ecology Progress Series* 352, pp 145-159.

James Douglass – Co-Principal Investigator: Dr. Douglass' main field of study is seagrass ecology. He will be overseeing the seagrass metrics such as species distribution and density. He will also prepare the Public Service Outreach youtube video.

Curriculum Vitae

James G. Douglass, PhD
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Education:
2008- PhD Marine Science, College of William and Mary
2002- BS Biology, Rice University

Appointments:

2018 – Present	Associate Professor – Seagrass Science, Florida Gulf Coast University, FL
2012 – 2018	Assistant Professor – Seagrass Science, Florida Gulf Coast University, FL
2010 – 2012	Postdoctoral Research Associate, Northeastern University, MA
2008 – 2010	Postdoctoral Fellow, Smithsonian Marine Station at Fort Pierce, FL

TEACHING

Teaching Experience at FGCU: OCE 1001C Marine Systems, ISC 3120 Scientific Process, PCB 3436C Marine Ecosystems Monitoring and Research Methods, OCB 4633C Marine Ecology, OCB 4936 Senior Seminar Marine Science, BSC 4930 Field Studies in Marine Biology, ISC 4930 CT: Seagrass Ecology,
EVR 4930 ST: Conservation Marine Biology, EVR 6907 Independent Study, EVS 6920 Graduate Seminar: Seagrass Ecology
Graduate Students Mentored (as primary thesis advisor): Shannan C. McAskill Defended Summer 2015, Thomas J. Behlmer Jr. Defended Summer 2016, Lisa Rickards Defended July

2018, Sarah Harrington Defense TBA, Liza Rollins Defense TBA, Amanda Sang Defense TBA, Rachel Pinel Defense TBA, Ashley Szumski, Topic TBD, Brondum Krebs, Topic TBD

RESEARCH

Publications and Technical Reports since 2010:

JG Douglass, RH Chamberlain, Y Wan, PH Doering (2020) Submerged vegetation responses to climate variation and altered hydrology in a subtropical estuary: interpreting 33 years of change. Estuaries and Coasts. 19 pp. http://link.springer.com/article/10.1007/s12237-020-00721-4

JG Douglass, R Paperno, EA Reyier, AH Hines (2018) Fish and seagrass communities vary across a marine reserve boundary, but seasonal variation in small fish abundance overshadows top-down effects of large consumer exclosures. Journal of Experimental Marine Biology and Ecology 507: 39-52. https://doi.org/10.1016/j.jembe.2018.07.003

SC McAskill, JG Douglass (2017) Salinity and temperature alter *Pomacea maculata* herbivory rates on *Vallisneria americana*. Journal of Molluscan Studies doi:10.1093/mollus/eyx034

JL Ruesink, JJ Stachowicz, PL Reynolds, C Boström, M Cusson, J Douglass, J Eklöf, AH Engelen, M Hori, K Hovel, K Iken, PO Moksnes, M Nakaoka, MI O'Connor, JL Olsen, EE Sotka, MA Whalen, JE Duffy (2017) Form-function relationships in a marine foundation species depend on scale: a shoot to global perspective from a distributed ecological experiment. Oikos doi:10.1111/oik.04270

MES Bracken, JG Douglass, V Perini, GJ Trussell (2017) Spatial scale mediates the effects of biodiversity on marine primary producers. Ecology 98:1434-1443

JE Duffy, PL Reynolds, C Boström, JA Coyer, M Cusson, S Donadi, JG Douglass, JS Eklöf, AH Engelen, BK Eriksson, S Fredriksen, L Gamfeldt, C Gustafsson, G Hoarau, M Hori, K Hovel, K Iken, JS Lefcheck, P-O Moksnes, M Nakaoka, MI O'Connor, JL Olsen, JP Richardson, JL Ruesink, EE Sotka, J Thormar, MA Whalen, JJ Stachowicz (2015) Biodiversity mediates top–down control in eelgrass ecosystems: a global comparative-experimental approach. Ecology Letters 18:696-705

CW Gunnels IV, D Buzasi, MK Cassani, J Douglass, T El-Hefnway, EM Everham III, A Hartley, J Herman, M Mujtaba, J Muller, A Nicolas, L Southard, S Thomas, NE Demers (2015) Engaging students in ethical considerations of the scientific process through a simulated funding panel. CUR Quarterly 36:12-18

JG Douglass (2014) South Florida Water Management District, 2014 Systems Status Report: CERP Northern Estuaries Region, Caloosahatchee Estuary Submerged Aquatic Vegetation 1998-2013

JG Douglass, EA Canuel, JE Duffy (2011) Food web structure in a Chesapeake Bay eelgrass bed as determined through gut contents and ^{13}C and ^{15}N isotope analysis. Estuaries and Coasts 34: 701-711.

JG Douglass, KE France, JP Richardson, JE Duffy (2010) Seasonal and interannual change in a Chesapeake Bay eelgrass community: insights into biotic and abiotic control of community structure. Limnology and Oceanography 55: 1499-1520.

Recent Grants and Awards:

Martin Foundation, Seagrass Research, 2020-2021. $32,750.

US Environmental Protection Agency, Enhanced water quality and seagrass monitoring in the Caloosahatchee Estuary, 2019-2021. $264,039. *With FGCU's Puspa Adhikari and Hidetoshi Urakawa, and Sanibel Captiva Conservation Foundation's Rick Bartleson.*

Coastal and Heartland National Estuary Partnership Comprehensive Conservation and Management Plan Restoration Funding Program. Quantifying the water quality benefits of submerged aquatic vegetation (SAV) restoration, 2020-2021. $45,000. *With Edwin Everham and David Ceilley.*

FGCU Scholarship-research Venture Fund Committee. Seagrass Health and Restoration: Sediment Dynamics. $16,780. *With David Fugate.*

South Florida Water Management District. Ecological and Environmental Scientific and Technology Support Services: University Support. *With several colleagues from the FGCU Marine and Ecological Sciences Department. Status granted but no monies received yet.*

City of Naples, FL. Naples Bay Oyster Reef Restoration Ecological Monitoring, 2018-2021. $50,000. *With Serge Thomas.*

Snook and Gamefish Foundation, subcontract through Johnson Engineering Incorporated: *Vallisneria americana* restoration research assistance, 2018 $5000

National Science Foundation, Collaborative Research: The tropicalization of Western Atlantic seagrass beds, 2018-2020 $57,496

South Florida Water Management District, Resolving Uncertainties in Restoration of Seagrasses in the Caloosahatchee Estuary: Epiphytes, 2015-2016 $25,000

Lee County, FL Gulf Coast University Ecological Baseline Survey of North Spreader Canal, Cape Coral, 2014-2015 $34,452

South Florida Water Management District, Caloosahatchee River Estuary Patch-Scale Submersed Aquatic Vegetation Monitoring 2013-2014, $47,600

South Florida Water Management District, Aerial Imagery Acquisition, West Coast Boca Grande to Wiggins Pass, 2014, $41,300

Florida Department of Environmental Protection, Aerial Imagery Acquisition, Rookery Bay National Estuarine Research Reserve, 2014, $25,875,

South Florida Water Management District, Caloosahatchee River Estuary Patch Scale Submersed Aquatic Vegetation Monitoring and Evaluation 2012-2013, $43,200

Other:.

References

Bilkovic, D, M Mitchell, J Davis, E Andrews, A King, P Mason, J Herman, N Tahvildari, and J Davis. 2017. *Review of boat wake wave impacts on shoreline erosion and potential solutions for the Chesapeake Bay. STAC Publication Number 17-002.* William & Mary, 68.

Brown, M, K Kaufman, B Welch, B Orlando, and J Ott. 2016. "Summary report for the Charlotte Harbor region." In *Seagrass Integrated Mapping and Monitoring Report No. 2 Fish and Wildlife Research Institute Technical Report TR-17, version 2*, by L A Yarbro and Carlson P R Jr., 176-189. St. Petersburg, Florida: Florida Fish and Wildlife Conservation Commission. doi:10.13140/RG.2.2.12366.05445.

Crawford, R.E. 2002. "Secondary wake turbidity from small boat operation in a shallow sandy bay." *Journal of Coastal Research* 50-65.

Dixon, L.K. 2000. "Establishing light requirements for the seagrass Thalassia testudinum: an example from Tampa Bay, Florida." In *Seagrasses: Monitoring, Ecology, Physiology, and Management*, edited by S.A. Bortone, 9-31. CRC Press, Florida.

Douglass, J.G., R.H. Chamberlain, Y. Wan, and P.H. Doering. 2020. "Submerged vegetation responses to climate variation and altered hydrology in a subtropical estuary: interpreting 33 years of change." *Estuaries and Coasts.* doi:10.1007/s12237-020-00721-4.

Fugate, D.C., and C.T. Friedrichs. 2003. "Controls on suspended aggregate size in partially mixed estuaries." *Estuarine, Coastal and Shelf Science* 58: 389-404.

Hemminga, M A, and C M Duarte. 2000. *Seagrass Ecology.* New York: Cambridge University Press.

Hotaling, A. 2014. *Seagrass Restoration in a Boating Environment.* Dissertation presented to the University of Florida.

Koch, E W, J D Ackerman, J Verduin, and M van Keulen. 2006. "Fluid dynamics in seagrass ecology- from molecules to ecosystems." In *Seagrasses: biology, ecology, and conservation*, by A W D Larkum, R J Orth and C Duarte, 193-225. Springer.

Koch, E.W. 2002. "Impact of boat-generated waves on a seagrass habitat." *Journal of Coastal Research* 37: 66-74.

Madley, K, J Krolic, and B Sargent. 2004. "Assessment of boat propeller scar damage within the Greater Charlotte Harbor Region." Report by Fish and Wildlife Research Institute to the Charlotte Harbor NEP.

Rapaglia, J., L. Zaggia, K. Ricklefs, M. Gelinas, and Bokuniewicz. 2011. "Characteristics of ships' dression waves and associates sediment resuspension in Venice Lagoon, Italy." *Journal of Marine Systems* 85: 45056.

Rickards, L M. 2018. *Seagrass abundance and distribution in relation to changing envronmental factors in Ester Bay, Florida.* Thesis presented to Florida Gulf Coast University.

Worm, E B, N Barbier, Beaumont N, and et al. 2006. "Impacts of biodiversity loss on ocean ecosystem services." *Science* 314: 787-790.

Additional Project Proposal Documents (not included in the 10-page Project Narrative limit):