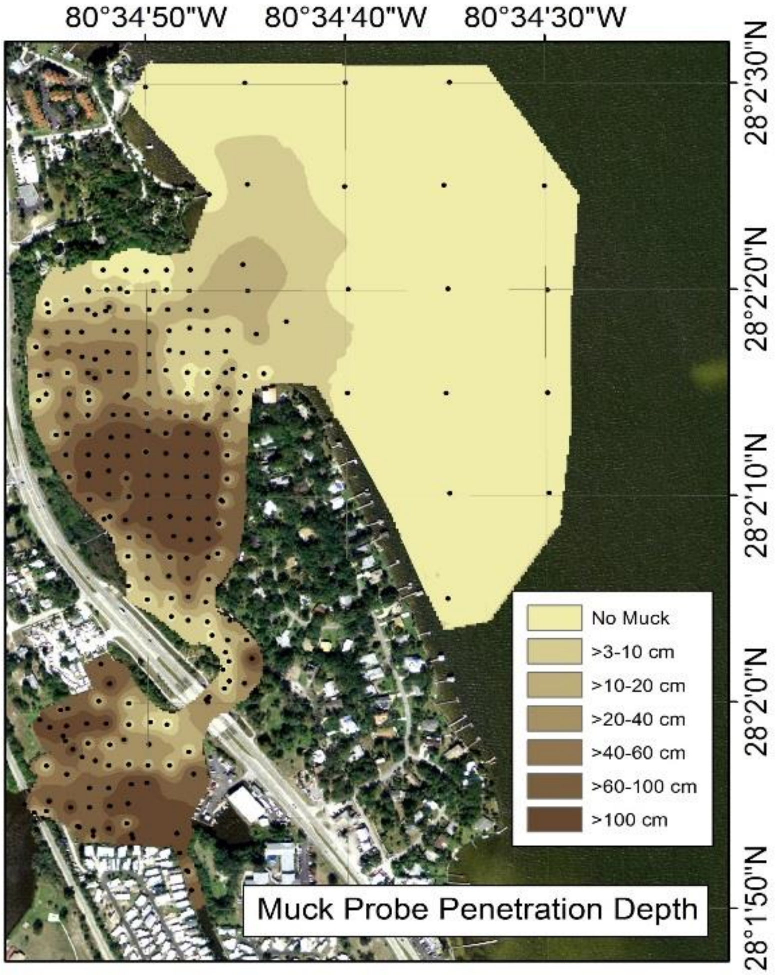
Impacts of Environmental Muck Dredging
2014-2015

Final Project Report to Brevard County Natural Resources Management Department
Funding provided by the Florida legislature as part of
DEP Grant Agreement No. S0714 – Brevard County Muck Dredging



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July, 2016

Cover Image: Contour map of muck thickness in Turkey Creek from the adjacent Indian River Lagoon (IRL) to the Florida East Coast (FEC) railroad bridge. (Courtesy of Robert Trocine)

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Impacts of Environmental Muck Dredging 2014-2015 at Florida Institute of Technology Final Report, July 2016

Investigation of the Impacts of Environmental Muck Dredging in the Indian River Lagoon

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Executive Summary

In order to address serious water quality issues associated with muck sediment in the Indian River Lagoon, the Florida Legislature in the 2014 session directed one million dollars to the Florida Institute of Technology through Brevard County to investigate the effects of environmental muck dredging in the Indian River Lagoon. A collaborative interdisciplinary effort, through the Indian River Lagoon Research Institute (IRLRI) at Florida Institute of Technology, developed five research projects to help better manage future muck sediment removal efforts throughout the state of Florida: (1) Muck Dredging Research Project Management, (2) Biological Responses to Muck Removal, (3) The Efficiency of Muck Removal from Indian River Lagoon and Water Quality after Muck Removal, (4) Movement Measurements of Muck and Fluidized Mud at Dredge Sites, and (5) A Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of Indian River Lagoon. Reported here are results of those investigations.

1. *Muck Dredging Research Project Management*

Five interdisciplinary projects developed by the Indian River Lagoon Research Institute (IRLRI) at Florida Institute of Technology are coordinated through the muck dredging research project management office: (1) Muck Dredging Research Project Management, (2) Biological Responses to Muck Removal, (3) The Efficiency of Muck Removal from Indian River Lagoon and Water Quality after Muck Removal, (4) Movement Measurements of Muck and Fluidized Mud at Dredge Sites, and (5) A Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of Indian River Lagoon. Regular meetings of the Florida Institute of Technology Environmental Muck Dredging (FIT-EMD) research principal investigators with representatives from Brevard County Natural Resource Management Department, Florida Department of Environmental Protection and St. Johns River Water Management District, and a team of external scientific consultants facilitate the exchange of scientific findings among all the investigators and optimize the outcomes of these research investigations. In addition, the project management office engages the public about muck dredging research through presentations open to the public and through social media.

2. *Biological Responses to Muck Removal*

Muck at the bottom of the Indian River Lagoon (IRL) creates an inhospitable environment for plants and animals. In addition, indirect effects of muck, such as nutrient flux into overlying waters can fuel algal blooms, creating stress on pelagic and benthic organisms. As muck is removed from the IRL through environmental dredging efforts, it is essential that we document post-dredge vs pre-dredge ecological conditions, confirming whether or not selected benthic and pelagic components of the IRL system are enhanced. This report details the monitoring of key biological populations (seagrasses, drift algae, invertebrate infauna, and fishes) in Turkey Creek (City of Palm Bay, Brevard County) and the adjacent IRL targeted for environmental muck dredging, as well as in control areas in the IRL for comparison.

Biological data were generally collected monthly through the duration of this study (May 2015-December 2015). Data have been collected and analyzed on the occurrence of seagrass (*Halodule wrightii*) and drift algae, including their % cover, canopy heights, % occurrence, and biomass. *H. wrightii* was not present in transect sampling within Turkey Creek, nearest the planned dredge site. *H. wrightii* was most abundant, when present, in the shallower nearshore portions of transects (40-70 cm depth) within the adjacent IRL, and generally declined in October and December, 2015. In contrast, drift algae, comprised mostly of *Gracilaria* spp. and one or two other abundant species, were most abundant in Turkey Creek, relative to the sites in the IRL proper. Drift algae were most abundant in May 2015 in Turkey Creek and the adjacent lagoon area. Drift algae were more pervasive temporally and spatially compared to seagrasses, but did decline in the winter; nearly absent in the December 2015 sampling. In addition, the abundances and distributions of 59 species of invertebrate benthic infauna were determined via surface sediment grabs. Sediments were evaluated with regard to grain size and organic content, and for correlations between those two sediment properties and species diversity and richness. Richness and diversity of infaunal invertebrate communities were greatest at the IRL sites, almost nil within muck, and intermediate in Turkey Creek adjacent to the planned dredge site. Sediments at these sites displayed a gradient of Fine-Grained Organic-Rich Sediment (FGORS) characteristics, which co-varied with the occurrence of certain species and with the diversity and richness patterns. Diversity and abundance are greater in cleaner sediments with relatively low FGORS scores.

Fish populations, abundances and distributions, were also determined via monthly seine net sampling. Pelagic schooling anchovies (*Anchoa* spp.) comprised 92.2% of the entire seine catch, which reflects the typical numerical dominance of these fishes within the IRL system. The high variability in anchovy catches reflect the patchy distribution of the schools and their movement into and out of Turkey Creek. Demersal juvenile fishes were dominated by mojarras (*Eucinostomus* spp. and *Diapterus* spp.; 3.2% of the total catch), and the important commercial/recreational fisheries family Sciaenidae (including silver perch, red drum, Atlantic croaker, spot, sea trout and kingfish; 2.3% of the total catch). The temporal patterns of abundance of these juveniles are influenced by the temporal and spatial patterns in adult spawning behavior. These baseline data will enable us, once dredging in Turkey Creek has occurred, to make comparisons in biological populations and communities before and after environmental muck dredging.

3. The Efficiency of Muck Removal from the Indian River Lagoon and Water Quality after Muck Removal

Muck removal is an integral part of the restoration process in the Indian River Lagoon (IRL) system. This fine-grained, organic-rich material (muck) (1) is easily resuspended to increase turbidity, (2) consumes oxygen, (3) creates an inhospitable benthic habitat, (4) serves as a reservoir for potential pollutants and (5) is an internal source of dissolved nitrogen and phosphorus that diffuse into lagoon waters at a rate commensurate with external sources in the North IRL. This study began in February 2015 with a muck survey of Turkey Creek in advance of proposed dredging during 2016. Little or no muck was present in the adjacent IRL near the mouth of Turkey Creek in contrast with layers that were 1- to 3-m thick throughout most of the lower creek. The estimated total volume of wet muck in the creek from this study is 111,000 m^3 (145,000 yd^3). Muck sediments from the creek contained >75% water by weight (>90% water by volume), 76-99% silt + clay, and 11-22% organic matter (4-7% organic carbon, 0.4-0.8% organic N and 0.10-0.17% total phosphorus). These values match earlier characterizations of muck deposits.

Water quality surveys were carried out monthly from April to December 2015 at five stations. Continuous profiles for salinity, temperature, dissolved oxygen and pH were obtained and 2-5 discrete water samples were collected at each station (135 total samples over 9 months). Water samples were analyzed for (1) turbidity (NTU) and total suspended solids (TSS in mg/L), (2) total concentrations of particulate iron, aluminum, silicon, nitrogen, phosphorus and organic carbon and (3) concentrations of dissolved ammonium, nitrate + nitrite, organic carbon, phosphate, total nitrogen and total phosphorus. Data from the water quality surveys will be used in the post-dredging assessment of the effectiveness of muck removal.

The average chemical forms of nitrogen in the water column (n = 135 samples), with percent of the total nitrogen in parenthesis, were as follows: dissolved organic nitrogen (57.8%), particulate organic nitrogen (32.1%), ammonium (8.9%) and nitrate + nitrite (1.2%). Large spikes in concentrations of ammonium (up to 50 µM or 0.7 mg N/L) were found in small depressions in Turkey Creek and linked to releases from muck sediments. These high values were ~10-fold greater than median concentrations of ~5 µM (0.07 mg N/L) in the overall study area. Concentrations of nitrate + nitrite were regularly higher in fresher water near the Florida East Coast railroad bridge (4-6 µM; 0.06-0.08 mg N/L) relative to average values near the mouth of Turkey Creek of ~1 µM (0.014 mg N/L).

For phosphorus, the chemical forms in the water column (n = 135 samples), with percent of the total phosphorus in parenthesis, averaged as follows: particulate organic phosphorus (48.7%), phosphate (29.7%) and dissolved organic phosphorus (21.6%). Concentrations of dissolved phosphate as high as 10 µM (0.31 mg P/L) were found in the same small depressions with high ammonium values. These phosphorus spikes also were linked to releases from muck sediments. The median phosphate value in Turkey Creek was 0.8 µM (0.025 mg P/L). The lowest concentration of dissolved phosphate was 0.03 µM (0.0009 mg P/L) in the adjacent IRL during December.

Tracking changes in fluxes of nitrogen and phosphorus from muck sediments is an important part of the post-dredging assessment. Fluxes of nitrogen (essentially all as ammonium) and phosphorus (essentially all as phosphate) from muck sediments averaged ~ 10 and 1 metric tons/km^2/yr, respectively, with a large contribution to bottom water ammonium and phosphate concentrations.

The post-dredging assessment of the effectiveness of muck removal from Turkey Creek will include the following components: (1) a muck survey, (2) determination of the composition of remaining sediment in the creek after dredging, (3) comparison of pre- and post-dredging concentrations, forms and distribution of selected water quality parameters, especially dissolved oxygen, particulate organic carbon and dissolved and particulate nitrogen and phosphorus and (4) determination of nitrogen and phosphorus fluxes from bottom sediment to the water column.

4. Movement Measurements of Muck and Fluidized Mud at Dredge Sites

Muck is typically greater than 75% water by weight (Trefry et al., 1987) and like water, it moves as fluid mud (Mehta et al., 1994) when disturbed by wind waves and currents. The purpose of measuring muck and fluidized mud movement is to provide management information that can be applied to calculate the mass of moving particulate material just above the bottom. This moving dense fluid is a “carrier” of nutrients. Data concerning the magnitude of moving muck and fluid mud in terms of transport fluxes in bottom waters can be used in calibration of sediment and water quality models.

Muck movement and fluxes measured from sonde deployments in Palm Bay and Turkey Creek closely match the magnitude of fluxes reported in previous studies (Mehta et al., 1994; Maglio et al., 2016; Bostater and Rotkiske, 2015). The moving muck and fluid mud collected within the *in-situ* sondes is in agreement with the definitions used in previous research (Trefry et al., 1987; Teeter et al., 1992; Teeter, 1994; McAnally et al., 2007). At the mouth of Palm Bay, the measurements of moving fluid mud and muck suggest a net westward (upstream) flow and accumulation of moving fluid mud in the southwestern area of Palm Bay (east of US1). This was verified by sludge judge measurements of muck depths greater than 3 m. Stokes drift velocity (Craik, 2005) concerning residual upstream bottom transport also supports this westward (upstream) movement of particulates in the bottom boundary layer. The Stokes drift velocity in Palm Bay would be westward due to westward propagating wind driven gravity waves when the wind blows from east to west. Stokes drift theory in shallow bottom waters suggests that moving fluid mud and muck from outer Palm Bay will thus likely contribute to buildup of muck in the deep dredged area east of US1.

Particulates moving into the sondes located in the moving lutocline and nepheloid layers include estuarine flocs (colloidal aggregates). These fine grain flocs were clearly observable in optical and acoustic imagery. The irregular size of these floc aggregates was quantitatively analyzed and described. The magnitude of the floc material collected by the sondes within the moving fluid mud is similar to prior research in the Indian River Lagoon (Bostater and Rotkiske, 2016. Image analysis of flocs indicated predominant effective diameters of 0.1 mm to 10.2 mm. Mean cross-sectional floc diameter was 2.77 mm (2770 µm) ± 2.44 mm SD with a *median* floc effective cross-sectional area of ~30 mm^2. These particulates do not settle according to Stoke’s law for individual particle settling. Stokes settling law applies only for laminar flows and spherical particles.

Area wide station analysis utilizing all flux density sonde results indicate different magnitudes of material moving (1) west of the railroad bridge, (2) east of US1 and within Palm Bay, and (3) at the mouth of Palm Bay and nearby Indian River Lagoon. Station sonde fluxes at the mouth of Palm Bay were greater than 1200 g m^{-2} day^{-1}. A net upstream flux (towards Palm Bay and west of US1) in the lower 0.5 meter water column transect across the mouth of Palm Bay was measured. The total dry weight moving muck collected across a transect of six stations at the mouth of Palm Bay indicated a net upstream movement 93,000 g day^{-1} (~34,000 kg yr^{-1}). This net upstream result is also consistent with a Stokes drift towards US1 during the sampling period.

Area wide GIS spatial analysis demonstrates that sonde data processed in a gridded manner could be applied in modeling water quality and sediments. The gridded state variables include transport fluxes of particulate organic matter, particulate inorganic matter, particulate organic nitrogen, particulate organic phosphorus and particulate organic carbon movement. The data from this project estimated nutrient transport fluxes within the moving muck by utilizing muck-nutrient relations developed by Trefry, 2015.

The pre-dredging data developed can be used to assess the efficacy of future dredging in terms of muck movement reduction (MMR) by comparing the magnitude of moving muck (1) before dredging, (2) during dredging and (3) after dredging. This procedure has been used in a previous dredging study in the Indian River Lagoon (Maglio et al., 2016; Bostater and Rotkiske, 2015;

Rotkiske and Bostater, 2016) to estimate the reduction in moving muck after dredging. In summary, data derived from the sondes can provide important sediment flux (mass transport) of sediments in the bottom boundary layer and the moving lutocline for future bottom sediment forecast modeling.

5. Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of the Indian River Lagoon

A coupled hydrodynamic-water quality model of the Indian River Lagoon is designed as a tool for understanding the ecology, maintaining water quality goals, and forecasting the potential benefits of management strategies, including muck dredging. The overall goal is to integrate water quality and physical process data into the coupled model of the IRL for long-term calibrated and validated predictions of water quality. Questions to be answered include: 1) whether muck dredging will improve local water quality in the vicinity of Turkey Creek and other localities that are to be dredged over the next several years, 2) whether improved model guidance by measured *in situ* data and modeled watershed data will allow the relative effects of watershed inputs and nutrient flux from muck sediments to be resolved, 3) if muck dredging, either locally or regionally, can result in a lasting improvement of IRL water quality. Project tasks are aimed at evaluating the benefits of muck dredging in the north and central Indian River Lagoon, among other issues.

Model validation results show a good match between predicted and measured parameters such as salinity, temperature, water level, and dissolved oxygen. Model runs under various scenarios/cases were conducted to test potential water quality improvements that may result from muck dredging. Model Case 1 includes existing conditions with respect to watershed inputs, baseflows, and gauged freshwater flow into Turkey Creek from the C-1 control structure. Nutrient flux from the benthic boundary of Turkey Creek was set according to fluxes reported by Dr. John Trefry in Chapter 3 of this report. In the region surrounding Turkey Creek the flux was set to be equivalent to the IRL average. Model Case 2 assumed a 50% reduction in the ammonium-based nitrogen flux from muck sediment to the water column. Model results indicate a reduction of about 25% to 30% in total nitrogen concentration in the water column at the mouth of Turkey Creek after hypothetical reduction of ammonium flux based on muck removal. Model results also showed a detectable, but variable reduction of total nitrogen within 4 km of Turkey Creek entrance. A numerical (model) monitoring station in the IRL, 10 km to the south of Turkey Creek entrance, showed a detectible reduction in total nitrogen concentration for the first half of a 2-year model run. Other water quality variables are also calculated including forms of phosphorus, dissolved oxygen, and several others. These model data along with values for nitrogen components are stored in model data archives for further analysis.

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Chapter 1 Muck Dredging Research Project Management

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1.1 Summary

Five interdisciplinary projects developed by the Indian River Lagoon Research Institute (IRLRI) at Florida Institute of Technology are coordinated through the muck dredging research project management office: (1) Muck Dredging Research Project Management, (2) Biological Responses to Muck Removal, (3) The Efficiency of Muck Removal from Indian River Lagoon and Water Quality after Muck Removal, (4) Movement Measurements of Muck and Fluidized Mud at Dredge Sites, and (5) A Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of Indian River Lagoon. Regular meetings of the Florida Institute of Technology Environmental Muck Dredging (FIT-EMD) research principal investigators with representatives from Brevard County Natural Resource Management Department, Florida Department of Environmental Protection and St. Johns River Water Management District, and a team of external scientific consultants facilitate the exchange of scientific findings among all the investigators and optimize the outcomes of these research investigations. In addition, the project management office engages the public about muck dredging research through presentations open to the public and through social media.

1.2 Introduction

In order to address serious water quality issues associated with muck sediment in the Indian River Lagoon, the Florida Legislature in the 2014 session directed one million dollars to the Florida Institute of Technology through Brevard County to investigate the effects of environmental muck dredging in the Indian River Lagoon (IRL). A collaborative, interdisciplinary effort, through the Indian River Lagoon Research Institute (IRLRI), developed the following projects to help better manage future muck removal efforts throughout the state.

1. Muck Dredging Research Project Management

   Project Management coordinates effective communications of research plans and results between principal investigators, Brevard County Department of Natural Resources Management, other agencies, external reviewers and the public.

2. Biological Responses to Muck Removal

   In preparation for planned environmental muck dredging, this project monitors three essential measures of lagoon ecosystem health through the following studies: seagrass surveys; benthic infauna surveys; and fish surveys. When dredging occurs, the surveys conducted this year will serve as the baseline for comparison for determining whether these key populations recover or improve after the muck has been removed.

3. The Efficiency of Muck Removal from the IRL and Water Quality after Muck Removal.

   This project is addresses both the muck removal and water quality issues by (1) determining the muck removal efficiency using high-resolution measurements and (2) making *in situ* measurements and collecting water samples for chemical analysis to help assess the impact of muck removal on water quality.

4. Movement Measurements of Muck and Fluidized Mud at Dredge Sites.

   This project (1) measures *in-situ* movement (horizontal and vertical) of fluid mud and muck at transects and stations in Turkey Creek west of the railroad bridge, east of US 1 in Turkey Creek at 2 locations in the IR and (2) collects data at the stations and transects using newly developed fluid mud and muck sondes or probes. The data will help assess the impacts of muck removal on lagoon water quality and will provide new methods and information to assist in setting future dredging priorities.

5. Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of the IRL.

   A coupled hydrodynamic-water quality model of the IRL develops a tool for understanding the ecology, maintaining water quality goals, and forecasting the potential benefits of management strategies. The approximate model domain extends between north Mosquito Lagoon and Vero Beach.

In the Chapters 2 through 5, the principal investigators report on environmental conditions before dredging at Turkey Creek in Palm Bay, Florida. Each Chapter is intended to stand alone.

1.3 Approach

Each of the five projects is coordinated through the project management office. Regular meetings of the Florida Institute of Technology Environmental Muck Dredging (FIT-EMD) research principal investigators facilitate the exchange of scientific findings among all the investigators. Results of field and lab work as well as logistics discussions are shared with all interested parties. The project management office assembles and distributes written monthly, quarterly and final project reports. The project management office also keeps Brevard County Natural Resources Management Department staff up to date on muck dredging research findings by (1) sending email updates, (2) holding monthly scientific roundtable discussions with interested (IRL) agencies and organizations, (3) conducting quarterly scientific presentations and project review meetings, and (4) obtaining and incorporating peer review by external scientists. In addition, the project office engages the public about muck dredging research through presentations open to the public and through social media applications.

1.4 Results

Project design and research updates have been discussed at monthly and quarterly meetings throughout the year. Representatives from Brevard County Natural Resources Management Department, FDEP, SJRWMD and Harbor Branch Oceanographic Institute at FAU all receive the monthly and quarterly reports through the FIT-EMD mailing list. Anyone who has requested regular updates has been added to the list. Monthly and quarterly meeting dates are shown in Table 1.1.

Table 1.1 IRLRI Environmental Muck Dredging Research 2015 Monthly/Quarterly Meetings

- March 16, 2015 – Discussion of results, logistics and sampling strategies
- April 20, 2015 – Discussion of results, logistics and sampling strategies
- May 18, 2015* – Quarterly Meeting at Florida Tech; After updates from each PI, discussion items included alteration to some of the field sampling locations, transplantation of seagrass, how deep the dredging should be in Turkey Creek and dredging permit progress.
- July 20, 2015 – Discussion of results, logistics and sampling strategies
- August 10, 2015* – Quarterly at Brevard County Department of Natural Resource Management; The FIT-EMD team regular August monthly meeting was conducted at the Brevard County Natural Resources Management Department office in Viera. Suggestions from IRLRI PIs for continuation and new projects were entertained during the meeting. On hand were County staff, FIT administrative staff, and external reviewers.
- September 14, 2015 – Since the August meeting discussions continued among those attending the review meeting to provide feedback to all those who proposed projects. Scopes of Work (SOWs) were developed for each project proposed based on the feedback received from the review process. These SOWs were submitted to the County for additional review and comment. As a result of this repetitive, interactive process, all of the new and continuation projects are ready to begin.
- November 9, 2015* – Quarterly Meeting at Florida Tech; Discussion focused on initiation of dredging, logistics and continuation of current projects and initiation of new projects.
- December 14, 2015 – Discussion of results, logistics and sampling strategies during dredging.
- February 1, 2016* – Combined January/February meeting. Discussion of results, logistics and sampling strategies during dredging.

**indicates quarterly meeting*

External scientific review is important for the ongoing work. At least three independent reviewers have offered comments throughout the year, including reviews of current research direction as well as future proposed efforts. An external review panel was assembled and offered comments, criticisms and recommendations for new and continuing projects proposed to start in 2016.

In addition to coordinating the research efforts, reaching out to the community is important to explain the impacts of IRL muck and the potential benefits associated with muck removal in the overall context of IRL restoration. Highlights of outreach efforts undertaken by the PIs on this project are summarized in Table 1.2 below. Twitter and Facebook continue to be used to describe some muck basics, issues associated with muck, the ongoing research relevant to muck, the need for muck removal and the progress on muck removal and public presentations by the FIT Environmental Muck Dredging Research Team. Follow @IRLMuck #IRLMuck.

Table 1.2 Indian River Lagoon Research Institute (IRLRI) Muck Research Related Presentations

- *March 13, 2015 – John Windsor gave a presentation to the Senior Life Expo describing better management of Indian River Lagoon resources, which included describing muck and removing muck.*
- *April 2, 2015 – Muck removal from the Indian River Lagoon was the title of a talk by Dr. John Trefry presented to the Space Coast Progressive Alliance.*
- *April 22, 2015 – Dr. Trefry gave muck removal presentation before the Indian River Lagoon Counties Collaborative meeting at the Indian River County Commission chambers.*
- *May 18, 2015 – John Windsor gave a short presentation on the necessity of muck removal research to a group of concerned citizens attending "An Estuary Affair" at Florida Institute of Technology.*
- *May 22, 2015 – Muck removal investigations were part of the IRLRI (Indian River Lagoon Research Institute) presentation by Dr. Robert Weaver at the Indian River Lagoon Counties Collaborative.*
- *May 26, 2015 – John Windsor appeared briefly at the Brevard County Commission meeting to let them know that the FIT-EMD was working on the muck removal investigations.*
- *July 7, 2015 – John Windsor discussed muck removal at the Eau Gallie Rotary Club meeting.*
- *August 21, 2015 – Dredging research in Indian River County was the subject of a presentation by Robert Weaver to the Florida Inland Navigation District Board.*
- *August 25, 2015 – John Windsor provided public comments to the Melbourne City Council on an issue regarding the disposal of muck sediment from the Eau Gallie River.*
- *September 26/27, 2015 – IRLRI PIs attended the first annual IRLRI Tech Con in Melbourne, Florida. Much discussion at the conference was focused on impacts of muck and strategies for muck removal and management. FIT-EMD PIs will be assisting in the organization of next year's meeting. Drs. Weaver and Zarillo gave talks describing muck removal and modeling the effects of muck removal on Indian River Lagoon.*

Table 1.2 Indian River Lagoon Research Institute (IRLRI) Muck Research Related Presentations (Cont'd)

- *October 13, 2015 – Dr. Trefry spoke to the Board of County Commissioners, Indian River County, about impact of muck on Indian River Lagoon and the necessity for its removal from the Lagoon. He also emphasized preventing muck from entering the Indian River Lagoon.*
- *October 20, 2015 – Dr. Trefry spoke to the Exchange Club of South Brevard about impact of muck on Indian River Lagoon and the necessity for its removal from the Lagoon. He also emphasized preventing muck from entering the Indian River Lagoon.*
- *November 6, 2015 – Dr Zarillo discussed his Indian River Lagoon modelling efforts at the ShORE2015 Conference in Daytona Beach, Florida. Several other IRLRI PIs attended.*
- *February 10, 2016 – Drs. Johnson and Trefry presented muck related research as part of the Algal Bloom Initiative meeting at Harbor Branch Oceanographic Institute in Fort Pierce*
- *February 11, 2016 – Dr. Austin Fox presented a paper at the Indian River Lagoon Symposium 2016 entitled Identifying Controls on Fluxes of Dissolved Nitrogen from Sediments in the Northern Indian River Lagoon by Austin L. Fox, John H. Trefry, Robert P. Trocine, and Stacey L. Fox, Florida Institute of Technology, Melbourne, FL.*
- *February 11, 2016 – Daniel Hope presented a paper at the Indian River Lagoon Symposium 2016 entitled Organic Sediment Characteristics and Benthic Infaunal Diversity in the Indian River Lagoon by Daniel Hope, Tony Cox, Angelica Zamora-Duran, and Kevin B. Johnson, Florida Institute of Technology, Melbourne, FL*
- *February 11, 2016 – Angelica Zamora-Duran presented a paper at the Indian River Lagoon Symposium 2016 entitled Benthic Foraminifera as Bioindicators of Environmental Conditions in the Indian River Lagoon by Angelica Zamora-Duran, Anthony Cox, Daniel Hope, and Kevin B. Johnson, Florida Institute of Technology, Melbourne, FL*
- *February 24, 2016 – Dr. Austin Fox presented a paper at Oceans 2016 in New Orleans entitled Physical, chemical and biological controls of nutrient fluxes from fine-grained, organic-rich sediments in the Indian River Lagoon, Florida by Austin L. Fox, John H. Trefry, Robert P. Trocine, Stacey L. Fox, Florida Institute of Technology, Melbourne, FL*

An important element that should be captured from all the research and dredging activities that have occurred to date and planned over the next few years is "What Lessons Did We Learn?" An interdisciplinary team of Coastal Zone Management and Environmental Resource Management graduate students recently began to develop an Indian River Lagoon Muck Management Manual. The lessons learned from the IRL muck dredging experience will be of value to coastal environmental muck dredging projects not just for the entire IRL, but also throughout the state of Florida.

Chapter 2 Biological Responses to Muck Removal

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2.1 Summary

Muck at the bottom of the Indian River Lagoon (IRL) creates an inhospitable environment for plants and animals. In addition, indirect effects of muck, such as nutrient flux into overlying waters can fuel algal blooms, creating stress on pelagic and benthic organisms. As muck is removed from the IRL through environmental dredging efforts, it is essential that we document post-dredge vs pre-dredge ecological conditions, confirming whether or not selected benthic and pelagic components of the IRL system are enhanced. This report details the monitoring of key biological populations (seagrasses, drift algae, invertebrate infauna, and fishes) in Turkey Creek (City of Palm Bay, Brevard County) and the adjacent IRL targeted for environmental muck dredging, as well as in control areas in the IRL for comparison.

Biological data were generally collected monthly through the duration of this study (May 2015-December 2015). Data have been collected and analyzed on the occurrence of seagrass (*Halodule wrightii*) and drift algae, including their % cover, canopy heights, % occurrence, and biomass. *H. wrightii* was not present in transect sampling within Turkey Creek, nearest the planned dredge site. *H. wrightii* was most abundant, when present, in the shallower nearshore portions of transects (40-70 cm depth) within the adjacent IRL, and generally declined in October and December, 2015. In contrast, drift algae, comprised mostly of *Gracilaria* spp. and one or two other abundant species, were most abundant in Turkey Creek, relative to the sites in the IRL proper. Drift algae were most abundant in May 2015 in Turkey Creek and the adjacent lagoon area. Drift algae were more pervasive temporally and spatially compared to seagrasses, but did decline in the winter; nearly absent in the December 2015 sampling. In addition, the abundances and distributions of 59 species of invertebrate benthic infauna were determined via surface sediment grabs. Sediments were evaluated with regard to grain size and organic content, and for correlations between those two sediment properties and species diversity and richness. Richness and diversity of infaunal invertebrate communities were greatest at the IRL sites, almost nil within muck, and intermediate in Turkey Creek adjacent to the planned dredge site. Sediments at these sites displayed a gradient of Fine-Grained Organic-Rich Sediment (FGORS) characteristics, which co-varied with the occurrence of certain species and with the diversity and richness patterns. Diversity and abundance are greater in cleaner sediments with relatively low FGORS scores.

Fish populations, abundances and distributions, were also determined via monthly seine net sampling. Pelagic schooling anchovies (*Anchoa* spp.) comprised 92.2% of the entire seine catch, which reflects the typical numerical dominance of these fishes within the IRL system. The high variability in

anchovy catches reflect the patchy distribution of the schools and their movement into and out of Turkey Creek. Demersal juvenile fishes were dominated by mojarras (*Eucinostomus* spp. and *Diapterus* spp.; 3.2% of the total catch), and the important commercial/recreational fisheries family Sciaenidae (including silver perch, red drum, Atlantic croaker, spot, sea trout and kingfish; 2.3% of the total catch). The temporal patterns of abundance of these juveniles are influenced by the temporal and spatial patterns in adult spawning behavior. These baseline data will enable us, once dredging in Turkey Creek has occurred, to make comparisons in biological populations and communities before and after environmental muck dredging.

2.2 Introduction

In association with Brevard County's dredging plans, we have monitored biological populations in a region targeted for environmental muck dredging. This monitoring has included measurements of environmental conditions, especially the sediments, and population ecology of seagrasses, drift algae, infauna, and fishes of the Indian River Lagoon. Muck removal is intended to improve IRL ecosystems, providing an opportunity for stressed populations to rebound. Measuring critical ecosystems near dredging sites, before the dredging actually occurs, prepares us for [future] during- and post-dredging comparisons, which will allow us to evaluate the success of muck removal. Sampling areas proximal to planned dredging sites, as well as away from dredge sites at thriving areas, allows interpretations to be more conclusive on the driving forces behind observed changes.

Objective

- Pre-dredging assessment of seagrasses, benthic fauna and fishes near dredging sites, contrasted with away or control sites.

Seagrasses and Drift Algae

Seagrasses are key indicators of lagoon health, promote biodiversity, and form critical habitat that serves as a nursery for juvenile fish populations (Virnstein and Morris 1996, Morris et al. 2001). They thrive in medium to low nutrient conditions in clear shallow water. Drift algae, while a natural part of estuarine and lagoon systems, tend to thrive with higher nutrients. Abundant drift algae can smother and/or shade seagrasses. Thus, the relative abundance of these two types of primary producers can indicate much about the relative condition of the ecosystem and possible eutrophic nitrification. In Turkey Creek (Palm Bay), sediments in the deeper areas are muck, while sediments in the shallower waters are not purely muck, but still contain high Fine-Grained Organic-Rich Sediments (FGORS) (see Trefry and Trocine 2011 for muck and FGORS definitions based upon sediment characteristics and chemistry). Sparse seagrasses (*Halodule wrightii*) occur in this body, and it is common for drift algae (*Gracilaria* spp.) to accumulate and rest on top of seagrass. Sediment conditions and the apparent competition of algae with struggling seagrass make it a good test system to see if removal of FGORS can improve the benthic conditions sufficiently for measurable improved seagrass growth. Because infaunal (Wong and Dowd 2015) and fish (Hori et al. 2009) communities are known to thrive in seagrasses, there is also ample potential for indirect effects.

Infauna

Macro- and microinvertebrates in estuarine sediments are food for benthic foraging fish and their burrows and movements serve to aerate the sediments (Gonzalez-Ortiz et al. 2014). These organisms are perhaps the most directly affected by the conditions of sediments, and are presumed to be negatively impacted by high organic content and unable to live in muck. However, the effects of

FGORS and muck on infaunal populations and communities have not been empirically tested or demonstrated in the literature.

A common and potentially important infaunal organism in Turkey Creek is the foraminiferan *Ammonia parkinsoniana*. *Ammonia* was the first genus assigned to Foraminifera in 1772 (Holzmann 2000) and since then has been a focus of research due to global distribution and variable morphology, especially since morphology has been shown to vary due to pollution (Boltovskoy et al. 1991**;** Alve, 1995; Colburn 1998; Frontalini 2015) Over 46 species, subspecies and varieties have been described (Holzmann 2000). *Ammonia* are common in benthic, nearshore environments, with *Ammonia parkinsoniana* being found in shallower waters (Jorissen 1988). *Ammonia parkinsoniana* tolerate wide ranges of temperature and salinity, and hypoxic conditions (Cushman, 1970; Karlsen et al. 2000). Foraminifera have been used as environmental bioindicators of water quality and pollution in estuarine ecosystems (Ishman et al. 1997; Gapotchenko et al. 2000; Karlsen et al. 2000; Alves Martins et al. 2015), although one has to be cautious about interpreting the implications of their presence if patches frequently surge in abundance and disappear (Buzas et al. 2015). Foraminifera can be used as a tool for assessing and monitoring the ecosystems due to their distribution, abundance, short generation times, reliable fossil record, and environmental sensitivity (Schönfeld et al. 2012). Indices have been proposed whereby resource managers can monitor environmental conditions and recovery by watching foraminiferan assemblages (Sen Gupta et al. 1996; Hallock et al. 2003). In addition to monitoring efforts, paleoecological data from fossilized foraminiferan tests provide invaluable temporal perspectives to ecologists and restoration planners (Willard and Cronin2007). Due to their tolerances to organic sediments, it is anticipated that *A. parkinsoniana*'s abundance and distribution may be responsive to the removal of FGORS sediments and the subsequent reduction of the ammonia, hypoxia, and hydrogen sulfide associated with those sediments.

Fishes

Fishes constitute one of the most valuable and visible components of the Indian River Lagoon ecosystem. The highly diverse ichthyofauna of the IRL includes many species that support recreational fisheries, with other species filling important ecological roles. The life history strategy of IRL species reflect several basic patterns. Some species spend their entire lives from egg through adult stage within the lagoon. Others spawn near the inlets or offshore, producing planktonic larvae that ultimately settle as juveniles in various habitats in the lagoon. Regardless of the reproductive strategy used, most species rely on juvenile nursery habitats within the lagoon. Human impacts on these juvenile habitats are considered among the greatest potential factors that can influence the population structure and dynamics of the species.

In the 1990s, the State of Florida began a very intensive survey of juvenile fishes throughout the IRL and many other estuarine habitats around Florida. The Fisheries Independent Monitoring Program (FIM) developed standardized sampling protocols that are utilized in a broad sampling program through the IRL and other targeted estuaries (FWCC 2014). Data collected by this decades-long fisheries survey can be used to identify natural variations in juvenile abundance and distribution, and to assess potential anthropogenic impacts on fish populations (e.g., Tremain and Adams 1995; Paperno and Mille 2001; Paperno et al. 2006).

The FIM program uses a stratified random sampling procedure to establish sampling sites throughout the entire Indian River Lagoon region. The researchers expend a tremendous amount of effort on the sampling, and their data have helped define the temporal and spatial patterns of habitat utilization of lagoon species, as well as quantifying short-term and interannual variations in abundance. However, the lagoon is so vast that annual sampling density in any given region, such as Turkey Creek, is generally low, precluding fine-scale assessment of individual habitats or events.

The FIM sampling strategy, at a far smaller spatial and temporal scale, was employed for this project to generate a far more detailed picture of the temporal and spatial distribution of fishes within and adjacent to the planned muck removal site within the mouth of Turkey Creek (“Palm Bay”). These data can be compared with the wider FIM database to evaluate site specific attributes of the fish fauna within Turkey Creek and adjacent IRL habitats.

The adult fishes that utilize the Turkey Creek habitats are not vulnerable to capture using the FIM juvenile fish sampling techniques. Interviews with anglers fishing in Turkey Creek, and our personal experiences, have identified a number of adult fishery species, including sheepshead (resident on dock pilings and oyster/rock piles), jacks and red drum (highly mobile schooling species), tarpon and (juvenile) bull sharks (generally solitary mobile predators). The mobile predators tend to follow schools of prey, including anchovies, mullet, and herrings, so their utilization of the Turkey Creek habitats can be highly variable.

2.3 Approach (Including referenced methods)

Biological monitoring was conducted in the region near the mouth, but within Turkey Creek (“Palm Bay”), where environmental muck dredging will soon occur. In addition, biological monitoring was conducted at various sites away from the dredging for comparison with the biological work adjacent to the anticipated dredging.

Sampling Sites and Methods - Seagrasses and Drift Algae

Four 100-m transects were surveyed perpendicular to the shoreline at 3 major sites: within Turkey Creek (TC), in the Indian River Lagoon (IRL) near Turkey Creek (TCL), and in the IRL near Crane Creek (CCL) (Figure 2.1). Quadrats were laid down every 10 m along the transect lines, and seagrasses and drift algae were scored according to standard methods (Virnstein & Morris 1996, Morris et al. 2001). Measurements included seagrass visual estimate % cover (estimated coverage upon imagining the seagrass crowded into corner of quadrat at a high density), seagrass % coverage or occurrence (proportion of 100 quadrat sub-squares having at least 1 blade of seagrass), seagrass density (# of shoots per area), seagrass canopy height (the length of blade from sediment to tip), drift algae % occurrence (the proportion of 100 quadrat sub-squares having any drift algae), drift algae biomass estimate (estimated coverage upon imagining drift algae crowded into corner of quadrat), and drift algae canopy height (Virnstein & Morris 1996, Morris et al. 2001). Sampling was conducted monthly from May-December, 2015. Seagrass and algal abundances were plotted as means ± SE. Where appropriate, statistical comparisons were made via ANOVA.

Sampling Sites and Methods – Benthic Fauna

Sediment grabs for infaunal analysis were collected at the 50-m mark along all seagrass transects described above (Figure 2.1) via Petite Ponar Grab (n=3 per transect). In addition, 4 sites were selected in the heart of the most concentrated muck sediments, including 2 sites in Turkey Creek muck (TCM, n=3 each) and 2 sites in Crane Creek muck (CCM, n=3 each) (see Figure 2.1). Sampling and identification of infauna were conducted consistent with the methods of ongoing benthic studies of the IRL (Mason 1998, Cooksey and Hyland 2007, Tunberg et al. 2008b). Abundances, diversity, and richness of fauna were tested for correlations with sediment parameters, including % organic content (dry weight), % water content by weight, % silt/clay content (dry weight), and score on a subjective hydrogen sulfide odor index. Where appropriate, statistical analyses included ANOVA for spatial comparisons on a given day, ANOVA for temporal comparisons for a given site, NMDS community analysis with posthoc ANOSIM, and regression correlation analysis comparing biological data to corresponding sediment data.

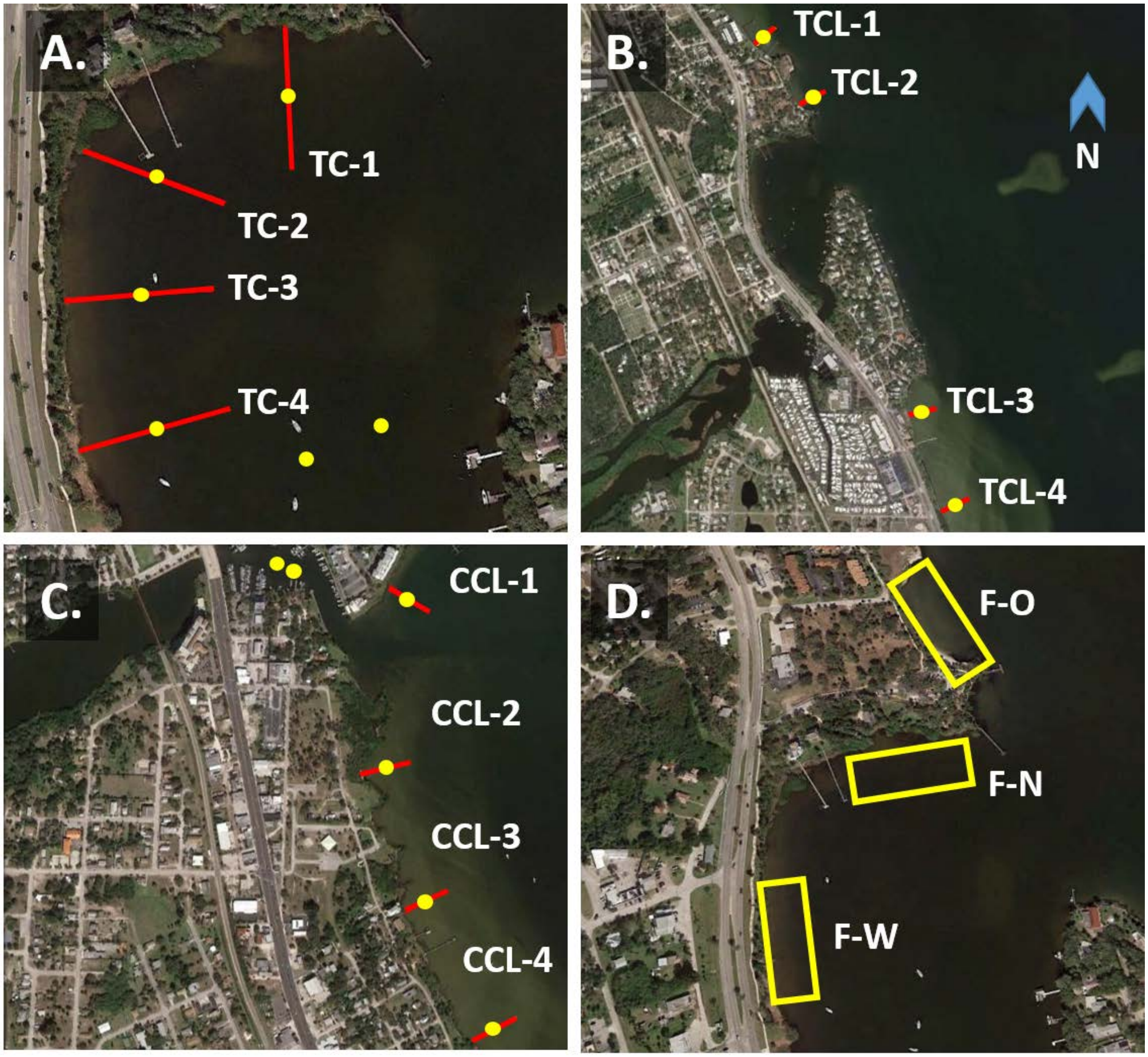


Figure 2.1. Primary study sites, including A. Turkey Creek ("Palm Bay") and locations of seagrass transects TC-1-TC-4. B. Comparison study site in the Indian River Lagoon near the mouth of Turkey Creek (TCL) and locations of TCL transects (TCL-1-TCL-4). C. Comparison study site in the Indian River Lagoon near the mouth of Crane Creek (CCL) and locations of CCL transects (CCL-1-CCL-4). Yellow dots indicate locations of infaunal sampling (triplicates of monthly sampling at each marked location). D. Fish sampling sites along the western shore of Turkey Creek (F-W), north shore of Turkey Creek (F-N) and outside of the mouth of Turkey Creek (F-O). Transect lengths (red lines) are 100 m. Seine sites (yellow boxes) are 9 by 15.5 m.

Sampling Sites and Methods – Fishes

Fish samples were collected monthly from April 2015 through December 2015 from a series of 4 sites along the western shore of Turkey Creek (F-W in Figure 2.1D), 4 sites along the north shore of Turkey Creek (F-N), and 2 sites outside the mouth of Turkey Creek (F-O). All sampling was done following standardized Fisheries Independent Monitoring Program (FIM) seining protocols (FWCC 2012). Fishes were collected with a 21.3-m long center bag seine x 1.8 m deep, and constructed of 3.2-mm knotless nylon Delta mesh. A 15.5-m rope was tied to the towing poles at each end of the seine, and 9 m-long ropes were attached to poles placed in the sediment at the beginning of each tow.

These guide ropes ensured that the seine sampled a standardized area of 140 m^2 (9 m by 15.5 m). Sample locations within each of the 3 regions were haphazardly selected by water depth and substrate. Within each Turkey Creek site, 2 samples were collected by towing the seine along the shore at an approximate starting depth of 50-75 cm. Two samples were taken further from shore, generally at a starting depth of about 1 m. The location of the deeper tows were restricted by the beginning of increasingly soft sediments, defined as when the seine personnel sank knee deep (about 30 cm) in muck, and could no longer effectively drag the net. Regions F-W and F-N were the only areas within Turkey Creek where the seine net could be effectively deployed.

Following completion of a seine tow, fishes were identified to the lowest practical taxonomic level and counted. A sample splitter was occasionally used to estimate numbers of very large catches of anchovies and several other species. Standard lengths of up to 25 specimens of each taxon were recorded. Voucher specimens were placed on ice for laboratory identification, if necessary.

Data analysis began by converting abundance data to density data (number of fish/100 m^2). Monthly mean densities were then calculated for inside Turkey Creek (generally 8 samples) and outside Turkey Creek (2 samples). For each dominant species, a 2-way ANOVA was used to test for temporal and spatial patterns in their utilization of the habitats in and adjacent to Turkey Creek. To determine if different sized or life stages of fishes have different patterns of habitat utilization, length-frequency data for total catch of each dominant taxon were compared between the Turkey Creek and data provided by the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program (FIM) from habitats within 1 km north and south of the mouth of Turkey Creek. A Kolmogorov-Smirnov (K-S) test was used to compare length-frequency distributions.

To examine potential community level patterns in fish abundance and distributions, fish population data from Turkey Creek samples collected from May to December 2015 were compared to data from samples taken from 1991 to 2014 by the FIM program from sites within 1 km north and south of Turkey Creek. An analysis of similarity (ANOSIM), using a Bray-Curtis similarity index, was used to determine the similarity of the fish community within the embayment of Turkey Creek to the community of fishes along the open Indian River Lagoon shoreline.

Quality Assurance and Quality Control

Personnel and equipment – To ensure consistency of approach, execution, and interpretation, the same personnel have been employed continually since the launch of the project. With regard to their training, they have been trained by personnel at the St. Johns River Water Management District (SJRWMD) and the Smithsonian Marine Station (SMS) for the seagrass/drift algae surveys and benthic infauna sampling, respectively. Staff at SJRWMD and SMS have been sampling these biological communities in Indian River Lagoon ecosystems for at least two decades. In addition to basic knowledge of how to sample, it is desirable to be able to compare our results to data generated by the sampling programs of these other agencies. Therefore, we have made an effort to have methods, equipment, and techniques mirror those used in other sampling occurring in the lagoon. This includes the same quadrat methods employed by SJRWMD for seagrass and drift algae sampling and the same Petite Ponar Grab methods utilized by SMS for benthic infauna collection. Instrumentation and the intended data collection activities are itemized on a process checklist, which is consulted during monthly preparations for data collection. Team member Angelica Zamora-Duran is the quality assurance assistant for field deployments and data collection.

Water quality – salinity, temperature, dissolved oxygen (DO), depth, and clarity of the water in the regions of seagrass and infaunal sampling are collected with appropriate instruments. Salinity, temperature, and DO are collected with a YSI meter, which is calibrated against a laboratory refractometer, thermometer, and DO meter, respectively, at least once per month.

Seagrass and drift algae surveys – The identification of seagrasses and drift algae has been carefully checked against all species occurring in the area and then verified by other seagrass experts. By utilizing the quadrat method recommended for local use by employees of the SJRWMD (Morris et al., 2001; Virnstein & Morris 1996), we are ensuring robust and replicate observations at each single point along a transect. Our personnel calibrate their transect scoring via a joint quadrat evaluation at the onset of each sampling day. Regarding *regional* seagrass transect replication, our methods exceed those employed by SJRWMD, with whom our personnel have trained and methods mirrored. For instance, SJRWMD generally uses a single transect to evaluate seagrasses in a particular area, whereas we use four, all within a few hundred meters of one another. The greater spatial resolution is intended to better characterize a focused area, namely the targeted dredge site and the control sites. Multiple observations to characterize an area is an important part of quality assurance, preventing a few anomalous observations from driving misleading interpretations.

Benthic infauna – The depth of sediment penetration and consistency of sediment volume collection by the Petite Ponar grab (PPG) have been tested and compared in sediments of different grain size and quality. This has enabled us to confidently calculate the numbers of infaunal organisms per area and volume of sediment. In addition, we have sampled with sediment cores deeper than the PPG penetrates to gain knowledge of the frequency with which organisms are beyond the reach of the

PPG, and under which conditions. Horizontal 1-cm slices of test cores confirmed that most organisms are being captured in grabs that penetrate only 3 cm, especially in mucky and intermediate sediments. Sandy sediments can have a relative few organisms beyond the reach of the PPG and this should be kept in mind when interpreting PPG data and making comparisons between the sediments. Species identifications have been confirmed by experts in the respective taxonomic fields. Additional species verification is planned via DNA analysis with comparisons against next generation sequencing databases. When species are unconfirmed, they are maintained under an alias (e.g., Polychaete A) that is universally used by all technicians until the identity is certain. Type specimens of both confirmed and undetermined species are maintained in labeled Eppendorf vials and preserved in 4% formalin. Our replication to represent an infauna collection site is identical to that utilized by SMS (n=3). Proper replication is essential for quality assurance because it prevents a single anomalous observation from driving misleading interpretations. Infaunal methodology intended to ensure accuracy and reliability of data is consistent with methods described in Mason (1998), Cooksey and Hyland (2007), and Tunberg et al. (2008b).

Sediment collection – sediment grabs for chemical and physical analysis are collected from the same locations, and with the same replication and methodology, as infauna collection. Regarding water content determination, the decanting of water in the field is consistent and removes obviously separate water from around the sample, after which the sediment is placed in a Ziploc bag. The entire sample is then used for water content comparison. To determine the combined silt-clay content, the sample is washed through 63 micron mesh, and the dry weights determined and compared. The qualitative determination of hydrogen sulfide content is a subjective test and we therefore have 3 personnel independently smell the sediment samples and make a sulfide score determination without knowing how others have scored the samples.

Fishes – Sampling effort was standardized using FWCC (2014) protocols for the FIM Program with a 21.3-m center bag seine. Measured lines were used to maintain the seine mouth width at 15.5 m and the tow length at 9 m, covering an area of 140 m^2. Sample processing also followed the FIM protocols for subsampling (if necessary) using a volumetric sample splitter for counting and measuring a subsample of abundant fishes (typically anchovies and mojarras). The subsample split factor was then applied to the subsample count to produce an estimate of the total number of fishes in the catch.

Fish identifications were conducted in the field by at least four trained personnel, who all had to agree with the species identification. If unanimity of identification was not achieved, representative specimens were examined in the field and the laboratory using published field guides (Lippson and Moran 1974; Ray and Robins 1999; Hoese and Moore 2008). All data were recorded and checked in the field on waterproof data sheets.

Data Handling – Data spreadsheets are checked by two personnel for correctness at the close of each data entry session. Spreadsheet files are backed up monthly, with fish data stored on a Google Drive site.

2.4 Results and Discussion

2.4.1. Seagrasses and Drift Algae

Depths of seagrass transects were variable with tide and wind conditions. Nearshore transects were between 40-70 cm in depth within 20 m of shore and increased to 95-135 cm depth at 50 m from shore, and then maintained a relatively level depth out to the 100-m quadrat. Seagrasses, where they occur, show a declining trend through our sampling period, based upon % cover (Figure 2.2), visual percent cover (Figure 2.3), and shoot counts (Figure 2.4). Seagrasses are less abundant in the slightly deeper water towards the end of transects (90 and 100-m markers). These data also show the consistent lack of occurrence of seagrasses within Turkey Creek throughout the year (Figures 2.2A, 2.3A, and 2.4A), while the IRL sites have seagrass and the opportunity for seasonal patterns to be observed. It should be noted that struggling sparse patches of *Halodule wrightii* were observed in Turkey Creek during the high growth season (late spring/early summer), but were not abundant enough to occur in random transects and quadrats. Canopy height, equivalent to shoot length, is more unpredictable, but generally peaked in May for the IRL near Turkey Creek (TCL), subsequently declining in the ensuing 2015 seasons (Figure 2.5C). In the IRL near Crane Creek (CCL) canopy height was even more inconsistent, with some locations peaking later in the year (August, Figure 2.5B).

Drift algae were evaluated along the same transects as those designed for seagrasses. Unlike seagrasses, drift algae were abundant in Turkey Creek along all transects throughout much of the year. Drift algae largely disappeared from the Indian River Lagoon sites in the fall (October, Figure 2.6 B&C), and were entirely absent from all sites in the winter (December, Figure 2.6 A-C). Drift algal biomass patterns (Figure 2.7) were similar to percent cover (Figure 2.6). Drift algal canopy heights were greater in the spring (May), often 10-15 cm, and decreased to mostly under 5 cm in the summer (August) and fall (October) before disappearing (Figure 2.8). During the peak of the year, Turkey Creek (TC) drift algal canopy heights (Figure 2.8A) often range from 10-16 cm, forming a strong shade blanket over any aspirant shoots of seagrass in the area. This shading is occurring during what would otherwise be the primary seagrass growth season.

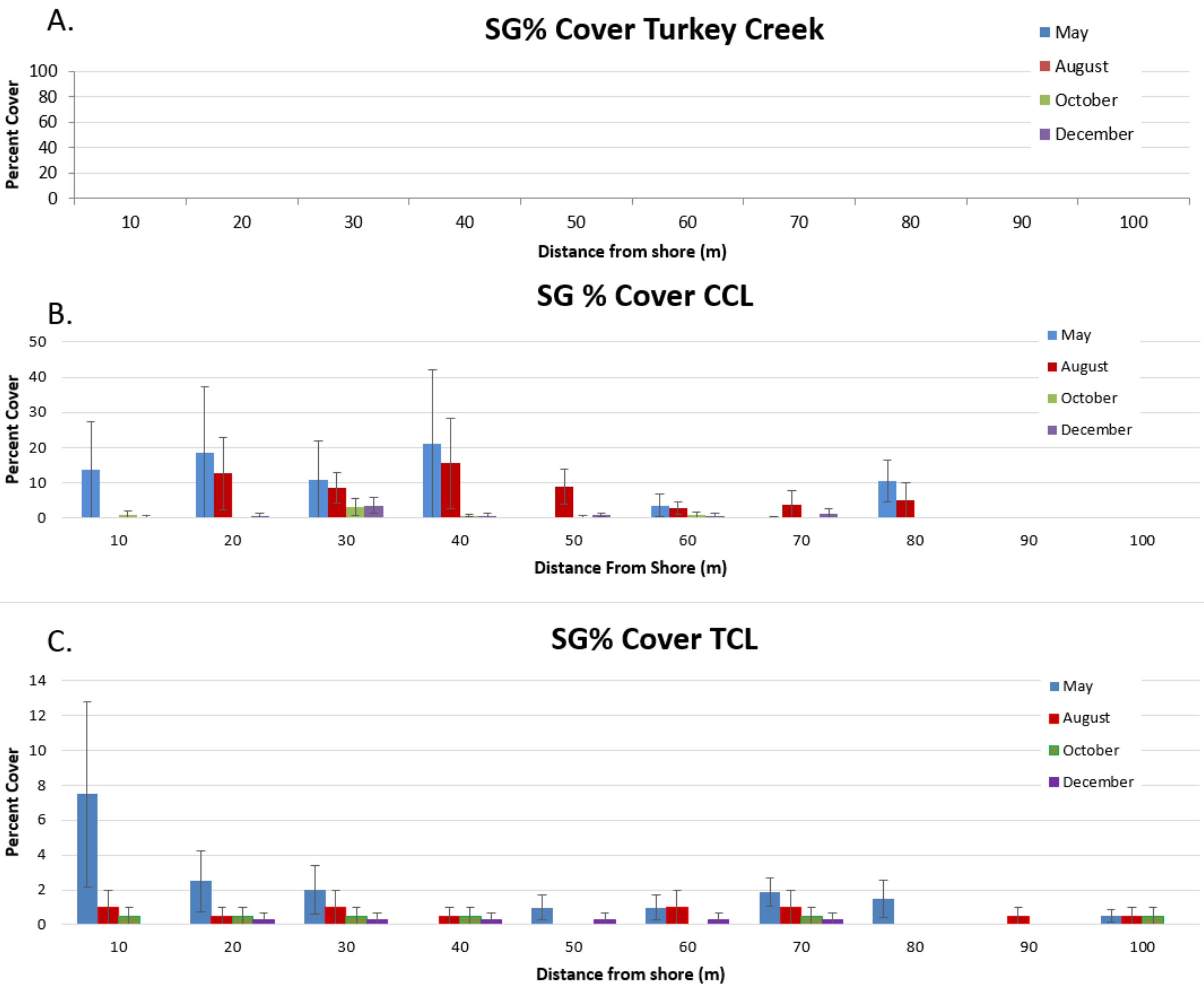


Figure 2.2. Seagrass mean % cover (% occurrence) at A) Turkey Creek (no seagrasses observed in random transects) B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Note the different scales. Error bars = ±1SE.

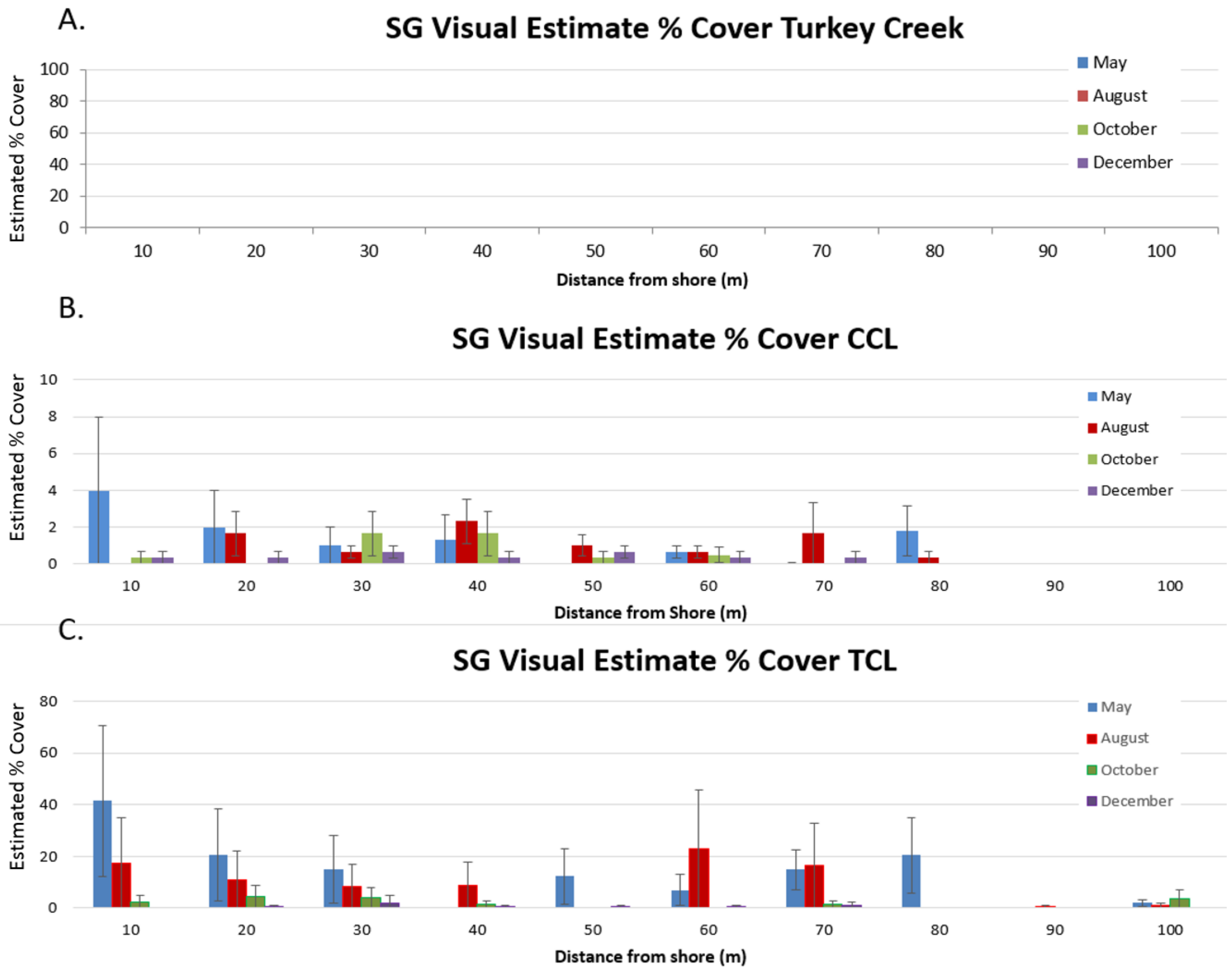


Figure 2.3. Seagrass mean visual estimate % cover at A) Turkey Creek (no seagrasses observed in random transects) B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Note the different scales. Error bars = ±1SE.

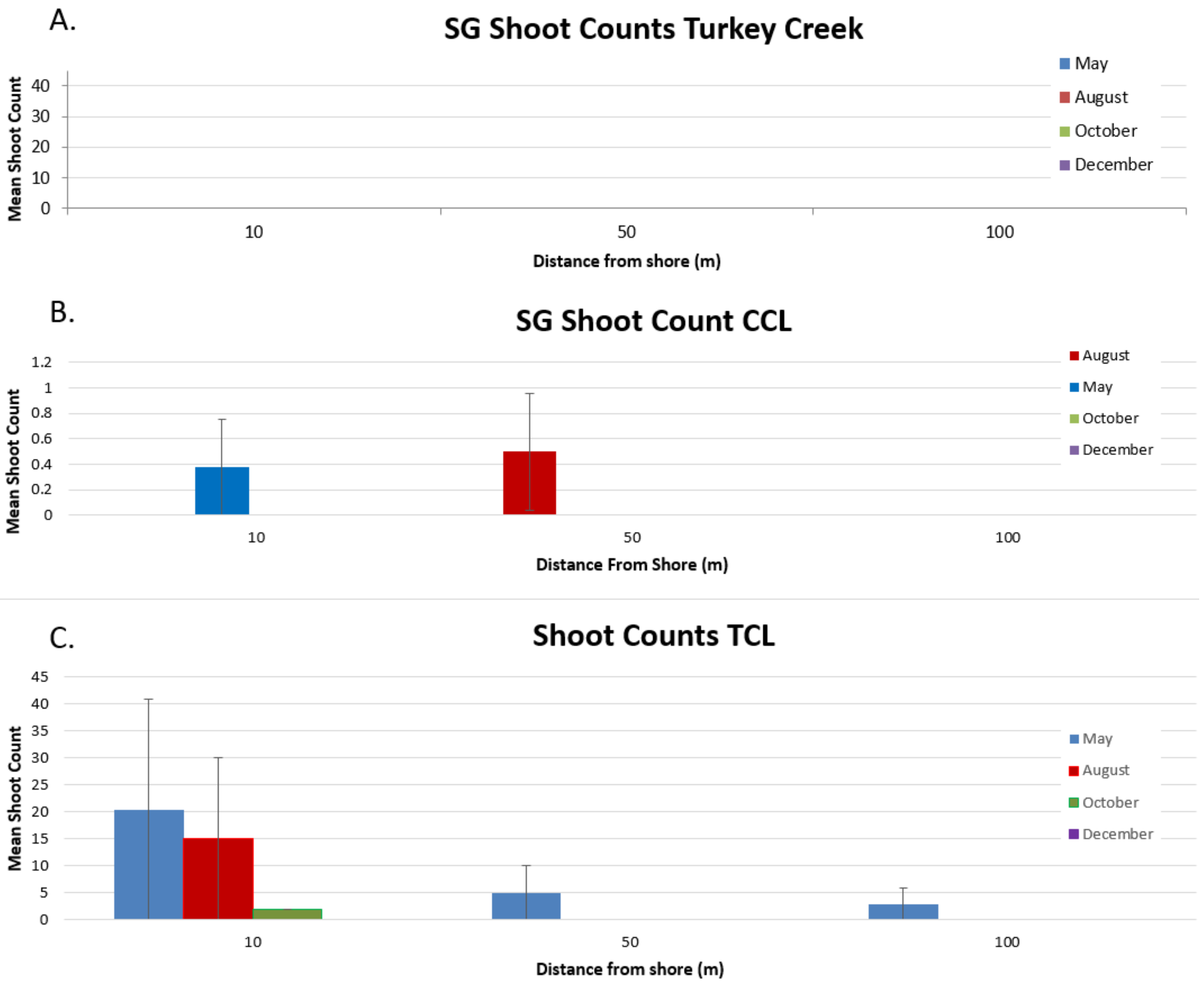


Figure 2.4. Seagrass mean shoot counts at A) Turkey Creek (no seagrasses observed in random transects) B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Note the different scales. Error bars = ±1SE.

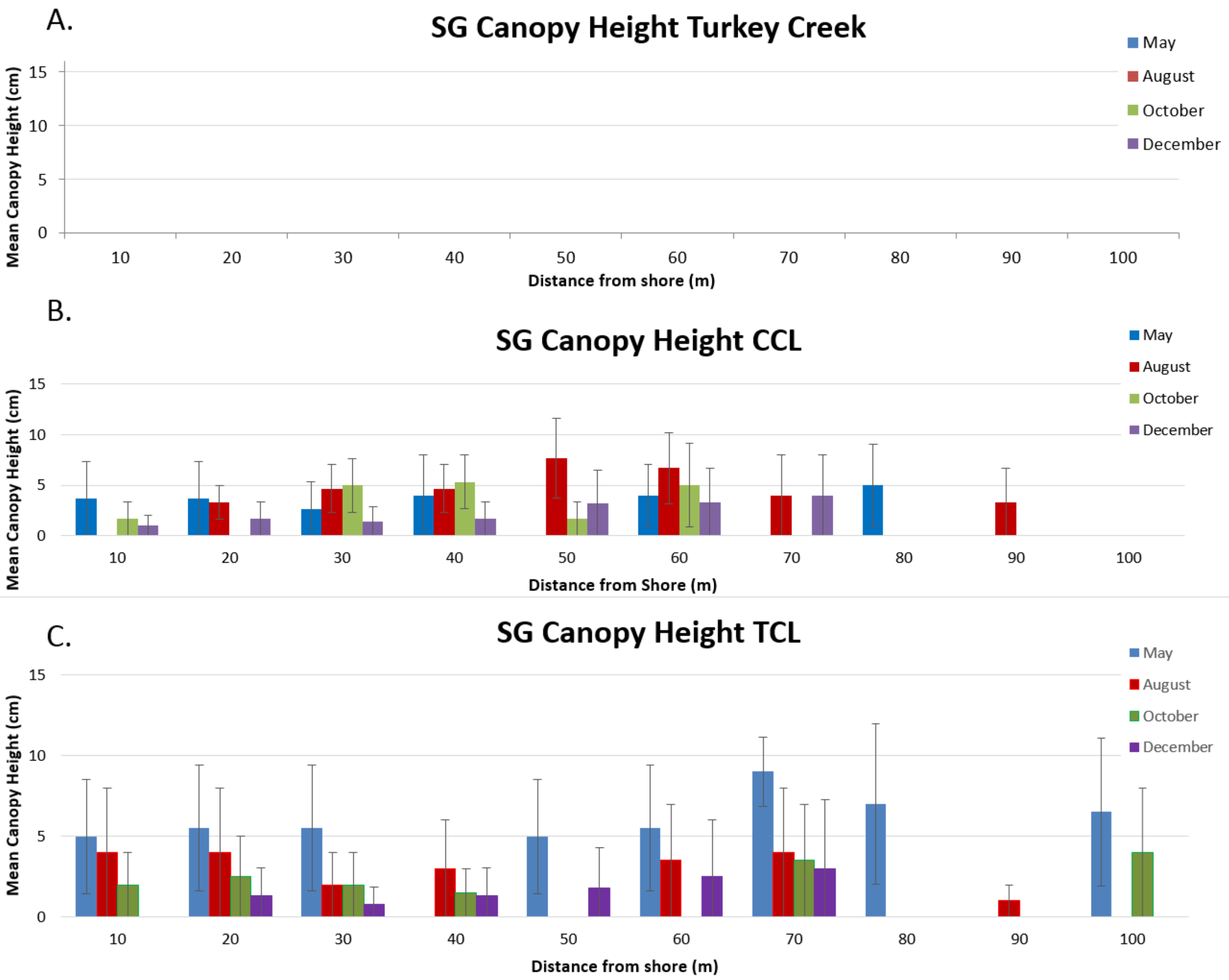


Figure 2.5. Seagrass mean canopy height at A) Turkey Creek (no seagrasses observed in random transects) B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Error bars = ±1SE.

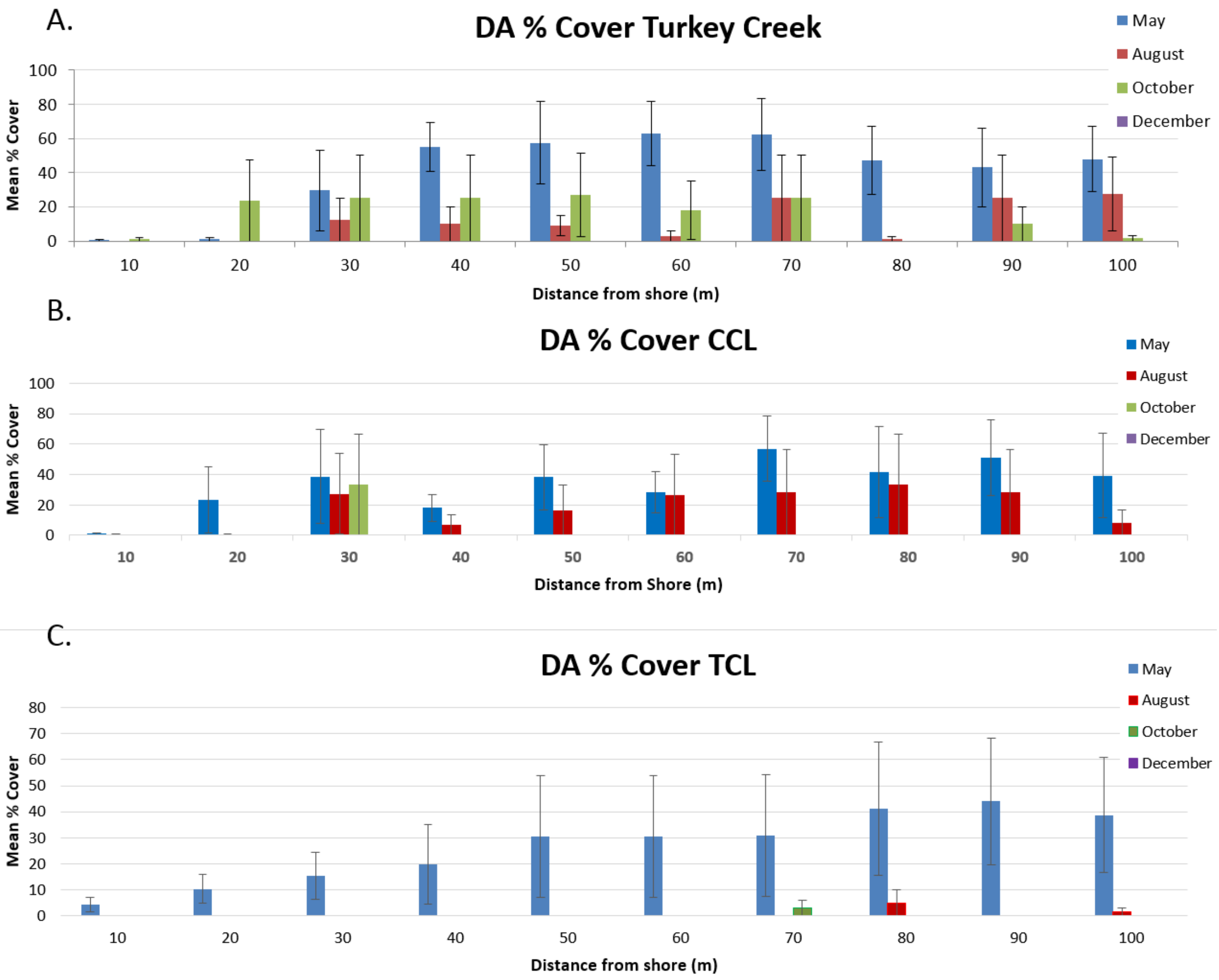


Figure 2.6. Drift algae mean percent cover at A) Turkey Creek B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Error bars = ±1SE.

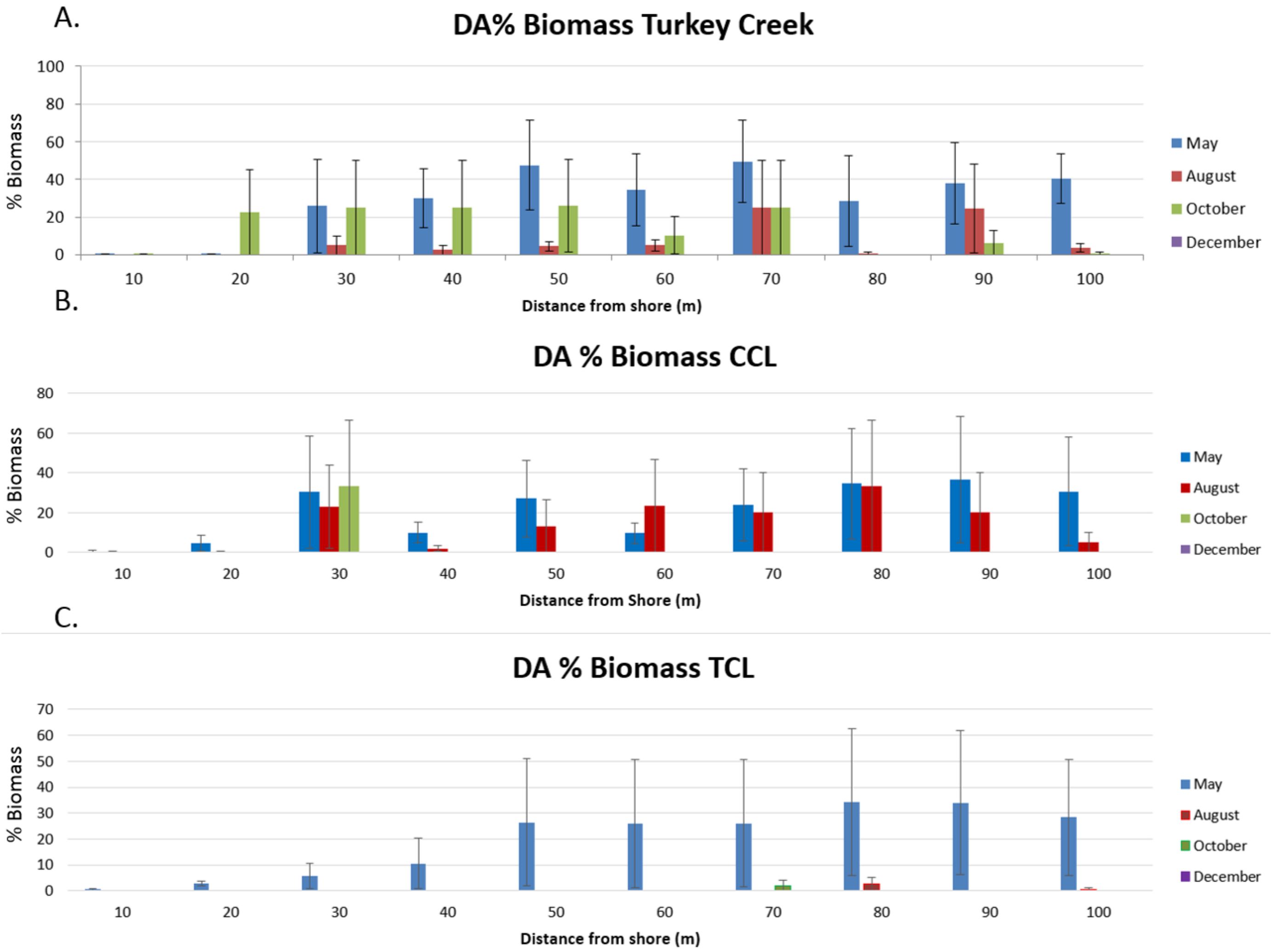


Figure 2.7. Drift algae mean percent biomass at A) Turkey Creek B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Note different scales. Error bars = ±1SE.

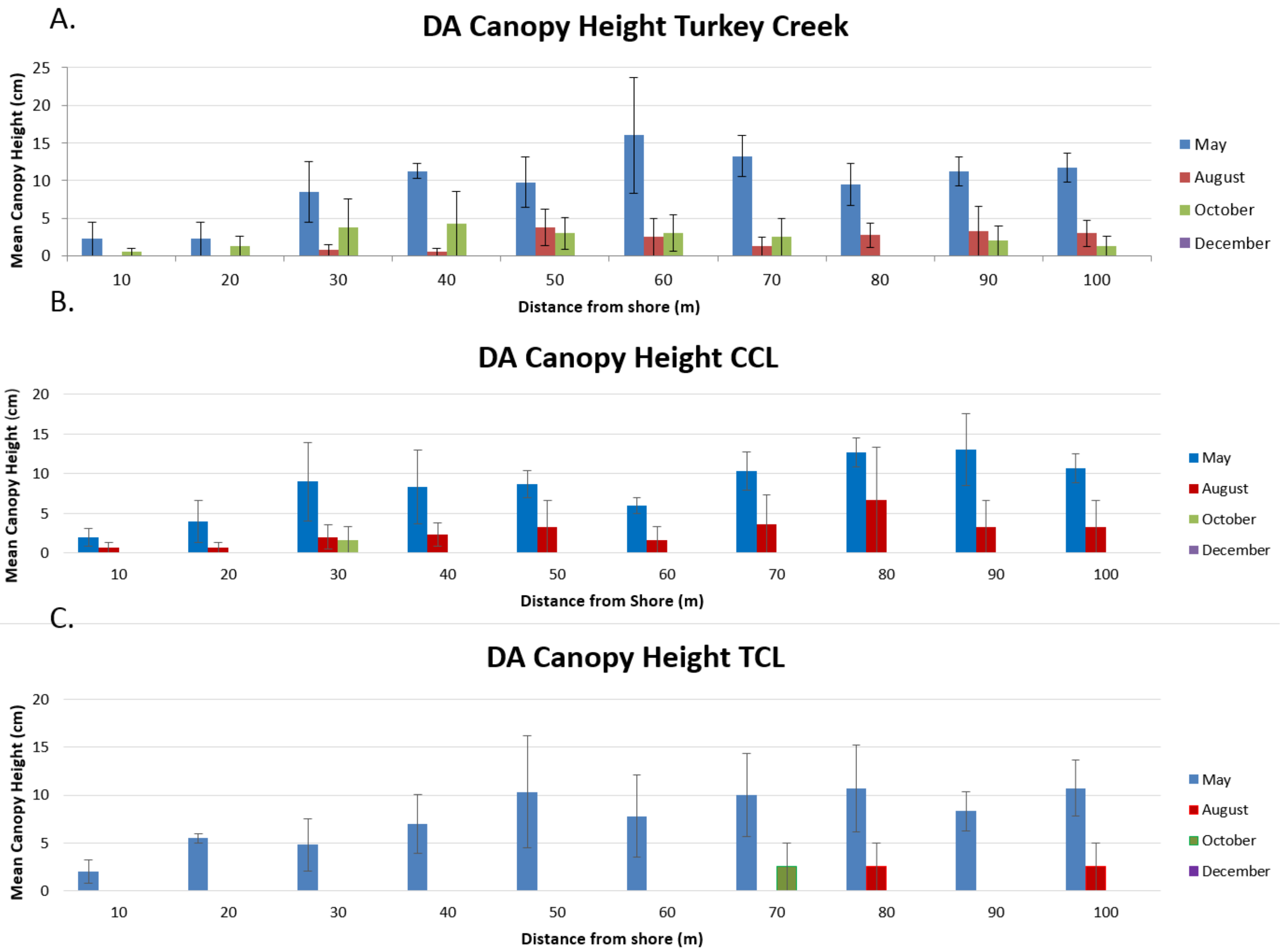


Figure 2.8. Drift algae mean canopy height at A) Turkey Creek B) The IRL near Crane Creek, and C) The IRL near Turkey Creek. Selected months represent seasons. Error bars = ±1SE.

Sediments and Infauna

Sediments were evaluated with regard to the primary features that indicate the degree of fine-grained, organic-rich sediments (FGORS) in the samples. FGORS indicator parameters are % water content (by weight) (Figure 2.9), % silt/clay content (dry weight) (Figure 2.10), % organic content (dry weight) (Figure 2.11), and a subjective odor (H_2S) score (Figure 2.12). Sediments with very high FGORS components are what the popular press refers to as “muck”. In all cases, selected “muck” sites in Turkey Creek (TCM, Figure 2.1A) and Crane Creek (CCM) (Figure 2.1C), were confirmed to have very high FGORS scores (Figures 2.9-2.12) relative to the sites with seagrass transects. Turkey Creek (TC) had intermediate scores for all muck indicators, while the lagoon sites (TCL and CCL) had the lowest scores (Figures 2.9-2.12). Muck, lagoon, and intermediate stations having statistically distinct FGORS characteristics is worth noting because it is a gradient in these organic sediments that we hypothesize may drive species diversity and abundances.

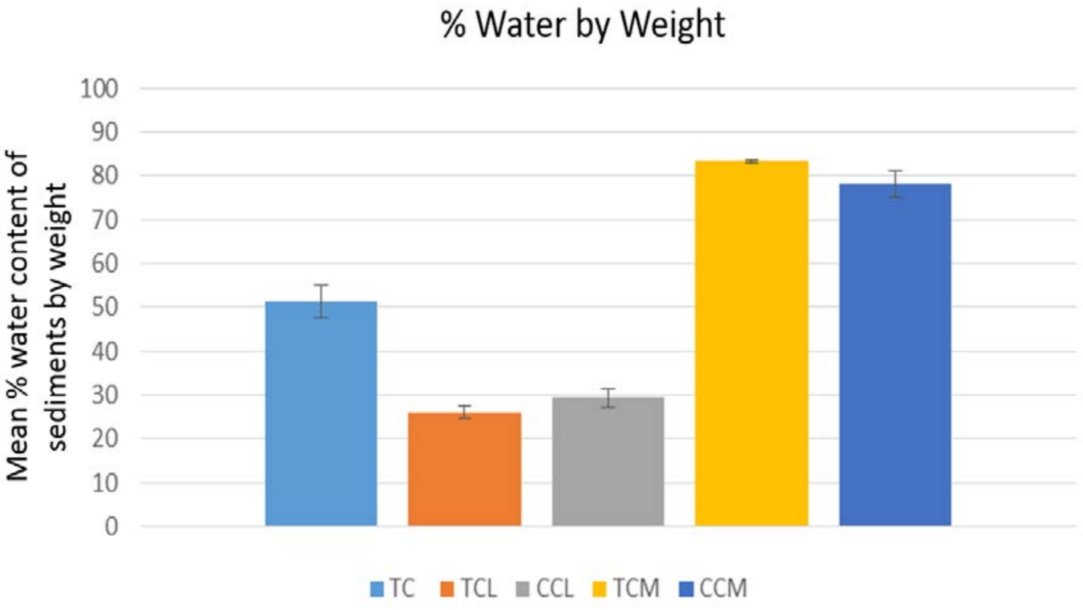


Figure 2.9. Mean % water content of sediments by weight. Sites from nearest to furthest from the dredging site are Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Muck sites (TCM, CCM) have statistically higher water content relative to other stations. Turkey Creek (TC) has a statistically distinct intermediate water content relative to other stations. Error bars are ±1SE.

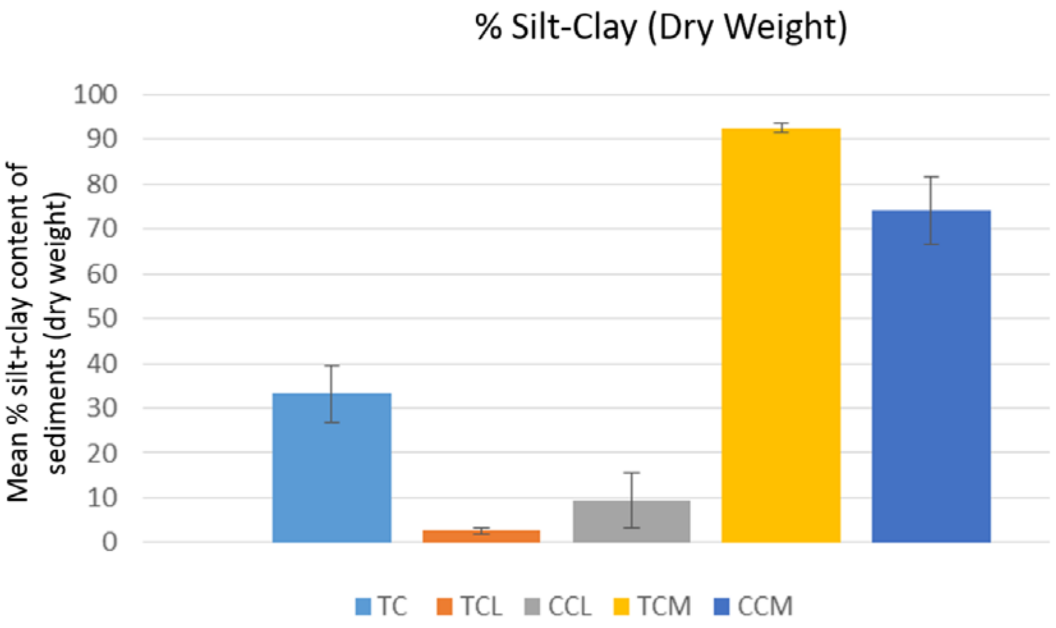


Figure 2.10. Mean % silt+clay content of sediments (dry weight). Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Muck sites (TCM, CCM) have statistically higher silt+clay relative to non-muck stations. Turkey Creek (TC) has a statistically distinct intermediate silt+clay relative to muck and lagoon stations. Error bars are ±1SE.

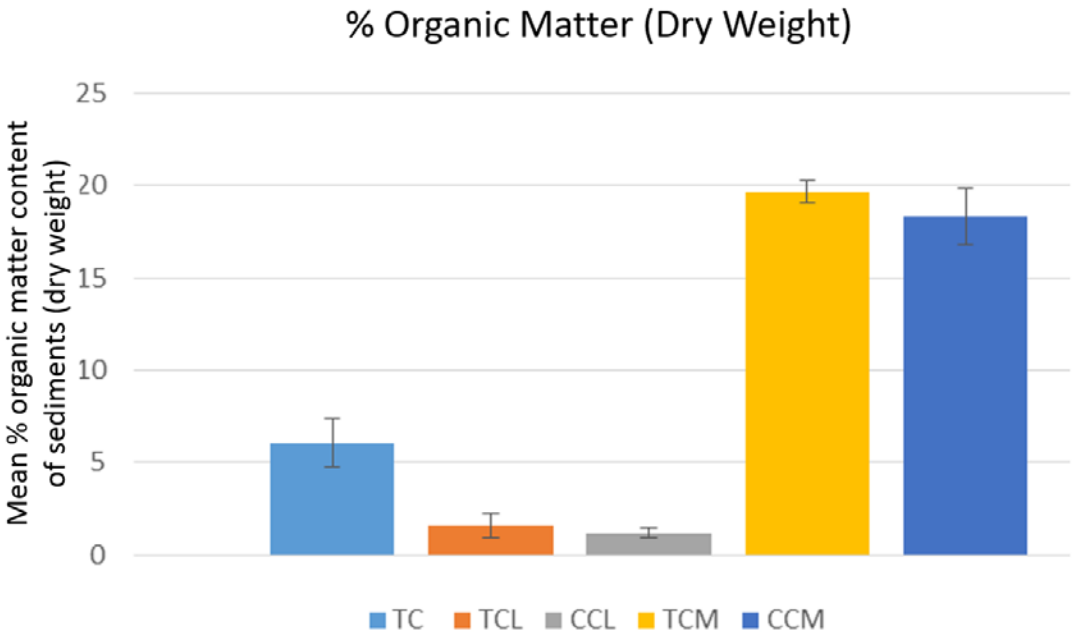


Figure 2.11. Mean % organic matter content of sediments (dry weight). Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Muck sites (TCM, CCM) have statistically higher organic content relative to all other stations. Turkey Creek (TC) has a statistically distinct intermediate organic content relative to muck and lagoon stations. Error bars are ±1SE.

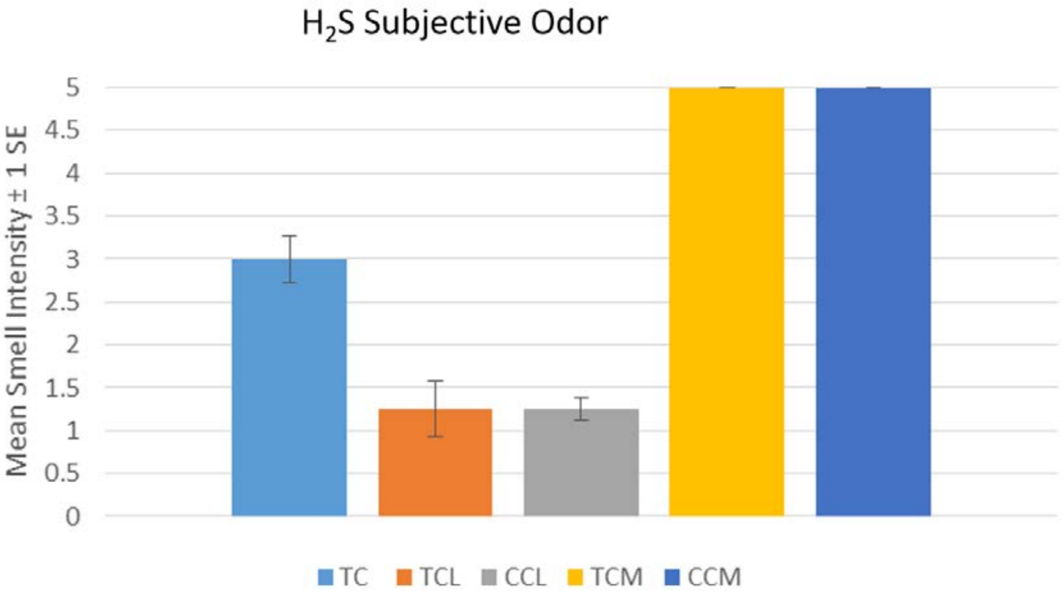


Figure 2.12. Mean subjective sulfur odor (smell intensity index). Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Muck sites (TCM, CCM) have statistically higher odor index relative to other stations. Turkey Creek (TC) has a statistically distinct intermediate odor index relative to muck and lagoon stations. Error bars are ±1SE.

Infaunal species were less diverse in intermediate FGORS sediments (TC) and almost zero in confirmed muck sediments (CCM and TCM) (Table 2.1 and Figure 2.13). Muck sites (TCM and CCM) usually supported no species, but a single sampling event did find some animals in two grabs. Species richness (Figure 2.14) followed similar patterns. Species included foraminiferans, gastropod mollusks, bivalve mollusks, decapod crustaceans, gammarid amphipods, caprellid amphipods, polychaete annelids, ostracod crustaceans, tanaid crustaceans, nematodes and others. A cumulative list of all species found at respective sites is given in Table 2.1 (n=12 grabs at each major site monthly throughout the year).

Table 2.1. Cumulative infaunal species list for all sites: Turkey Creek (TC), Turkey Creek Muck (TCM), Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and Indian River Lagoon near Crane Creek (CCL).
An asterisk indicates abundant species. Of the non-muck sites, CCL had the greatest, TC had the lowest, and TCL was intermediate in abundances. High abundance thresholds warranting special notation in this table were different for the three sites. Abundant organisms noted below (*) exceeded 150, 300, and 500 individuals m^{-2} for TC, TCL, and CCL, respectively.

TC	**TCL**	**CCL**	**CCM**	**TCM**
S=46	S=59	S=57	S=1	S=4
Acteocina atrata	_Acteocina atrata_	_Acteocina atrata_	_Ammonia parkinsoniana_	_Acteocina canaliculata_
*Acteocina canaliculata	_*Acteocina canaliculata_	_*Acteocina canaliculata_		_Ammonia parkinsoniana_
Alpheus heterochaelis	_*Ammonia parkinsoniana_	_*Ammonia parkinsoniana_		Clam A
*Ammonia parkinsoniana	_Amygdalum papyrium_	_Amygdalum papyrium_		_Parastarte triquetra_
*Amygdalum papyrium	_Angulus versicolor_	_Angulus versicolor_		
Annelid H	*Annelid H	*Annelid H		
Annelid I	Annelid I	_Astyris lunata_		
Astyris lunata	_Astyris lunata_	_Bulla occidentalis_		
Bulla occidentalis	_Bulla occidentalis_	_Callinectes sapidus_		
Callinectes sapidus	_Capitella capitata_	_Capitella capitata_		
Capitella capitata	Clam A	Clam A		
Clam A	Clam B	*Clam B		
Clam B	Clam F	Clam F		
Cumacean A	Crab B	Crab B		
Cyrtopleura costata	_Crepidula atrasolea_	*Cumacean A		
*Diopatra sp A	*Cumacean A	_Cyrtopleura costata_		
Eurypanopeus depressus	_Cynoscion nebulosus_	_Diopatra sp A_		
*Eusirus cuspidatus	_Cyrtopleura costata_	_*Eusirus cuspidatus_		
*Gammarid Amphipod C	_*Diopatra sp A_	Gammarid Amphipod C		
Gammarid Amphipod D	_Eurypanopeus depressus_	Gammarid Amphipod D		
Gammarid Amphipod F	_Eusirus cuspidatus_	*Gammarid Amphipod F		
Gammarid Amphipod G	Gammarid Amphipod C	Gammarid Amphipod G		
Hemipholis elongata	Gammarid Amphipod D	_Hargeria rapax_		
Mercenaria mercenaria	Gammarid Amphipod G	_Hemipholis elongata_		
Nematode A	_Hargeria rapax_	_Mercenaria mercenaria_		
*Nereis A	_Hemipholis elongata_	Metacaprella sp A		
Odostomia laevigata	_Limulus polyphemus_	Nematode A		
Ostracod B	_Mercenaria mercenaria_	_*Nereis A_		

Table 2.1. Continued.

TC	TCL	CCL	CCM	TCM
*Parastarte triquetra	Metacaprella sp A	_Odostomia laevigata_		
Pectinaria gouldii	Nematode A	_*Parastarte triquetra_		
*Peratocytheridea setipunctata	_*Nereis A_	_Pectinaria gouldii_		
Phascolion cryptus	_Odostomia laevigata_	_*Peratocytheridea setipunctata_		
Polychaete D	Ostracod B	_Periglypta listeri_		
Polychaete L	_*Parastarte triquetra_	_Phascolion cryptus_		
Polychaete M	_Pectinaria gouldii_	Polychaete A		
Polychaete N	_*Peratocytheridea setipunctata_	Polychaete C		
Polychaete O	_Phascolion cryptus_	Polychaete D		
Polychaete Q	Polychaete D	Polychaete H		
*Polychaete T	Polychaete H	Polychaete K		
Shrimp A	*Polychaete L	Polychaete L		
Sipuncula B	Polychaete M	Polychaete M		
Snail F	*Polychaete N	Polychaete N		
Snail H	Polychaete O	Polychaete O		
Snail K	Polychaete P	Polychaete P		
Tanaid A	Polychaete R	Polychaete Q		
*Tanaid B	Polychaete S	Polychaete R		
	*Polychaete T	Polychaete S		
	Polychaete U	*Polychaete T		
	Shrimp B	Shrimp A		
	Sipuncula B	Snail F		
	Snail C	Snail H		
	Snail F	Snail J		
	Snail H	Snail K		
	Snail J	Snail M		
	Snail K	*Tanaid A		
	Snail M	*Tanaid B		
	*Tanaid A	Tanaid C		
	Tanaid B			
	Tanaid C			

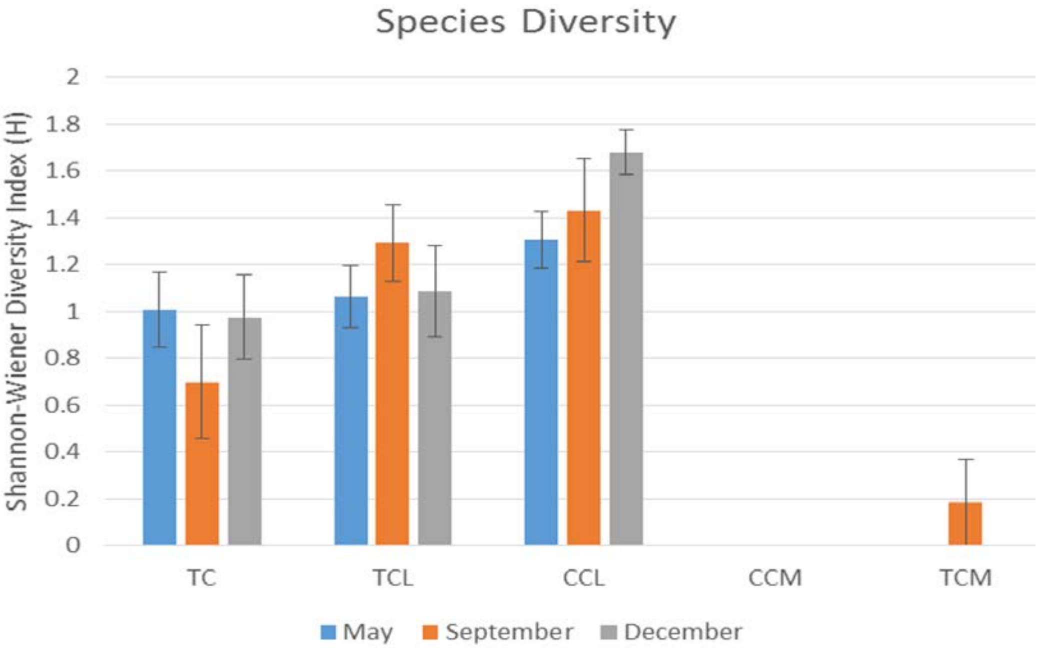


Figure 2.13. Mean infaunal biodiversity throughout the year at five sites. Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Error bars are ±1SE.

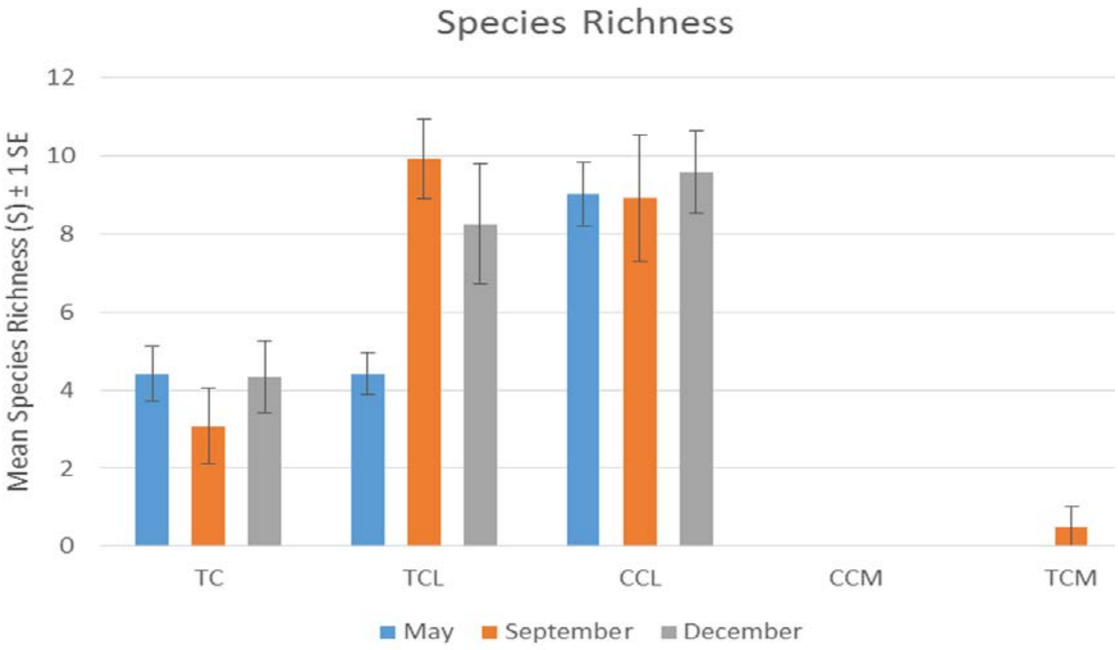


Figure 2.14. Mean infaunal species richness throughout the year at five sites. Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Error bars are ±1SE.

Species richness and diversity showed correlations with sediment characteristics. Log relationships were shown where lower FGORS scores (i.e., relatively low organic, silt/clay, or water content) correlated with high diversity and richness. Figure 2.15 shows correlations for biological infaunal data collected in October, November, and December, paired with sediment samples collected concurrently. Relationships were similar when regressed against all FGORS parameters. The relationships are here demonstrated with species richness against % Organic Matter (Figure 2.15A) and % Silt Clay content (Figure 2.15B).

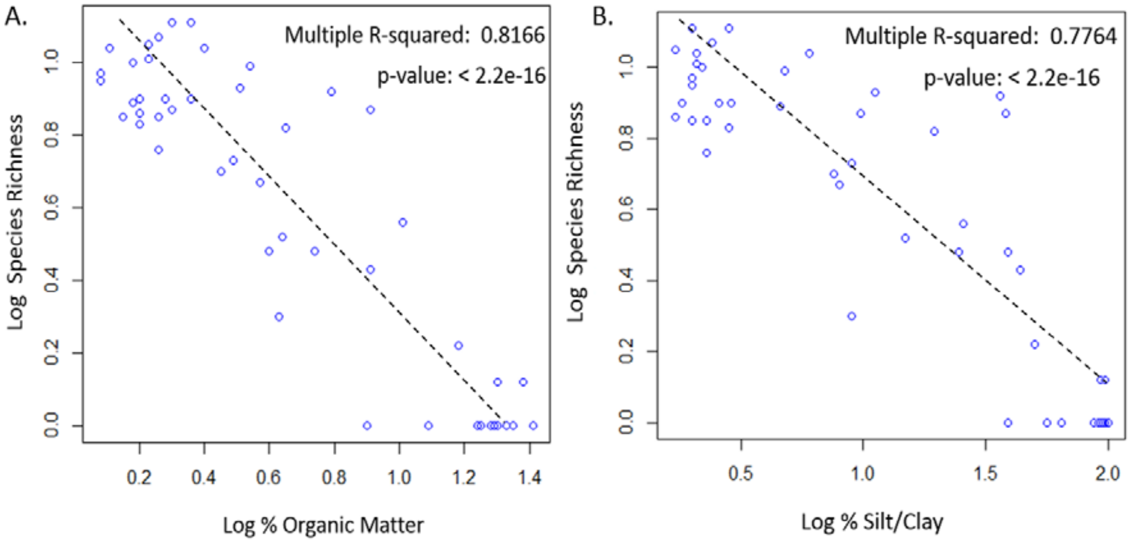


Figure 2.15. A. [log] infaunal species richness vs. [log] % sediment organic matter (dry weight). B. [log] species richness vs. [log] % silt/clay (dry weight).

Community analysis reveals that species abundance is more distinctive temporally (changes through the seasons, represented by selected months) at sandier (low FGORS) sites (Figure 2.16B, R=0.42, p=0.001) compared to a similar analysis done with high FGORS sites (Figure 2.16A), R=0.12, p=0.001).

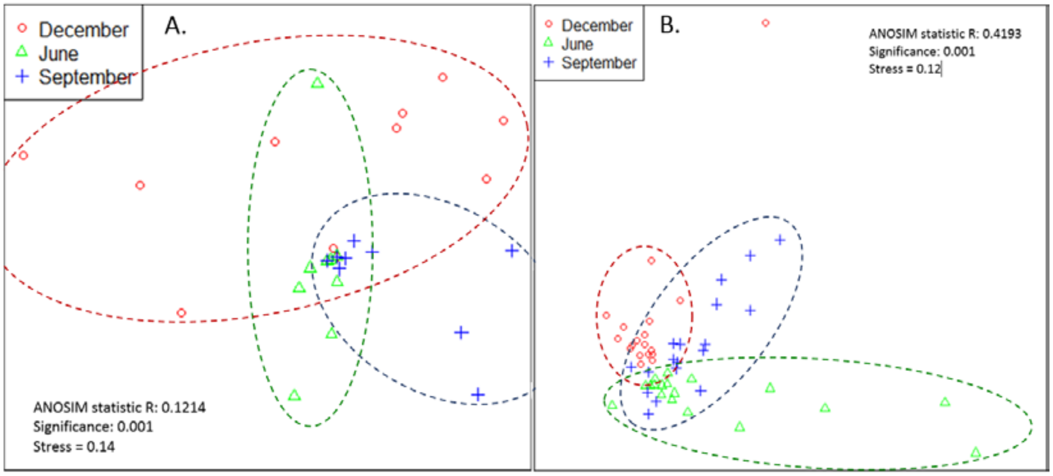


Figure 2.16. NMDS infaunal community analysis using abundance of species (Bray Curtis Distance Analysis). A. FGORS sites. B. Sandy sites.

Focusing on *Ammonia parkinsoniana*, a foraminiferan potentially useful as an indicator species because of its tolerance of high organic low quality sediments (Ishman et al. 1997; Gapotchenko et al. 2000; Karlsen et al. 2000; Alves Martins et al. 2015), abundances within Turkey creek (TC) were greatest in May 2015, with abundances dropping off except along one transect in July (Figure 2.17). *A. parkinsoniana* was ephemeral or episodic, nearly disappearing in June 2015, then resurging before disappearing completely in September. This is likely a phenomenon known in foraminiferans as "pulsing patches" (Buzas et al. 2015).

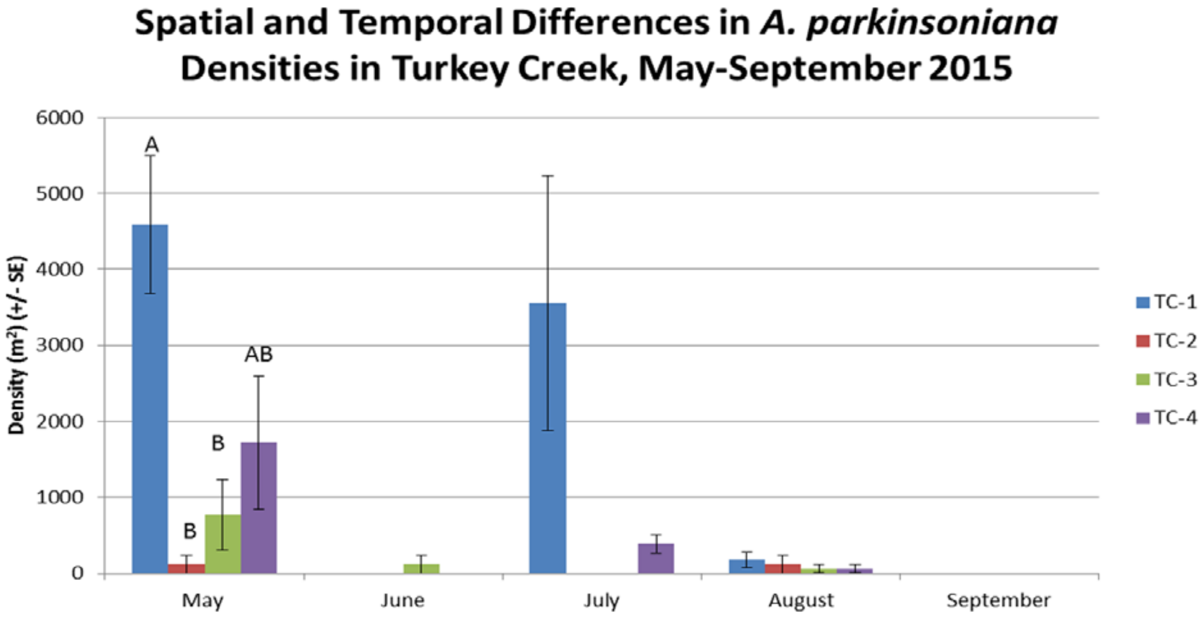


Figure 2.17. Abundance of foraminifera (*Ammonia parkinsoniana*) in Turkey Creek from May-September, 2015. TC1-TC4 are individual transects. Disparate letters within a month's sampling indicate statistically significant differences.

Ammonia parkinsoniana abundance, when they are consistently present and reasonably abundant (see May and June, Figure 2.17) correlates with FGORS characteristics. Using [log] % Silt/Clay from aforementioned fall sediment samples as a representative parameter, [log] *A. parkinsoniana* abundance showed the best correlation in May, when it was most abundant and consistently present across transects (Figure 2.18A).

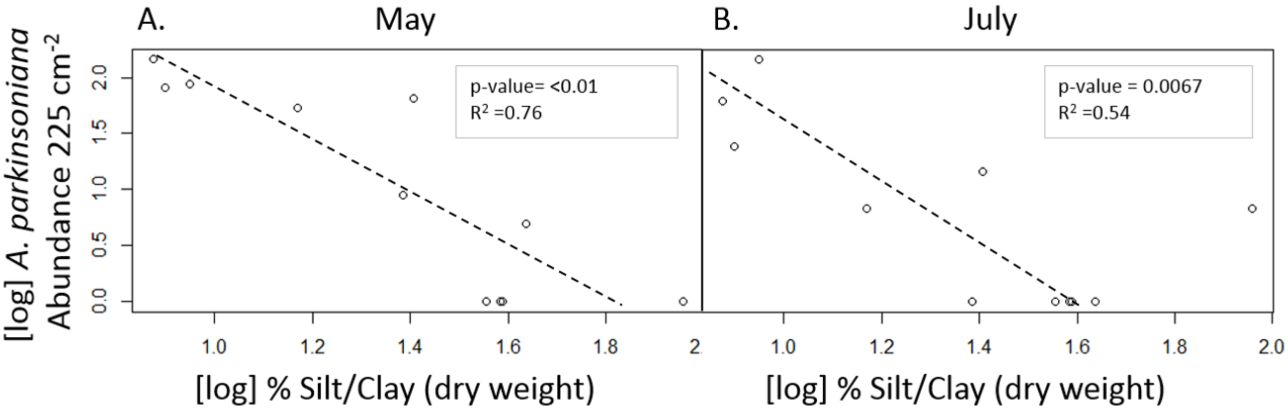


Figure 2.18. Foraminiferan (*Ammonia parkinsoniana*) abundance in Turkey Creek as a function of % silt/clay during A) May and B) July, the most abundant months of *A. parkinsoniana* occurrence in 2015.

2.4.2. Fishes

A total of 129,873 fishes from 56 taxa were collected from April through December 2015 (Table 2.2). The fishes captured in the seine were dominated by small pelagic schooling species and demersal juvenile fishes. Pelagic anchovies (*Anchoa* spp.) comprised 92.2% of the entire seine catch, indicating the numerical dominance of these fishes in the Turkey Creek region of the IRL ecosystem. Juvenile mojarras (*Eucinostomus* spp. and *Diapterus* spp.; 3.2% of the catch) dominated the demersal fishes. Demersal juveniles of the commercially important fisheries family Sciaenidae (including silver perch, red drum, Atlantic croaker, spot, sea trout and kingfish) comprised 2.3% of the total catch. Temporal and spatial patterns of distribution of dominant and important taxa are discussed below.

Abundance and size data for individual taxa reflect seasonal recruitment patterns and spatial distributions that vary in response to fish behavior and environmental influences. Distribution, density and size data collected for the dominant species during 2015 are presented below. To put fish data from the 2015 sampling in Turkey Creek into a broader temporal and spatial context, size distribution data from selected fish taxa within Turkey Creek in 2015 were compared with FIM data collected from in and around Turkey Creek from 1991 to 2014. FIM data were also used to compare total fish community structure observed in 2015 in Turkey Creek with the community structure of adjacent habitats collected over previous decades.

<u>Anchovies:</u> Although these small pelagic schooling fishes (primarily bay anchovy, *Anchoa mitchilli*) greatly dominated the total catch, the schooling and highly mobile behavior of these fishes resulted in extremely patchy temporal and spatial distributions (Figure 2.19). The presence of schools of anchovies were generally immediately visible at the onset of sampling, and larger predatory fishes (such as jacks and tarpon) were observed feeding in the vicinity. Schools frequently moved in and out of the Turkey Creek habitat. It was common to catch them in several seine hauls on Day 1 of a 2 day sampling period within any month and find them essentially absent on Day 2 of the sampling period, reflecting their ability to move quickly in and out of Turkey Creek.

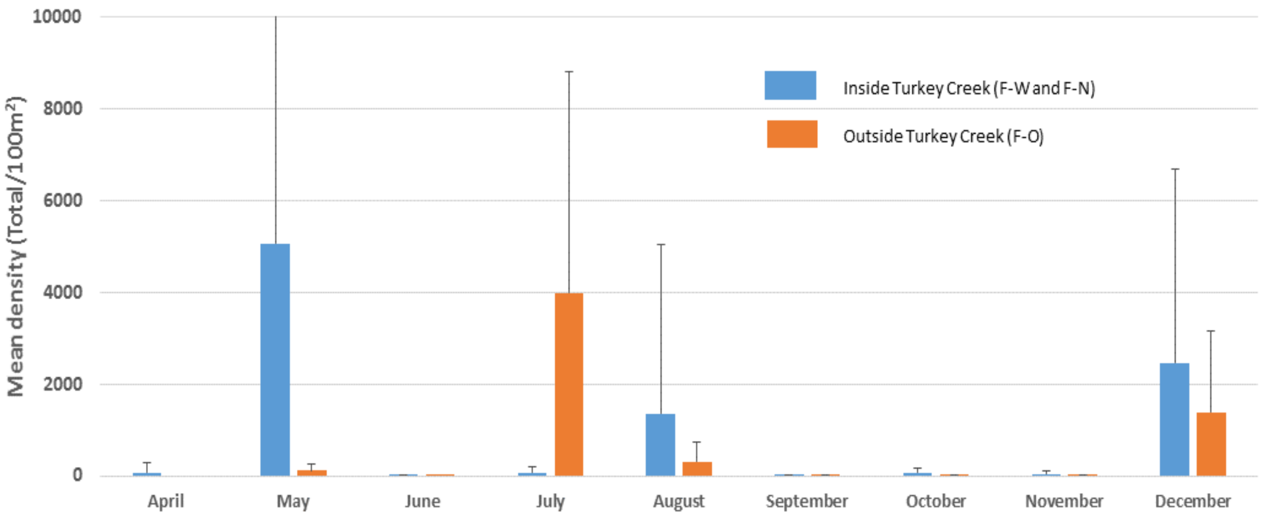


Figure 2.19. Mean (+/- S.D.) density (number/100 m^2) of anchovies (*Anchoa* spp.) captured monthly from inside Turkey Creek (typically 8 samples per month) and just north of the mouth of Turkey Creek (2 samples per month).

Table 2.2 Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL.

FISH											
Scientific Name	Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**TOTAL**
Anchoa spp.	Anchovies	1,045	57,406	46	12,005	16,149	104	889	520	31,599	**119,763**
Eucinostomus spp.	Mojarras	381	433	193	297	294	27	38	109	433	**2,205**
Bairdiella chrysoura	Silver perch	595	246	158	915	91	0	10	5	0	**2,020**
Diapterus spp.	Irish pompano/mojarra	36	12	37	447	914	59	51	208	181	**1,945**
Opisthonema oglinum	Atlantic thread herring	0	1,310	0	0	0	0	0	0	0	**1,310**
Sciaenops ocellatus	Red drum	0	0	0	0	1	0	10	1	383	**395**
Micropogonias undulatus	Atlantic croaker	189	9	4	1	15	0	0	59	0	**277**
Brevoortia spp.	Menhadens	187	69	3	0	0	0	0	0	1	**260**
Lagodon rhomboides	Pinfish	154	51	4	38	6	0	0	0	0	**253**
Mugil curema	White mullet	0	0	0	2	1	1	71	117	23	**215**
Menidia spp.	Silversides	0	0	1	14	126	0	30	4	6	**181**
Menticirrhus americanus	Southern Kingfish	0	1	1	0	1	0	3	89	63	**158**
Harengula spp.	Sardines/pilchards	51	9	0	1	28	0	0	0	48	**137**
Cynoscion spp.	Sea trout	0	29	0	8	5	0	3	77	3	**125**
Mugil spp.	Mullet	105	0	1	1	0	0	0	0	0	**107**
Archosargus probatocephalus	Sheepshead	2	14	7	47	3	0	3	1	0	**77**
Strongylura spp.	Needlefish	0	3	37	6	9	8	3	3	3	**72**
Oligoplites saurus	Leatherjacket	0	19	5	16	4	5	5	5	0	**59**
Leiostomus xanthurus	Spot	0	53	0	0	0	0	0	0	0	**53**
Trinectes maculatus	Hogchoker	2	2	5	4	11	0	0	1	10	**35**
Gobiosoma robustum	Code goby	1	6	1	4	3	0	8	0	3	**26**
Carangidae spp.	Jacks	0	5	0	0	0	0	18	0	0	**23**
Gobiidae spp.	Gobies	0	0	11	9	2	0	0	0	0	**22**
Syngnathus scovelli	Gulf pipefish	4	9	1	1	1	0	0	0	0	**16**
Ariopsis felis	Hardhead catfish	1	4	0	1	1	0	5	0	0	**12**
Elops saurus	Ladyfish	0	8	0	1	0	0	0	0	1	**10**
Dasyatis sabina	Atlantic stingray	2	1	0	1	5	0	0	0	0	**9**

Table 2.2 Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL (continued).

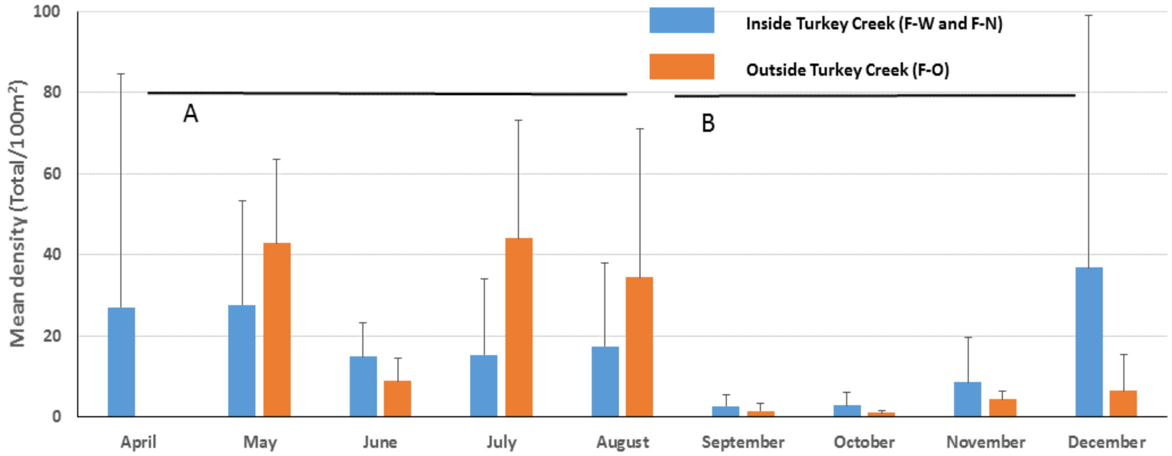
Scientific Name	Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**TOTAL**
Lutjanus griseus	Gray snapper	0	1	0	1	2	1	3	1	0	**9**
Chaetodipterus faber	Spadefish	6	2	0	0	0	0	0	0	0	**8**
Citharichthys spilopterus	Bay whiff	8	0	0	0	0	0	0	0	0	**8**
Fundulus spp.	Killifish	0	0	7	0	0	0	0	0	0	**7**
Microgobius gulosus	Clown goby	3	3	1	0	0	0	0	0	0	**7**
Sphyraena barracuda	Great barracuda	0	0	1	3	1	2	0	0	0	**7**
Syngnathus louisianae	Chain pipefish	0	4	1	0	0	0	0	0	0	**5**
Haemulon spp.	Grunts	4	0	0	0	0	0	0	0	0	**4**
Paralichthys spp.	Flounder	0	3	0	1	0	0	0	0	0	**4**
Caranx hippos	Crevalle jack	0	1	0	0	0	0	1	1	0	**3**
Hypleurochilus pseudoaequipinnis	Oyster blenny	0	0	0	2	1	0	0	0	0	**3**
Mugil cephalus	Striped mullet	1	0	0	0	1	0	1	0	0	**3**
Orthopristis chrysoptera	Pigfish	0	2	1	0	0	0	0	0	0	**3**
Paralichthys lethostigma	Southern flounder	3	0	0	0	0	0	0	0	0	**3**
Pogonias cromis	Black drum	0	0	1	1	0	0	0	0	1	**3**
Sphoeroides testudineus	Checkered pufferfish	0	0	2	0	0	0	0	0	1	**3**
Achirus lineatus	Lined Sole	0	0	0	1	1	0	0	0	0	**2**
Cynoglossidae spp.	Tonguefish	0	0	0	0	2	0	0	0	0	**2**
Sciaenidae spp.	drum juveniles	2	0	0	0	0	0	0	0	0	**2**
Trachinotus carolinus	Florida pompano	0	0	0	0	0	0	0	2	0	**2**
Archosargus sp.	Sheepshead/sea bream hybrid	0	0	0	1	0	0	0	0	0	**1**
Centropomus spp.	Snook	0	0	1	0	0	0	0	0	0	**1**
Chilomycterus shoepfi	Striped burrfish	0	0	0	0	0	0	0	0	1	**1**
Chloroscombrus chrysurus	Atlantic bumper	0	1	0	0	0	0	0	0	0	**1**
Eugerres plumieri	Striped mojarra	0	1	0	0	0	0	0	0	0	**1**
Gobiosoma bosc	Naked goby	1	0	0	0	0	0	0	0	0	**1**

Table 2.2 Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL (continued).

Scientific Name	Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**TOTAL**
Gymnura micrura	Smooth butterfly ray	0	1	0	0	0	0	0	0	0	**1**
Hyporhamphus meeki	False silver halfbeak	0	1	0	0	0	0	0	0	0	**1**
Sphoeroides nephelus	Southern pufferfish	0	0	0	0	0	1	0	0	0	**1**
	TOTAL	**2,783**	**59,719**	**530**	**13,829**	**17,679**	**212**	**1,155**	**1,206**	**32,760**	**129,873**

INVERTEBRATES											
Callinectes sapidus	Blue crab	8	2	0	7	6	0	3	1	1	**28**
Penaeidae spp.	Shrimp	0	23	1	5	1	2	42	13	7	**94**
	TOTAL	**8**	**25**	**1**	**12**	**7**	**2**	**45**	**14**	**8**	**122**

Mojarras: Two groups of juvenile mojarras were the most abundant of the demersal species found in Turkey Creek habitats, and were widely dispersed among all the sampling regions. Small juvenile *Eucinostomus* spp. and *Diapterus* spp. are difficult to identify to species, so the fishes were generally identified to the genus level. These groups of mojarras had different seasonal patterns within Turkey Creek, but no significant differences in densities among the sampled habitats (Figure 2.20). *Eucinostomus* spp. were abundant throughout the spring and summer, but experienced a significant decline (ANOVA, p<0.05) in abundance through the fall. In contrast, *Diapterus* spp. increased in abundance in two summer months, followed by a drop in the fall.



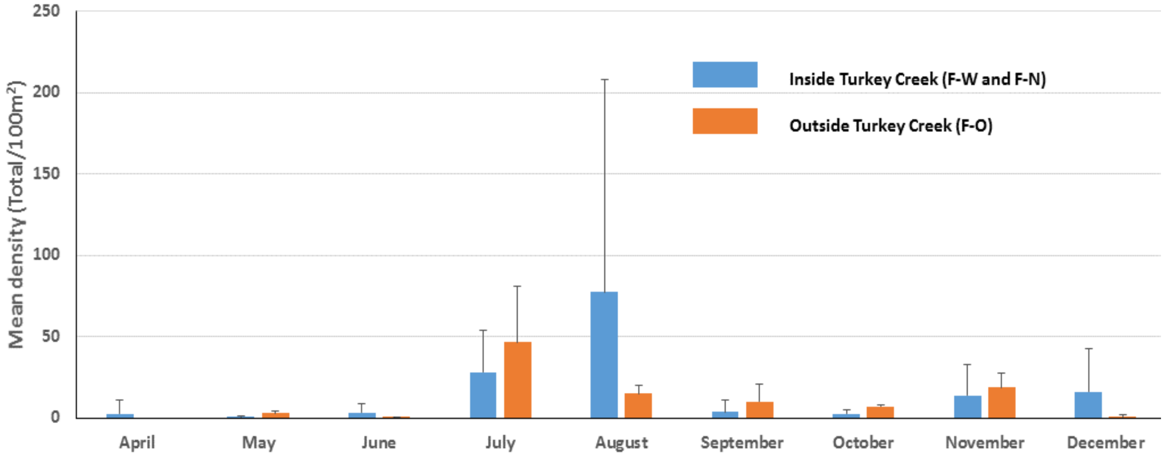


Figure 2.20. Mean (+/- S.D.) density (number/100 m^2) of mojarras: top) *Eucinostomus* spp. and bottom) *Diapterus* spp. captured monthly from inside Turkey Creek (typically 8 samples per month) and just north of the mouth of Turkey Creek (2 samples per month; April not sampled). Lines with different letters indicate temporal periods with significantly different fish densities (ANOVA, p<0.05).

The occurrence of juvenile *Eucinostomus* spp. throughout the study was composed of fishes ranging from 15-90 mm SL. The collection of small juveniles during most months suggests a protracted spawning season for these fishes, while *Diapterus* spp. (15-90 mm) were common primarily during the summer. Adults of these species range from 150-350 mm SL, and are presumed to spawn in offshore or inlet habitats (Kerschner et al. 1985).

Both genera exhibited major declines in abundance beginning in September. These declines may have been due to seasonal or age-related migration out of the Turkey Creek habitat. However, intense rainfall in September resulted in very high flow of freshwater from the Turkey Creek watershed (USGS, 2016; Figure 2.21), reducing salinities at the sampling stations from 20-25 ppt during the summer months to values less than 10 ppt in September.

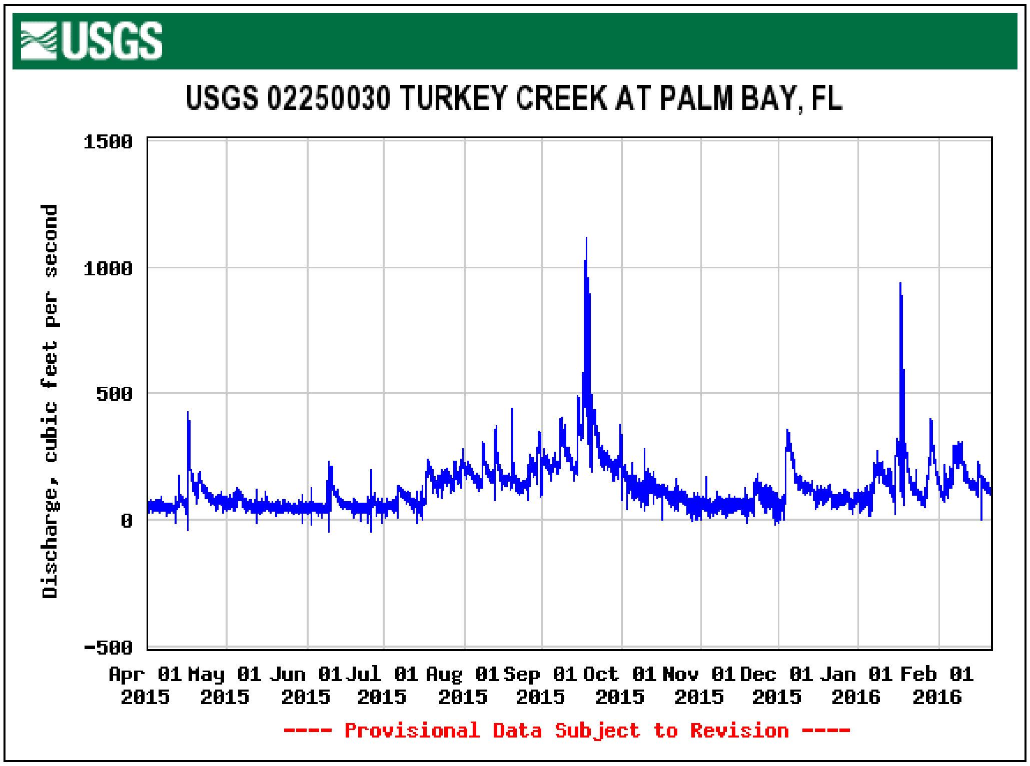


Figure 2.21. Water discharge at the USGS gage station number 02250030 on Turkey Creek, located approximately 3 km upstream of the mouth of the creek into the Indian River Lagoon (USGS 2016).

A further evaluation of how similar the mojarra populations at the sampling stations inside and adjacent to Turkey Creek can be developed by comparing these data with the data collected by the FIM program. The FIM sampling protocol divides the Indian River Lagoon into 1 km^2 blocks (Figure 2.22), then uses a random stratified sampling process to select precise locations for sampling on each day. FWCC graciously provided us with their entire Indian River Lagoon database. Grid 364 includes the Turkey Creek habitats sampled by the current program. We isolated the FIM samples collected from 1991 to 2014 from Grid 364 (including Turkey Creek), Grid 368 (immediately south of Turkey Creek) and Grid 360 (immediately north of Turkey Creek). We then further sorted the samples to include only those collected with a 21.3 m seine net, and along the shorelines, rather than out in the middle of the IRL.

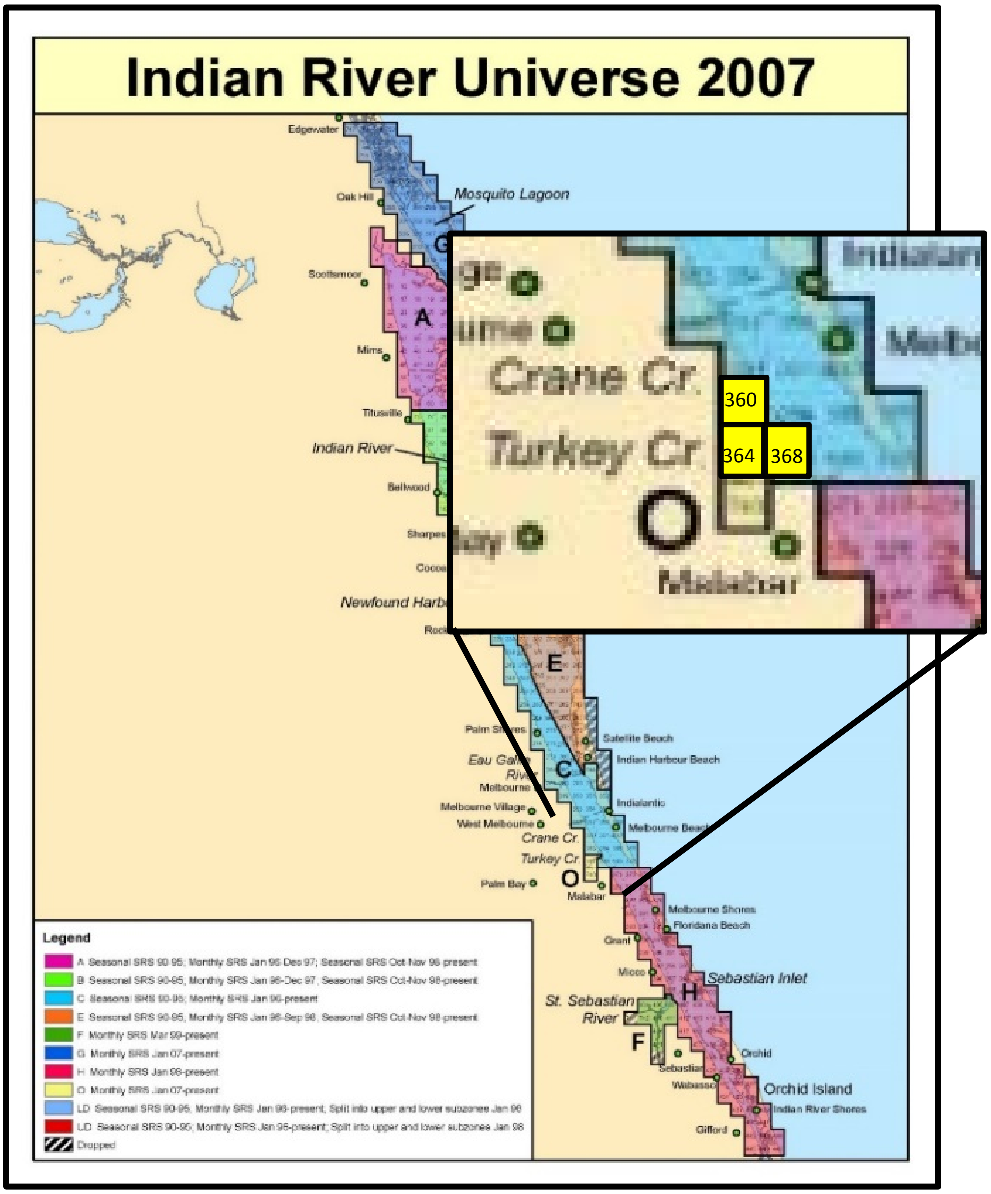


Figure 2.22. Sampling grid established by the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program for selecting seine sampling stations. Grid 364 includes the embayment at the mouth of Turkey Creek. FIM Fisheries data collected from Grid 364, Grid 360 (north of Turkey Creek) and Grid 368 (south of Turkey Creek) were used for comparison with data collected by this sampling program.

A comparison of the length-frequency data collected by this project and by the extensive FIM sampling effort shows that the length distribution of *Eucinostomus* spp. collected within Turkey Creek by our project in 2015 is not significantly different from that collected by the FIM sampling within Turkey Creek during 1991-2014 (Grid 364), north of Turkey Creek (Grid 360) and south of Turkey Creek (Grid 368) (Kolmogorov-Smirnov [KS] Test, p>0.05). Data presented in Figure 2.23 are the total abundance of all fish in each length class collected by the total sampling effort; the K-S test evaluates potential differences in relative frequencies of size classes among the sampling groups.

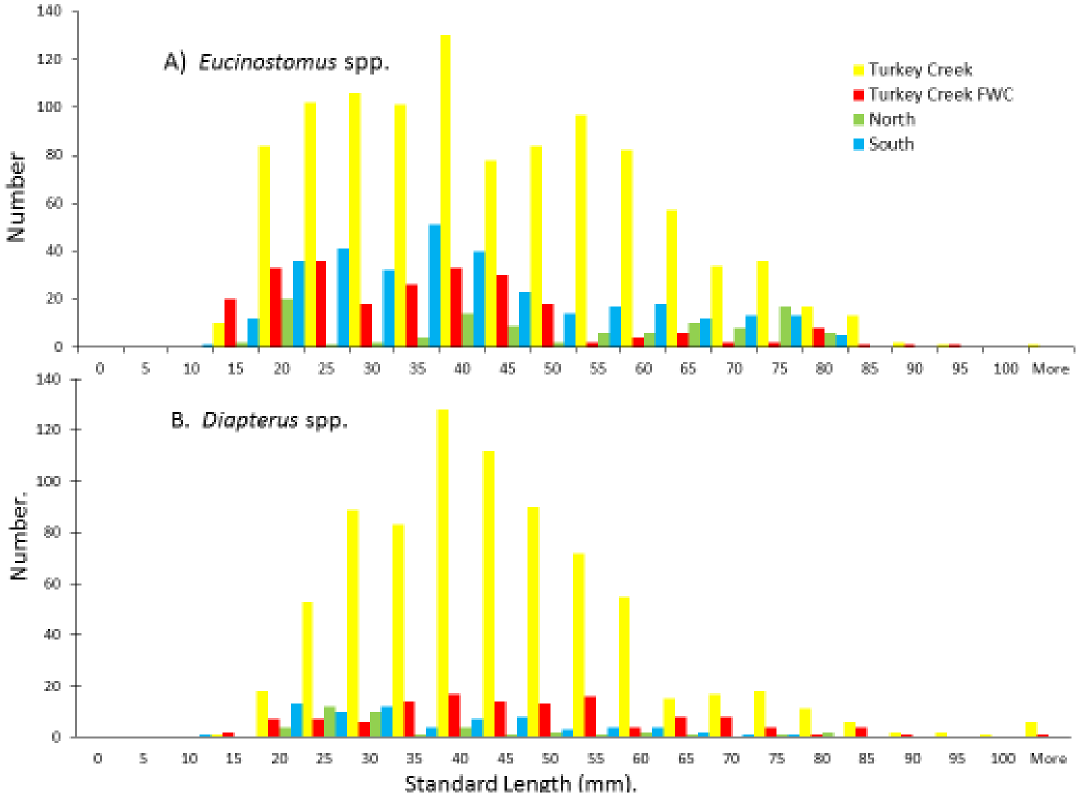


Figure 2.23. Length-frequency distributions of mojarras: A) *Eucinostomus* spp. and B) *Diapterus* spp. collected by this program (yellow bars) and FIM (Grid 364/Turkey Creek = red bars; Grid 360 north of Turkey Creek = green bars; Grid 368 south of Turkey Creek = blue bars).

These data indicate that the mojarra species are widely dispersed across the western side of the IRL around Turkey Creek, and that Turkey Creek itself is not a unique habitat for the taxa. However, these species are important prey species for larger predators, including many of the recreationally-important fishes. Factors affecting their abundance and growth may thus impact the prey base for predators. The mojarras typically inhabit sandy habitats, often extending into adjacent seagrass beds. They have a highly protrusible mouth that enables them to capture small epibenthic and infaunal prey such as polychaete worms, amphipods, cumaceans, and small bivalves (Kerschner et al. 1985; Mota et al. 1995). Given this ability to feed in sandy substrates, they are well adapted to thrive in the narrow band of sand and shallow mud around the periphery of the mouth of Turkey Creek. Analyses of the stomach contents of mojarras collected during 2015 is presently underway, which will permit comparison of their feeding with the prey base available in muck and sand habitats in the region. Preliminary evidence presented in this report suggests that muck habitats contain very few, if any, suitable prey taxa. We hypothesize that the removal of muck from Turkey Creek will expose sandy substrates that can develop a community of benthic species and ultimately provide resources to support a larger abundance of juvenile mojarras. This increase in mojarra population size may, in turn, enhance the prey base for the larger predatory fishes (e.g. sea trout, red drum, tarpon, juvenile bull sharks) that utilize Turkey Creek.

Silver Perch: This small member of the drum family was the third most abundant species collected during 2015 sampling. It was significantly more abundant in Turkey Creek and the adjacent sampling site outside Turkey Creek from April through July, but was almost entirely absent in the latter half of the year (Figure 2.25; 2 way ANOVA, $p<0.05$). Densities within Palm Bay were generally highest in the northern stations (F-N), where the substrate included patches of oyster shell and *Gracilaria* drift algae, as compared to the western shoreline stations (F-W) which were characterized by sand/muck substrate.

Silver perch spawn in early spring in estuarine channels, with larvae and early juveniles generally occurring in mesohaline seagrass, sand and oyster habitats and adults moving into higher salinity regions (Rooker et al. 1998; Hanke et al. 2013). Length frequency and seasonal abundance data from the Turkey Creek region provide some support for this trend, with the smaller juveniles found within Turkey Creek in spring (Figure 2.24 and 2.25), and larger specimens taken in the IRL north and south of the mouth of Turkey Creek. A further analysis of FIM data that encompasses a wider range of lagoon habitats may provide a more conclusive analysis of this potential trend.

Analysis of the feeding habits of silver perch in the northern Gulf of Mexico show that primary prey items of small juveniles include epibenthic crustaceans such as mysid shrimp and amphipods (Waggy et al. 2007). These prey are often associated with physical structures such as oyster shell, seagrass and drift algae. Stomach contents of fish collected by this program are presently being analyzed for comparison with benthic infauna/epifaunal samples still being processed. The presence of muck in much of Turkey Creek presumably limits the abundance of these organisms. The removal of muck should expose more suitable substrate for these prey taxa, providing a greater food base to support silver perch and other demersal fishes.

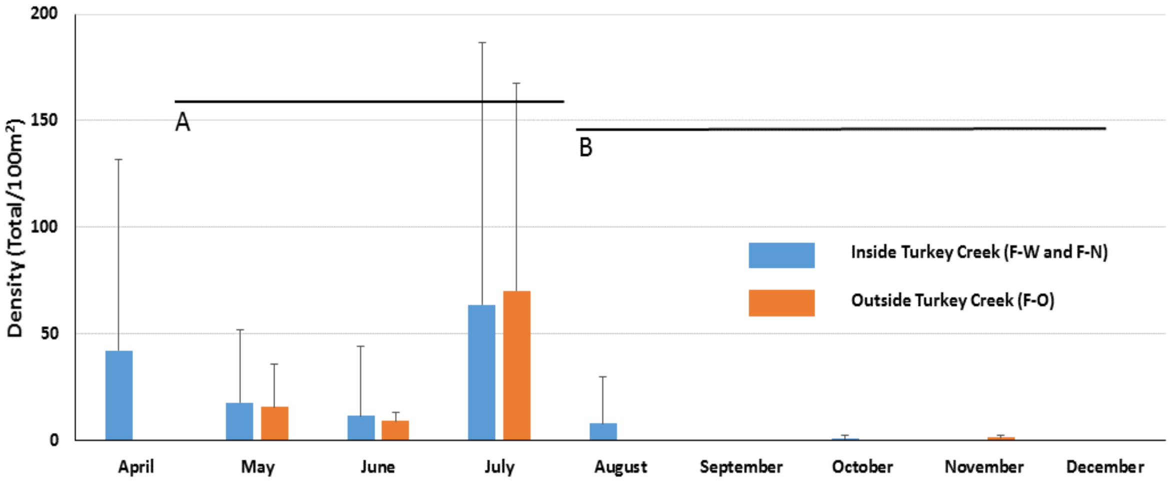


Figure 2.24. Mean (+/- S.D.) density (number/100 m^2) of silver perch (*Bairdiella chrysoura*) captured monthly from inside Turkey Creek (typically 8 samples per month) and just north of the mouth of Turkey Creek (2 samples per month; not sampled in April). Lines with different letters indicate temporal periods with significantly different fish densities (2-way ANOVA, p<0.05).

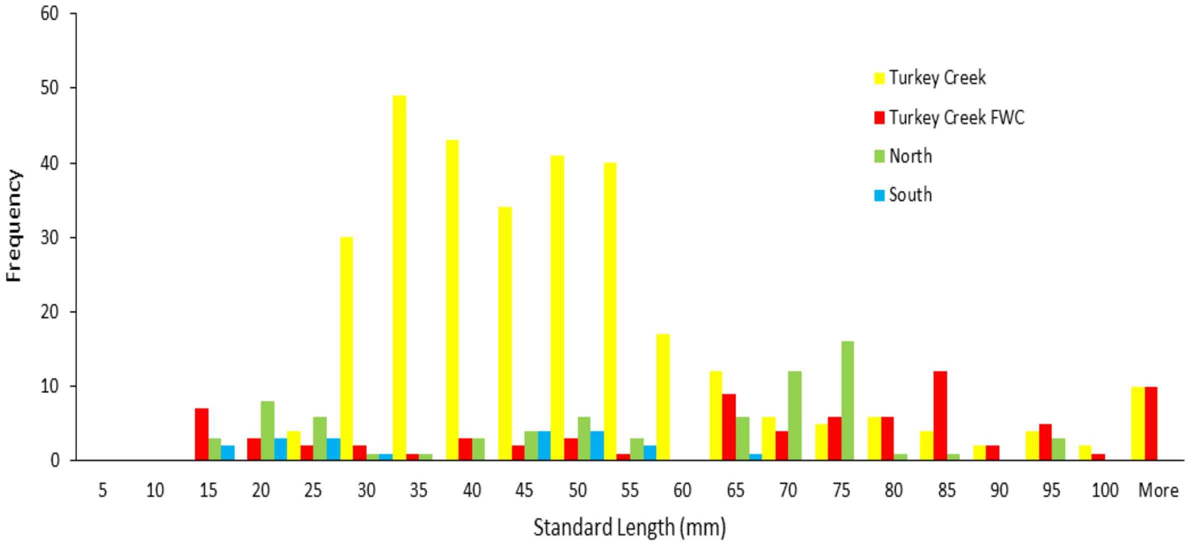


Figure 2.25. Length-frequency distributions of silver perch (*Bairdiella chrysoura*) collected by this program (yellow bars) and FIM (Grid 364/Turkey Creek = red bars; Grid 360 north of Turkey Creek = green bars; Grid 368 south of Turkey Creek = blue bars).

Red drum: This species supports one of the most valuable fisheries in the Indian River Lagoon and coastal waters throughout the southeast and Gulf coasts of the United States. Adults typically spawn around inlets and nearshore waters during the fall, with larvae ultimately settling into demersal estuarine habitats (Peters et al. 1987; Rooker et al. 1997). Although they may utilize a wide array of estuarine nursery habitats, Rooker et al. 1998 determined that seagrass meadows provide better protection from predators than featureless habitats.

Red drum were observed in large numbers only in December 2015 (Figure 2.26). These newly recruited juveniles were found entirely within the Turkey Creek habitats in both the western sandy habitats and the northern region that contained more oyster shell and other structure. They were not taken in the sandy habitat outside of the mouth of Turkey Creek.

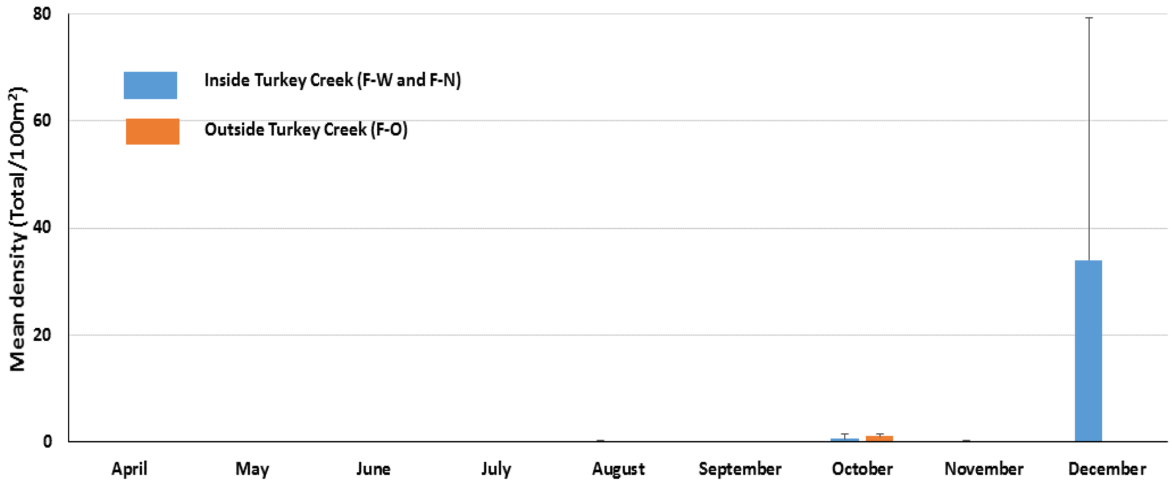


Figure 2.26. Mean (+/- S.D.) density (number/100 m^2) of red drum (*Sciaenops ocellatus*) captured monthly from inside Turkey Creek (typically 8 samples per month) and just north of the mouth of Turkey Creek (2 samples per month; not sampled in April).

A comparison of length-frequency data of the juvenile red drum collected inside Turkey Creek in December 2015 with data collected by the FIM Program show that the fish inside Turkey Creek were significantly smaller than juveniles collected by FIM inside, north, and south of Turkey Creek (Figure 2.27; K-S test, $p<0.05$). Small juveniles in this size range in Tampa Bay fed on small crustaceans such as mysids, amphipods and newly-settled shrimp (Peters and McMichael, 1987). An analysis of the stomach contents of the fish collected in December 2015 is underway, and will enable determination of whether their prey are restricted to sandy/shell substrate, or if they can forage over muck-dominated habitats. Continued sampling through 2016 will attempt to track this cohort if it remains viable within Turkey Creek.

We anticipate that the removal of muck from Turkey Creek will increase the prey base of juvenile red drum, but the lack of seagrass or other extensive structure may reduce the survival of red drum that inhabit sandy substrate. Development of seagrasses may occur naturally in the Turkey Creek habitats, and we will conduct pilot experiments after the conclusion of dredging. Alternatively, it may also be possible to restore oyster beds or provide other habitat structure that can enhance the survival of these valuable juveniles.

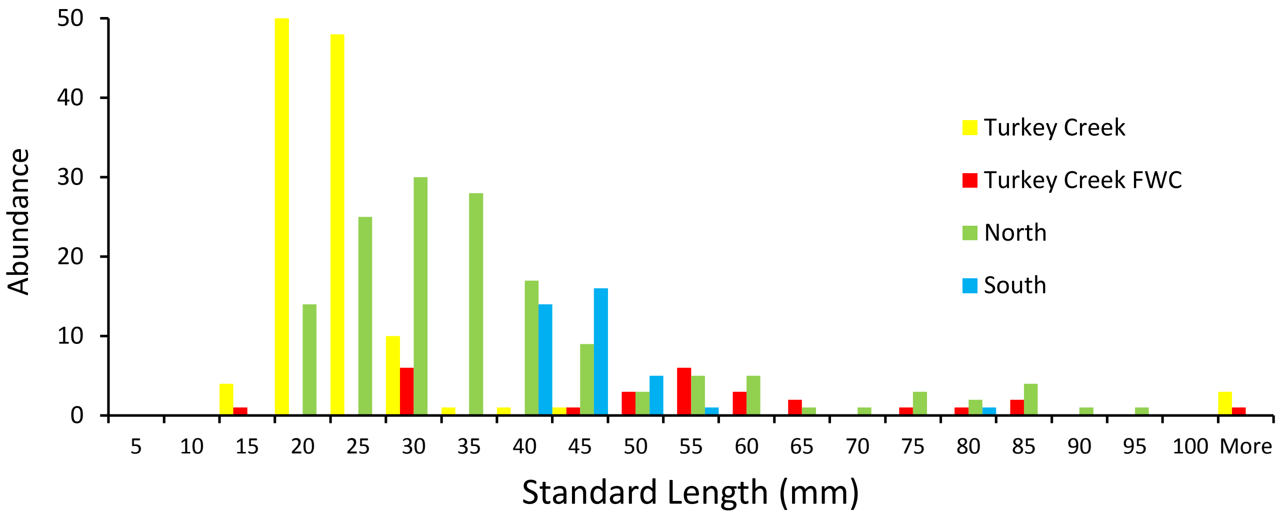


Figure 2.27. Length-frequency distributions of red drum (*Sciaenops ocellatus*) collected by this program (yellow bars) and FIM (Grid 364/Turkey Creek = red bars; Grid 360 north of Turkey Creek = green bars; Grid 368 south of Turkey Creek = blue bars).

<u>Sea trout:</u> Juvenile sea trout (*Cynoscion* spp.) were found sporadically at low densities inside Turkey Creek, but one episode of high density was detected outside the mouth of Turkey Creek in November 2015 (Figure 2.28). Primarily identifiable as spotted sea trout (*Cynoscion nebulosus*), these juveniles were presumably produced by adults spawning in estuarine channels during the preceding summer (Johnson and Seaman, 1986; McMichael and Peters, 1989). No significant differences were noted among sizes of juvenile seatrout collected by this sampling program and FIM sampling in adjacent habitats (Figure 2.29).

Juvenile sea trout are generally considered to prefer living in and around seagrass beds. The seagrass provides protection from predators and ready access to the planktonic prey (copepods) of small juvenile sea trout and epibenthic crustaceans (e.g. mysids and amphipods) of larger juveniles (McMichael and Peters, 1989).

If seagrass (*Halodule wrightii*) is able to grow within the dredged Turkey Creek, the removal of muck from the habitat may provide new habitat for juvenile sea trout and contribute to the fish populations within the wider IRL.

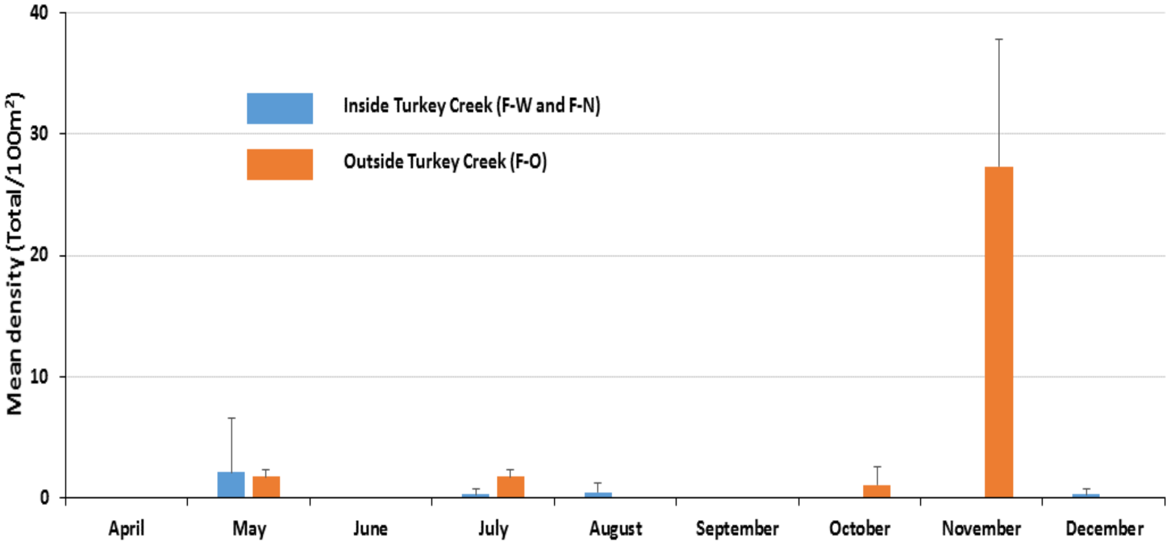


Figure 2.28. Mean (+/- S.D.) density (number/100 m^2) of juvenile seatrout (*Cynoscion* spp.) captured monthly from inside Turkey Creek (typically 8 samples per month) and just north of the mouth of Turkey Creek (2 samples per month; not sampled in April).

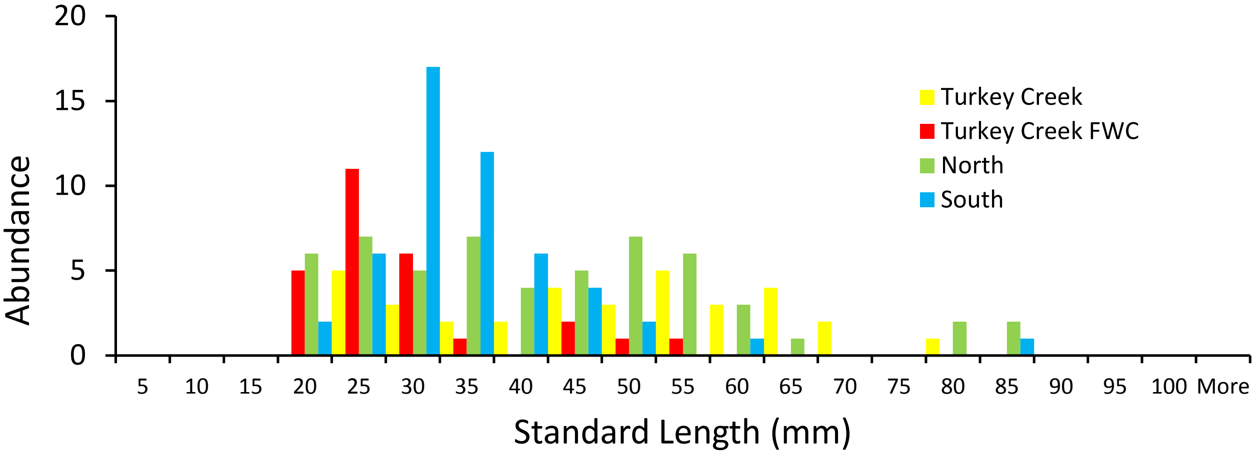


Figure 2.29. Length-frequency distributions of juvenile seatrout (*Cynoscion* spp.) collected by this program (yellow bars) and FIM (Grid 364/Turkey Creek = red bars; Grid 360 north of Turkey Creek = green bars; Grid 368 south of Turkey Creek = blue bars).

Sheepshead: This species is the target of many anglers fishing from docks or by the US 1 bridge in Turkey Creek. Adults use their strong jaws and teeth to feed on barnacles and other hard-shelled organisms attached to the hard substrates, and they are thus readily accessible to anglers fishing from docks. Jennings (1985) reports that sheepshead apparently spawn in nearshore waters in spring, with larvae recruiting to estuarine habitats. Upon settlement, they initially feed on soft-bodied demersal prey in seagrass and sandy sediments, switching to hard-shelled prey as they grow.

As expected from the seasonal spawning pattern, juvenile sheepshead were found in late spring through mid-summer, but primarily near the hard sand substrates outside Turkey Creek (Figure 2.30). A comparison of length data from this survey and the FIM surveys suggest that recruitment into the region comes from the south (Figure 2.31). The largest fish taken in our survey were obtained when we were able to seine around the periphery of a bed of oyster shells, and near dock structures.

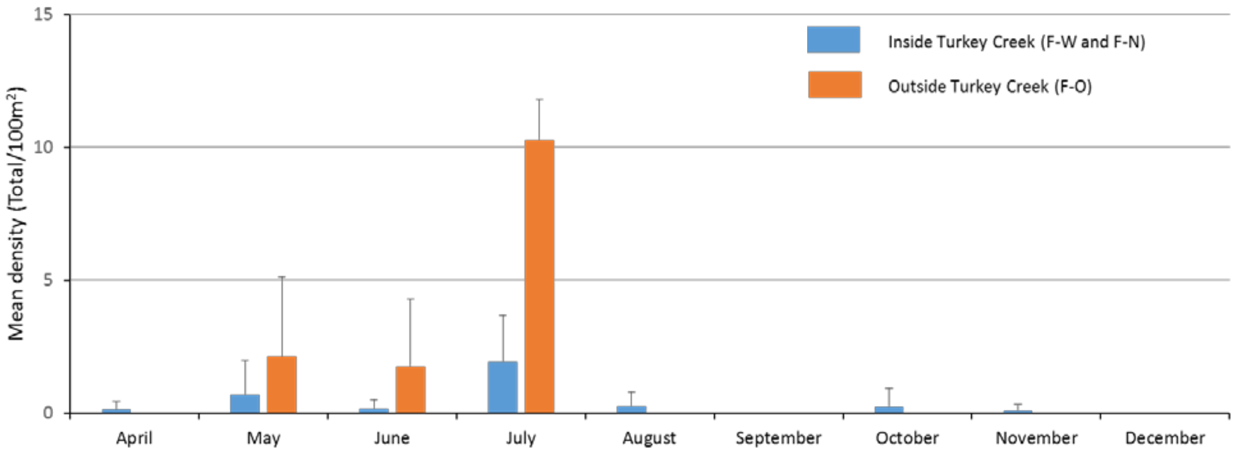


Figure 2.30. Mean (+/- S.D.) density (number/100 m^2) of sheepshead (*Archosargus probatocephalus*) captured monthly from inside Turkey Creek (typically 8 samples per month) and just north of the mouth of Turkey Creek (2 samples per month; not sampled in April).

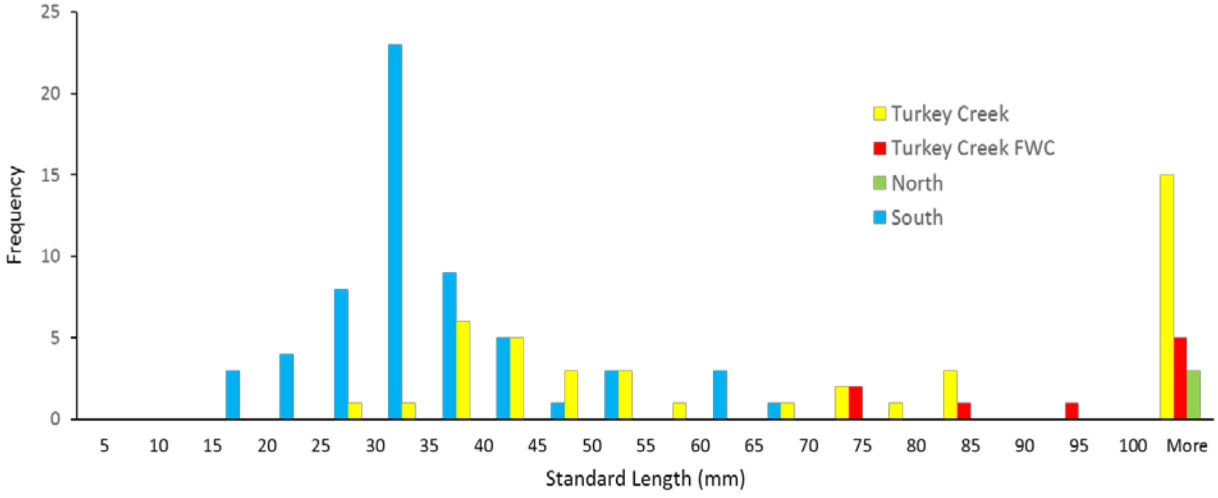


Figure 2.31. Length-frequency distributions of sheepshead (*Archosargus probatocephalus*) collected by this program (yellow bars) and FIM (Grid 364/Turkey Creek = red bars; Grid 360 north of Turkey Creek = green bars; Grid 368 south of Turkey Creek = blue bars).

Fish Community Similarity: The overall similarity in fish community composition among sites was assessed to determine if Turkey Creek supports an assemblage of fishes that differs from the surrounding habitats. Three analyses of similarity (ANOSIM) were conducted, using a Bray-Curtis similarity index. Interpretation of the ANOSIM focuses on the R-values that indicate similarity of paired populations or data sets. R-values are restricted to the range 0 to 1. R = 0 indicates complete overlap (no difference in species composition between sites) while R = 1 indicates complete separation (none of the species found in site 1 are present in site 2 and vice versa).

First, two data sets collected within Turkey Creek were compared to test if the two data sets provided an internally consistent assessment of community structure. The data sets include our seine data collected in 2015 and FIM data collected with a similar seine net inside Turkey Creek from 1990 to 2014. The ANOSIM R-value for the comparison of our data and the FIM data is 0.296 (p = 0.001), indicating that there is a similarity between the data sets (Figure 2.32). The inherent variation in FIM population estimates obtained over a 25-year period, reflecting annual variation in fish population dynamics and environmental conditions, and our more intense sampling within 9 months of a single year contribute to the R-value of 0.296.

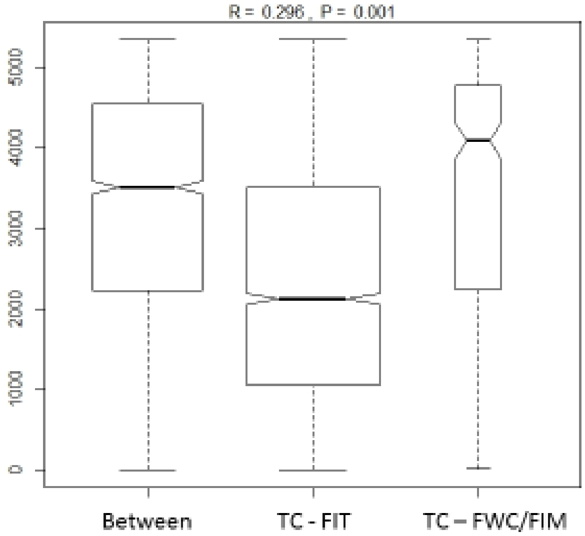


Figure 2.32. Analysis of Similarity (ANOSIM) results of a comparison of data collected from within Turkey Creek; our study (FIT) which collected data for 9 months in 2015, and the FIM data set which collected data from 1990 to 2014.

Comparisons of our fish data collected inside Turkey Creek to that collected by FIM from sites along the exposed western shore of the Indian River Lagoon (up to 1 km north and 1 km south of the mouth of Turkey Creek), show lesser similarities in community structure among habitats that found within Turkey Creek. The community assessment of fishes north of Turkey Creek and within Turkey Creek generated an ANOSIM R-value = 0.406 (p = 0.001) (Figure 2.33). A similar comparison of fish communities south of Turkey Creek and within Turkey Creek (Figure 2.34) detected a stronger difference in community structure (ANOSIM R-value = 0.471 (p = 0.01).

As we complete a full year of sampling in March, we will repeat these community assessments, using a two-way ANOSIM that will enable assessment of seasonality as well as spatial patterns in community structure. The results of these analyses may be of significant use in characterizing the structure of the fish community within Turkey Creek before and after muck removal.

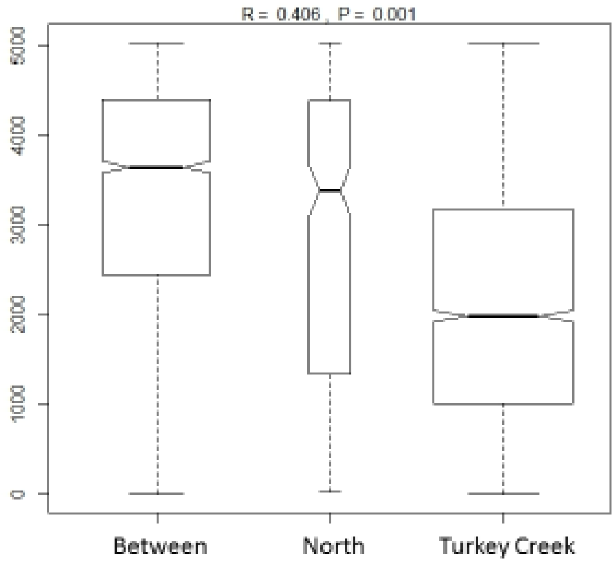


Figure 2.33. Analysis of Similarity (ANOSIM) results of a comparison of our data collected from within Turkey Creek in 2015 and the FIM data set from Grid 360 north of the mouth of Turkey Creek from 1990 to 2014.

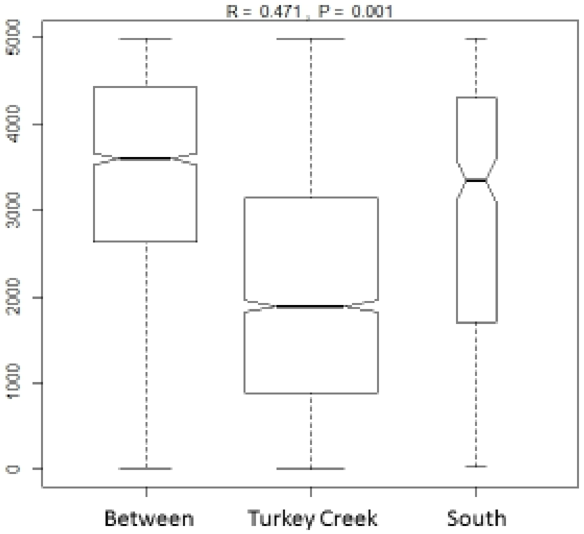


Figure 2.34. Analysis of Similarity (ANOSIM) results of a comparison of our data collected from within Turkey Creek in 2015 and the FIM data set from Grid 368 south of the mouth of Turkey Creek from 1990 to 2014.

2.5 Conclusions

Seagrasses and Drift Algae

The area to be dredged (Turkey Creek) has scattered seagrass (*Halodule wrightii*), but they are sparse and no patches were captured in transect quadrats. The intermediate organic sediments of Turkey Creek likely contribute, and may be the primary reason, for seagrasses struggling in what would otherwise appear to be an ideal location. In addition to the accumulation of organic sediments stressing the seagrasses, the drift algae, which likely benefit from the abundance of nutrients fluxing into the water column from benthic and suspended sediments, also shade, smother and stress struggling *H. wrightii*. It is anticipated that dredging of FGORS sediments in this location could potentially improve water column and benthic conditions for seagrasses in Turkey Creek.

This collection of 2015 baseline data, encompassing regular seasonal distributions and variations in the absence of any dredging, will allow for comparisons of seagrass growth during and after future dredging. In addition, the simultaneous monitoring of seagrasses in the IRL locations will allow future comparisons with areas less influenced or uninfluenced by dredging activity. Seagrasses, being an indicator of environmental health, a food source for large animals, and a nursery ground for many fisheries, will help in the assessment of the success of future environmental muck dredging. Drift algae, while food and habitat themselves, are also competitive with seagrasses and more effective at using excess nutrients. Drift algae are thus also important as a form of reciprocal indication of water quality relative to seagrasses. Seagrass and drift algae baseline data are critical to future evaluations of potential environmental improvements.

Benthic Infauna

Benthic invertebrate animals are intimately connected with the sediments in which they live and are likely to be most affected by, and responsive to, changes in those sediments. This study has shown species richness, diversity, and the abundances to vary with some predictability with the degree of FGORS characteristics in sediments. Highly organic sediments have fewer numbers of individuals and lower diversity and richness. FGORS qualifying fully as “muck” usually have no animal life. Rare occasions where animals were observed in muck were not bolstered by consistency in replicate samples, and it seems likely that these few animals were interlopers, possibly even stressed or dying in the inhospitable environment. The correlations of infaunal communities with FGORS characteristics give rise to the hope they may serve as effective indicators of change in sediment and water quality. As dredging occurs in Turkey Creek, the exposed sediments will be subsequently colonized by infaunal organisms. Sandier benthic sediments with fewer organics, a desirable outcome of environmental muck dredging, should yield more diverse, rich, and abundant successive infaunal communities.

Fishes

Turkey Creek currently supports an abundant and diverse assemblage of fishes. The composition of the fish assemblage changes rapidly as pelagic schooling species, such as the numerically dominant anchovies, mullets and herrings, move into and out of the region. Larger predatory fishes such as jacks, tarpon and red drum are assumed to track the movements of the abundant prey species.

The species composition and abundance of demersal juvenile fishes changes more slowly, reflecting seasonal patterns in reproduction and growth that vary among species. The most abundant demersal juveniles are mojarras, some species of which appear to persist in the region throughout much of the year. The most important fishery species that utilize the demersal Turkey Creek habitat include juvenile red drum in winter and sheepshead in the late spring and summer. These juveniles feed on benthic infauna and epifauna, which are very sparse in muck habitats.

The removal of muck may increase the area where a benthic prey community can develop, and a larger habitat area where juveniles can forage on the prey. The complexity of the substrate presently exposed in Turkey Creek, and to be exposed after muck removal, may further influence the ability of juvenile fishes to avoid predators.

We will attempt, working with Sea and Shorelines, LLC, we will attempt to determine if seagrasses can indeed thrive within the outer Turkey Creek basin after the completion of dredging. Another form of habitat complexity that can enhance juvenile fish survival is the physical complexity provided by living or dead oyster shell bars, rocks and other hard substrate. These complex habitats can be developed below the photic zone of the turbid habitat, or even in shallow water if seagrasses do not thrive in the ecosystem.

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Chapter 3 The Efficiency of Muck Removal from the Indian River Lagoon and Water Quality after Muck Removal

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3.1 Summary

Muck removal is an integral part of the restoration process in the Indian River Lagoon (IRL) system. This fine-grained, organic-rich material (muck) (1) is easily resuspended to increase turbidity, (2) consumes oxygen, (3) creates an inhospitable benthic habitat, (4) serves as a reservoir for potential pollutants and (5) is an internal source of dissolved nitrogen and phosphorus that diffuse into lagoon waters at a rate commensurate with external sources in the North IRL. This study began in February 2015 with a muck survey of Turkey Creek in advance of proposed dredging during 2016. Little or no muck was present in the adjacent IRL near the mouth of Turkey Creek in contrast with layers that were 1- to 3-m thick throughout most of the lower creek. The estimated total volume of wet muck in the creek from this study is 111,000 m^3 (145,000 yd^3). Muck sediments from the creek contained >75% water by weight (>90% water by volume), 76-99% silt + clay, and 11-22% organic matter (4-7% organic carbon, 0.4-0.8% organic N and 0.10-0.17% total phosphorus). These values match earlier characterizations of muck deposits.

Water quality surveys were carried out monthly from April to December 2015 at five stations. Continuous profiles for salinity, temperature, dissolved oxygen and pH were obtained and 2-5 discrete water samples were collected at each station (135 total samples over 9 months). Water samples were analyzed for (1) turbidity (NTU) and total suspended solids (TSS in mg/L), (2) total concentrations of particulate iron, aluminum, silicon, nitrogen, phosphorus and organic carbon and (3) concentrations of dissolved ammonium, nitrate + nitrite, organic carbon, phosphate, total nitrogen and total phosphorus. Data from the water quality surveys will be used in the post-dredging assessment of the effectiveness of muck removal.

The average chemical forms of nitrogen in the water column (n = 135 samples), with percent of the total nitrogen in parenthesis, were as follows: dissolved organic nitrogen (57.8%), particulate organic nitrogen (32.1%), ammonium (8.9%) and nitrate + nitrite (1.2%). Large spikes in concentrations of ammonium (up to 50 µM or 0.7 mg N/L) were found in small depressions in Turkey Creek and linked to releases from muck sediments. These high values were ~10-fold greater than median concentrations of ~5 µM (0.07 mg N/L) in the overall study area. Concentrations of nitrate + nitrite were regularly higher in fresher water near the Florida East Coast

railroad bridge (4-6 µM; 0.06-0.08 mg N/L) relative to average values near the mouth of Turkey Creek of ~1 µM (0.014 mg N/L).

For phosphorus, the chemical forms in the water column (n = 135 samples), with percent of the total phosphorus in parenthesis, averaged as follows: particulate organic phosphorus (48.7%), phosphate (29.7%) and dissolved organic phosphorus (21.6%). Concentrations of dissolved phosphate as high as 10 µM (0.31 mg P/L) were found in the same small depressions with high ammonium values. These phosphorus spikes also were linked to releases from muck sediments. The median phosphate value in Turkey Creek was 0.8 µM (0.025 mg P/L). The lowest concentration of dissolved phosphate was 0.03 µM (0.0009 mg P/L) in the adjacent IRL during December.

Tracking changes in fluxes of nitrogen and phosphorus from muck sediments is an important part of the post-dredging assessment. Fluxes of nitrogen (essentially all as ammonium) and phosphorus (essentially all as phosphate) from muck sediments averaged ~ 10 and 1 metric tons/km^2/yr, respectively, with a large contribution to bottom water ammonium and phosphate concentrations.

The post-dredging assessment of the effectiveness of muck removal from Turkey Creek will include the following components: (1) a muck survey, (2) determination of the composition of remaining sediment in the creek after dredging, (3) comparison of pre- and post-dredging concentrations, forms and distribution of selected water quality parameters, especially dissolved oxygen, particulate organic carbon and dissolved and particulate nitrogen and phosphorus and (4) determination of nitrogen and phosphorus fluxes from bottom sediment to the water column.

3.2 Introduction

Muck removal from the Indian River Lagoon (IRL) and adjacent creeks is an important component of the overall lagoon restoration. Improved water quality is a primary goal of muck dredging because as water quality improves, the chance for successful restoration of the ecosystem is greatly enhanced. We believe that muck removal must be relatively complete because residual muck still releases nutrients and impedes the recovery of seagrass and bottom-dwelling organisms. This assumption certainly can be tested during this study that was designed to address both muck removal and water quality issues in Turkey Creek, one of the sites to be dredged in 2016 with recent funding from the State of Florida.

The goal of this study was to obtain a detailed data set that describes the distribution and composition of muck and water quality parameters in Turkey Creek so that an assessment of the effectiveness of dredging can be carried out. To meet this goal, the following activities were completed in Turkey Creek during 2015: (1) determination of the spatial distribution, total volume and composition of muck sediments, (2) nine monthly water quality surveys at five locations in the study area with analysis of dissolved and particulate chemicals and (3) as a complementary effort to this study, some sediment flux measurements were made to determine releases of nitrogen and phosphorus from bottom sediment to the overlying water column.

Black, organic-rich (>10% organic matter), mud-rich (>60% silt + clay), high water content (>75% water by weight, >90% water by volume) sediments (referred to loosely as muck in this report) are not naturally occurring in the IRL. Earlier studies of muck in the IRL (Trefry et al., 1987, 1990) reported muck, as defined above, to be most prevalent in creeks adjacent to the lagoon (e.g., Crane Creek, Turkey Creek), the Intracoastal Waterway and deeper pockets of water near tributary sources. A 1989 muck survey of the Indian River Lagoon System from Ponce de Leon Inlet to St. Lucie Inlet concluded that the spatial occurrence of muck was limited to <10% of the lagoon (Trefry et al., 1990). These fine-grained, organic-rich sediments are a primary repository for contaminants in coastal estuaries (National Research Council, 1997), including the IRL (Trocine and Trefry, 1996, Trefry and Trocine, 2011). Identifying the distribution of anoxic muck sediments and definitively identifying changes in environmental quality after dredging may provide important insight regarding the health of the lagoon and future remediation strategies.

In 2006-7, Trefry and Trocine (2011) revisited 73 locations in the IRL to re-assess muck deposits that were sampled in 1989. Muck layers increased in thickness at 51 of 73 stations over 17 years, yet 7 of 11 stations that contained no muck in 1989 remained muck free. The total muck thickness for 2006–7 (~63 cm/site) was ~67% greater than in 1989 (~38 cm/site). They estimated that muck covered ~10% of the lagoon during both periods. Clearly, the muck problem had not gone away.

Concentrations of metals and organic contaminants in muck sediments were determined previously and a sizeable data set is available (Windsor and Surma, 1993; Trocine and Trefry 1996; Windsor, 2004; Trefry et al., 2011). Results for potential contaminants were assessed using sediment quality guidelines wherein an Effects Range-Low (ERL) and Effects Range-Median (ERM) are used to identify concentrations that may induce sediment toxicity (Long et al., 1995). The ERL and ERM are defined as the 10th and 50th percentiles, respectively, from a list of ascending concentrations of contaminants in sediments that may cause adverse biological effects. These sediment quality guidelines were developed to identify specific sites where additional investigation is warranted rather than specifically identifying toxic sediment. For metals, no concentrations of the five metals with realistic values for the ERL and ERM (Ag, Cd, Hg, Pb or Zn) exceeded their respective values for the ERM in surface sediments from the IRL in 1992 or 2006–7 (Trefry and Trocine, 2011). Surface sediments from Crane Creek and Eau Gallie Harbor had Hg and Zn concentrations that exceeded the ERL during both 1992 and 2006-7 (Trefry and Trocine, 2011). Lead concentrations exceeded the ERL at 4 locations in 2006–7 relative to none in 1992, possibly due to inputs from old upstream sources during the 2004 hurricanes. Nearly all muck sediment samples collected in

2006-7 had lower concentrations of total polycyclic aromatic hydrocarbons (TPAH) than in 1992. No TPAH concentrations exceeded the ERM or ERL (ERL = 4 µg/g) during these sediment surveys (Windsor, 2004, Trefry et al., 2008). Overall, no serious problems with metals and organic substances have been reported for the IRL System. Instead, the primary issue of concern centers on nutrients and algal blooms.

Very few studies of the impacts of dredging in creeks have been carried out for the IRL System. About ~60,000 m^3 (86,000 yd^3) of sediment were removed from Crane Creek during 1998; yet, Trefry et al. (2004) estimated that ~82,000 m^3 of muck were present in the creek in 2002, with more than half deposited east of U.S. Route 1. These results are largely due to the fact that removal of muck from Crane Creek was limited because no dredging occurred near docks and seawalls. Based on measured sedimentation rates, the annual volume of sediment deposited in Crane Creek was estimated to be 800 ± 300 m^3/yr. At that rate, an amount of sediment equivalent to the 60,000 m^3 dredged in 1998 would be deposited in ~75 years (Trefry et al., 2004). As a consequence of dredging, Garcia (1998) showed that the salt wedge in Crane Creek moved several hundred meters upstream and generally increased dissolved oxygen concentrations, except in deeper depressions (up to 4.2 m) created by dredging. This same scenario is predicted for Turkey Creek. Previously in Turkey Creek, Trefry et al. (2002) found that only a thin veneer of fine-grained sediment remained after dredging muck from the Palm Bay area between U.S. Route 1 and the mouth of the creek. This area has had ≥1 m of muck added since 2002.

3.3 Approach

3.3.1 Muck Survey, Sediment and Water Collection

This study was initiated with a muck survey that was carried out during February 2015 using a 4-cm diameter, capped polyvinyl chloride (PVC) pole with a T-shaped handle; the pole was marked in centimeter gradations (Figure 3.1A). The pole was lowered into the water column until the surface layer of sediment was encountered; this depth was recorded as the water depth. The pole was then pushed into the sediment until a firm bottom was struck and the total depth minus the water depth was recorded as the thickness of the muck layer. Muck often adhered to the pole along the entire muck interval to provide validation of the thickness of the muck layer. The survey included 253 probe measurements of water depth and muck thickness within a gridded area of the creek (grid and data in Appendix A). The data for water depth and muck thickness were tabulated and contour maps were generated using ArcGIS (Version 10.2.2.3552, Esri, Redlands, CA).

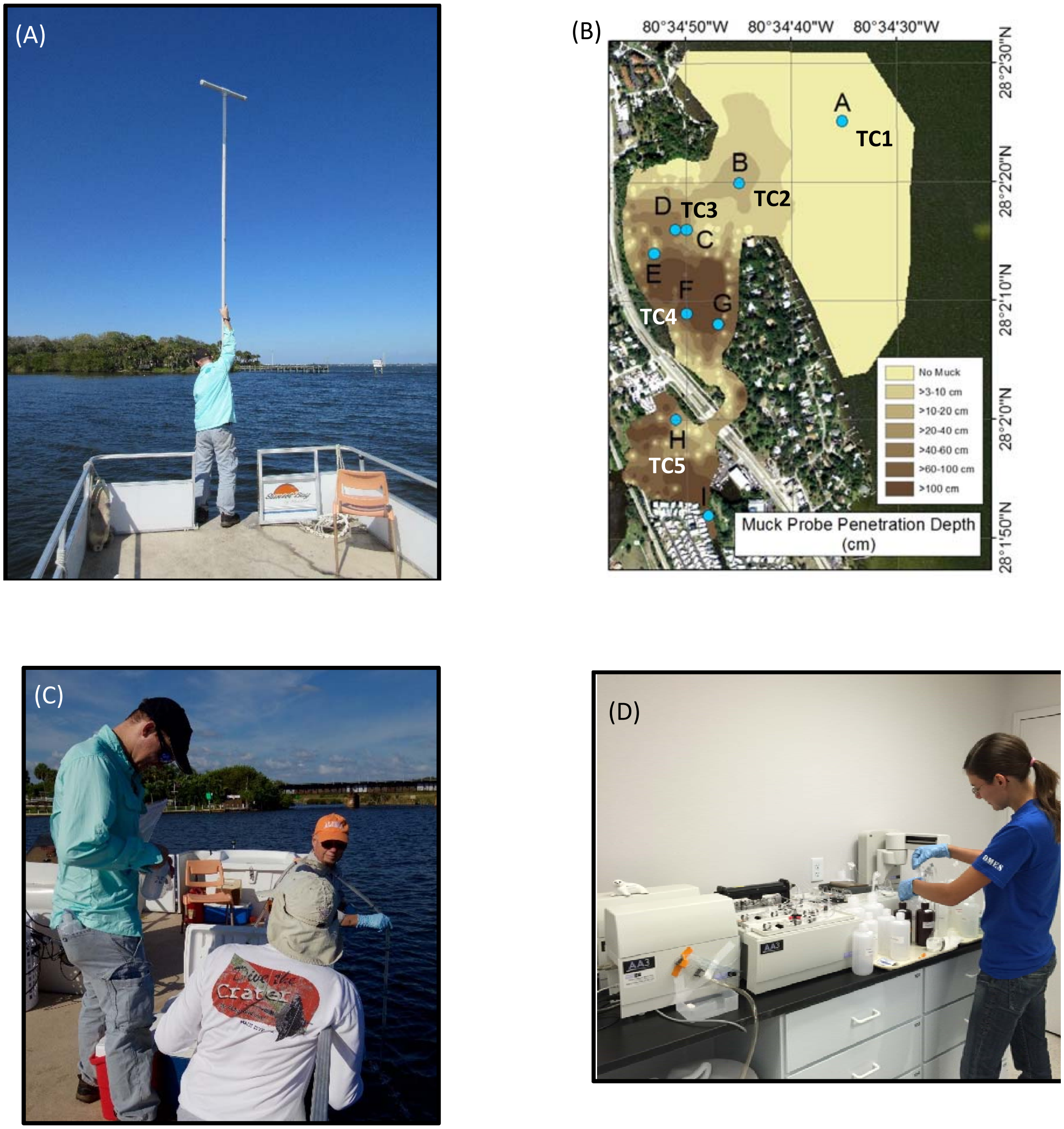

Figure 3.1. (A) Using a PVC pole to determine water depth and muck thickness, (B) map showing sampling locations for sediment (labelled A-I) and water (labelled TC1-TC5), larger scale maps are presented in Section 3.4.1, (C) pumping water for chemical analysis using a peristaltic pump with Tygon tubing, and (D) SEAL AA3 three-channel auto-analyzer for nutrient analysis.

Sediment samples for chemical analysis were collected at nine locations (Figure 3.1B) using a small ponar grab. Sediment from the top 2 cm of the grab was placed in double Ziploc bags for grain size and in polycarbonate vials (~70 mL) for other chemical analyses.

Nine pre-dredging water quality surveys were carried out during 2015 (April-December). Water samples were collected from 2-5 depths at the same five stations during each survey (Figure 3.1B). Vertical profiles for salinity, temperature, pH and dissolved oxygen were obtained using a YSI 6600 V2 sonde (Yellow Springs Instruments). The sonde was calibrated at the beginning of each day following the manufacturer's specifications. Discrete samples were collected through Tygon tubing attached to a peristaltic pump (Figure 3.1C). Samples were placed in acid-washed low-density polyethylene bottles and stored in coolers until returned to the Marine & Environmental Chemistry Laboratories at Florida Institute of Technology (FIT). Filtration was carried out within 2-3 hours through 47-mm diameter, 0.4-µm pore size polycarbonate filters (for Fe, Al, Si, P) and 47-mm diameter, 0.7-µm pore size glass fiber filters (for dissolved C, N and P species and particulate C and N).

3.3.2 *Laboratory Analyses: Sediments*

All sediment samples, except sub-samples for grain size, were freeze dried and powdered using a SPEX Model 8000 Mixer/Mill. In preparation for analysis for Al, Fe, Si and P, 10-20 mg of freeze-dried, homogenized sediment or Certified Reference Material (CRM) sediment MESS-3, from the National Research Council of Canada (NRC), were totally digested in sealed Teflon tubes using concentrated, high-purity HF and HNO_3 following methods of Trefry and Trocine (1991). Complete digestion of the sediment was chosen because it accounts for the entire amount of each element in the sample.

Concentrations of Al, Fe and Si in digested sediments were determined by flame atomic absorption spectrometry (FAAS) using a Perkin-Elmer Model 4000 atomic absorption spectrometer following U.S. EPA (1991) methods. Values for P were determined by inductively coupled plasma-mass spectrometry (ICP-MS) based on EPA Method 6020 (U.S. EPA, 1991) using a Varian Model 820-MS instrument with Collision Reaction Interface and a Model SPS3 sample preparation system. Concentrations of these elements in the sediment CRM MESS-3 were within the 95% confidence intervals for certified values. Analytical precision for individual elements in sediments ranged from 0.7 to 6% (as relative standard deviation, RSD). Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

Grain size analyses were carried out using the classic method of Folk (1974) that includes a combination of wet sieving and pipette techniques. Loss on Ignition (LOI) at 550˚C was determined following the method of Heiri et al. (2001). Values for LOI estimate the fraction of organic matter in the sample and are used in conjunction with concentrations of organic C, total N and total P to make inferences about sediment sources. Concentrations of $CaCO_3$ were determined by heating the sediment that had been treated for LOI at 550˚C to 950˚C following the method of Heiri et al. (2001).

Concentrations of total organic carbon (TOC) were determined using freeze-dried sediment that was treated with 10% (v/v) hydrochloric acid to remove any inorganic carbon, washed with carbon-free, high purity water (HPLC grade) and dried. Then, approximately 200-800 mg of pre-treated sediment were weighed into ceramic boats and combusted with pure oxygen at 950˚C using a LECO Corporation (St. Joseph, MI) TruMac C/N/S system with quantification of the resultant CO_2 gas using an infrared detection cell. Sediment total nitrogen concentrations were determined using separate samples that were untreated prior to analysis to avoid losses of nitrogen during acidification. Nitrogen analyses of sediments also were carried out using the LECO system at 950˚C with quantification of the N_2 gas produced via a thermal conductivity detector. Concentrations of C and N in the sediment CRM MESS-3, SRM #2704 and LECO reference sample 502-309 were within the 95% confidence intervals for certified values. Analytical precision was 1.5% for TOC and 2% for total nitrogen. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

3.3.3 *Laboratory Analyses: Water Dissolved Chemicals*

Samples for nutrient analysis were vacuum filtered through polycarbonate filters (Poretics, 47-mm diameter, 0.4-µm pore size) in a laminar-flow hood. Ammonium was quantified following standard methods (#4500-NH_3, Clesceri et al., 1989). Ammonium reacts with phenol to form indophenol with a blue color that adsorbs light at 630 nm in direct proportion to ammonium concentrations. Standards were prepared from dried ammonium chloride (Clesceri et al., 1989) and analyzed twice using UV-visible spectrometry with each batch of samples to ensure accuracy. All values were within the 95% confidence interval for the prepared standard. Analytical precision for lab duplicates (RSD) was 2.4%. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

Concentrations of nitrate-nitrite were determined following standard methods (Jones, 1984). Nitrate is reduced to nitrite by shaking with spongy cadmium. Nitrite then reacts with sulfanilamide to form a diazo compound and is then coupled with N-(1-naphthyl) ethylenediamine dihydrochloride to form a pink azo dye. The absorbance of this azo dye was determined by UV-visible spectrometry at 540 nm. The National Institute of Standards and Technology (NIST) traceable Dionex 5-Anion Standard was analyzed as a reference standard with each batch of samples to ensure accuracy; all values were within 10% of the known concentration. Analytical precision for lab duplicates (RSD) was 6.1 ± 4.8%. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

Concentrations of total dissolved nitrogen were determined using a SEAL AA3 HR Continuous Segmented Flow AutoAnalyzer following manufacturer's method no. G-218-98. Organic and inorganic nitrogen compounds were converted to nitrate using UV and persulfate digestion. Nitrate was reduced to nitrite using a cadmium column. Nitrite was reacted with sulfanilamide to form a diazo compound which was coupled with N-(1-naphthyl) ethylenediamine dihydrochloride to form a pink azo dye. The absorbance of this azo dye was determined by UV-visible spectrometry at 540 nm. Standards were prepared from dried ammonium chloride (Clesceri et al., 1989) analyzed twice with each batch of samples to ensure accuracy; all values were within 10% of the known concentration. Analytical precision for lab duplicates (RSD) was 2.1 ± 1.8%. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

Concentrations of ortho-phosphate were determined following method 4500-P (Clesceri et al., 1989). Ortho-phosphate was reacted with ascorbic acid, molybdate and antimony to yield a phospho-molybdenum blue complex. The absorbance at 880 nm was determined using UV-visible spectrometry. The NIST-traceable Dionex 5-Anion Standard was analyzed as a reference standard with each batch of samples to ensure accuracy; all values were within 95% confidence interval for this standard. Analytical precision for lab duplicates (RSD) averaged 1%.

Alkalinity was determined following method 2320-B (Clesceri et al., 1989). Samples were titrated with 0.01N HCl to a known endpoint. Alkalinity in mg $CaCO_3$/L is directly proportional to the volume of acid added. Standard seawater solution (OSIL, UK) was analyzed as a reference standard with each batch of samples; all values were within 95% confidence interval for the standard. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

Concentrations of total dissolved phosphorus were determined using a SEAL AA3 HR continuous Segmented Flow AutoAnalyzer following manufacturer's method no. G-219-98. UV and persulfate digestion were used to free organically-bound phosphorus. Ortho-phosphate was reacted with ascorbic acid, molybdate and antimony to yield a phospho-molybdenum blue complex. The absorbance at 880 nm was determined using UV-visible spectrometry. The NIST-traceable Dionex 5-Anion Standard was analyzed as a reference standard with each batch of samples to ensure accuracy; all values were within 10% of the known concentration. Analytical precision for lab duplicates (RSD) was 2.6 ± 2.4%.

3.3.4 *Laboratory Analyses: Water Particulate Chemicals*

Samples of suspended matter were collected by vacuum filtering water through polycarbonate filters (Poretics, 47-mm diameter, 0.4-µm pore size) in a laminar-flow hood in our clean room at FIT. Prior to the field effort, the filters were acid washed in 5N HNO_3, rinsed three times with deionized water (DIW), dried and then weighed to the nearest µg under cleanroom conditions. Precision for replicate filtrations averaged <4% (i.e., ±0.04 mg/L). Samples for particulate organic carbon (POC) were filtered through pre-combusted Gelman Type A/E glass fiber filters mounted on acid-washed filtration glassware within a Class-100 laminar-flow hood. Particle-bearing filters were sealed in acid-washed petri dishes, labeled and then double-bagged in plastic and stored until dried and re-weighed at FIT.

Suspended particles, as well as separate milligram quantities of standard reference material (SRM) #2704, a river sediment issued by the NIST, were digested in stoppered, 15-mL Teflon test tubes using Ultrex II HNO_3 and HF as described by Trefry and Trocine (1991). Concentrations of particulate Al, Fe and Si were determined by flame atomic absorption spectrometry and concentrations of particulate P were determined by inductively-coupled plasma mass spectrometry (ICP-MS) using a Varian 820 instrument. Analytical precision for individual elements in sediments ranged from 1-5%. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

Concentrations of particulate organic carbon (POC) and total nitrogen were determined by first treating particles on the glass fiber filter with 10% (v/v) hydrochloric acid to remove any inorganic carbon, washed with carbon-free, high purity water (HPLC grade) and dried. Then, the filters with approximately 200-800 mg of pre-treated suspended sediment were weighed into ceramic boats and combusted with pure oxygen at 950˚C using a LECO TruMac C/N/S system with quantification of the resultant CO_2 gas using an infrared detection cell. Total nitrogen concentrations were determined using separate glass fiber filters that were untreated prior to analysis to avoid losses of nitrogen during acidification. Nitrogen analyses of suspended particles also were carried out using the LECO system at 950˚C with quantification of the N_2 gas produced via a thermal conductivity detector. Concentrations of C and N in the sediment CRM MESS-3, SRM #2704 and LECO reference sample 502-309 were within the 95% confidence intervals for certified values. Analytical precision was 1.5% for TOC and 2% for total nitrogen. Additional QA/QC information and data are provided in Section 3.3.5 and Appendix B.

3.3.5 Quality Assurance and Quality Control (QA/QC)

The QA/QC program used in the Marine & Environmental Chemistry Laboratories at FIT for sediment and water collection and analysis followed the general guidelines provided below.

(i) *Sample Handling.* Sediment samples were transferred to a refrigerator or if sampled as cores, were immediately processed for sub-sampling (and then refrigerated if necessary). Water samples were collected and preserved using appropriate containers and reagents. Solutes were measured within appropriate holding times. All water samples were kept chilled, either on ice or in refrigerators, until analyzed.

(ii) *Quality Control Measurements for Analyses.* Quality control measures included instrument calibration, matrix spike analysis, field replicates, duplicate sample analysis, standard reference material analysis, procedural blank analysis, and standard checks. With each batch of 20 field samples a procedural blank, standard reference materials, a field and laboratory duplicate, and a matrix spike sample were analyzed. Data quality objectives for these quality control measurements are provided in Table 3.1.

(iii) *Matrix spike analysis.* A matrix spike sample (method of additions analysis) was run with every batch of 20 samples. Results from the method of additions analysis provide information on the extent of any signal suppression or enhancement due to the matrix. When necessary (spike results outside 85-115% limit), samples were analyzed by methods of additions.

(iii) *Duplicate sample analysis.* To estimate precision of the analyses, a duplicate field sample was analyzed with each batch of 20 samples.

(iv) *Standard reference material analysis.* A common method used in evaluating the accuracy of environmental data is to analyze standard reference materials, samples for which consensus or "accepted" analyte concentrations exist. The marine sediment (MESS3) from the NRC of Canada and a river bottom sediment from the NIST (#2704, Buffalo River Sediment) were analyzed with every batch of sediment samples.

(vi) *Procedural blank analysis.* A procedural blank was processed and analyzed with each batch of samples to monitor potential contamination resulting from laboratory reagents, glassware, and processing procedures.

Table 3.1. Data quality objectives for the proposed study.

Element or Sample Type Criteria	Minimum Frequency	Data Quality Objective/Acceptance
Initial Calibration	Prior to every batch of samples Standard Curve	3-5 point curve depending on the element and a blank Correlation coefficient r ≥ 0.999 for all analytes
Continuing Calibration	Must end every analytical sequence or after every 8-10 samples	% RSD ≤15% for all analytes
Certified and Standard Reference Materials	Two per batch of 20 samples	Values must be within 20% of accepted values for >85% of the certified analytes
Method Blank	Two per batch of 20 samples	No more than 2 analytes to exceed 5x MDL
Matrix Spike and Spike Method Blank	Two per batch of 20 samples	80-120%
Lab Duplicate	Two per batch of 20 samples	RSD <25% for 65% of analytes

Results for accuracy, precision, matrix spikes, field replicates and method detection limits are provided in Appendix B.

Electronic balances used for weighing samples and reagents were calibrated prior to each use with their internal electronic calibration and then verified with certified standard weights (NIST-traceable). All pipets (electronic or manual) were calibrated prior to use. Each of the spectrometers used for metal analysis was initially standardized with a three- to five-point calibration; a linear correlation coefficient of $r \geq 0.999$ was required before experimental samples could be analyzed. Analysis of complete three- to six-point calibrations or single standard checks occurred after every eight samples until all analyses were complete. The RSD between complete calibration and standard checks was required to be <10% or recalibration and reanalysis of the previous samples was performed.

All weighing-related manipulation of the filters used for suspended solids quantification took place under cleanroom conditions, including controlled temperature and relative humidity. Each filter was weighed twice in random order, with a minimum of 5% of the filters being weighed in triplicate. Static effects on filter weight were controlled by the placement of two ^{210}Po anti-static devices near the weighing-pan within the balance. The standard deviation in the weights for each filter had to be <2 µg for the value to be accepted.

3.4 Results and Discussion

3.4.1 Muck Survey

Water depths and thicknesses of muck layers were determined at 199 locations in Turkey Creek, extending from the mouth at the IRL to the Florida East Coast (FEC) railroad bridge (Figures 3.2 and 3.3). An additional 54 measurements were made either in the adjacent IRL or as replicates in Turkey Creek. The average water depth in the creek was 1.8 ± 0.9 m with a range of 0.4-4.4 m (Figure 3.2 and Table 3.2). Water depths in the creek were <1.5 m at ~50% of the stations, 1.5-3 m at ~40% of the stations and >3 m at only ~10% of the stations (Table 3.2).

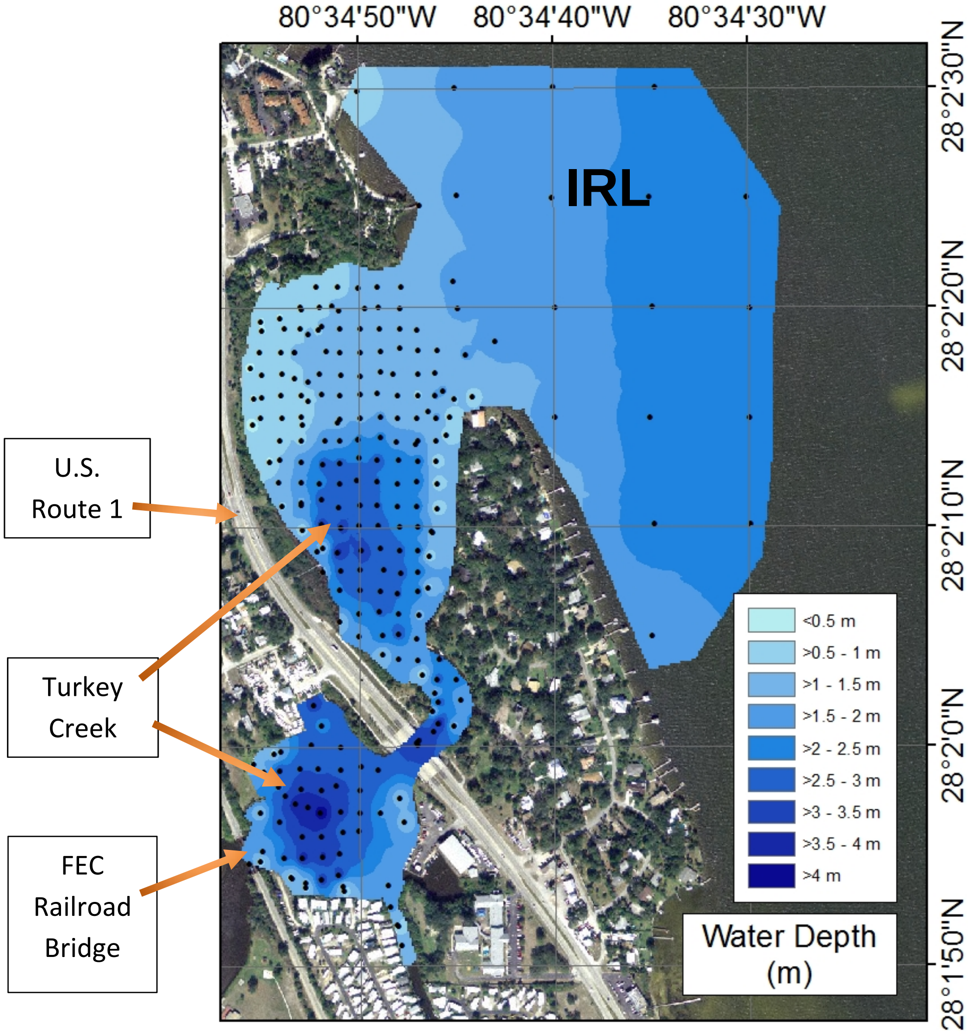

Figure 3.2. Contour map of water depth in Turkey Creek from the adjacent Indian River Lagoon (IRL) to the Florida East Coast (FEC) railroad bridge. Dots show probing locations.

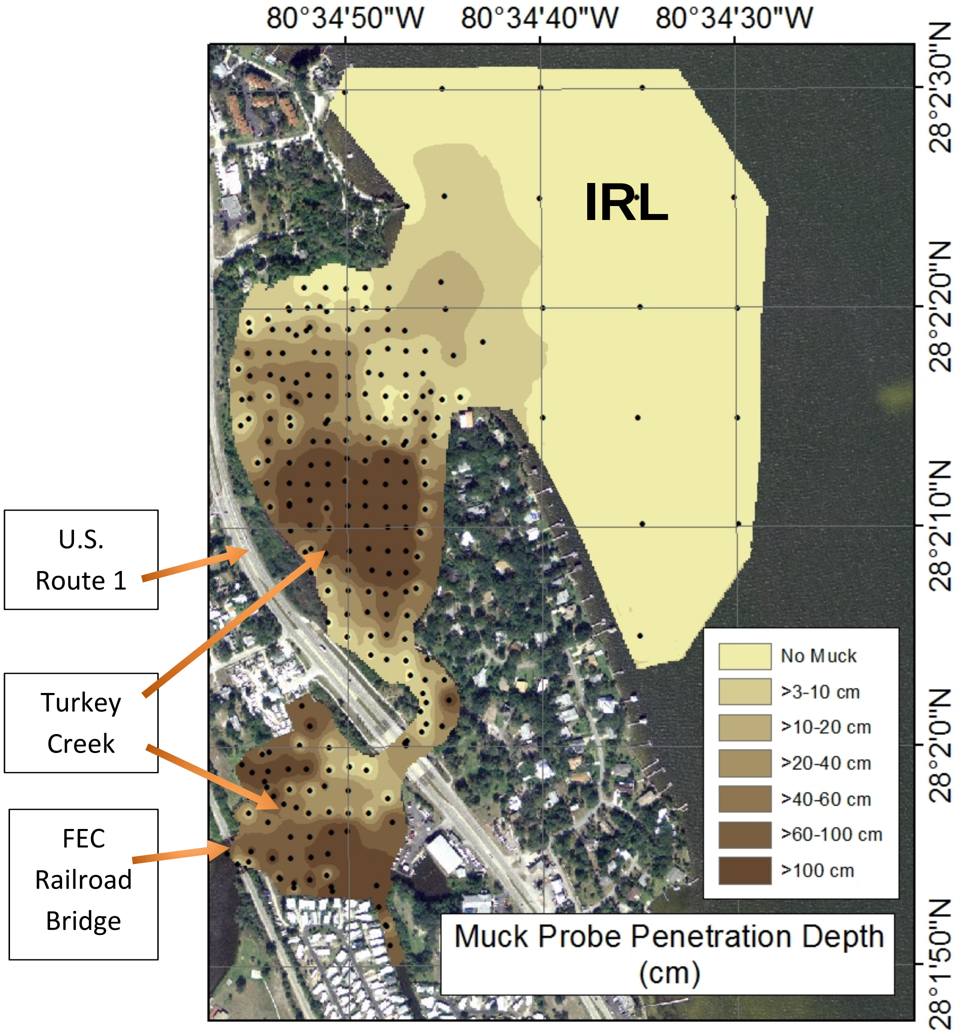

Figure 3.3. Contour map of muck thickness in Turkey Creek from the adjacent Indian River Lagoon (IRL) to the Florida East Coast (FEC) railroad bridge. Dots show probing locations.

Results from our muck survey showed that little or no muck was present in the adjacent IRL near the mouth of Turkey Creek (Figure 3.3). This observation, coupled with the relatively shallow IRL, suggests that muck carried to the mouth of the creek and into the IRL is readily advected away from the immediate area. Likewise, little or no muck was found in shallow water (depth, 0.4-1 m) at the northern lobe of Palm Bay in Turkey Creek, just west of the confluence of the creek with the IRL (Figure 3.3). In contrast, muck layers as thick as 3 m were found in 2- to 4-m deep water in the southern portion of the creek (Figure 3.2 and 3.3). Muck was absent from about ~26% of the stations in Turkey Creek (Table 3.2). Muck thicknesses of ~1-3.1 m were found at ~23% of the creek stations; the remaining ~51% of the creek stations contained <1 m of muck (Figure 3.3 and Table 3.2).

Table 3.2. Water depths (n = 199) and muck thicknesses (n = 199) for Turkey Creek.

Water Depth (m)	# of Locations	Muck Thickness (m)	# of Locations
0.4 – 1.0	42	0	52
>1.0 - 1.5	55	>0 – 0.25	37
>1.5 - 2.0	19	>0.25 – 0.50	28
>2.0 – 2.5	26	>0.50 – 0.75	23
>2.5 – 3.0	39	>0.75 – 1.0	14
>3.0 – 3.5	12	>1.0 – 1.5	15
>3.5 – 4.4	6	>1.5 – 2.0	8
		>2.0 – 2.5	9
		>2.5 – 3.1	13

Muck thicknesses >1.5 m were typically (37 of 44 stations) found at water depths of 1.5-3.1 m (Figure 3.4A). Data for the 52 locations with no detectable muck plot along a straight line labelled "+0 m" on a plot of water depth versus muck + water depth (Figure 3.4B). The lines at +1 m, +2 m and +3 m (Figure 3.4B) show the increases in water depths that would be observed if all the muck was removed from each site in the creek. This increase in water depth, as much as 3 m, could increase the residence time of deeper bottom water in the creek. These new basins also may become traps for incoming fine-grained, organic-rich sediments. If so, they may become seasonally anoxic reservoirs for dissolved ammonium and hydrogen sulfide as discussed below in

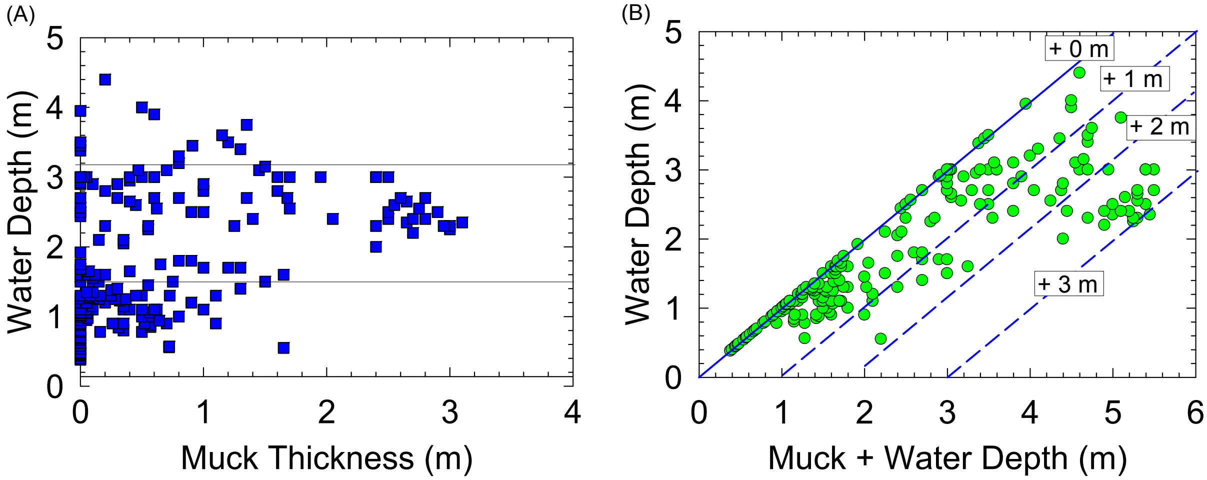

Figure 3.4. Water depth in Turkey Creek versus (A) thickness of the muck layer, and (B) muck thickness plus water depth. Lines on (B) show where no muck is found (+ 0 m) and where muck + water depth is +1, +2 and +3 m relative to water depth.

the water quality section (3.4.3). One possible way to limit the number of traps for incoming fine-grained, organic-rich sediment is to fill them with sand (written communication, Virginia Barker). With this approach, some traps would still need to be retained to capture future inputs of muck components from upstream or undredged nearshore areas in the creek. Deeper traps would decrease the exposed surface area relative to the volume of muck.

The muck thickness data were used to estimate the total volume of wet muck in Turkey Creek from the mouth to the FEC railroad bridge. The volumes of muck in gridded areas were added to obtain a sum of 111,000 m^3 (145,000 yd^3) of wet muck (Appendix A shows map of gridded cells and supporting data). Contractors for Brevard County obtained a total muck volume of 176,000 m^3 (230,000 yd^3) using a metal rod that in many cases penetrated deeper than our PVC pipe by 15-30 cm (6-12 inches), thereby yielding a larger muck volume. If we increase our volume of muck by adding 30 cm to our volume calculation (either to approximate the deeper penetration of the metal rod or planned dredging to ~30 cm into the underlying sand layer), we obtain a volume of 148,000 m^3 (194,000 yd^3). Both methods (PVC pipe and metal rod) have some limitations, yet the estimated overall agreement between the two methods is within ~20%, including a correction for the metal rod versus PVC pipe (~160,000 ± 20,000 m^3 or 210,000 ± 25,000 yd^3).

3.4.2 Muck Composition and Fluxes of Nitrogen and Phosphorus from Sediments

Nine representative samples of surface sediment, including both muck and sand (Figure 3.5), were collected during the muck survey and analyzed for water content, Al, Fe, Si, TOC, total N, total P, $CaCO_3$ and grain size. Sediment % water by volume ranged from ~45% in sandy sediments (station A) to >90% in muck (stations F-H, Figure 3.5 and Table 3.3). Muck was previously defined as having >75% water (by weight or ~90% water by volume, Trefry et al., 1987, 1990). Only the four southernmost stations (F-I) contained sediment with >75% water by weight (Table 3.3). The organic matter content of sediments from the study area (expressed as LOI at 550°C) ranged from 1.6% in sandy sediment (station A) to 21.7% in muck (station F, Figure 3.5 and Table 3.3). Muck was previously defined as containing >10% organic matter (Trefry et al., 1987). Again, only the four southernmost stations (F-I) fit the original muck definition.

Three of the four samples identified as muck based on % water and LOI also met the 1987 criteria with >75% silt + clay (Table 3.4 and Figure 3.6). In contrast, sediment at station I, located in a canal south of the harbor area, contained only 35.5% silt + clay (Table 3.4 and Figure 3.6). Over time and with increased sampling, a continuum of muck compositions is evolving. We will work to refine or expand our definition of muck as this project continues.

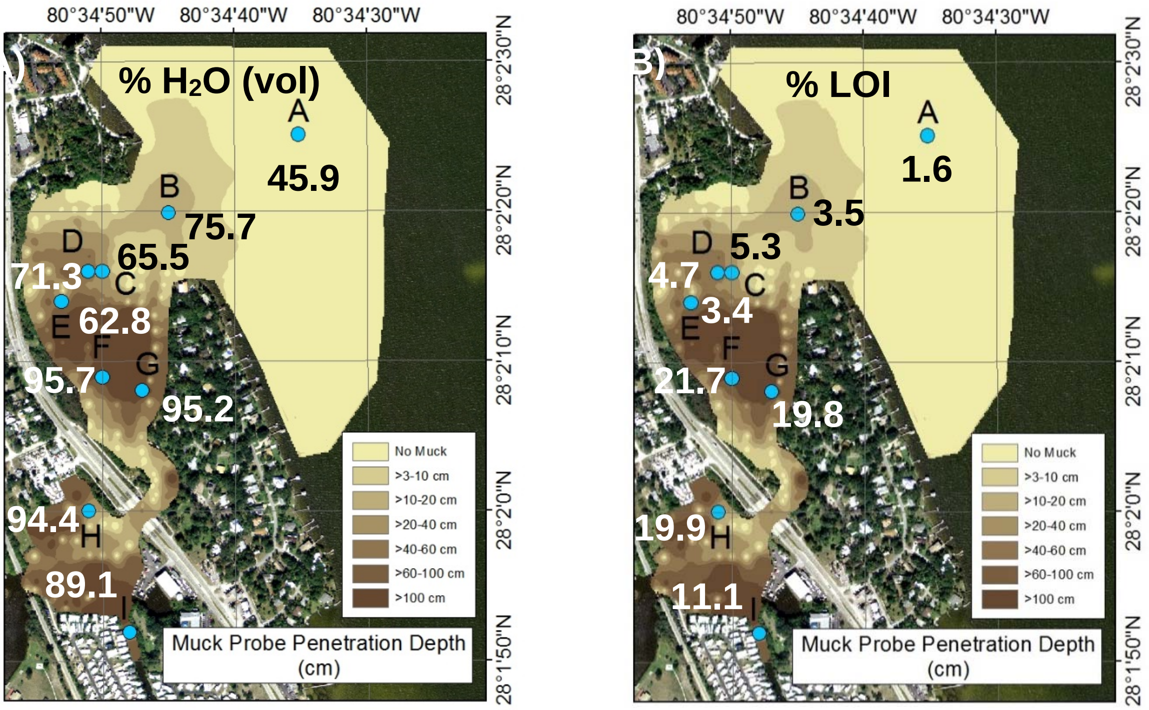

Figure 3.5. Contour maps for muck thickness in Turkey Creek and the adjacent Indian River Lagoon (IRL). Blue dots show where surface sediments were collected. Numbers on (A) show % water in sediments by volume and (B) % loss on ignition (LOI) at 550˚C for sediments.

Table 3.3. Concentrations of selected elements in surface sediments from Turkey Creek. Station locations shown on Figure 3.5. Shading identifies samples that fit the 1987 definition of muck.

Station	Al (%)	Fe (%)	Si (%)	TOC[b] (%)	LOI[c] (%)	$CaCO_3$ (%)	H_2O (wt. %)	H_2O (vol. %)	N (%)	P (%)
A	0.29	0.25	34.7	0.20	1.6	5.2	24.6	45.9	0.03	0.01
B	2.11	1.45	31.4	1.43	5.3	4.0	54.5	75.7	0.18	0.07
C#1[a]	0.86	0.75	36.5	0.87	3.5	2.5	42.2	65.5	0.12	0.03
C#2[a]	0.82	0.73	36.3	0.89	3.4	2.5	-	-	0.12	0.04
D	1.16	1.05	36.9	1.33	4.7	2.9	48.9	71.3	0.16	0.05
E	0.82	0.78	37.9	0.94	3.4	2.1	39.4	62.8	0.11	0.04
F	4.80	4.28	16.9	7.09	21.7	12.3	89.6	95.7	0.81	0.15
G	4.51	3.51	19.1	6.49	19.8	13.4	88.4	95.2	0.83	0.14
H	3.87	2.51	18.1	6.84	19.9	12.3	86.7	94.4	0.63	0.16
I	2.44	2.39	29.2	4.12	11.1	4.8	75.8	89.1	0.40	0.10

[a] Field replicates. [b] TOC = Total Organic Carbon. [c] LOI = Loss on Ignition at 550˚C.

Table 3.4. Grain size distribution and aluminum content for surface sediments from Turkey Creek and the adjacent Indian River Lagoon. Station locations on Figure 3.6. Shading identifies samples that fit the 1989 definition of muck.

Station	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Silt & Clay (%)	Al (%)
A	2.6	94.7	0.5	2.2	2.7	0.29
B	0.8	82.4	8.1	8.7	16.8	2.11
C	0	91.6	3.2	5.2	8.4	0.84
D	1.6	85.3	7.2	6.0	13.2	1.16
E#1[a]	0	89.4	4.9	5.6	10.5	0.82
E#2[a]	0.1	81.8	9.0	9.0	18.0	0.82
F	0	1.3	73.5	25.2	98.7	4.80
G	0	7.3	51.4	41.3	92.7	4.51
H	0	23.8	48.0	28.1	76.1	3.87
I	0	64.9	20.4	15.1	35.5	2.44

[a] Field replicate.

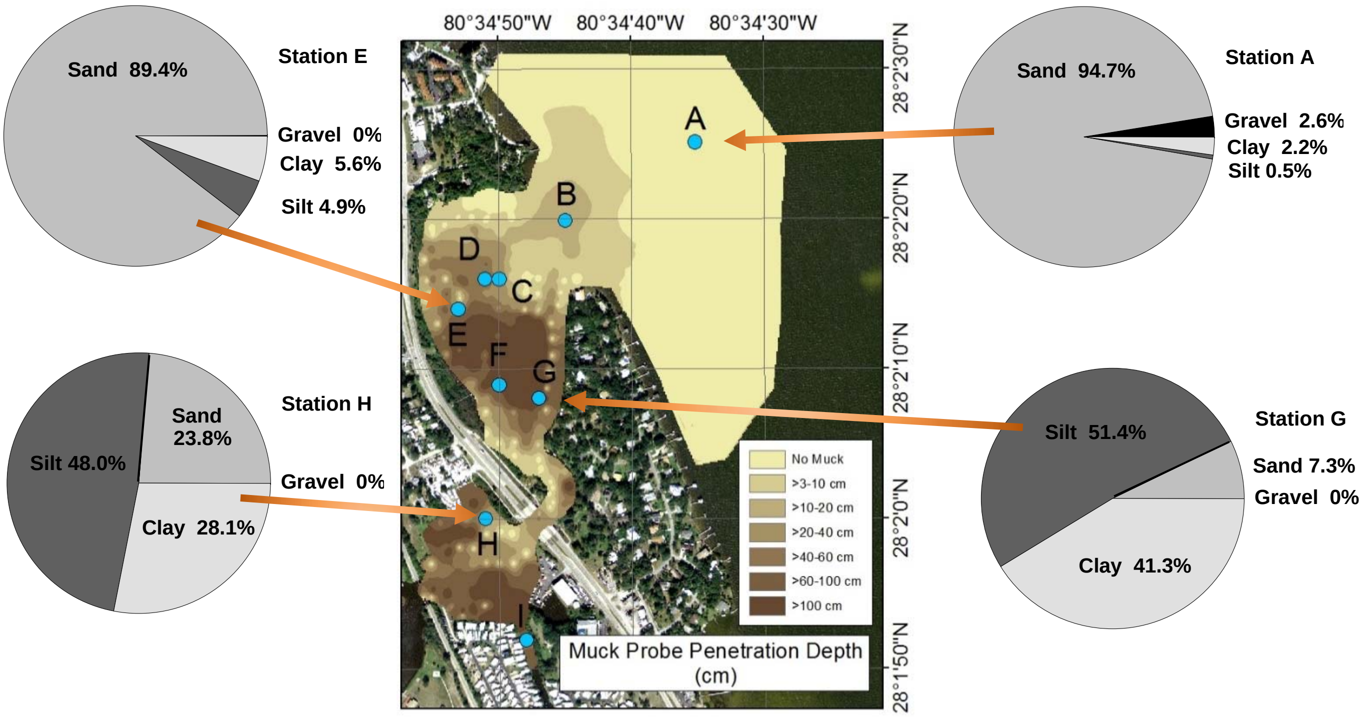

Figure 3.6. Contour map for muck thickness in Turkey Creek and the adjacent Indian River Lagoon. Blue dots show where surface sediments were collected. Pie graphs show grain size distribution at selected stations.

Values for LOI correlated very strongly (*r* >0.9) with concentrations of TOC (Figure 3.7A). The slope of the line for TOC versus LOI was 0.35; this slope means that the organic matter collected in Turkey Creek averages ~35% C. Data for both LOI and TOC were generated for this study. Concentrations of total organic carbon correlated very strongly with total P and total N (Figure 3.7B, C). The four muck samples had an average C/P molar ratio of 115, close to the Redfield ratio of 106 (published C/N/P atomic [molar] ratio of 106/16/1 in phytoplankton and in deep seawater by Redfield, 1934, Figure 3.7B). The C/P ratio for the non-muck samples was less reliable because

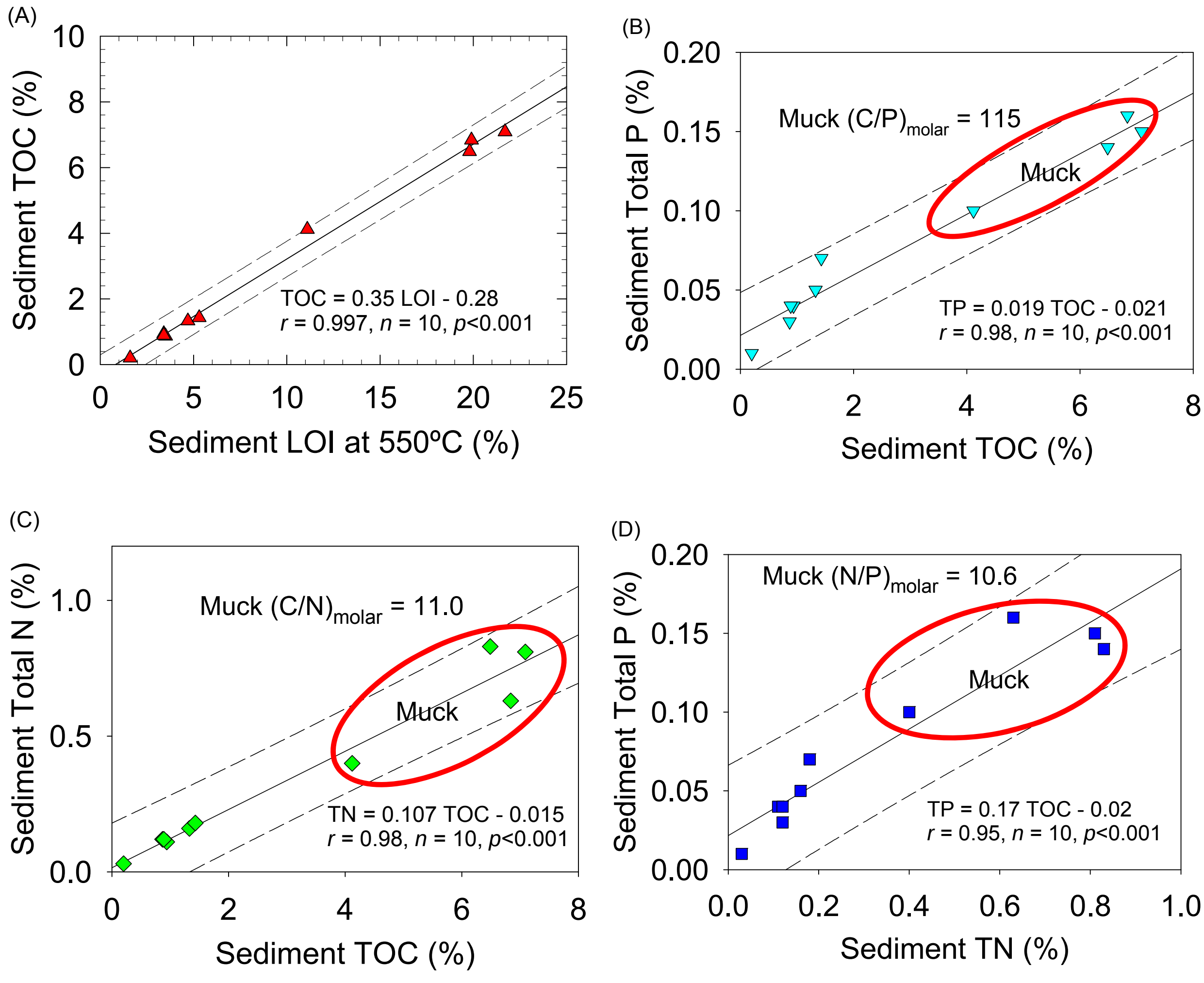

Figure 3.7. (A) Sediment total organic carbon (TOC) versus sediment Loss on Ignition (LOI) at 550°C, (B) sediment total phosphorus versus sediment TOC, (C) sediment total nitrogen versus TOC and (D) sediment total phosphorus versus total nitrogen. Muck samples plot within the ovals on (B), (C) and (D). The molar ratio for the four muck samples is listed next to each oval. Solid lines and equations on each graph are from linear regression analysis, dashed lines show 95% prediction intervals, *r* is the correlation coefficient and *p* is the *p* statistic.

of the very low amounts of organic matter present in the sediment. In contrast, the average molar C/N ratio of 11.0 for four muck samples (Figure 3.7C) was ~67% greater than the Redfield ratio of 6.6, suggesting that the muck sediment was depleted in N, possibly due to releases of dissolved ammonium from the muck to the water column. The average molar ratio of 10.6 for N/P was ~35% lower than 16 predicted by the Redfield ratio. This result also supports N depletion in the sediments and suggests that losses of P are relatively small and P fluxes from the sediments seem to have a lower impact on sediment P concentrations. The TOC and total N values are for organic C and organic N in sediments whereas the total P values include both organic and inorganic P where the inorganic P may be associated with weathered phosphorite rock. During 2016, we plan to analyze some samples for both organic and inorganic P and then reevaluate the C/P and N/P ratios.

Concentrations of iron in sediments from the study area also correlated strongly with Al values (Figure 3.8A); however, the slope of the line (0.78) was higher than found in typical continental crust (0.54, Wedepohl, 1995), likely the result of enhanced iron from runoff of Fe from irrigation water and/or the presence of iron- and magnesium-rich clay minerals such as vermiculite in sod from the Turkey Creek basin. Concentrations of total Si in the sediments were inversely correlated with aluminum values (Figure 3.8B). This observation is due to the presence of quartz (SiO_2) sand in the sample. Indeed, the maximum concentration of Al (~5%) was found for a sample with ~17% silicon (Figure 3.8B), suggesting that the Si/Al atom ratio was ~3:1. All of this geochemical information can be used to help us identify sediment sources and look at variations and changes in sediment type following dredging.

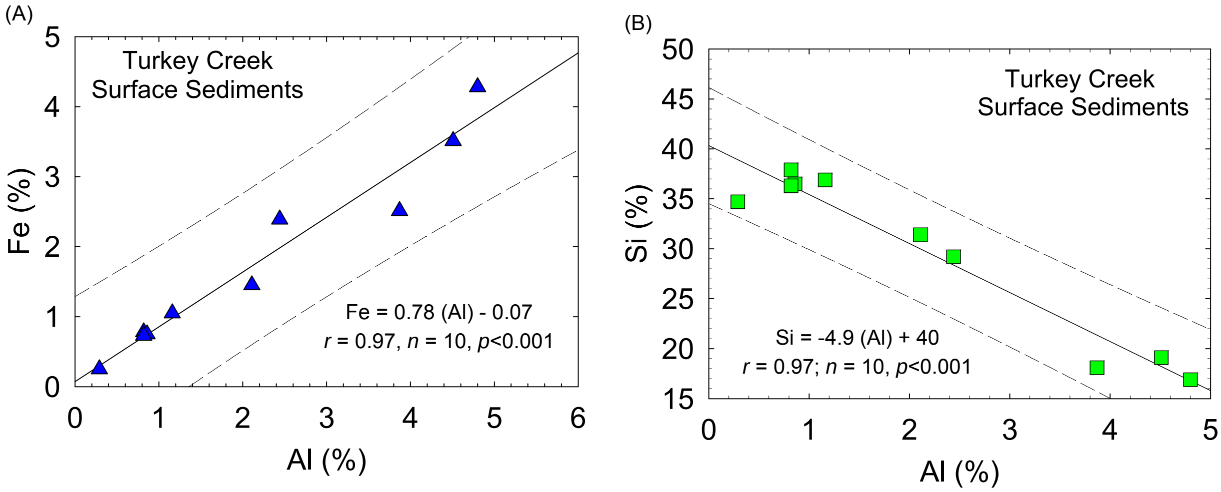

Figure 3.8. (A) Sediment total iron (Fe) versus total aluminum (Al) and (B) sediment total silicon (Si) versus Al. Solid lines and equations on each graph are from linear regression analysis, dashed lines show 95% prediction intervals, *r* is the correlation coefficient and *p* is the *p* statistic.

Ongoing efforts in our Algal Blooms study (funded by St. Johns River Water Management District) seek to better address losses of N with depth (time) in sediments (e.g., Trefry et al., 2014, 2015). As a complement this project, we have collected several short (30-40 cm) sediment cores from Turkey Creek for chemical analysis to investigate changes in water content, TOC, total nitrogen and other parameters below the sediment-water interface. We continue to collect and analyze cores from Turkey Creek. Results for one core from station TC4 are presented here for perspective. Water content was >90% (by wt.) in the top 6 cm and decreased to ~83% at 32-38 cm, possibly due to upward advection of water caused by sediment compaction. The complete core contained muck as defined by >75% water by weight. Concentrations of Al were relatively uniform at 4.7 ± 0.4% and concentrations of TOC averaged 6.9 ± 0.7% with one C-rich sample (TOC = 9.24%) at 2-4 cm. Other than the C-rich layer, no discernible downcore trend was observed for TOC. Concentrations of total N were very uniform in the core with an average of 0.77 ± 0.02%; however, a decrease in the N/Al ratio was observed in the top 10 cm of the core, possibly due to diagenetic loss of N. Ongoing efforts in our Algal Blooms study seek to better address loss of N with depth (time) in sediments (e.g., Trefry et al., 2014, 2015).

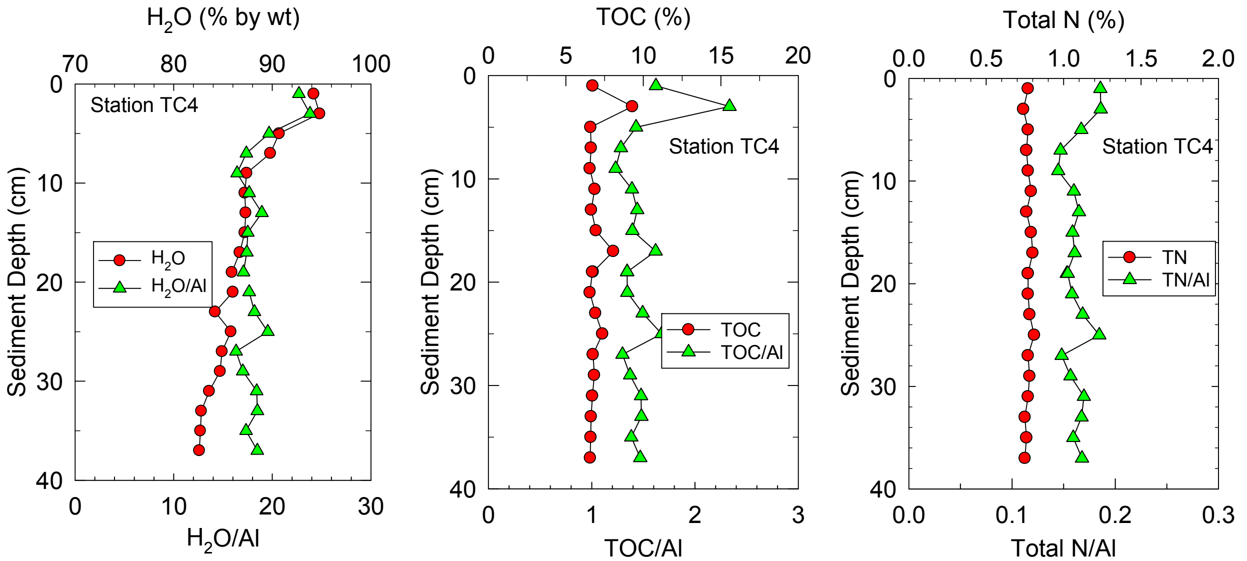

Figure 3.9. Vertical profiles for (A) water content, (B) total organic carbon (TOC) and (C) total nitrogen plus ratios of the three components to aluminum (Al) for a sediment core from station TC4 (location in Figure 3.1).

Prompted by high ammonium values in bottom water at station TC5 (see Section 3.4.3.2 below), we added another component to this study by collecting sediments from station TC5 (location on Figure 3.1B) on June 6, 2015 to determine fluxes of nitrogen and phosphorus from sediments to the overlying water column. We carried out the flux measurements as described in Trefry et al. (2014). Interstitial water was collected from duplicate sediment cores using whole-core squeezers (Trefry et al., 2014). Ammonium concentrations in the interstitial water peaked at near 1,000 μM (14 mg N/L), almost 200 times greater than in the bottom water. The calculated flux of dissolved ammonium from sediments at station TC5 (~16 nmol/cm^2/hr) is equivalent to ~20 metric tons N/km^2/yr. This flux is similar to previously obtained values for sediments from Eau Gallie Harbor and the IRL near Rockledge where the muck composition is similar to that found in Turkey Creek; the average N flux for the North IRL is 10 tons N/km^2/yr (Trefry et al., 2014, 2015). The flux for phosphate at station TC5 was 1.5 nmol/cm^2/hr or ~4 metric tons/km^2/yr, more than double the average of 1.5 tons P/km^2/yr for the North IRL. The vertical profile for dissolved sulfide (Figure 3.10B) shows that dissolved sulfide concentrations peaked at ~3,000 μM (~96 mg S/L). Sulfide also is diffusing out from sediments to the overlying water in Turkey Creek. We have added a significant sediment flux program to our proposed 2016 Turkey Creek effort and will be carrying out flux studies at five sites in Turkey Creek before and after dredging.

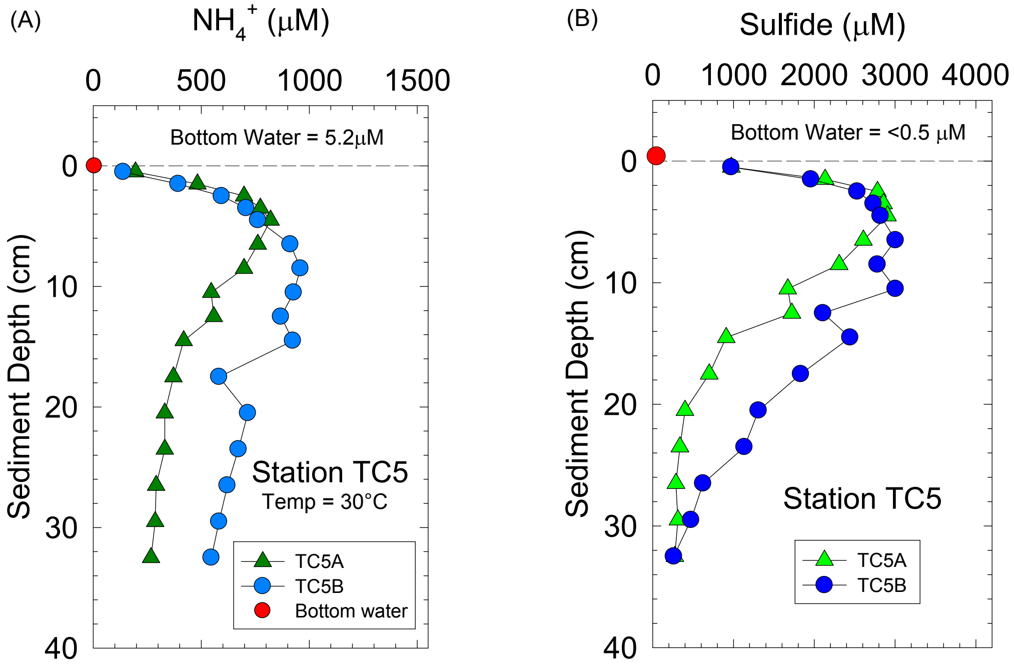

Figure 3.10. Vertical profiles for (A) dissolved ammonium and (B) dissolved sulfide in sediment interstitial water at station TC5 on May 5, 2015 (location shown on Figure 3.1).

3.4.3 Water Quality Surveys

3.4.3.1 Overview

Monthly water quality surveys were carried out at five locations in Turkey Creek and the adjacent IRL (Figure 3.11) from April through December, 2015. Stations TC1, TC2 and TC3 were located at water depths of 1.1-2.2 m; stations TC4 and TC5 were situated in small depressions (water depths >3m) to the east (TC4) and west (TC5) of US1 (Figure 3.11). The complete data set is presented in Appendix C. Both molar and mass/volume units are used for water quality parameters in tables, figures and appendices. Data in the text are presented in molar units with the occasional addition of mass/volume units in parentheses. Salinity values are dimensionless because the Practical Salinity Scale is based on a ratio, not a concentration (e.g., Millero, 2006).

The following brief overview of our complete data set for water quality precedes a more detailed discussion of parameters that will be used to assess post-dredging conditions (Table 3.5). Over the nine-month period, the freshest water was at the surface in Turkey Creek during July (S = 0.64 at

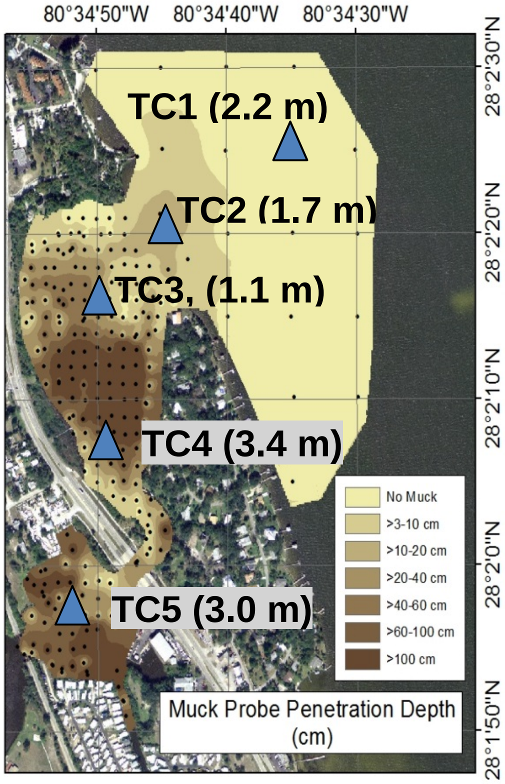

Figure 3.11. Locations of water quality stations TC1-TC5 with average water depths at each station and contour lines for muck thicknesses from our February 2015 survey.

Table 3.5. Summary of 2015 data from (A) continuous profiles obtained using a YSI Sonde 6600 and (B) 135 discrete water samples (15/month). The text in parentheses for maximum (max) and minimum (min) values gives station identification, water depth and month sampled.

(A) 2015	Salinity	Temp (˚C)	DO (% sat)	DO (mg/L)	pH
Mean	19.4	27.6	59	4.8	7.75
SD[a]	5.6	3.1	26	6.3	0.35
Max	28.3 (TC1, 1.8 m Jul)	32.7 (TC4, 0.5 m Aug)	100 (TC1, May, Sep)	7.7 (TC1, 2m Dec)	8.33 (TC1, 2 m Dec)
Min	0.64 (TC5, 0.5 m Jul)	22.6 (TC5, 2.8 m Dec)	<3 (TC5, 2.5 m Aug)	<0.2 (TC5, 2.5 m Aug)	7.01 (TC4, 3.2 m Apr)
Median	18.8	28.1	64	4.6	7.80

(B) 2015	NH_4^+ (μM)	NH_4^+ (mg N/L)	Nitrate Nitrite (μM)	Nitrate Nitrite (mgN/L)	Total Dis. N (μM)	Total Dis. N (mgN/L)	PO_4^{3-} (μM)	PO_4^{3-} (mgP/L)	Total P (μM)	Total P (mgP/L)
Mean	7.8	0.109	0.9	0.0126	54.6	0.76	1.27	0.0393	2.00	0.062
SD[a]	10.5	0.147	1.3	0.0182	21.5	0.30	1.74	0.0539	1.69	0.052
Max	64.7	0.906	7.9	0.1110	168	2.35	9.97	0.309	9.8	0.304
	(TC4, 3 m Sep)		(TC5, 2.8 m Nov)		(TC4, 3 m Aug)		(TC5, 2.5 m Aug)		(TC5, 2.5 m Aug)	
Min	2.1	0.029	0.1	0.0014	21.4	0.30	0.03	0.001	0.54	0.017
	(TC4, 0.5 m Oct)		(TC4, 3 m Aug)		(TC4, 1 m Apr)		(TC1, 0.5 m Dec)		(TC1, 1.5 m Jun)	
Median	4.6	0.064	0.5	0.0070	47.6	0.67	0.8	0.0248	1.5	0.046

[a]SD = standard deviation.

station TC5). The highest salinity water was in the IRL during July (S = 28.3 at station TC1), just prior to a large increase in runoff to the IRL from Turkey Creek. Water temperatures ranged from 22.6-32.7˚C with highest temperatures in August and lowest temperatures in December (Table 3.5). Temperatures in the open IRL (station TC1) averaged ~1.6 ± 0.7˚C lower than in the creek during all months except July-September when water temperatures in the lagoon averaged ~0.87 ± 0.06˚C lower than in the creeks (Appendix C). Highest concentrations and saturation values for dissolved oxygen were found in the IRL (station TC1) throughout the year (Table 3.5, Appendix C). Bottom water in both small depressions (stations TC4 and TC5) became anoxic during July-August with persistence into September (Table 3.5, Appendix C). Overall, average concentrations of ammonium were ~9 times greater than nitrate + nitrite, yet these three forms of dissolved inorganic N accounted for an average of only ~15% of the total dissolved N (Table 3.5). The dominant form of dissolved nitrogen was dissolved organic nitrogen (DON) as previously reported for Turkey Creek (e.g., Dierberg, 1991) and the IRL (e.g., Lapointe et al., 2015). In contrast, on average, phosphate made up ~60% of the total dissolved P. Highest concentrations of ammonium, total dissolved N, phosphate, and total dissolved P were found in the bottom water at stations TC4 and TC5 during August-September (Table 3.5). These high values are linked to releases from muck sediments as discussed below. The highest concentration of nitrate + nitrite also was found in the deeper depression at station TC5 during November, most likely from nitrification of ammonia that was released from the sediments and oxidized when oxygen levels in this basin increased during November and December (Table 3.5, Appendix C). Average and highest values for phosphate were greater than those for nitrate + nitrite, but not ammonium (Table 3.5).

3.4.3.2 Water Quality in the IRL (Station TC1) versus Turkey Creek (Station TC5): Dissolved Components

Dredging in Turkey Creek will likely have some effect on water quality in both the creek and adjacent lagoon. Our nine-month study of five water quality stations covers several different areas including (1) the more restricted area between the FEC railroad bridge and U.S. Route 1 in Turkey Creek (station TC5), (2) the bay area of Turkey Creek east of U.S. Route 1 (stations TC2-4) and (3) the adjacent IRL (station TC1). To show the pre-dredging water quality across the area, we will compare water quality for station TC1 in the IRL with station TC5 between US1 and the FEC railroad bridge. These two stations represent the IRL and Turkey Creek water masses that mix across the area to be dredged.

Salinities in bottom water (1-2.5 m) at station TC1 ranged from ~16 (Sep-Nov) to ~28 in July (Figure 3.12). In contrast, at station TC5, bottom water (1.5-3.2 m) salinities were in narrow ranges of ~17-19 from July-December and ~23-25 for April-June (Figure 3.13). Surface water at station TC1 ranged from 10-26 with the higher salinities from April-July before the onset of heavy rainfall during September-October (Figure 3.12). In contrast, surface water salinities at station TC5 ranged from 0.6-4 for eight of the nine months (Figure 3.13). These expected salinity differences emphasize the distinction between the western and eastern reaches of the study area. Temperatures at station TC1 were within ≤2˚C of those at station TC5 during all sampling periods with highest temperatures at both stations in August (32-33˚C) and lowest temperatures (22-23˚C) in December (Figures 3.12 and 3.13). Temperature does not greatly differentiate the water masses across the study area.

Oxygen saturation was consistently higher at station TC1 than TC5 (Figures 3.12 and 3.13). For example, the lowest degree of oxygen saturation at station TC1 was 50-60% during July-September whereas bottom water oxygen saturation at station TC5 was <50% for every month except December with 80% saturation (Figure 3.13). Furthermore, water at station TC5 ranged from nearly anoxic to only ~20% saturation during April and from August to October (Figure 3.13). The observed differences in oxygen levels at the two stations corresponded with large differences in concentrations of inorganic nutrients as described below.

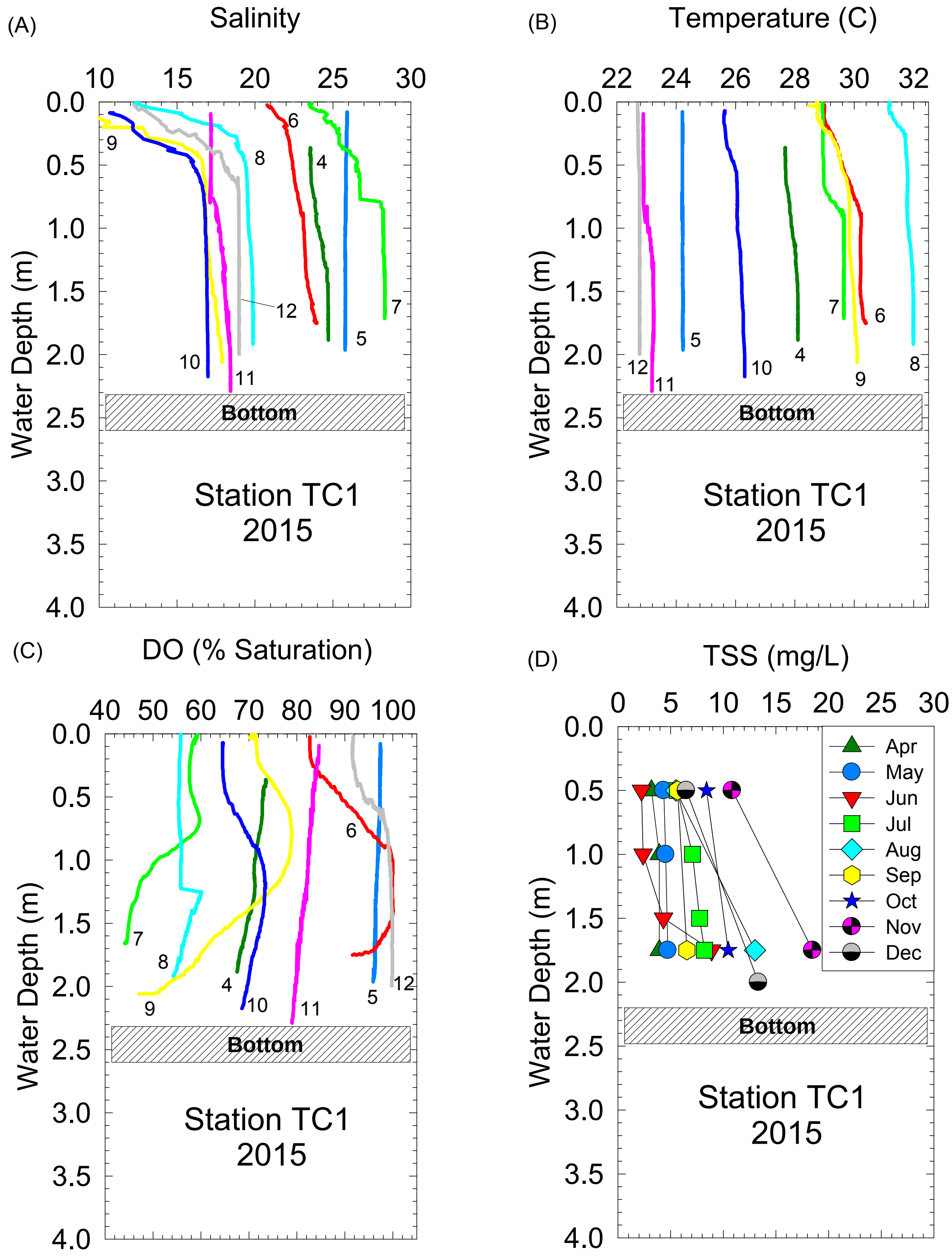

Figure 3.12. Vertical profiles for (A) salinity, (B) temperature, (C) % oxygen saturation and (D) total suspended solids (TSS) for station TC1 in Turkey Creek for monthly surveys from April- December 2015. Numbers on A, B and C refer to the number of month when profile was obtained.

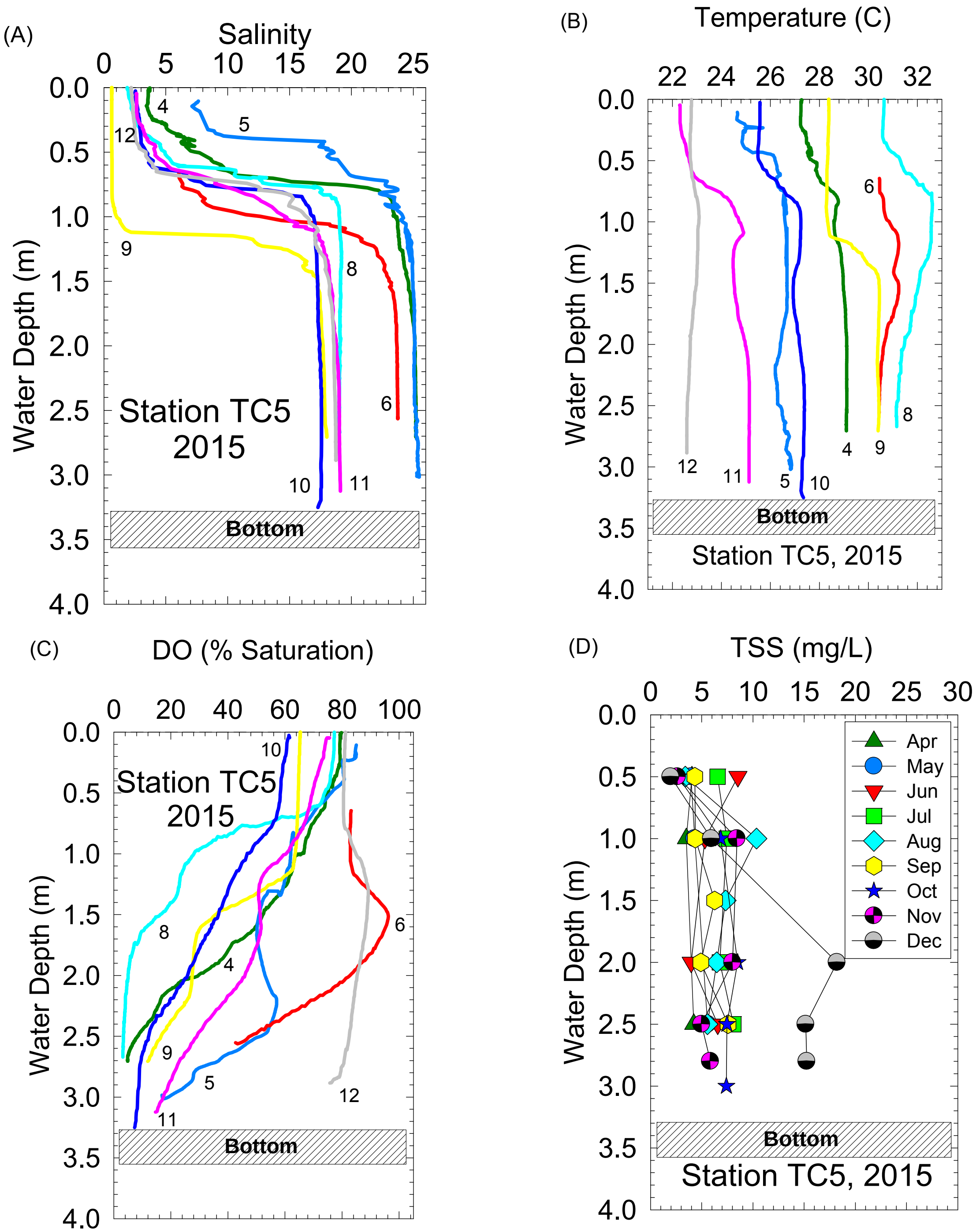

Figure 3.13. Vertical profiles for (A) salinity, (B) temperature, (C) % oxygen saturation and (D) total suspended solids (TSS) for station TC5 in Turkey Creek for monthly surveys from April-December 2015. Numbers on A, B and C refer to the number of month when profile was obtained.

Concentrations of TSS at station TC1 were <5 mg/L during April-June with a peak value of 18.5 mg/L in bottom water during a windy period in November (Figure 3.12). Values for TSS at station TC5 were in the range of ~2-10 mg/L as at station TC1 with the exception of values of 13-18 mg/L in bottom water at station TC5 during a period of swift currents in December (Figure 3.13).

Concentrations of dissolved ammonium at station TC1 were 6- to 30-fold greater than concentrations of nitrate + nitrite during all months except November when ammonium enrichment was only 1.3- to 3.3-fold greater than nitrate + nitrite (Figure 3.14). Vertical profiles for ammonium and nitrate + nitrite at station TC1 were relatively uniform during each sampling period due to active mixing in these 2-m deep lagoon waters (Figure 3.14). Trends for ammonium and nitrate + nitrite were greatly different at station TC5 (Figure 3.15). In the upper 1 m at station TC5, concentrations of ammonium were <10 µM (<0.14 mg N/L) as found throughout the water column at station TC1 (Figures 3.14 and 3.15). In contrast, concentrations of ammonium in the bottom meter of water at station TC5 were very high at 20-50 µM during August, September and December (Figure 3.15). These elevated ammonium concentrations in bottom water resulted from releases of nitrogen (99% as ammonium) from the sediment interstitial water as discussed above (Section 3.4.2 and Figure 3.10A).

We used our flux data for station TC5 to help validate the statement that sediments are a key source of ammonium to the creek system. The previously noted ammonium flux during June of ~12 nmol/cm^2/hr (~15 tons N/km^2/yr) from sediments at station TC5 releases 288 nmol NH_4^+ in 24 hours to 0.1 L of water (1 cm^2 x 100 cm depth of bottom water = 100 cm^3 = 0.1 L) to yield a water column ammonium concentration of ~2.9 µM (0.288 nmol/0.1 L). Ammonium concentrations in the bottom meter of water at station TC5 were 12 µM in May and 50 µM in August (Figure 3.15). It would take only ~4 days to add enough ammonium to reach the May value of 12 µM and ~17 days to yield a bottom water ammonium value of 50 µM obtained in August. Bottom water at station TC5 seems quite stagnant over the summer when concentrations of both ammonium and hydrogen sulfide became quite high. This calculation confirms the importance of muck as an important source of dissolved N to Turkey Creek and the IRL. Our ongoing work on the Algal Bloom Investigation and plans for more flux and water quality measurements in Turkey Creek should continue to improve the link between muck and excessive productivity in the IRL.

Concentrations of dissolved nitrate + nitrite were high in the surface water at station TC5 during September, October, November and December (Figure 3.15B) due to freshwater runoff from Turkey Creek (Figure 3.13A shows salinity). The highest concentrations of nitrate + nitrite during the 9 months (Table 3.7) were observed in bottom water at station TC5 during October and November (Figure 3.15B). This enrichment of nitrate + nitrite most likely resulted from partial nitrification of the large inventory of ammonium present during August and September (Figures

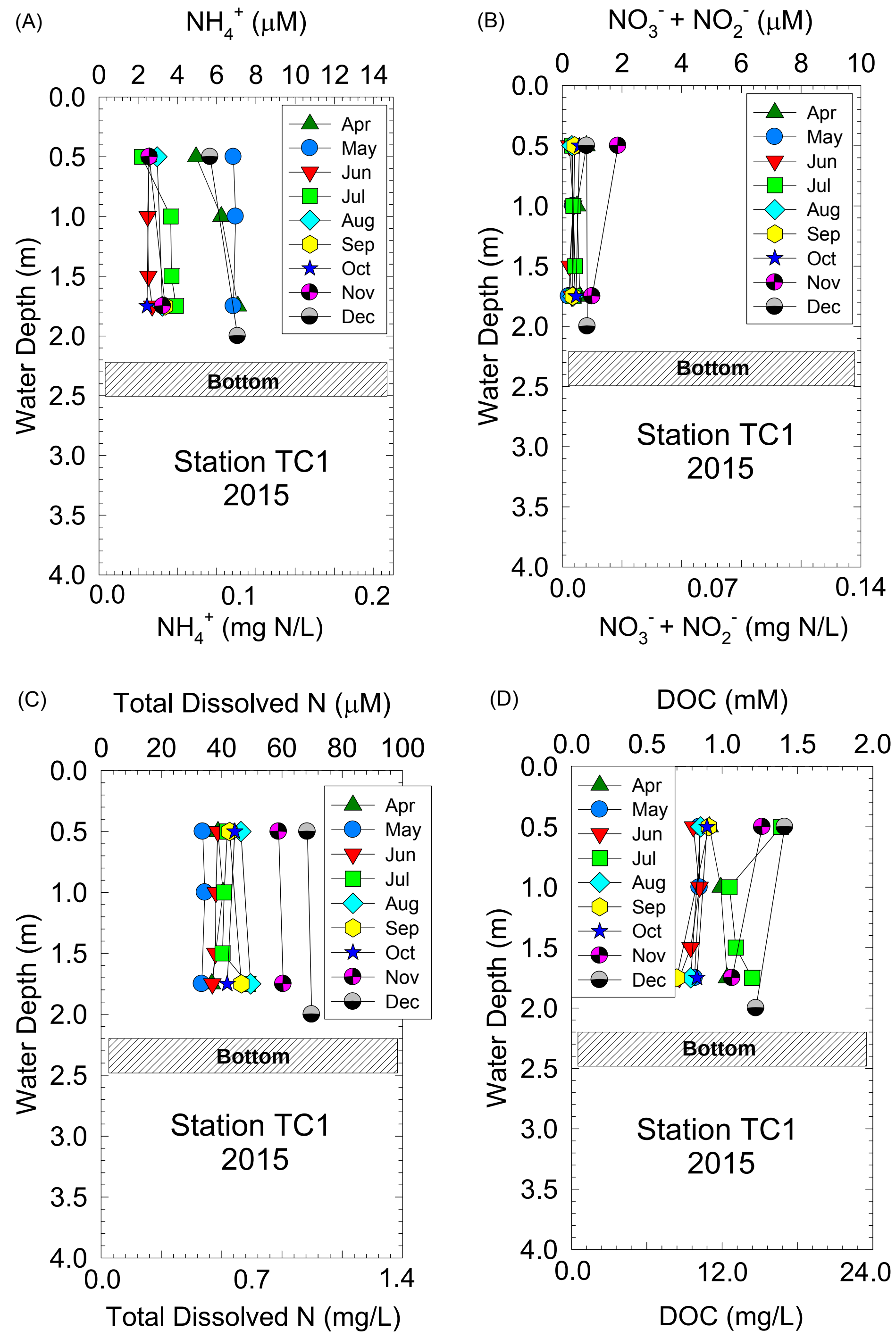

Figure 3.14. Vertical profiles for (A) dissolved ammonium, (B) dissolved nitrate + nitrite, (C) total dissolved nitrogen and (D) dissolved organic carbon (DOC) for station TC1 in Turkey Creek for nine monthly surveys from April-December 2015.

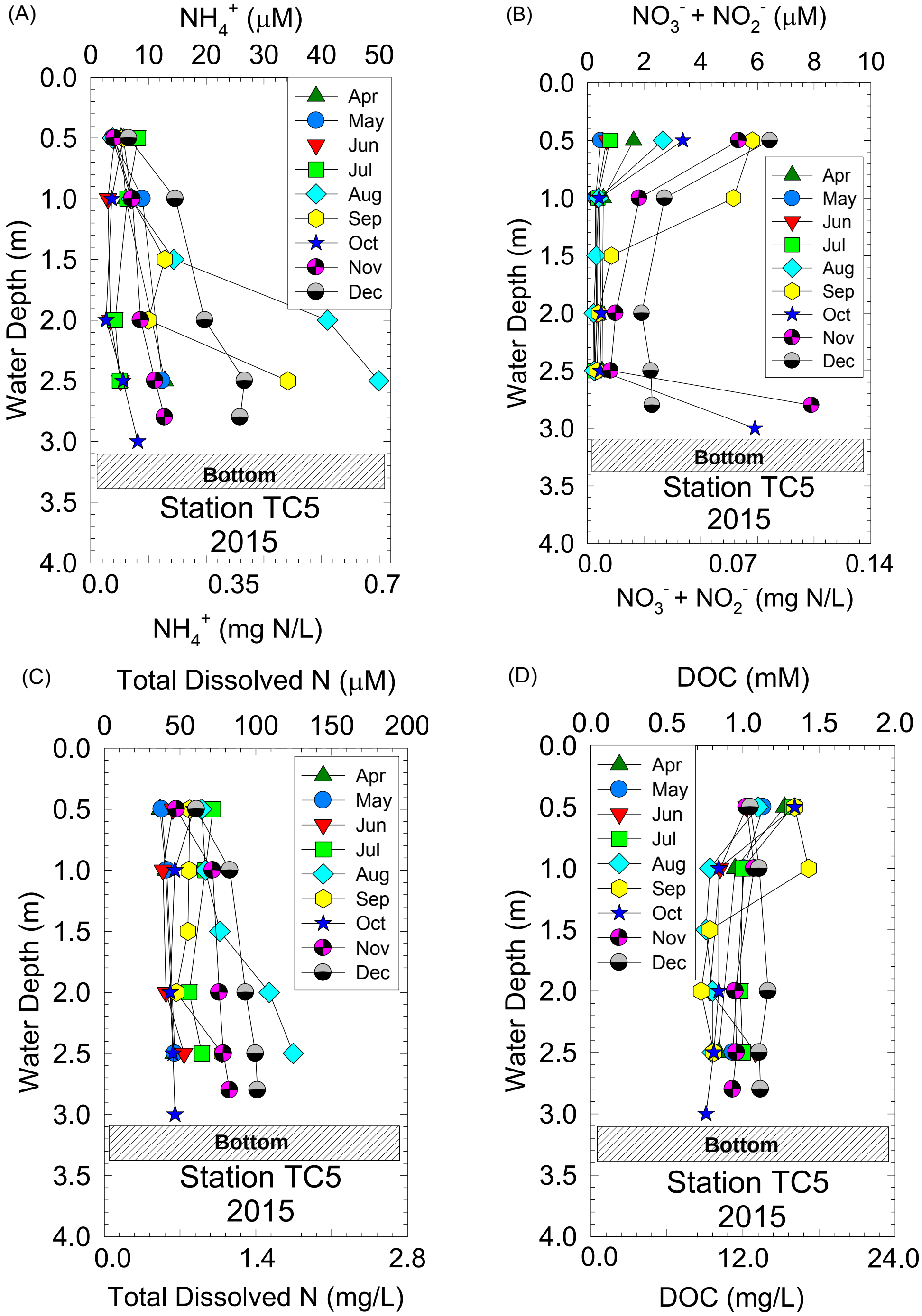

Figure 3.15. Vertical profiles for (A) dissolved ammonium, (B) dissolved nitrate + nitrite, (C) total dissolved nitrogen and (D) dissolved organic carbon (DOC) for station TC5 in Turkey Creek for nine monthly surveys from April-December 2015.

3.15A, B). Increased oxygen in the bottom water during late fall must have been sufficient to promote bacterial oxidization of ammonium to nitrite and nitrate (Figures 3.13C and 3.15B).

Vertical profiles for total dissolved nitrogen, which includes ammonium, nitrate + nitrite, and dissolved organic nitrogen (DON) are generally uniform within a given sampling period. Values for DON at station TC1 for April-October (40 ± 10 µM) increased to ~60-70 µM (~0.84-0.98 mg N/L) during November and December. At station TC5, concentrations of total dissolved nitrogen were 30-70 µM and uniform with depth during most months; a sharp increase in values in the bottom water during August and December was caused by increased ammonium concentrations.

Vertical profiles for phosphate at station TC1 show uniform distribution during each survey with a 20-fold range in values from 0.05 µM (~1.5 µg P/L) in December to 1.1 µM (~34 µg/ P/L) in October (Figure 3.16A). Vertical trends for total dissolved phosphorus were similar to those for phosphate at station TC1 with about a 3-fold range in values from a low of 0.56 µM in December to 1.0 µM in October (Figure 3.16B). Phosphate made up only ~10% of the total dissolved phosphorus in December and ~58% in October. Yet, concentrations of dissolved organic phosphorus (DOP = TDP – SRP) for December (0.5 µM) and October (0.8 µM) were more similar. The lowest concentration of phosphate at station TC5 (0.8 µM in July) was 16 times higher than the lowest value at station TC1. Likewise, the highest phosphate value at station TC5 (10 µM in October) was ~9 times higher than the highest concentration of phosphate at TC1 (1.1 µM). These differences are most likely related to release of phosphate from muck in Turkey Creek. Values for DOP at station TC5 (0.3 µM) averaged half the values for station TC1.

Most of the vertical and seasonal trends observed for nutrients at station TC1 also were observed at stations TC2 and TC3 (Appendix C). Likewise, vertical and seasonal trends discussed for station TC5 also were observed at station TC4 (Appendix C). Stratification was more pronounced at station TC5 than at station TC4 where a thicker surface layer of fresher, cooler water was observed. Concentrations of dissolved ammonium in bottom water at station TC5 were 20-50% lower than at station TC4; however, the layer of ammonium-rich bottom water at station TC5 was at least twice as thick as at station TC4. Concentrations of dissolved phosphate in bottom water at station TC 5 were lower and less uniform than observed at station TC 4. The dissolved parameters in the water quality data set for Turkey Creek tell a rich spatial and seasonal story, one that should provide a solid framework for comparison with post-dredging results.

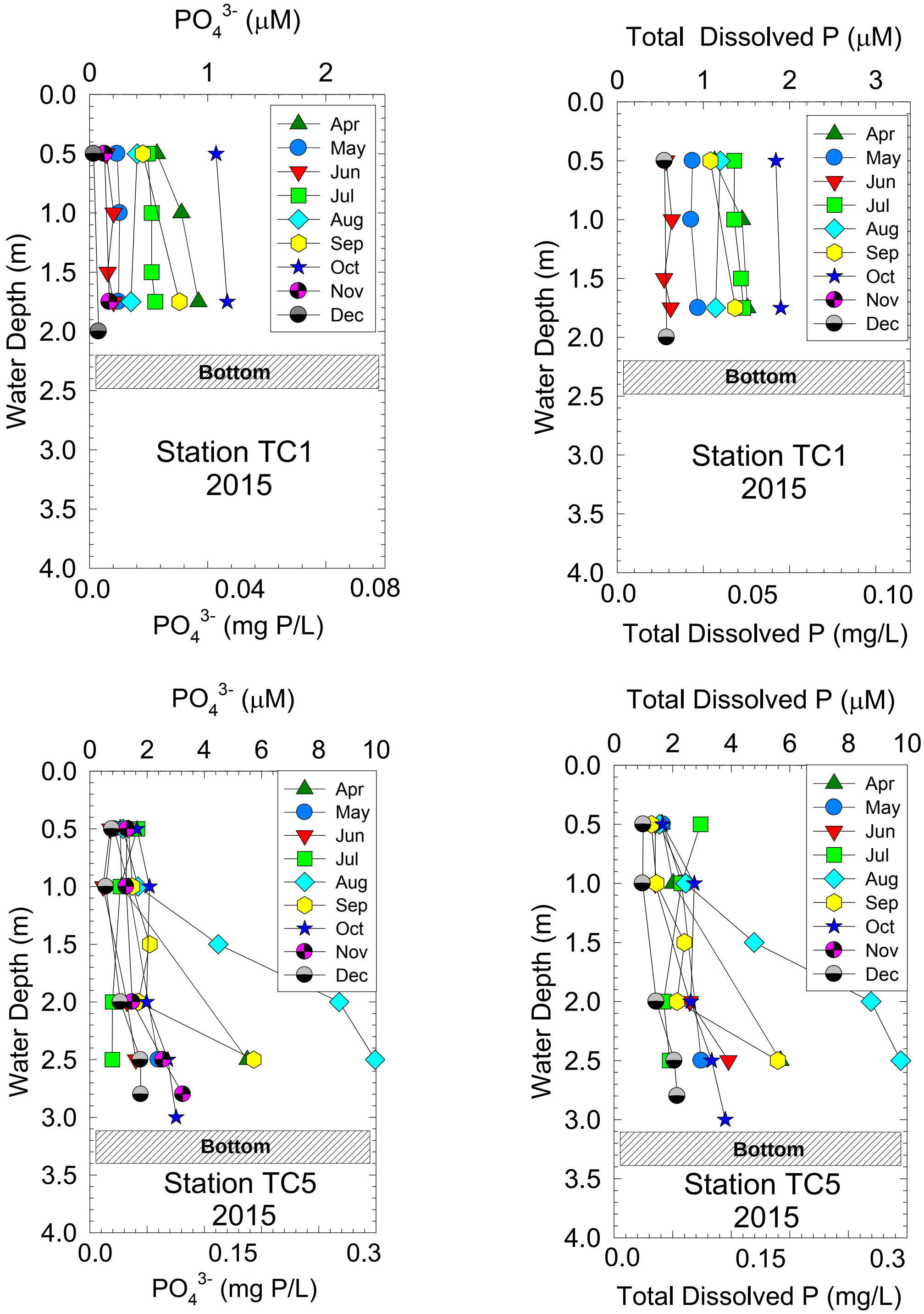

Figure 3.16. Vertical profiles for (A) dissolved phosphate (PO_4^{3-}) and (B) total dissolved phosphorus at station TC1, and (C) dissolved phosphate and (D) total dissolved phosphorus at station TC5 (with scale change for x-axis) in Turkey Creek for nine monthly surveys from April-December 2015.

3.4.3.3 Water Quality in the IRL (Station TC1) versus Turkey Creek (Station TC5): Particulate Components

A strong linear relationship was observed for turbidity (in nephelometric turbidity units, NTU) versus TSS (Figure 3.17A). The slope of the line (0.46) is consistent with a previous slope of 0.44 for results from the Indian River Lagoon System by Trefry et al. (2007, Figure 3.17B). Thus, TSS concentrations (in mg/L) are about twice the turbidity values (in NTU). Four samples collected during 2015 from water depths of 2-3 m at stations TC4 and TC5 showed deviations from the expected trend (Figure 3.17A), deviations that had not previously been seen by us in the IRL (e.g., Trefry et al., 2007). The sample that plotted below the lower prediction interval on Figure 3.17A appeared to be very fine-grained on the filter and contained a very high POC of 44%. Based on previous discussion about the carbon content of typical organic matter in the marine environment, the sample with 44% carbon contained 11% N and had a low C/N atomic ratio of 4.8, not uncommon for bacteria (Zimmerman et al., 2014). In contrast, the three samples with data that plotted above the upper confidence limit on Figure 3.17A averaged ~33% organic C and 6.0% organic nitrogen. These other anomalies also are possibly linked to a local source of organic matter.

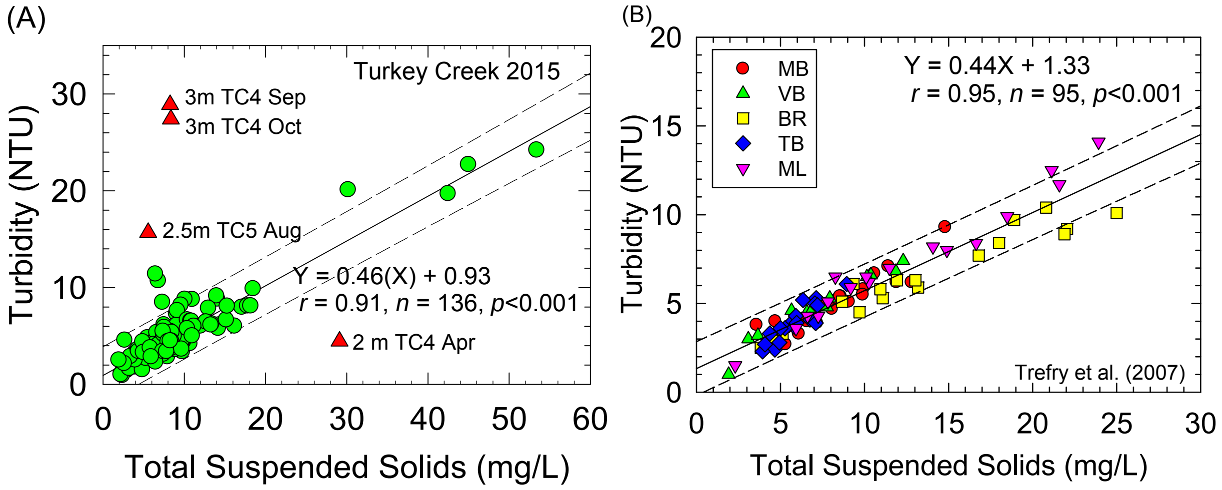

Figure 3.17. (A) Turbidity (in nephelometric turbidity units, NTU) versus total suspended solids TSS), (B) Turbidity versus TSS from Trefry et al. (2007) for samples from the Indian River Lagoon System (MB = Melbourne, VB = Vero Beach, BR = Banana River Lagoon, TB = Turnbull Creek area, ML = Mosquito Lagoon). Solid lines and equation are from linear regression analysis, dashed lines show 95% prediction interval. Anomalous data points are identified by water depth, location and month during 2015.

As previously discussed, the organic matter (% OM) content of the suspended matter was ~3 times the % TOC value (% OM = 0.35 POC + 0.8, Figure 3.7A). Therefore, the suspended matter from station TC1 ranges from ~30% OM (POC = 10%) to essentially 100% OM (POC = 35%) with an average of ~60% OM (POC data on plotted Figure 3.18). Suspended matter from station TC5 is more organic rich with an average closer to 80% OM. While sampling at station TC5, observable plant debris was regularly floating by us in the surface water. Concentrations of POC were inversely correlated with Al (Figure 3.20A) where Al is a proxy for clay mineral (aluminosilicate) content. The x-intercept on Figure 3.20A is at ~5% Al and represents 100% aluminosilicates and 0% organic matter. At POC = 20%, the Al content is ~2%, and thus the sample is ~60% OM and 40% aluminosilicate. Using this designation for the organic and inorganic content of the suspended matter, we can track changes in both the amount (TSS) and composition of the suspended matter after dredging.

The suspended matter at station TC1 contained a lower range of values for total particulate N and P than found at station TC5, consistent with the trend for more organic-rich particles at station TC5 (Figures 3.18 and 3.19). The particulate (C/N) atomic ratio averaged ~6.2 (Figure 3.20B and Appendix C) for the pre-dredge samples and is in reasonable agreement with Redfield ratio (C/N = 6.6). Anomalous total particulate P values were found in bottom water at stations TC 4 and 5 and high total particulate Fe values were observed in surface water at stations TC4 and 5. Iron is flowing in with creek water and the Fe is likely precipitating as an Fe (III) oxide with a positive charge and possibly scavenging negatively-charge phosphate ions from the water column to increase P concentrations in suspended and bottom sediments (e.g., Gunnars et al., 2002). Within this large data set for particles, we have a wide selection of biogeochemical tools to help explain changes that occur after dredging.

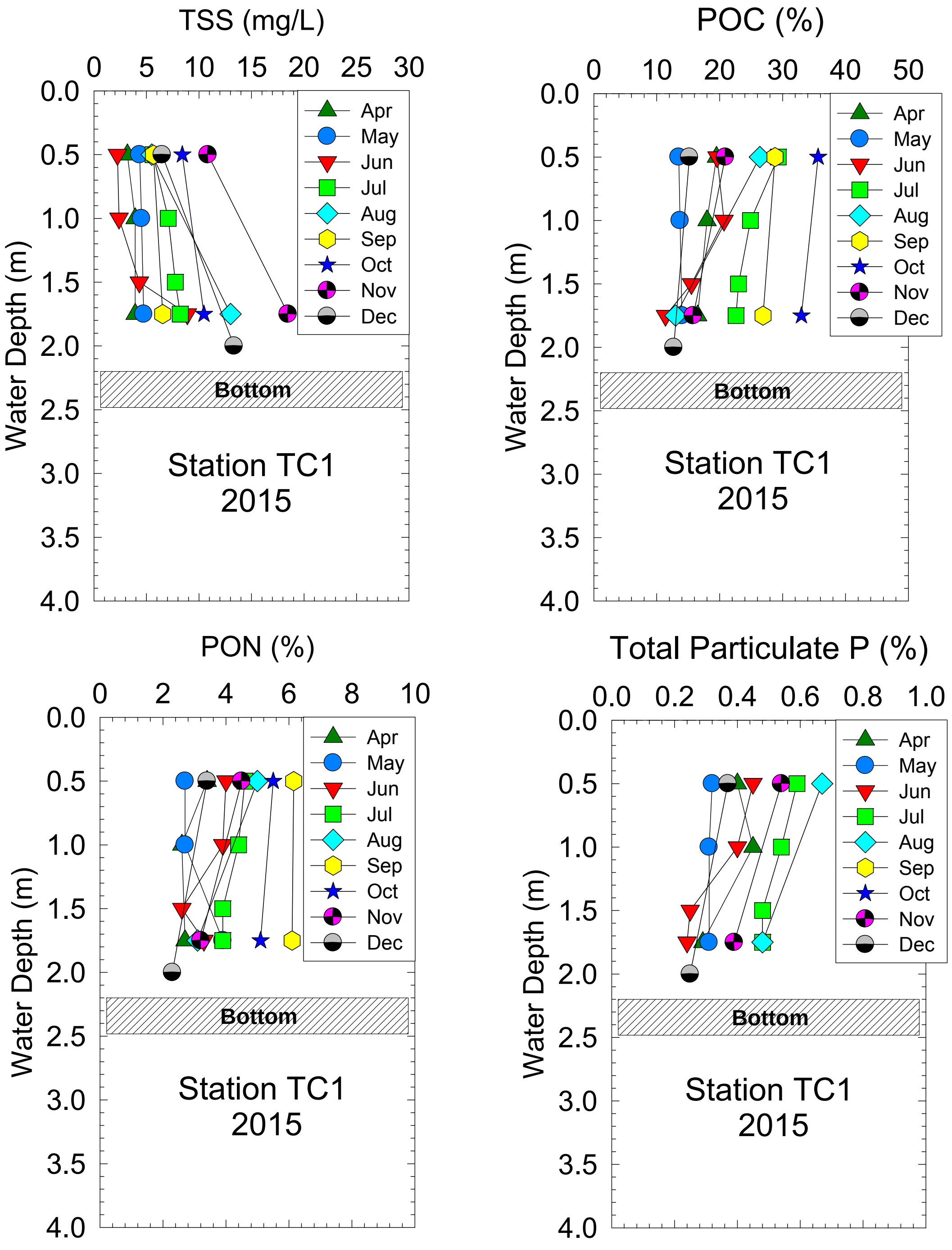

Figure 3.18. Vertical profiles for (A) total suspended solids (TSS), (B) particulate organic carbon (POC), (C) particulate organic nitrogen (PON), and (D) total particulate phosphorus at station TC1 in Turkey Creek for nine monthly surveys from April-December 2015.

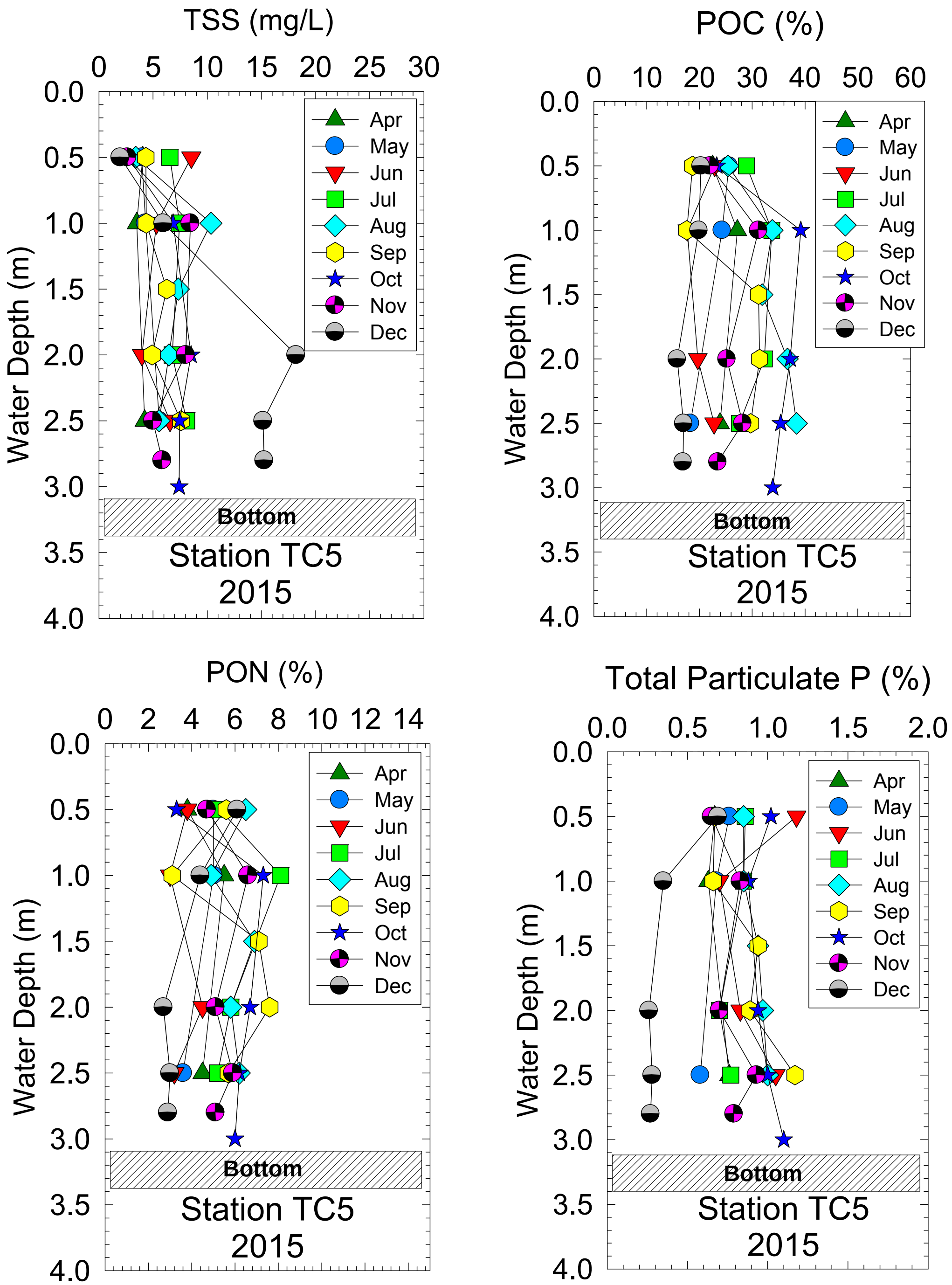

Figure 3.19. Vertical profiles for (A) total suspended solids (TSS), (B) particulate organic carbon (POC), (C) particulate organic nitrogen (PON), and (D) total particulate phosphorus at station TC5 in Turkey Creek for nine monthly surveys from April-December 2015.

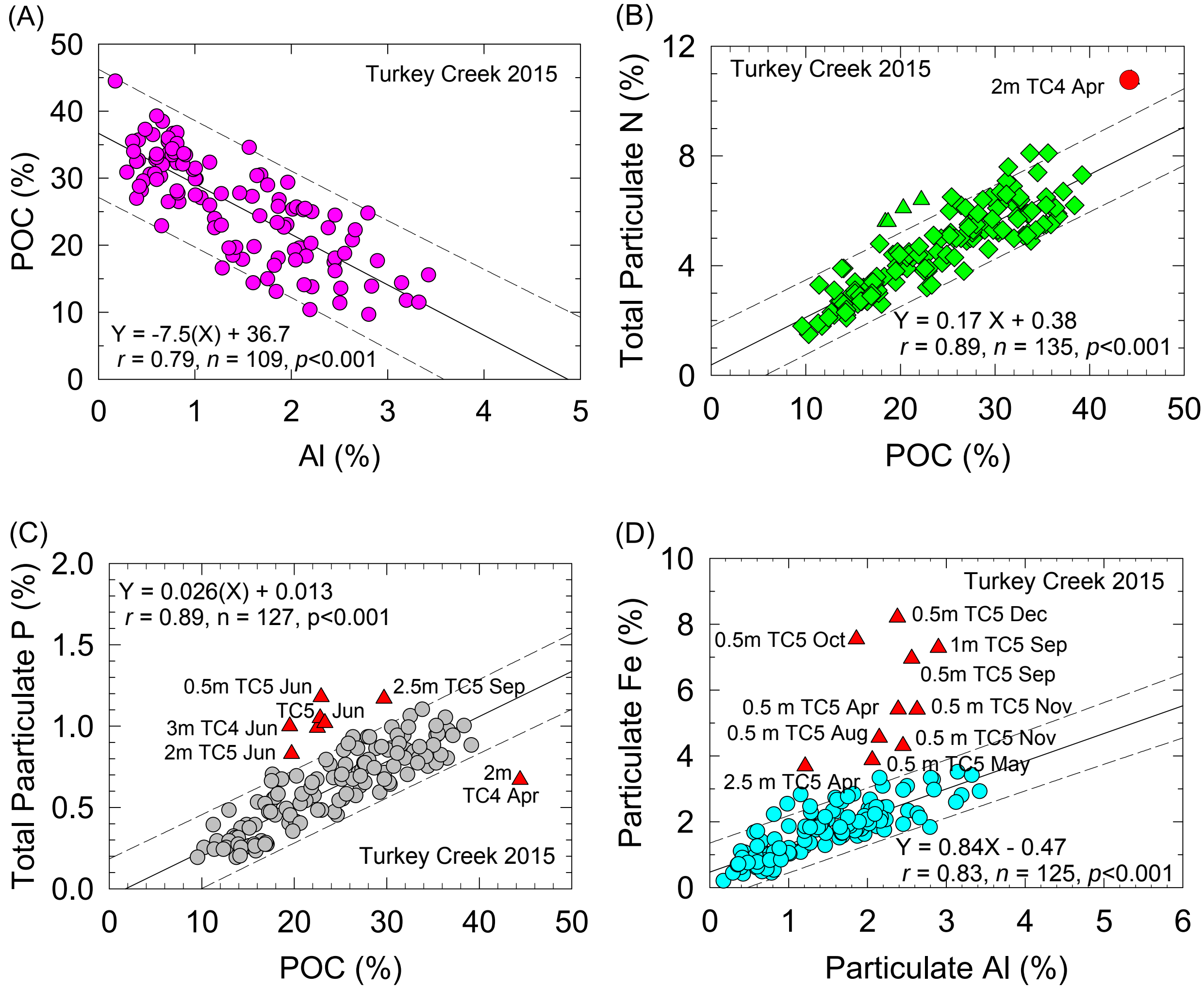

Figure 3.20. (A) Particulate organic carbon (POC) versus aluminum (Al), (B) total particulate nitrogen versus POC, (C) total particulate phosphorus versus POC and (D) total particulate iron versus total particulate Al. Solid lines and equation are from linear regression analysis, dashed lines show 95% prediction interval. Anomalous data points are identified by water depth, location and month during 2015.

3.4.4 Chemical Forms of Dissolved and Particulate Nitrogen and Phosphorus

The growth of algae and phytoplankton generally depends on the dissolved inorganic forms of nitrogen (ammonium, nitrate, and nitrite) and phosphorus (phosphate). In some instances, simple organic molecules such as urea (CH_4N_2O) or methylphosphonic acid [$CH_3P(OH)_2$] may be used by primary producers as sources of dissolved nitrogen and phosphorus (e.g., Kudo et al., 2015; Van Mooy et al., 2015). For this study, the pre-dredge data for the various forms of nitrogen and phosphorus provide another point of reference to assess post-dredging results.

The most abundant form of nitrogen in the water column in Turkey Creek and the adjacent IRL was DON with an average of 46 ± 14 µM (0.64 ± 0.20 mg N/L, Table 3.6) that accounted for an average of 58 ± 11% of the total nitrogen in the water column (Table 3.7 and Figure 3.21). Dierberg (1991) reported an average DON value of 47 ± 11 µM (0.66 ± 0.15 mg N/L) for Turkey Creek during normal flow in 1988 and 1989; these values were not statistically different from our results for 2015 (Table 3.6).

Particulate N, the fraction associated with suspended sediments, made up an average of 32 ± 12% of the total nitrogen in our water samples (Table 3.7 and Figure 3.21). In contrast, Dierberg (1999) found very low concentrations for particulate N during normal flow in the creek because concentrations of suspended sediment upstream were low (Table 3.6). Dierberg (1991) found particulate N values closer to our values for Turkey Creek and the adjacent IRL during storm flow (Table 3.9). The fine-grained, organic-rich sediment east of the FEC railroad bridge is easily resuspended and regularly yields higher values for particulate N in the lower creek than during non-storm periods in upstream waters.

Ammonium was the most abundant form of dissolved inorganic N found in our study area and was present at an average of ~9 times greater than nitrate + nitrite (Tables 3.8). Dierberg (1991) reported higher nitrate + nitrite values than ammonium concentrations for upstream in Turkey Creek. We know that the area between the FEC railroad bridge and the mouth of Turkey Creek receives a large flux of ammonium from the muck sediments that likely shifts the [ammonium/(nitrate + nitrite)] ratio in favor or ammonium. The average $[NH_4^+]/[NO_3^- + NO_2^-]$ was ~20 with a range of 0.77 to 480 (Appendix C).

When just the soluble forms of nitrogen are considered, DON makes up 40-95% of the total dissolved nitrogen (Table 3.10). This predominance of DON is a common observation for estuaries and creeks in Florida, including Turkey Creek (e.g., Dierberg, 1991; Lapointe et al., 2015). Higher concentrations of ammonium than nitrate + nitrite help support the importance of muck sediments as a source of dissolved nitrogen to Turkey Creek and the adjacent IRL. The dissolved nitrogen in muck is >99% ammonium with concentrations as high as 3000 µM (42 mg N/L).

Table 3.6. Concentrations of the various forms of nitrogen in the water column of Turkey Creek and the adjacent IRL. Dates and locations of maxima and minima are shown in [ ]. Units are µM and {mg N/L}.

Parameter 2015	Ammonium (µM) {mg N/L}	Nitrate-nitrite (µM) {mg/L}	DON[1] (µM) {mg/L}	Particulate N (µM) {mg/L}
This study				
Mean	8.0 {0.11}	0.93 {0.013}	46.1 {0.64}	28.2 {0.39}
Std. Dev	10.5 {0.17}	1.27 {0.018}	14.2 {0.20}	22.2 {0.31}
Max	64.7 {0.91} [TC4, 3 m Sep]	7.91 {0.111} [TC5, 2.8 m Nov]	105 {1.5} [TC4, 3 m Aug]	224 {3.1} [TC4, 2 m Apr]
Min	2.2 {0.031} [TC1, 0.5 m Jul]	0.13 {0.002} [TC4, 3 m Aug]	17 {0.24} [TC1, 1 m Apr]	6.3 {0.09} [TC5, 0.5 m Oct.]
Turkey Creek normal flow (Dierberg, 1991)				
Mean	1.9 {0.026}	4.6 {0.065}	47.1 {0.66}	2.9 {0.04}
Std Dev	1.1 {0.016}	4.8 {0.067}	10.7 {0.15}	2.1 {0.03}
Turkey Creek storm flow (Dierberg, 1991)				
Maximum	14.3 {0.2}	17.9 {0.25}	71 {1.0}	21 {0.3}

[1] DON = Dissolved Organic Nitrogen.

Table 3.7. Percentages of the various forms of nitrogen in the waters of Turkey Creek and the adjacent IRL.

Parameter	Ammonium (%)	Nitrate-nitrite (%)	DON[1] (%)	Particulate N (%)
Mean	8.9	1.2	57.8	32.1
Std. Dev	7.2	1.7	10.5	12.0
Max	42.2 [TC4, 3 m Sep]	9.5 [TC4, 0.5 m Nov]	79.5 [TC1, 0.5 m Jun]	80.5 [TC4, 2 m Apr]
Min	2.0 [TC4, 2 m Apr]	0.07 [TC4, 3 m Aug]	17.2 [TC4, 2 m Apr]	9.6 [TC5, 0.5 m Oct]

[1] DON = Dissolved Organic Nitrogen.

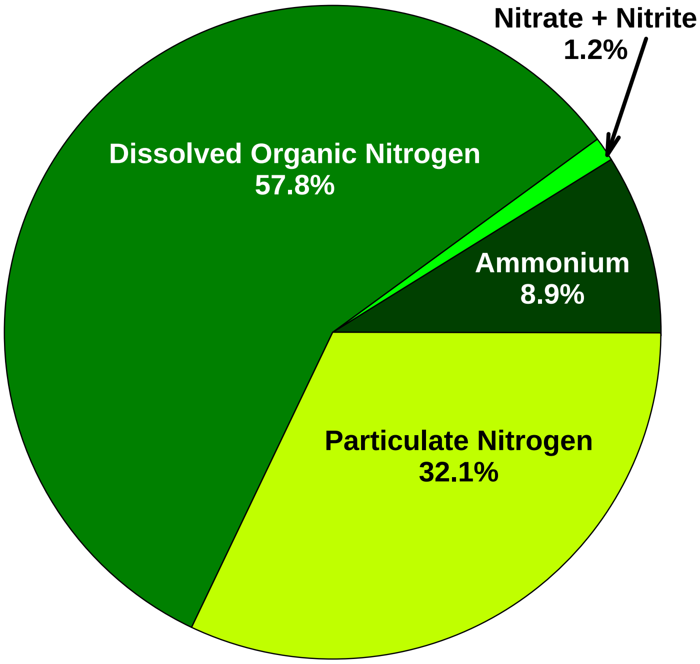

Figure 3.21. Pie diagram showing the percentages of the different chemical forms of nitrogen in the waters of Turkey Creek and the adjacent Indian River Lagoon.

Table 3.8. Percentages of the various forms of dissolved nitrogen in the waters of Turkey Creek and the adjacent IRL.

Parameter	Ammonium (%)	Nitrate-nitrite (%)	Dissolved Organic N (%)
Mean	12.6	1.7	85.7
Std. Dev	9.1	2.1	9.2
Max	56.1 [TC4, 3 m Sep]	12.7 [TC5, 3 m Oct]	94.7 [TC4, 2 m Oct]
Min	4.4 [TC1, 0.5 m Nov]	0.08 [TC4, 3 m Aug]	43.8 [TC4, 3 m Sep]

A more even distribution was found among the three forms of phosphorus (dissolved phosphate, DOP and particulate phosphorus) than nitrogen in the water column in our study area (Figure 3.22). Our values for dissolved phosphate are higher and more variable than reported by Dierberg (1991; Table 3.9). We look forward to upstream sampling during 2016 to determine whether the higher phosphate values in Turkey Creek and the adjacent IRL are linked to increased concentrations upstream or to release of dissolved phosphate from muck. As was the case for dissolved nitrogen, the highest concentrations of dissolved phosphate and DOP were found in deeper water at stations TC4 and TC5 (Table 3.9). Lower DOP values were found at stations TC1 and TC2 (Table 3.9). In contrast with nitrogen, the percent abundance of DOP at 29% was lower than the DON value of 60% (Tables 3.10 and 3.7). The dissolved forms of phosphorus, phosphate and DOP, each made up about half of the soluble phosphorus (Table 3.11).

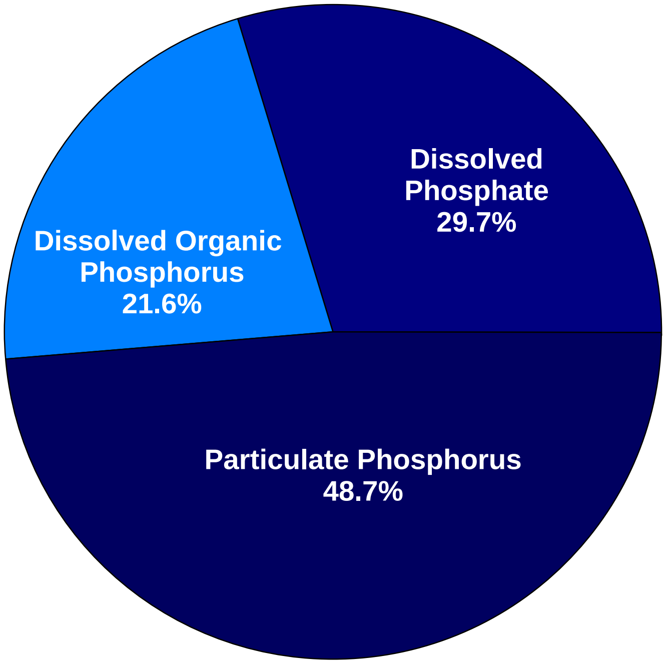

Figure 3.22. Pie diagram showing the percentages of the different chemical forms of phosphorus in the waters of Turkey Creek and the adjacent Indian River Lagoon.

Table 3.9. Concentrations of the various forms of phosphorus in the water column of Turkey Creek and the adjacent IRL.

Parameter	Phosphate (µM) {mg/L}	Dissolved Organic P (mg/L)	Particulate P (mg/L)
This Study			
Mean	1.27 {0.039}	0.69 {0.021}	1.67 {0.052}
Std. Dev	1.74 {0.054}	0.38 {0.012}	0.95 {0.029}
Max	9.97 {0.309} [TC5, 2.5 m Aug]	2.3 {0.071} [TC5, 2.5 m Jun]	6.3 {0.195} [TC4, 2 m Apr]
Min	(0.03) {0.001} [TC1, 0.5 m Dec]	<0.2 {<0.004} [TC5, 2.5 m Aug]	0.31 {0.010} [TC1, 1 m Jun]
Turkey Creek normal flow (Dierberg, 1991)			
Mean	0.64 {0.020}	1.6 {0.05}	0.42 {0.013}
Std Dev	0.34 {0.011}	0.32 {0.01}	0.32 {0.010}

Table 3.10. Percentages of the various forms of phosphorus in the waters of Turkey Creek and the adjacent IRL.

Parameter	Phosphate (%)	Dissolved Organic P (%)	Particulate P (%)
Mean	29.7	21.6	48.7
Std. Dev	19.5	14.2	17.2
Max	86.1 [TC5, 2.5 m Aug]	49.2 [TC1, 1.75 m May]	97.6 [TC3, 0.9 m May]
Min	4.6 [TC5, 0.9 m May]	<1 [TC4, 3 m Aug]	15.4 [TC5, 2.5 m Apr]

Table 3.11. Percentages of the various forms of dissolved phosphorus in the waters of Turkey Creek and the adjacent IRL.

Parameter	Phosphate (%)	Dissolved Organic P (%)
Mean	52.4	47.6
Std. Dev	23.4	23.4
Max	100 [TC4, 3 m Aug]	94 [TC1, 0.5 m Dec]
Min	6 [TC1, 0.5 m Dec]	<1 [TC4, 3 m Aug]

3.5 Conclusions

The conclusions from this study are presented as a series of bulleted items with supporting references to figures, tables and text from this section (3) of the report. Results from a few very preliminary calculations are included to provide a quantitative context and starting point for answering a variety of research and management questions.

(1) Muck with thicknesses >25 cm covers ~50% of the area of Turkey Creek studied.

Based on Figure 3.3 and Table 3.2 that show ≥25 cm of muck in ~100 of ~200 grids (see Appendix A). With a grid size of ~800 m^2, the area with muck is ~80,000 m^2.

(2) Present water depths in Turkey Creek will likely increase by 1-3 m after dredging.

Figure 3.4B.

(3) Turkey Creek muck contains >90% water by volume (>75% water by weight), 70-90% silt + clay, 10-20% organic matter with 0.4 to >0.8% N and 0.1-0.16% P.

Tables 3.3 and 3.4 and Appendix C.

(4) The masses of N and P in the muck sediments of Turkey Creek are estimated to be ≈600 metric tons of N and ≈130 metric tons of P.

Based on muck volume of 160,000 m^3 (page 3-15, combined FIT and Brevard contractor) and the composition data listed above.

N = (160,000 m^3) x (0.2 fraction solid sediment for 80% water) x (solid sediment density of 2.5 metric tons sediment/m^3) x (0.006 is fraction N for 0.6% N) = 480 metric tons of N

Repeat for P with 0.13% P (0.0013 fraction P) = 104 metric tons P

(5) Fluxes of nitrogen (as ammonium) and phosphorus (as phosphate) are on the order of 20 and 4 metric ton/km^2/yr to yield annual fluxes of N and P from sediments of 1.6 and 0.32 metric tons/yr, respectively.

Based on muck area of 80,000 m^2 = 0.08 km^2 (100 cells x 30 m x 28 m)
N flux = (0.08 km^2) x (20 metric tons N/km^2/yr) = 1.6 metric tons N/yr = 1,600,000 g N/yr
P flux = (0.08 km^2) x (4 metric tons P/km^2/yr) = 0.32 metric tons P/yr = 320,000 g P/yr

(6) Vertical profiles for dissolved ammonium and phosphate show increased concentrations of 4- to >10-fold in the bottom water of shallow, low oxygen depressions during summer. These data provide direct evidence for the measurable impact of fluxes of N and P from sediments to the waters of Turkey Creek.

> Average concentrations of ammonium and phosphate for the upper water column in Turkey Creek were 2-6 µM (0.03-0.08 mg N/L) and 0.2-1.5 µM (0.006-0.050 mg P/L), respectively. (Figures 3.14-16)
> Concentrations of ammonium and phosphate for shallow depressions in Turkey Creek during summer were ~8 µM (0.1 mg N/L) and ~1.3 (µM (0.04 mg P/L), respectively. (Figures 3.14-16)

(7) Releases of ammonium and phosphate from sediments as shown above would, if retained in the creek and not flushed to the IRL, hypothetically yield ammonium concentrations of ~5 mg N/L and 1 mg P/L relative to average values of 0.1 mg N/L and 0.04 mg P/L.

> Volume of water in Turkey Creek study is 300,000 m^3 {(80,000 m^2 + 80,000 m^2) x 1.8 m} or 300,000 m^3 x 1000 L/m^3 = 300 x 10^6 L. (Appendix A)
>
> Ammonium from muck per year would yield a total concentration (if all was retained) of [(1,600,000 g/300 x 10^6 L)] = 0.0053 g/L = ~5 mg N/L.
>
> Phosphate from muck per year would yield a total concentration (if all was retained) of [(320,000 g/300 x 10^6 L)] = 0.0011 g P/L = ~1 mg P/L.

(8) The average percentage of chemical forms of nitrogen in the waters of Turkey Creek and the adjacent IRL during 2015 were as follows: dissolved organic nitrogen (57.8%), ammonium (8.9%), nitrate + nitrite (1.2%) and particulate organic nitrogen (32.1%). The organic forms of N comprise ~90% of the total dissolved N in the water column.

The average chemical forms of phosphorus in the waters of Turkey Creek and the adjacent IRL were as follows: dissolved organic phosphorus (21.6%), phosphate (29.7%), and particulate organic phosphorus (48.7%). The organic forms of P comprise ~70% of the total dissolved P in the water column.

(9) The varied data set for muck and water in Turkey Creek obtained during 2015 offers several possible means for assessing the effectiveness of muck dredging including the following: (a) the amount of solid-phase N and P removed, (b) changes in concentrations of ammonium, phosphate, dissolved oxygen and other parameters in creek water and (c) decreases in the flux of N and P from sediments to overlying water of Turkey Creek.

3.6 References

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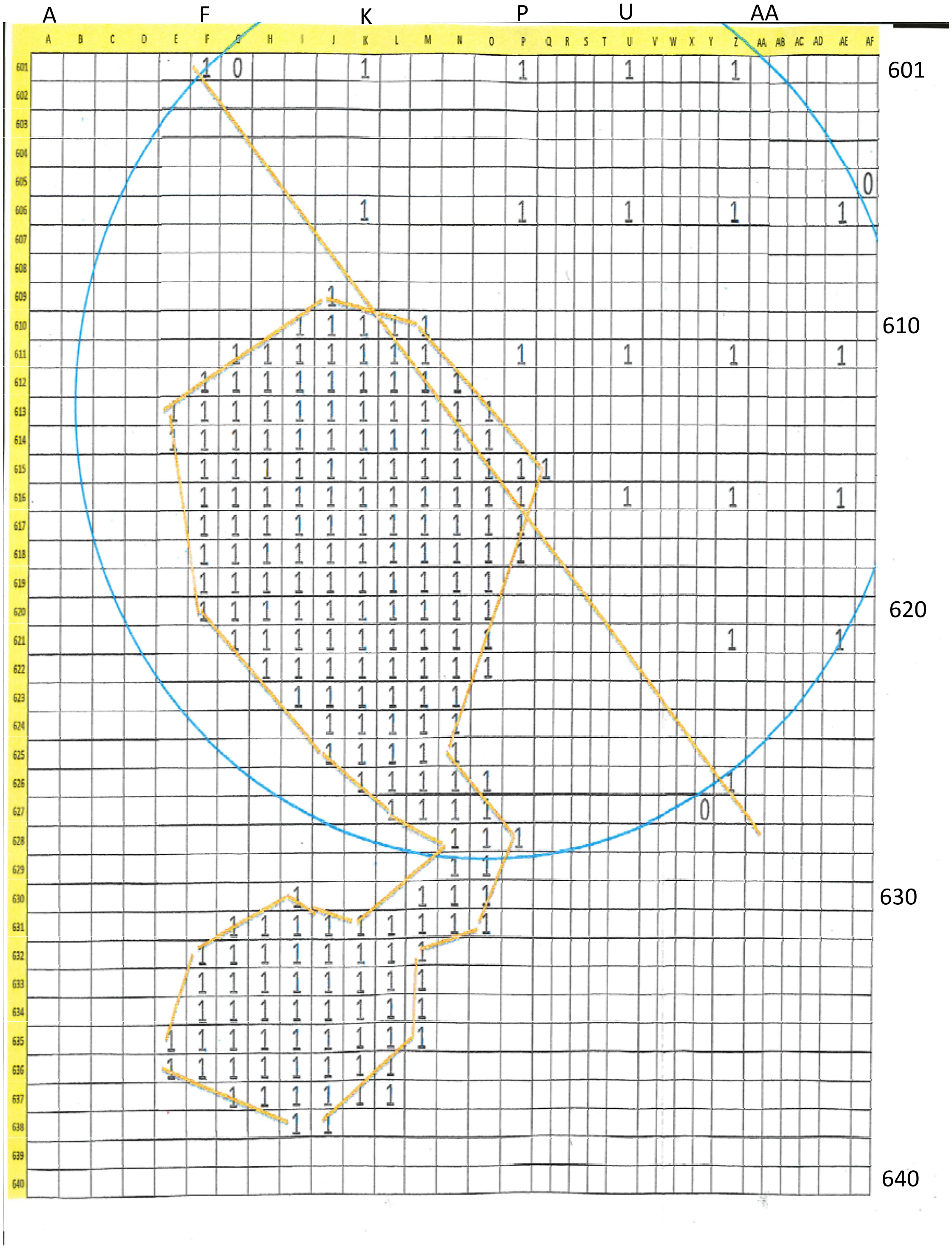
3.7 Appendices

Appendix A. Sampling grid and data from muck survey. Grids are identified by letter and number. Dimensions (N-S, 1 sec of latitude, 30.5 m) (E-W, 1 sec of longitude, 27.5 m).



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
601						1	0				1					1					1					1						
602																																
603																																
604																																
605																																0
606											1					1					1					1					1	
607																																
608																																
609										1																						
610									1	1	1	1	1																			
611							1	1	1	1	1	1	1			1					1					1					1	
612						1	1	1	1	1	1	1	1	1																		
613					1	1	1	1	1	1	1	1	1	1	1																	
614					1	1	1	1	1	1	1	1	1	1	1																	
615						1	1	1	1	1	1	1	1	1	1	1	1															
616						1	1	1	1	1	1	1	1	1	1	1					1					1					1	
617						1	1	1	1	1	1	1	1	1	1	1																
618						1	1	1	1	1	1	1	1	1	1	1																
619						1	1	1	1	1	1	1	1	1	1																	
620						1	1	1	1	1	1	1	1	1	1																	
621							1	1	1	1	1	1	1	1	1											1					1	
622								1	1	1	1	1	1	1	1																	
623									1	1	1	1	1	1																		
624										1	1	1	1	1																		
625										1	1	1	1	1																		
626											1	1	1	1	1											1						
627												1	1	1	1										0							
628														1	1	1																
629														1	1																	
630									1				1	1	1																	
631							1	1	1	1	1	1	1	1	1																	
632						1	1	1	1	1	1	1	1																			
633						1	1	1	1	1	1	1	1																			
634						1	1	1	1	1	1	1	1																			
635					1	1	1	1	1	1	1	1	1																			
636					1	1	1	1	1	1	1	1																				
637							1	1	1	1	1	1																				
638									1	1																						
639																																
640																																

Appendix A (continued) Data from muck survey.

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
L610	28.0392	80.5803	1.0	1.00	0.00	Sand
L611	28.0389	80.5803	1.3	1.30	0.00	Sand
L612	28.0386	80.5803	1.3	1.46	0.16	Light muck
L613	28.0384	80.5803	1.3	1.38	0.08	Hard to light muck
L614	28.0381	80.5803	1.2	1.24	0.04	Wet Sand
L615	28.0378	80.5803	1.2	1.25	0.05	Sandy
L616	28.0375	80.5803	1.6	1.65	0.10	
L617	28.0373	80.5803	2.1	2.45	0.35	Soupy muck
L618	28.0370	80.5803	2.7	3.30	0.60	Soupy muck
L619	28.0367	80.5803	2.5	5.00	2.50	Fine soup on top
L620	28.0364	80.5803	2.5	5.40	2.90	Very soft, hard sand bottom
L621	28.0361	80.5803	2.6	5.30	2.75	Not hard bottom at 5.3m
L622	28.0359	80.5803	3.0	5.40	2.40	Sand at bottom
L623	28.0356	80.5802	3.0	5.40	2.40	Hard at 5.4m
L624	28.0353	80.5803	2.7	3.00	0.30	Shell hash, 30cm of hash
L625	28.0351	80.5803	2.6	3.05	0.45	Sand at 3.05m
L626	28.0348	80.5802	2.5	2.50	0.00	At marking 10 (holding on), shell
L627	28.0345	80.5802	0.9	0.88	0.00	Sand 15 ft from shore
K626	28.0347	80.5806	1.5	1.50	0.00	Sand 20ft from shore
K625	28.0350	80.5806	2.3	2.50	0.20	Hard at 2.5m
K624	28.0353	80.5806	2.8	3.00	0.20	Hard at 3m, sand and shell
K623	28.0356	80.5806	3.0	3.60	0.60	
K622	28.0358	80.5805	3.1	4.55	1.45	
K621	28.0361	80.5806	3.0	5.50	2.50	hard at 5.5m
K620	28.0364	80.5806	2.7	5.50	2.80	dense muck at mid muck
K619	28.0367	80.5806	2.7	3.50	0.80	muck over shell hash
K618	28.0370	80.5806	2.5	3.50	1.00	Sand at 3.5
K617	28.0372	80.5806	2.1	2.40	0.35	Hard shell at 2.4
K616	28.0375	80.5805	1.4	1.70	0.30	Light muck but gritty
K615	28.0378	80.5805	1.2	1.55	0.32	Low water content - gritty muck
K614	28.0380	80.5805	1.2	1.40	0.20	Hard to no penetration/ patchy thickness
K613	28.0383	80.5805	1.3	1.62	0.37	

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
K611	28.0389	80.5805	1.2	1.25	0.05	
K610	28.0392	80.5806	1.1	1.10	0.00	Hard sand 30 feet from shore
J625	28.0349	80.5808	0.9	0.90	0.00	sand 10 feet from shoe
J624	28.0353	80.5808	2.5	2.50	0.00	Hard sand 30 feet from shore
J623	28.0356	80.5808	2.9	3.20	0.30	Hard at 3.2, soft at muck top
J622	28.0358	80.5809	3.8	5.10	1.35	At piling #2, really soft on really hard
J621	28.0361	80.5808	3.1	3.80	0.70	Soft over hard
J620	28.0364	80.5809	3.0	3.50	0.50	Soft over hard
J619	28.0367	80.5808	2.9	3.90	1.00	Soft over hard, feels very fine
J618	28.0369	80.5808	2.6	5.15	2.55	Not as hard at 5.15
J617	28.0372	80.5808	1.8	2.40	0.65	Shelly at 2.4, jack hammer to 3.0
J616	28.0375	80.5808	1.4	1.63	0.25	Soft, hard at 1.63
J615	28.0378	80.5808	1.1	1.70	0.60	Stiff muck/grainy. Hard at 1.7
J614	28.0381	80.5808	1.1	1.72	0.62	Hard at 1.72
J613	28.0383	80.5808	1.3	1.53	0.28	Hard at 1.53
J612	28.0386	80.5808	1.2	1.25	0.10	Wet sand not muck
J611	28.0389	80.5808	1.1	1.10	0.00	
J610	28.0392	80.5809	0.8	0.80	0.00	40 feet from shore
M627	28.0345	80.5800	1.6	1.65	0.05	Soft sand/shell at top, 25 feet from shore
M626	28.0348	80.5800	3.0	3.60	0.60	In channel, high density at 3.6. Stiff, but not hard at 3.6
M625	28.0350	80.5800	2.5	3.40	0.90	Stiffer muck, not completely hard bottom
M624	28.0353	80.5800	2.6	3.17	0.62	Stiffer muck, not completely hard bottom. Stiff at 3.17
M623	28.0355	80.5800	2.7	5.30	2.60	Hard at 5.3
M622	28.0358	80.5800	2.7	5.30	2.65	Hard at 5.3
M621	28.0361	80.5800	2.3	5.25	3.00	Hard at 5.25
M620	28.0364	80.5800	2.3	4.70	2.40	Shelly at 4.7, a bit loose
M619	28.0367	80.5800	2.3	5.25	2.95	
M618	28.0370	80.5800	2.4	5.45	3.10	Chunky big stuff, wiggles around

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
M616	28.0375	80.5800	1.1	1.10	0.00	Hard
M615	28.0378	80.5800	1.1	1.05	0.00	Hard
M614	28.0381	80.5801	1.1	1.15	0.05	Wet sand
M613	28.0384	80.5800	1.35	1.40	0.05	Wet sand
M612	28.0386	80.5800	1.50	1.65	0.15	Wet sand with minor muck
M611	28.0389	80.5800	1.50	1.60	0.10	Wet sand with minor muck
M610	28.0392	80.5800	1.35	1.45	0.10	Wet sand with minor muck
I623	28.0356	80.5811	1.20	1.20	0.00	Wet sand with minor muck, 30 feet from shore
I622	28.0358	80.5812	1.60	1.80	0.20	Sandy muck, hard bottom, patchy
I621	28.0362	80.5811	3.40	4.70	1.30	Soft/hard at bottom
I620	28.0365	80.5811	3.00	4.70	1.70	Soft/hard at bottom, hammer to 5.2 hard
I618	28.0369	80.5811	2.80	3.80	1.00	Hard at 3.8
I617	28.0372	80.5810	1.70	2.70	1.00	Hard at 2.0
I616	28.0375	80.5809	1.30	1.80	0.50	Grainy/stiff muck
I615	28.0378	80.5811	1.00	1.50	0.50	Hard surface layer
I614	28.0381	80.5811	1.10	1.60	0.50	Hard bottom - sand
I613	28.0384	80.5810	1.15	1.50	0.35	Hard bottom - sand
I612	28.0387	80.5811	1.10	1.50	0.40	Wet sand
I611	28.0389	80.5809	1.05	1.10	0.05	Wet sand, shell hash
I610	28.0392	80.5812	0.70	0.70	0.00	
H611	28.0389	80.5814	0.95	1.00	0.05	
H612	28.0386	80.5813	1.10	1.20	0.10	
H613	28.0383	80.5815	1.10	1.45	0.35	Hard bottom
H614	28.0380	80.5813	1.10	1.70	0.60	
H615	28.0377	80.5813	1.00	1.80	0.80	Hard bottom
H616	28.0374	80.5814	0.95	0.95	0.00	
H597	28.0428	80.5813	1.26	1.26	0.00	Hard
K601	28.0416	80.5806	0.85	0.85	0.00	Hard, very dark shallow water
P601	28.0417	80.5792	1.55	1.55	0.00	Hard
U601	28.0417	80.5778	1.74	1.74	0.00	Hard sand 30 feet from shore
Z601	28.0417	80.5763	2.15	2.15	0.00	Hard
AE606	28.0403	80.5750	2.20	2.20	0.00	Hard

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
U606	28.0403	80.5778	1.86	1.86	0.00	Hard
P606	28.0403	80.5792	1.70	1.75	0.05	Sandy, very loose muck
P606A	28.0402	80.5797	1.10	1.10	0.00	Hard
P610	28.0392	80.5792	1.60	1.72	0.12	Sandy Muck
P611	28.0389	80.5792	1.56	1.74	0.18	
U611	28.0389	80.5778	1.95	1.95	0.00	In channel, hard
Z611	28.0389	80.5764	2.20	2.20	0.00	Hard
AE611	28.0389	80.5750	2.25	2.25	0.00	Hard
AE616	28.0375	80.5750	2.34	2.34	0.00	Hard, deep water
Z616	28.0375	80.5764	2.18	2.18	0.00	Hard
U616	28.0375	80.5778	1.74	1.74	0.00	Hard
Z621	28.0362	80.5764	2.25	2.28	0.03	Loose wet sand layer
Z626	28.0347	80.5764	1.65	1.65	0.00	Hard
AE621	28.0362	80.5750	2.3	2.32	0.02	Fine wet sandy layer on top
R613	28.0385	80.5786	1.75	1.80	0.05	Between Markers 1-2 in channel
P613	28.0383	80.5790	1.56	1.70	0.14	Stiff clay, in channel
O615A	28.0378	80.5794	1.64	1.76	0.12	Between Markers 3-4 in channel
O616A	28.0376	80.5796	1.52	1.65	0.13	Between markers 5-6 in channel, really loose top
N617A	28.0372	80.5798	1.55	1.62	0.07	Between Markers 7-8 in channel, very flocky top
N617	28.0372	80.5797	1.6	1.66	0.06	
N618	28.0370	80.5797	2.4	3.80	1.40	
N619	28.0367	80.5797	2.4	5.20	2.80	
N620	28.0364	80.5797	2.2	4.90	2.70	
N621	28.0361	80.5797	2.4	5.10	2.70	
N622	28.0358	80.5797	2.35	5.00	2.65	Unsure of water depth
N623	28.0356	80.5797	2.4	4.45	2.05	
N624	28.0353	80.5797	2.25	2.80	0.55	Muck and sand, 10m offshore
N625	28.0350	80.5797	1.3	1.55	0.25	Gravel and muck
N626	28.0347	80.5798	1.65	1.72	0.07	Sandy (wet)
N627	28.0344	80.5797	1.68	1.68	0.00	Hard
O627	28.0345	80.5794	2.65	3.05	0.40	Sandy
O624	28.0354	80.5796	0.78	0.78	0.00	Hard, 5m offshore

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
O621	28.0361	80.5795	0.45	0.45	0.00	Rock/oyster reef
O621A	28.0361	80.5795	2.05	2.15	0.10	Shells
O620	28.0364	80.5795	0.57	0.57	0.10	Rock/oyster reef
O619	28.0367	80.5795	0.68	0.68	0.00	Rock/oyster reef
O618	28.0370	80.5795	0.66	0.66	0.00	Hard (reef), 10m offshore
O617	28.0372	80.5795	1.45	2.00	0.55	
O617A	28.0373	80.5793	0.65	0.65	0.00	Rock/oyster reef, 10m offshore
O616	28.0375	80.5795	1.65	2.05	0.40	Hard bottom (rock)
O615	28.0378	80.5795	1.6	1.72	0.12	Mucky, hit hard bottom
O614	28.0381	80.5795	1.26	1.36	0.10	Hit hard bottom
O613	28.0384	80.5794	1.28	1.35	0.07	
N612	28.0386	80.5797	1.25	1.40	0.15	
N613	28.0384	80.5797	1.06	1.11	0.05	
N614	28.0381	80.5797	0.98	1.04	0.06	Sandy (wet)
N615	28.0378	80.5797	0.9	0.90	0.00	Hard
N616	28.0375	80.5797	1.06	1.06	0.00	Sand
P616	28.0375	80.5793	0.58	0.58	0.00	Near Marker 5: hard, sandy
P615	28.0377	80.5792	0.95	0.95	0.00	Hard
Q615	28.0378	80.5789	0.88	0.88	0.00	Hard
I612	28.0386	80.5811	0.92	1.00	0.08	Sandy wet
I611	28.0389	80.5811	0.82	0.82	0.00	Hard
H611	28.0389	80.5814	0.58	0.58	0.00	Hard
H612	28.0386	80.5814	0.9	1.02	0.12	Wet sand
H613	28.0383	80.5815	0.9	1.20	0.30	
H614	28.0380	80.5815	0.9	1.30	0.40	Very variable, definitely muck
H615	28.0378	80.5814	0.84	1.52	0.68	
H616	28.0375	80.5814	0.76	0.82	0.06	
H617	28.0372	80.5814	0.84	1.15	0.31	
H618	28.0370	80.5814	1.80	2.70	0.90	
H619	28.0367	80.5814	2.00	4.40	2.40	
H620	28.0364	80.5814	2.30	5.30	3.00	Hard sandy bottom
H621	28.0364	80.5814	1.02	1.02	0.00	Sand
H622	28.0359	80.5814	0.80	1.15	0.35	
G621	28.0361	80.5817	0.56	1.28	0.72	Muck, 5m offshore
G620	28.0364	80.5817	0.90	1.16	0.26	

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
G618	28.0370	80.5817	1.06	1.62	0.56	
G617	28.0372	80.5817	0.90	1.60	0.70	
G616	28.0375	80.5817	0.94	1.58	0.64	Pockets of muck
G615	28.0378	80.5817	0.95	0.95	0.00	Hard, pockets of much
G614	28.0381	80.5817	0.90	1.42	0.52	Pockets of muck
G613	28.0383	80.5817	0.90	1.25	0.35	Pockets of muck
G612	28.0386	80.5816	0.78	0.94	0.16	
G611	28.0388	80.5817	0.44	0.44	0.00	Hard
F612	28.0386	80.5819	0.47	0.47	0.00	Hard, pockets of muck
F613	28.0383	80.5820	0.78	1.28	0.50	
F614	28.0381	80.5820	0.85	1.42	0.57	
F615	28.0378	80.5820	0.88	1.45	0.57	
F616	28.0375	80.5820	0.62	0.62	0.00	Hard
F617	28.0387	80.5820	0.48	0.48	0.00	Hard
F618	28.0370	80.5818	0.38	0.38	0.00	
F616A	28.0374	80.5821	0.38	0.38	0.00	Hard
F615A	28.0378	80.5821	0.40	0.40	0.00	Hard
E614	28.0381	80.5821	0.40	0.40	0.00	Hard
I619	28.0367	80.5811	2.40	4.90	2.50	
O628	28.0342	80.5795	2.90	3.00	0.10	Sandy
O629	28.0339	80.5794	3.00	3.00	0.00	Hard
N631	28.0334	80.5797	2.44	2.44	0.00	Rock, under bridge
O630A	28.0335	80.5795	3.05	3.05	0.00	Between Markers 13-14, hard
O630	28.0336	80.5794	3.95	3.95	0.00	Hard
N628	28.0343	80.5797	0.54	0.54	0.00	Hard
P628	28.0342	80.5792	2.10	2.25	0.15	Sandy muck
P629	28.0339	80.5791	1.50	3.00	1.50	
P630	28.0336	80.5792	1.30	1.75	0.45	Sandy muck
O629A	28.0340	80.5795	1.25	1.25	0.00	Hard
O629B	28.0338	80.5795	1.10	1.10	0.00	Hard
N631A	28.0334	80.5797	4.00	4.20	0.20	Under east side of bridge, 20cm muck
N631B	28.0334	80.5798	3.10	3.45	0.35	Under west side of bridge
L632	28.0331	80.5803	2.92	2.92	0.00	Hard
K632	28.0331	80.5805	2.56	2.56	0.00	Hard
J631	28.0333	80.5808	3.00	3.00	0.00	Hard

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
I629	28.0339	80.5812	3.20	4.00	0.80	Very loose
J632	28.0331	80.5808	2.70	2.70	0.00	Hard
I631	28.0334	80.5813	2.90	2.90	0.00	Hard
H632	28.0331	80.5814	3.00	4.60	1.60	
H633	28.0328	80.5814	3.50	3.50	0.00	Hard
H634	28.0326	80.5815	4.00	4.50	0.50	
H635	28.0322	80.5814	3.30	4.10	0.80	
H636	28.0319	80.5814	3.90	4.50	0.60	
H637	28.0316	80.5813	1.40	2.70	1.30	
H637A	28.0316	80.5813	0.70	0.70	0.00	Hard
I637	28.0317	80.5811	3.50	4.70	1.20	
I636	28.0320	80.5811	3.60	4.75	1.15	
I635	28.0322	80.5811	3.45	4.36	0.91	
I634	28.0325	80.5811	4.40	4.60	0.20	Sandy
I633	28.0328	80.5811	3.38	3.38	0.00	Hard
I632	28.0331	80.5812	2.80	4.40	1.60	
K633	28.0328	80.5806	3.00	3.40	0.40	Very loose, fine, flocky
K634	28.0325	80.5806	3.00	3.03	0.03	Hard
K635	28.0323	80.5806	2.70	4.38	1.68	
J633	28.0329	80.5809	3.10	3.57	0.47	Mushy bottom
J634	28.0325	80.5808	3.00	3.05	0.05	Super soft top - flock. Super hard bottom
J635	28.0323	80.5808	2.55	4.25	1.70	
J636	28.0320	80.5809	3.00	4.95	1.95	
J637	28.0317	80.5809	3.45	3.45	0.00	Hard
J637A	28.0316	80.5808	1.10	2.20	1.10	
J638	28.0315	80.5808	0.55	2.20	1.65	Stiff sandy wet with brown muck (not gray muck)
G637	28.0317	80.5815	1.10	2.10	1.00	Shelly at 1.1, hard bottom
G637A	28.0317	80.5816	0.65	0.75	0.10	Shell hash
G636	28.0319	80.5817	2.70	4.05	1.35	
G635	28.0324	80.5817	2.95	3.35	0.40	Mushy
G633A	28.0327	80.5816	3.05	4.45	1.40	
G633	28.0328	80.5817	2.30	2.85	0.55	Shelly
G633B	28.0329	80.5818	2.80	4.45	1.65	
G631	28.0334	80.5817	1.80	2.60	0.80	
G631A	28.0334	80.5818	0.60	1.00	0.40	

Station	Latitude (˚N)	Longitude (˚W)	Water Depth (m)	Total Depth (m)	Muck Depth (m)	Comment
F636	28.0320	80.5820	1.70	2.90	1.20	Shell hash, stiff clay
F636A	28.0319	80.5820	0.70	0.70	0.00	Hard
E636	28.0319	80.5822	1.60	1.60	0.00	Hard: shell and gravel
E636A	28.0320	80.5823	2.00	2.80	0.80	Under middle trestle, stiff clay
F634	28.0325	80.5820	1.05	1.05	0.00	Sand/shell
F632	28.0330	80.5819	1.30	2.40	1.10	Really soft top
E631	28.0332	80.5821	0.90	2.00	1.10	Really soft
L637	28.0316	80.5802	1.60	3.25	1.65	
M638	28.0313	80.5801	1.70	3.00	1.30	
M639	28.0311	80.5800	1.50	2.25	0.75	
M640	28.0308	80.5800	1.30	2.03	0.73	Clay layer at 1.9
M639A	28.0311	80.5800	0.25	0.25	0.00	East side of canal, hard
M634	28.0324	80.5799	1.20	2.10	0.90	
L634	28.0325	80.5803	1.92	1.92	0.00	Hard
M633	28.0327	80.5800	1.05	1.05	0.00	Hard
H634	28.0326	80.5813	3.95	4.55	0.60	
N631C	28.0334	80.5797	3.55	4.15	0.60	Loose under US1

Appendix B. Selected Quality Assurance and Quality Control Data

Quality Assurance and Quality Control Data for Sediment Metal Analyses.

Results for the Standard Reference Material (SRM) #2704 Buffalo River Sediment certified by the National Institute of Standards and Technology (NIST), Certified Reference Material (CRM) MESS-3 Marine Sediment certified by the National Research Council of Canada (NRC), and LECO Calibration Material 502-509 (Lot 1012).

Reference Material	Al (%)	Fe (%)	Si (%)	TOC (%)	LOI (%)	CaCO3 (%)	N (%)	P (µg/g)
SRM #2704	6.14	4.17	29.13	-	-	-	-	983
This Study	6.04	4.17	28.96	-	-	-	-	1011
SRM #2704	6.11	4.11	29.08	3.348	-	-	-	998
NIST Certified Values	± 0.16	± 0.10	± 0.13	± 0.016	-	-	-	± 28
CRM MESS-3	-	-	-	2.03	-	-	0.17	-
This Study	-	-	-	2.04	-	-	0.14	-
	-	-	-	2.03	-	-	0.14	-
	-	-	-	2.01	-	-	0.16	-
CRM MESS-3	8.59	4.34	27*	2**	-	-	-	0.12*
NRC Certified Values	± 0.23	± 0.11	-	-	-	-	-	-
LECO 502-309	-	-	-	11.66	-	-	0.91	-
This Study	-	-	-	11.68	-	-	0.90	-
	-	-	-	11.75	-	-	0.90	-
LECO 502-309	-	-	-	11.98**	-	-	0.93	-
LECO Calibration Values	-	-	-	± 0.44	-	-	± 0.04	-

* Information Value. **Total carbon (organic plus inorganic).

Sediment Metal Analysis
(continued)

Method Detection Limits (MDLs).								
	Al (%)	Fe (%)	Si (%)	TOC (%)	LOI (%)	CaCO3 (%)	N (%)	P (µg/g)
Method Detection Limit	0.01	0.01	0.03	0.03	0.1	0.2	0.02	0.9

Percent Spike Recovery.								
	Al	Fe	Si	TOC	LOI	$CaCO_3$	N	P
K622	94.9	95.1	102.8	-	-	-	-	108.4

Estimate of Precision as Percent Relative Standard Deviation (RSD) of Lab Duplicates.								
	Al	Fe	Si	TOC	LOI	CaCO3	N	P
K615	3.4	1.9	0.4	1.6	2.0	0	0	2.3
TCK (18-20 cm)							0.4	
TC3 (8-10 cm)				2.0	0	5.8	0	

Percent RSD = (standard deviation / mean) X 100.

QA/QC Data for Dissolved Nutrients

Method Detection Limit (MDLs).

	Ammonium	Nitrate-Nitrite	Total Nitrogen	Phosphate	Total Phosphorus
	(µM)	(µM)	(µM)	(µM)	(µM)
Method Detection Limit	0.3	0.2	0.03*	0.04	0.03*

* MDL for SEAL AA3 Autoanalyzer

Estimate of Precision as the average ± SD of the Relative Standard Deviation (RSD) of Lab Duplicates. The number of duplicates is indicated in parenthesis

	Ammonium	Nitrate-Nitrite	Total Nitrogen	Phosphate	Total Phosphorus
Average ± SD of RSD	(10) 2.4 ± 3.8	(10) 6.1 ± 4.8	(10) 2.1 ± 1.8	(10) 0.6 ± 1.2	(11) 2.6 ± 2.4

Quality Assurance and Quality Control Data for Suspended Solids' Metals, Carbon and Nitrogen Analyses.

Results for the Standard Reference Material (SRM) #2704 Buffalo River Sediment certified by the National Institute of Standards and Technology (NIST) and Leco Calibration Material 502-309 (Lot 1012).

Standard Reference Material	Al (%)	Fe (%)	Si (%)	P (µg/g)	POC (%)	N (%)
SRM #2704	5.96	4.14	29.11	990	-	-
This Study	6.26	4.11	29.12	1025	-	-
	6.14	4.13	29.09	973	-	-
	6.19	4.16	29.39	1010	-	-
	6.16	4.11	29.04	1020	-	-
	6.10	4.19	29.11	1001	-	-
	6.15	4.12	29.01	1007	-	-
	6.05	4.10	29.04	984	-	-
	6.10	4.13	29.00	989	-	-
	6.01	4.11	29.00	1010	-	-
	5.99	4.04	29.15	975	-	-
	6.11	4.17	29.08	1023	-	-
	6.13	4.19	29.05	976	-	-
	6.08	4.13	28.89	1002	-	-
	6.22	4.20	29.11	992	-	-
	5.97	4.02	29.09	1014	-	-
	6.22	4.20	29.12	1015		
	6.23	4.18	29.17	1006		
SRM #2704	6.11	4.11	29.08	998	-	-
	±	±	±			
NIST Certified Values	0.16	0.10	0.13	± 28	-	-
LECO 502-309	-	-	-	-	11.7	0.90
This Study	-	-	-	-	11.7	0.90
	-	-	-	-	11.7	0.89
	-	-	-	-	11.7	0.90
	-	-	-	-	11.7	0.92
					11.7	0.91
					11.8	0.94
LECO 502-309	-	-	-	-	11.98*	0.93
LECO Calibration Values	-	-	-	-	±0.44	± 0.04

* Total carbon (organic and inorganic).

Brevard County: Turkey Creek 2015

Quality Assurance and Quality Control Data for Suspended Solids' Metals, Carbon and Nitrogen Analyses.

Method Detection Limits (MDLs).

	Al (%)	Fe (%)	Si (%)	P (%)	POC (%)	N (%)
Particulate Method Detection Limit*	0.03	0.03	0.43	0.001	0.1	0.5
	(μg/L)	(μg/L)	(μg/L)	(μg/L)	DOC (mg/L)	(μg/L)
Dissolved Method Detection Limit	-	-	-	-	0.2	-

* Based on 1 mg of suspended matter.

Percent Spike Recovery.

	Al	Fe	Si	P
Particulate Metals	95.6	93.3	100.3	103.7
Mean	94.5	96.7	99.4	105.1
Standard Deviation	97.7	91.8	101.8	92.0
(n =)	94.7	96.2	93.9	93.3
	102.4	96.4	94.8	102.2
	92.9	93.5	99.7	93.9
	99.3	94.5	101.8	97.2
	99.0	97.6	96.1	94.7
	99.0	103.3	94.8	105.8
	102.0	97.3	96.7	94.2
	92.7	93.8	100.3	101.1
	99.7	94.3	96.0	94.7
	97.8	103.8	95.6	108.1
	101.5	93.9	98.2	92.2
	97.4	97.0	101.3	95.5
	97.0	93.5	97.2	93.4
	103.9	93.8	95.4	104.7
	98.2	94.9	98.1	92.0

Brevard County: Turkey Creek 2015

Quality Assurance and Quality Control Data for Suspended
Solids' Metals, Carbon and Nitrogen Analyses.

Estimate of Precision as Percent Relative Standard Deviation (RSD) of Lab and Field Duplicates.

	Al	Fe	Si	P	POC	N	DOC
TC4 (0.5 m) 5-4-15	0.3	4.6	0.5	6.6	2.4	4.2	1.1
TC4 (0.5 m) 6-16-15	-	-	-	-	-	-	0
TC2 (0.5 m) 7-16-15	1.7	2.8	1.6	1.1	0.2	1.3	1.7
TC1 (0.5 m) 9-9-15	3.1	4.2	3.1	6.8	3.4	8.0	4.5
TC1 (0.5 m) 10-14-15	0	8.5	3.4	4.4	1.0	0	1.3
TC3 (0.5 m) 12-14-15	4.7	2.9	2.3	0	0	2.3	0

Percent RSD = (standard deviation / mean) X 100.

Appendix C1. Concentrations of dissolved and particulate parameters for Stations 1-5 for April 22, 2015.

Brevard County: Turkey Creek, April 22, 2015 — Page 1 of 4

Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-$CaCO_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.419'N	0.5	4.9	0.81	38.8	0.57	1.13	0.92	117	23.6	27.7	72.9	5.03	7.24
	80° 34.574'W	1.0	6.2	0.49	40.4	0.78	1.45	0.99	123	24.1	27.9	71.3	4.89	7.28
		1.75	7.1	0.59	36.7	0.92	1.51	1.03	119	24.7	28.1	68.0	4.63	7.36
TC2	28° 02.334'N	0.5	5.2	0.51	37.8	0.63	1.34	0.95	120	23.9	28.1	71.3	4.88	7.31
	80° 34.748'W	1.0	5.6	0.49	37.4	0.70	1.31	0.86	122	24.1	28.1	67.6	4.62	7.33
		1.3	5.7	0.50	36.7	0.73	1.32	0.69	125	24.2	28.1	66.7	4.56	7.35
TC3	28° 02.267'N	0.5	4.6	0.43	44.1	0.62	1.77	1.05	137	23.6	28.2	71.8	4.92	7.36
	80° 34.828'W	0.9	4.5	0.40	36.3	0.52	1.25	0.90	133	23.8	28.2	69.3	4.74	7.37
TC4	28° 02.147'N	0.5	3.6	0.30	40.4	0.57	1.59	0.96	131	23.5	28.8	79.7	5.40	7.50
	80° 34.853'W	1.0	4.0	0.32	21.4	0.62	1.48	0.87	133	23.7	28.5	74.0	5.04	7.44
		2.0	5.6	0.83	54.2	1.29	3.48	1.02	134	24.8	28.8	42.0	2.82	7.27
		3.25	2.8	0.39	32.5	1.91	2.36	0.86	137	25.2	28.9	5.3	0.36	7.01
TC5	28° 01.953'N	0.5	5.3	1.63	36.8	1.06	1.63	1.27	164	7.3	27.7	75.0	5.67	7.06
	80° 34.852'W	1.0	6.1	0.57	40.5	1.11	2.02	0.95	133	23.6	28.6	65.5	4.45	7.19
		2.5	12.8	0.52	45.7	5.50	5.68	0.84	143	25.2	29.1	8.4	0.56	7.05

*Sonde

Brevard County: Turkey Creek, April 22, 2015 — Page 2 of 4

Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg $CaCO_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.419'N	0.5	68.6	11.3	543	17.7	35.1	11.0	117	23.6	27.7	72.9	5.03	7.24
	80° 34.574'W	1.0	86.9	6.9	567	24.1	45.0	11.9	123	24.1	27.9	71.3	4.89	7.28
		1.75	99.5	8.2	514	28.5	46.8	12.4	119	24.7	28.1	68.0	4.63	7.36
TC2	28° 02.334'N	0.5	72.9	7.2	530	19.6	41.4	11.4	120	23.9	28.1	71.3	4.88	7.31
	80° 34.748'W	1.0	78.5	6.8	524	21.8	40.7	10.3	122	24.1	28.1	67.6	4.62	7.33
		1.3	79.9	7.0	514	22.6	40.8	8.3	125	24.2	28.1	66.7	4.56	7.35
TC3	28° 02.267'N	0.5	64.4	6.1	618	19.4	55.0	12.6	137	23.6	28.2	71.8	4.92	7.36
	80° 34.828'W	0.9	63.0	5.5	509	16.1	38.6	10.8	133	23.8	28.2	69.3	4.74	7.37
TC4	28° 02.147'N	0.5	50.4	4.2	565	17.7	49.4	11.5	131	23.5	28.8	79.7	5.40	7.50
	80° 34.853'W	1.0	56.0	4.5	300	19.4	45.7	10.4	133	23.7	28.5	74.0	5.04	7.44
		2.0	78.5	11.6	759	39.9	107.9	12.2	134	24.8	28.8	42.0	2.82	7.27
		3.25	39.2	5.5	455	59.2	73.2	10.3	137	25.2	28.9	5.3	0.36	7.01
TC5	28° 01.953'N	0.5	74.3	22.9	515	32.8	50.4	15.3	164	7.3	27.7	75.0	5.67	7.06
	80° 34.852'W	1.0	85.5	7.9	568	34.5	62.5	11.4	133	23.6	28.6	65.5	4.45	7.19
		2.5	179	7.3	640	170.3	176.1	10.1	143	25.2	29.1	8.4	0.56	7.05

*Sonde

Appendix C1 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for April 22, 2015.

Brevard County: Turkey Creek, April 22, 2015 Page 3 of 4

Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (μM)	POC (%)	POC (mM)	PON (%)	PON (μM)
TC1	28° 02.419'N	0.5	3.2	1.9	25.0	2.09	2.27	12.8	0.4	0.41	19.5	0.052	3.4	7.7
	80° 34.574'W	1.0	3.9	1.8	25.0	1.87	1.93	11.8	0.5	0.57	18.0	0.059	2.6	7.3
		1.75	3.9	2.2	26.0	1.29	2.27	14.4	0.3	0.37	16.5	0.054	2.7	7.6
TC2	28° 02.334'N	0.5	3.0	1.4	26.0	2.21	2.28	13.5	0.4	0.39	20.2	0.050	4.0	8.5
	80° 34.748'W	1.0	4.2	2.2	26.0	1.76	2.12	13.6	0.4	0.52	14.9	0.052	3.0	8.9
		1.3	4.1	2.2	26.0	1.61	2.29	14.1	0.4	0.49	14.3	0.049	2.2	6.5
TC3	28° 02.267'N	0.5	4.9	2.3	24.0	1.50	2.04	9.8	0.6	0.88	17.8	0.073	4.8	16.9
	80° 34.828'W	0.9	8.4	4.1	25.0	3.20	2.79	16.0	0.3	0.78	11.7	0.082	1.8	10.8
TC4	28° 02.147'N	0.5	5.9	3.5	25.0	1.40	1.90	9.6	0.7	1.27	18.4	0.090	5.6	23.4
	80° 34.853'W	1.0	4.7	3.1	26.0	2.02	2.38	11.8	0.6	0.83	25.3	0.098	5.2	17.3
		2.0	29.1	4.5	26.0	0.18	0.19	1.0	0.7	6.29	44.4	1.074	10.8	224
		3.3	2.6	1.6	28.0	1.57	2.32	9.1	0.8	0.63	34.5	0.074	7.4	13.7
TC5	28° 01.953'N	0.5	4.0	3.1	5.0	2.39	5.42	11.5	0.7	0.87	22.5	0.076	3.8	11.0
	80° 34.852'W	1.0	3.5	2.7	25.0	1.60	2.72	9.6	0.6	0.71	27.2	0.079	5.5	13.7
		2.5	4.2	2.4	28.0	1.21	3.69	9.0	0.8	1.04	23.9	0.084	4.5	13.6

*Refractometer

Brevard County: Turkey Creek, April 22, 2015 Page 4 of 4

Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (μg/L)	POC (%)	POC (mg/L)	PON (%)	PON (μg/L)
TC1	28° 02.419'N	0.5	3.2	1.9	25.0	2.09	2.27	12.8	0.4	12.7	19.5	0.6	3.4	108
	80° 34.574'W	1.0	3.9	1.8	25.0	1.87	1.93	11.8	0.5	17.7	18.0	0.7	2.6	102
		1.75	3.9	2.2	26.0	1.29	2.27	14.4	0.3	11.4	16.5	0.6	2.7	106
TC2	28° 02.334'N	0.5	3.0	1.4	26.0	2.21	2.28	13.5	0.4	12.2	20.2	0.6	4.0	119
	80° 34.748'W	1.0	4.2	2.2	26.0	1.76	2.12	13.6	0.4	16.2	14.9	0.6	3.0	125
		1.3	4.1	2.2	26.0	1.61	2.29	14.1	0.4	15.3	14.3	0.6	2.2	90.7
TC3	28° 02.267'N	0.5	4.9	2.3	24.0	1.50	2.04	9.8	0.6	27.1	17.8	0.9	4.8	237
	80° 34.828'W	0.9	8.4	4.1	25.0	3.20	2.79	16.0	0.3	24.3	11.7	1.0	1.8	151
TC4	28° 02.147'N	0.5	5.9	3.5	25.0	1.40	1.90	9.6	0.7	39.3	18.4	1.1	5.6	328
	80° 34.853'W	1.0	4.7	3.1	26.0	2.02	2.38	11.8	0.6	25.7	25.3	1.2	5.2	243
		2.0	29.1	4.5	26.0	0.18	0.19	1.0	0.7	194.7	44.4	12.9	10.8	3138
		3.25	2.6	1.6	28.0	1.57	2.32	9.1	0.8	19.4	34.5	0.9	7.4	192
TC5	28° 01.953'N	0.5	4.0	3.1	5.0	2.39	5.42	11.5	0.7	27.1	22.5	0.9	3.8	154
	80° 34.852'W	1.0	3.5	2.7	25.0	1.60	2.72	9.6	0.6	22.1	27.2	1.0	5.5	193
		2.5	4.2	2.4	28.0	1.21	3.69	9.0	0.8	32.1	23.9	1.0	4.5	190

* Refractometer

Appendix C2. Concentrations of dissolved and particulate parameters for Stations 1-5 for May 4, 2015.

Brevard County: Turkey Creek, May 04, 2015 — Page 1 of 4

Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-$CaCO_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.421'N	0.5	6.9	0.35	33.7	0.23	0.87	0.85	128	25.8	24.2	96.2	6.96	8.24
	80° 34.638'W	1.0	7.0	0.36	34.4	0.25	0.86	0.85	130	25.8	24.2	97.3	7.04	8.21
		1.75	6.9	0.22	33.4	0.24	0.94	0.82	130	25.8	24.2	96.9	7.01	8.19
TC2	28° 02.336'N	0.5	6.7	0.33	34.4	0.20	0.87	0.87	136	20.5	24.8	82.3	6.08	8.00
	80° 34.762'W	1.0	5.5	0.18	35.2	0.19	0.74	0.87	129	25.3	24.1	88.1	6.40	8.19
		1.3	6.9	0.46	33.8	0.19	0.65	0.80	141	25.4	24.2	86.8	6.30	8.18
TC3	28° 02.273'N	0.5	3.3	0.62	35.4	0.54	1.31	1.06	168	16.4	24.4	78.3	5.96	7.89
	80° 34.830'W	0.9	6.9	0.46	34.6	0.19	0.85	0.84	132	24.3	24.9	67.5	4.86	8.00
TC4	28° 02.145'N	0.5	3.2	0.67	35.3	0.59	1.26	1.08	176	15.9	25.2	83.8	6.30	7.82
	80° 34.853'W	1.0	7.6	0.36	38.1	0.34	1.35	1.01	133	24.4	26.2	79.4	5.60	7.98
		2.0	10.0	0.42	40.2	0.49	1.35	0.92	127	25.1	25.9	73.2	5.17	7.99
		3.0	11.5	0.27	43.0	0.77	1.58	0.95	133	25.2	25.8	66.0	4.66	7.97
TC5	28° 01.944'N	0.5	3.8	0.48	37.8	0.85	1.66	1.13	175	17.8	26.2	77.6	5.67	7.81
	80° 34.876'W	1.0	9.0	0.30	41.3	1.35	2.31	1.01	133	23.6	26.6	62.1	4.37	7.90
		2.5	12.4	0.25	46.6	2.39	2.98	0.93	131	25.2	26.4	53.3	3.73	7.88

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg $CaCO_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.421'N	0.5	96.7	5.0	472	7.2	27.1	10.2	128	25.8	24.2	96.2	6.96	8.24
	80° 34.638'W	1.0	98.1	5.1	482	7.9	26.6	10.2	130	25.8	24.2	97.3	7.04	8.21
		1.75	96.7	3.1	468	7.6	29.0	9.8	130	25.8	24.2	96.9	7.01	8.19
TC2	28° 02.336'N	0.5	93.9	4.6	482	6.3	26.9	10.4	136	20.5	24.8	82.3	6.08	8.00
	80° 34.762'W	1.0	77.1	2.6	493	6.0	23.0	10.4	129	25.3	24.1	88.1	6.40	8.19
		1.3	96.7	6.4	474	6.0	20.0	9.6	141	25.4	24.2	86.8	6.30	8.18
TC3	28° 02.273'N	0.5	46.2	8.8	496	16.8	40.6	12.7	168	16.4	24.4	78.3	5.96	7.89
	80° 34.830'W	0.9	96.7	6.4	484	6.0	26.4	10.1	132	24.3	24.9	67.5	4.86	8.00
TC4	28° 02.145'N	0.5	44.1	9.3	495	18.4	39.0	13.0	176	15.9	25.2	83.8	6.30	7.82
	80° 34.853'W	1.0	106	5.1	533	10.4	42.0	12.1	133	24.4	26.2	79.4	5.60	7.98
		2.0	140	5.8	563	15.2	41.7	11.0	127	25.1	25.9	73.2	5.17	7.99
		3.0	161	3.7	602	23.9	49.0	11.4	133	25.2	25.8	66.0	4.66	7.97
TC5	28° 01.944'N	0.5	53.2	6.7	530	26.4	51.5	13.6	175	17.8	26.2	77.6	5.67	7.81
	80° 34.876'W	1.0	126	4.2	578	41.9	71.5	12.1	133	23.6	26.6	62.1	4.37	7.90
		2.5	174	3.4	653	74.0	92.2	11.2	131	25.2	26.4	53.3	3.73	7.88

*Sonde

Appendix C2 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for May 4, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µM)	POC (%)	POC (mM)	PON (%)	PON (µM)
TC1	28° 02.421'N	0.5	4.3	2.3	25.0	2.52	2.32	17.8	0.3	0.45	13.5	0.049	2.7	8.4
	80° 34.638'W	1.0	4.5	2.5	24.0	2.22	2.42	17.9	0.3	0.45	13.7	0.052	2.7	8.7
		1.75	4.7	2.5	24.0	2.14	2.38	17.9	0.3	0.47	14.0	0.055	3.9	13.2
TC2	28° 02.336'N	0.5	14.1	8.8	24.0	2.20	3.07	19.1	0.3	1.14	10.3	0.121	1.5	15.1
	80° 34.762'W	1.0	14.0	9.1	24.0	3.15	3.50	19.1	0.2	1.04	14.3	0.166	2.1	20.9
		1.3	30.2	20.1	24.0	2.84	3.27	18.8	0.2	1.85	13.8	0.347	3.9	84.1
TC3	28° 02.273'N	0.5	6.3	3.2	11.0	2.51	3.07	13.8	0.4	0.79	11.3	0.059	1.9	8.5
	80° 34.830'W	0.9	53.4	24.2	24.0	2.81	3.32	19.9	0.2	3.28	9.6	0.427	1.8	68.6
TC4	28° 02.145'N	0.5	4.7	3.4	12.0	2.46	4.31	15.4	0.5	0.82	17.7	0.070	3.4	11.5
	80° 34.853'W	1.0	7.9	3.7	22.0	2.46	2.95	14.7	0.5	1.35	16.1	0.105	3.2	18.0
		2.0	5.0	3.1	24.0	2.04	2.66	15.1	0.5	0.80	19.2	0.081	4.4	15.8
		3.0	6.2	3.6	24.0	1.83	2.83	14.9	0.5	1.03	16.9	0.087	3.4	14.9
TC5	28° 01.944'N	0.5	4.0	3.2	12.0	2.06	3.88	11.5	0.8	0.97	25.6	0.084	5.0	14.1
	80° 34.876'W	1.0	4.3	2.5	22.0	1.68	2.60	13.9	0.7	0.95	24.3	0.087	5.0	15.4
		2.5	5.6	4.2	25.0	2.16	3.32	15.6	0.6	1.04	18.3	0.085	3.6	14.3

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µg/L)	POC (%)	POC (mg/L)	PON (%)	PON (µg/L)
TC1	28° 02.421'N	0.5	4.3	2.3	25.0	2.52	2.32	17.8	0.3	13.9	13.5	0.6	2.7	117
	80° 34.638'W	1.00	4.5	2.5	24.0	2.22	2.42	17.9	0.3	14.0	13.7	0.6	2.7	122
		1.8	4.7	2.5	24.0	2.14	2.38	17.9	0.3	14.7	14.0	0.7	3.9	185
TC2	28° 02.336'N	0.5	14.1	8.8	24.0	2.20	3.07	19.1	0.3	35.3	10.3	1.5	1.5	212
	80° 34.762'W	1.0	14.0	9.1	24.0	3.15	3.50	19.1	0.2	32.1	14.3	2.0	2.1	293
		1.3	30.2	20.1	24.0	2.84	3.27	18.8	0.2	57.4	13.8	4.2	3.9	1180
TC3	28° 02.273'N	0.5	6.3	3.2	11.0	2.51	3.07	13.8	0.4	24.5	11.3	0.7	1.9	119
	80° 34.830'W	0.9	53.4	24.2	24.0	2.81	3.32	19.9	0.2	101.4	9.6	5.1	1.8	961
TC4	28° 02.145'N	0.5	4.7	3.4	12.0	2.46	4.31	15.4	0.5	25.4	17.7	0.8	3.4	161
	80° 34.853'W	1.0	7.9	3.7	22.0	2.46	2.95	14.7	0.5	41.7	16.1	1.3	3.2	252
		2.0	5.0	3.1	24.0	2.04	2.66	15.1	0.5	24.7	19.2	1.0	4.4	222
		3.0	6.2	3.6	24.0	1.83	2.83	14.9	0.5	32.0	16.9	1.0	3.4	209
TC5	28° 01.944'N	0.5	4.0	3.2	12.0	2.06	3.88	11.5	0.8	30.0	25.6	1.0	5.0	198
	80° 34.876'W	1.0	4.3	2.5	22.0	1.68	2.60	13.9	0.7	29.3	24.3	1.0	5.0	216
		2.5	5.6	4.2	25.0	2.16	3.32	15.6	0.6	32.3	18.3	1.0	3.6	201

* Refractometer

Appendix C3. Concentrations of dissolved and particulate parameters for Stations 1-5 for June 16, 2015.

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Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.416'N	0.5	2.6	0.24	38.7	0.14	0.57	0.81	122	22.4	29.6	89.2	6.00	8.01
	80° 34.577'W	1.0	2.5	0.37	38.1	0.20	0.64	0.85	123	23.1	30.2	99.9	6.62	8.01
		1.5	2.5	0.25	37.9	0.15	0.54	0.79	127	23.5	30.2	99.4	6.58	8.00
		1.75	2.7	0.32	36.9	0.20	0.62	0.72	128	24.0	30.4	92.0	6.06	7.97
TC2	28° 02.332'N	0.5	2.3	0.37	37.7	0.14	0.58	0.97	128	22.2	29.9	90.6	6.08	7.95
	80° 34.749'W	1.25	2.5	0.28	36.9	0.16	0.58	0.92	125	23.5	30.5	87.1	5.74	7.94
TC3	28° 02.266'N	0.5	-	-	-	-	-	-	-	21.7	30.4	98.8	6.58	7.96
	80° 34.831'W	0.9	-	-	-	-	-	-	-	22.9	30.7	95.7	6.31	7.96
TC4	28° 02.148'N	0.5	2.4	0.32	37.9	0.21	0.66	0.74	127	23.4	30.4	90.1	5.95	8.00
	80° 34.852'W	1.0	2.6	0.33	38.4	0.18	0.75	1.05	125	23.5	30.7	88.1	5.79	7.99
		2.0	2.9	0.31	39.1	0.42	1.09	0.68	131	25.0	31.5	60.0	3.85	7.99
		2.5	4.3	0.27	48.7	0.98	2.66	0.87	134	25.1	31.3	41.8	2.69	7.85
		3.0	3.6	0.32	43.3	1.12	1.91	0.72	135	25.1	31.0	18.9	1.22	7.70
TC5	28° 01.954'N	0.5	4.2	0.67	45.3	0.71	1.41	1.02	168	4.3	30.2	81.7	6.02	7.70
	80° 34.850'W	1.0	3.0	0.34	38.7	0.46	1.40	0.85	125	12.6	30.8	82.9	5.77	7.58
		2.0	3.4	0.32	40.7	1.30	2.58	0.78	130	23.7	30.5	54.6	3.59	7.76
		2.5	5.2	0.29	52.7	1.61	3.90	1.08	135	23.7	30.4	42.5	2.81	7.64

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.416'N	0.5	36.4	3.3	542	4.4	17.6	9.7	122	22.4	29.6	89.2	6.00	8.01
	80° 34.577'W	1.0	35.0	5.1	533	6.3	19.7	10.2	123	23.1	30.2	99.9	6.62	8.01
		1.5	35.0	3.5	531	4.7	16.9	9.5	127	23.5	30.2	99.4	6.58	8.00
		1.75	37.8	4.4	517	6.3	19.2	8.6	128	24.0	30.4	92.0	6.06	7.97
TC2	28° 02.332'N	0.5	32.2	5.1	528	4.4	18.0	11.7	128	22.2	29.9	90.6	6.08	7.95
	80° 34.749'W	1.25	35.0	3.9	516	5.0	18.0	11.1	125	23.5	30.5	87.1	5.74	7.94
TC3	28° 02.266'N	0.5	-	-	-	-	-	-	-	21.7	30.4	98.8	6.58	7.96
	80° 34.831'W	0.9	-	-	-	-	-	-	-	22.9	30.7	95.7	6.31	7.96
TC4	28° 02.148'N	0.5	33.6	4.5	531	6.4	20.5	8.9	127	23.4	30.4	90.1	5.95	8.00
	80° 34.852'W	1.0	36.4	4.6	538	5.4	23.1	12.6	125	23.5	30.7	88.1	5.79	7.99
		2.0	40.6	4.4	547	13.1	33.7	8.2	131	25.0	31.5	60.0	3.85	7.99
		2.5	60.2	3.8	683	30.5	82.3	10.4	134	25.1	31.3	41.8	2.69	7.85
		3.0	50.4	4.5	607	34.8	59.2	8.7	135	25.1	31.0	18.9	1.22	7.70
TC5	28° 01.954'N	0.5	58.8	9.4	635	22.0	43.8	12.3	168	4.3	30.2	81.7	6.02	7.70
	80° 34.850'W	1.0	42.0	4.7	542	14.4	43.4	10.2	125	12.6	30.8	82.9	5.77	7.58
		2.0	47.6	4.5	570	40.2	80.0	9.4	130	23.7	30.5	54.6	3.59	7.76
		2.5	72.9	4.1	738	49.8	120.9	13.0	135	23.7	30.4	42.5	2.81	7.64

*Sonde

Appendix C3 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for June 16, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (μM)	POC (%)	POC (mM)	PON (%)	PON (μM)
TC1	28° 02.416'N	0.5	2.2	1.1	24.0	1.43	1.87	16.8	0.5	0.32	19.6	0.036	4.0	6.4
	80° 34.577'W	1.0	2.4	0.9	24.5	2.64	2.24	18.1	0.4	0.31	20.7	0.041	3.9	6.7
		1.5	4.3	2.0	25.0	3.43	2.91	22.3	0.3	0.35	15.5	0.056	2.6	8.0
		1.75	8.9	4.4	26.0	3.33	3.40	20.1	0.2	0.69	11.4	0.084	3.3	21.0
TC2	28° 02.332'N	0.5	2.2	1.0	25.0	2.80	1.82	15.0	0.5	0.32	24.7	0.046	4.2	6.6
	80° 34.749'W	1.25	3.7	2.0	25.5	2.46	1.91	15.0	0.5	0.56	24.4	0.074	4.1	10.7
TC3	28° 02.266'N	0.5	-	-	-	-	-	-	-	-	-	-	-	-
	80° 34.831'W	0.9	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.148'N	0.5	3.3	1.6	24.0	2.67	2.11	13.7	0.6	0.60	22.2	0.060	6.4	14.9
	80° 34.852'W	1.0	5.1	2.7	26.0	1.88	1.55	11.0	0.6	0.95	26.7	0.114	3.8	13.9
		2.0	6.7	3.2	27.0	2.13	1.84	11.1	0.7	1.44	25.2	0.140	6.0	28.5
		2.5	8.0	2.8	27.5	1.21	1.23	6.7	1.0	2.54	22.5	0.149	4.3	24.4
		3.0	4.9	1.5	27.5	1.36	1.74	9.8	1.0	1.57	19.5	0.079	3.8	13.2
TC5	28° 01.954'N	0.5	8.5	4.6	10.0	1.28	2.45	7.4	1.2	3.25	22.9	0.163	3.8	23.1
	80° 34.850'W	1.0	5.3	2.7	26.0	2.05	2.33	11.4	0.7	1.20	17.7	0.078	3.0	11.4
		2.0	4.0	2.5	26.5	1.62	2.65	10.9	0.8	1.06	19.7	0.065	4.5	12.7
		2.5	6.6	3.6	26.5	0.66	1.39	5.1	1.1	2.22	22.8	0.125	3.2	15.0

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (μg/L)	POC (%)	POC (mg/L)	PON (%)	PON (μg/L)
TC1	28° 02.416'N	0.5	2.2	1.1	24.0	1.43	1.87	16.8	0.5	10.1	19.6	0.4	4.0	89.4
	80° 34.577'W	1.0	2.4	0.9	24.5	2.64	2.24	18.1	0.4	9.6	20.7	0.5	3.9	93.2
		1.5	4.3	2.0	25.0	3.43	2.91	22.3	0.3	10.8	15.5	0.7	2.6	112
		1.75	8.9	4.4	26.0	3.33	3.40	20.1	0.2	21.4	11.4	1.0	3.3	294
TC2	28° 02.332'N	0.5	2.2	1.0	25.0	2.80	1.82	15.0	0.5	10.0	24.7	0.5	4.2	93.1
	80° 34.749'W	1.25	3.7	2.0	25.5	2.46	1.91	15.0	0.5	17.2	24.4	0.9	4.1	150
TC3	28° 02.266'N	0.5	-	-	-	-	-	-	-	-	-	-	-	-
	80° 34.831'W	0.9	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.148'N	0.5	3.3	1.6	24.0	2.67	2.11	13.7	0.6	18.6	22.2	0.7	6.4	208
	80° 34.852'W	1.0	5.1	2.7	26.0	1.88	1.55	11.0	0.6	29.3	26.7	1.4	3.8	195
		2.0	6.7	3.2	27.0	2.13	1.84	11.1	0.7	44.6	25.2	1.7	6.0	399
		2.5	8.0	2.8	27.5	1.21	1.23	6.7	1.0	78.7	22.5	1.8	4.3	342
		3.0	4.9	1.5	27.5	1.36	1.74	9.8	1.0	48.7	19.5	0.9	3.8	185
TC5	28° 01.954'N	0.5	8.5	4.6	10.0	1.28	2.45	7.4	1.2	100.7	22.9	2.0	3.8	324
	80° 34.850'W	1.0	5.3	2.7	26.0	2.05	2.33	11.4	0.7	37.2	17.7	0.9	3.0	159
		2.0	4.0	2.5	26.5	1.62	2.65	10.9	0.8	32.9	19.7	0.8	4.5	179
		2.5	6.6	3.6	26.5	0.66	1.39	5.1	1.1	68.9	22.8	1.5	3.2	210

* Refractometer

Appendix C4. Concentrations of dissolved and particulate parameters for Stations 1-5 for July 16, 2015.

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Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-$CaCO_3$/L)	Salinity *	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.420'N	0.5	2.2	0.33	41.9	0.49	1.36	1.39	121	26.7	29.0	52.0	3.46	7.99
	80° 34.586'W	1.0	3.7	0.37	40.8	0.52	1.36	1.05	131	28.2	29.7	54.8	3.57	7.99
		1.5	3.7	0.42	40.3	0.52	1.44	1.09	140	28.3	29.7	44.7	2.91	7.99
		1.75	3.9	0.38	48.8	0.56	1.46	1.20	132	28.3	29.7	44.1	2.87	7.99
TC2	28° 02.333'N	0.5	3.7	0.29	41.9	0.51	1.45	1.03	131	27.1	29.1	47.2	3.12	7.96
	80° 34.753'W	1.25	3.8	0.29	50.7	0.57	1.61	1.15	133	28.2	29.8	38.5	2.50	7.96
TC3	28° 02.269'N	0.5	-	-	-	-	-	-	-	26.0	29.6	40.9	2.69	7.89
	80° 34.830'W	0.9	-	-	-	-	-	-	-	27.7	29.8	36.8	2.40	7.93
TC4	28° 02.146'N	0.5	4.9	0.28	67.2	1.17	2.64	1.11	126	-	-	-	-	-
	80° 34.850'W	1.0	3.8	0.36	56.5	0.76	2.15	1.03	128	Sonde malfunctioned in field				
		2.0	4.1	0.30	55.4	0.69	1.71	1.05	134	-	-	-	-	-
		2.5	4.2	0.40	64.1	0.67	1.70	1.04	132	-	-	-	-	-
		3.0	4.4	0.30	59.3	0.78	1.89	0.97	141	-	-	-	-	-
TC5	28° 01.949'N	0.5	8.2	0.80	71.7	1.66	2.95	1.32	156	-	-	-	-	-
	80° 34.853'W	1.0	6.3	0.38	66.7	1.06	2.30	1.00	137	-	-	-	-	-
		2.0	4.2	0.36	56.0	0.79	1.69	0.98	135	-	-	-	-	-
		2.5	5.0	0.26	64.4	0.78	1.90	1.00	136	-	-	-	-	-

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg $CaCO_3$/L)	Salinity *	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.420'N	0.5	30.8	4.6	587	15.3	42.1	16.7	121	26.7	29.0	52.0	3.46	7.99
	80° 34.586'W	1.0	51.8	5.1	572	16.2	42.1	12.6	131	28.2	29.7	54.8	3.57	7.99
		1.5	51.8	5.9	565	16.2	44.5	13.1	140	28.3	29.7	44.7	2.91	7.99
		1.75	54.6	5.3	684	17.2	45.3	14.4	132	28.3	29.7	44.1	2.87	7.99
TC2	28° 02.333'N	0.5	51.8	4.1	587	15.8	45.1	12.4	131	27.1	29.1	47.2	3.12	7.96
	80° 34.753'W	1.25	53.2	4.1	710	17.5	49.8	13.8	133	28.2	29.8	38.5	2.50	7.96
TC3	28° 02.269'N	0.5	-	-	-	-	-	-	-	26.0	29.6	40.9	2.69	7.89
	80° 34.830'W	0.9	-	-	-	-	-	-	-	27.7	29.8	36.8	2.40	7.93
TC4	28° 02.146'N	0.5	68.6	3.9	942	36.2	81.7	13.3	126	-	-	-	-	-
	80° 34.850'W	1.0	53.2	5.1	792	23.6	66.7	12.4	128	Sonde malfunctioned in field				
		2.0	57.4	4.3	776	21.4	53.1	12.6	134	-	-	-	-	-
		2.5	58.8	5.6	898	20.7	52.7	12.5	132	-	-	-	-	-
		3.0	61.6	4.2	831	24.3	58.5	11.7	141	-	-	-	-	-
TC5	28° 01.949'N	0.5	115	11.2	1010	51.6	91.4	15.9	156	-	-	-	-	-
	80° 34.853'W	1.0	88.3	5.3	934	32.9	71.3	12.0	137	-	-	-	-	-
		2.0	58.8	5.0	785	24.5	52.5	11.8	135	-	-	-	-	-
		2.5	70.1	3.7	902	24.2	58.8	12.0	136	-	-	-	-	-

*Sonde

Appendix C4 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for July 16, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (μM)	POC (%)	POC (mM)	PON (%)	PON (μM)
TC1	28° 02.420'N	0.5	5.6	4.0	28.0	1.97	1.61	7.6	0.6	1.07	29.3	0.137	4.6	18.5
	80° 34.586'W	1.0	7.1	4.2	30.0	2.22	1.74	10.3	0.5	1.23	24.9	0.147	4.4	22.2
		1.5	7.8	5.1	31.0	1.96	1.85	10.9	0.5	1.20	23.0	0.149	3.9	21.6
		1.75	8.2	5.5	31.0	1.93	1.77	10.1	0.5	1.27	22.6	0.155	3.9	22.9
TC2	28° 02.333'N	0.5	6.8	4.9	29.0	1.67	1.53	7.8	0.6	1.41	30.4	0.172	5.3	25.4
	80° 34.753'W	1.25	7.6	4.8	30.0	1.87	1.76	10.0	0.6	1.42	25.7	0.162	4.3	23.2
TC3	28° 02.269'N	-	-	-	-	-	-	-	-	-	-	-	-	-
	80° 34.830'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.146'N	0.5	9.8	3.4	29.5	0.84	0.87	3.8	0.9	2.94	26.4	0.215	6.2	43.3
	80° 34.850'W	1.0	8.9	3.6	30.0	0.82	0.93	4.4	0.9	2.45	32.2	0.239	6.2	39.4
		2.0	9.5	4.3	30.0	1.07	1.09	5.4	0.7	2.18	27.0	0.214	4.9	33.2
		2.5	9.8	4.0	30.0	1.01	1.19	6.2	0.7	2.32	27.4	0.224	5.0	35.1
		3.0	8.3	3.7	30.0	1.47	1.27	7.6	0.7	1.75	27.7	0.192	5.0	29.7
TC5	28° 01.949'N	0.5	6.5	2.8	15.5	1.76	2.75	7.3	0.9	1.82	28.9	0.158	5.3	24.8
	80° 34.853'W	1.0	7.5	3.1	29.0	0.74	1.01	4.0	0.9	2.05	33.7	0.209	8.1	43.1
		2.0	6.8	3.5	30.0	1.16	1.06	5.4	0.7	1.53	32.3	0.182	5.8	28.0
		2.5	8.1	3.8	30.0	1.28	1.34	5.8	0.8	2.01	27.6	0.186	5.2	30.0

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (μg/L)	POC (%)	POC (mg/L)	PON (%)	PON (μg/L)
TC1	28° 02.420'N	0.5	5.6	4.0	28.0	1.97	1.61	7.6	0.6	33.2	29.3	1.6	4.6	259
	80° 34.586'W	1.0	7.1	4.2	30.0	2.22	1.74	10.3	0.5	38.2	24.9	1.8	4.4	311
		1.5	7.8	5.1	31.0	1.96	1.85	10.9	0.5	37.2	23.0	1.8	3.9	302
		1.75	8.2	5.5	31.0	1.93	1.77	10.1	0.5	39.4	22.6	1.9	3.9	320
TC2	28° 02.333'N	0.5	6.8	4.9	29.0	1.67	1.53	7.8	0.6	43.8	30.4	2.1	5.3	356
	80° 34.753'W	1.25	7.6	4.8	30.0	1.87	1.76	10.0	0.6	43.8	25.7	1.9	4.3	325
TC3	28° 02.269'N	-	-	-	-	-	-	-	-	-	-	-	-	-
	80° 34.830'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.146'N	0.5	9.8	3.4	29.5	0.84	0.87	3.8	0.9	91.0	26.4	2.6	6.2	607
	80° 34.850'W	1.0	8.9	3.6	30.0	0.82	0.93	4.4	0.9	75.8	32.2	2.9	6.2	553
		2.0	9.5	4.3	30.0	1.07	1.09	5.4	0.7	67.5	27.0	2.6	4.9	466
		2.5	9.8	4.0	30.0	1.01	1.19	6.2	0.7	71.8	27.4	2.7	5.0	492
		3.0	8.3	3.7	30.0	1.47	1.27	7.6	0.7	54.1	27.7	2.3	5.0	417
TC5	28° 01.949'N	0.5	6.5	2.8	15.5	1.76	2.75	7.3	0.9	56.3	28.9	1.9	5.3	347
	80° 34.853'W	1.0	7.5	3.1	29.0	0.74	1.01	4.0	0.9	63.3	33.7	2.5	8.1	604
		2.0	6.8	3.5	30.0	1.16	1.06	5.4	0.7	47.4	32.3	2.2	5.8	393
		2.5	8.1	3.8	30.0	1.28	1.34	5.8	0.8	62.3	27.6	2.2	5.2	421

* Refractometer

Appendix C5. Concentrations of dissolved and particulate parameters for Stations 1-5 for August 26, 2015.

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Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.416'N	0.5	3.0	0.32	46.4	0.40	1.20	0.86	121	19.4	31.8	55.4	3.65	8.01
	80° 34.576'W	1.75	3.2	0.36	49.6	0.35	1.14	0.79	111	19.9	32.0	55.9	3.67	8.10
TC2	28° 02.334'N	0.5	3.2	0.40	49.3	0.54	1.25	0.74	123	19.4	32.1	44.8	2.94	7.93
	80° 34.752'W	1.25	3.2	0.50	47.9	0.65	1.44	0.76	120	19.7	32.1	31.7	2.08	7.95
TC3	28° 02.268'N	0.5	3.7	0.49	53.6	0.64	1.53	0.82	122	18.4	32.4	40.8	2.68	7.87
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	4.0	0.52	58.3	0.82	1.80	0.79	116	18.9	32.7	43.3	2.83	7.75
	80° 34.852'W	1.0	3.7	0.47	57.2	1.08	1.99	1.16	120	19.4	32.4	19.4	1.27	7.79
		2.0	3.7	0.38	55.7	0.90	1.85	0.80	125	19.5	32.2	10.8	0.70	7.81
		2.5	3.3	0.43	57.8	0.82	1.81	0.77	127	19.6	32.2	8.8	0.58	7.83
		3.0	62.5	0.13	168	8.78	8.59	0.82	137	19.6	31.4	4.6	0.30	7.24
TC5	28° 01.952'N	0.5	3.8	2.66	64.2	1.16	1.55	1.10	169	4.9	31.3	73.9	5.32	7.49
	80° 34.849'W	1.0	7.1	0.40	66.8	1.68	2.44	0.78	117	19.0	32.6	28.2	1.84	7.64
		1.5	14.4	0.32	76.3	4.49	4.78	0.76	122	19.1	32.1	16.3	1.07	7.65
		2.0	41.0	0.22	109	8.71	8.77	0.80	132	19.1	31.5	5.0	0.33	7.45
		2.5	49.9	0.24	125	9.97	9.79	0.80	137	19.0	31.2	3.4	0.23	7.39

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.416'N	0.5	41.6	4.5	650	12.5	37.0	10.3	121	19.4	31.8	55.4	3.65	8.01
	80° 34.576'W	1.75	45.4	5.0	695	10.9	35.4	9.5	111	19.9	32.0	55.9	3.67	8.10
TC2	28° 02.334'N	0.5	44.8	5.5	690	16.6	38.9	8.9	123	19.4	32.1	44.8	2.94	7.93
	80° 34.752'W	1.25	44.3	7.0	671	20.2	44.5	9.1	120	19.7	32.1	31.7	2.08	7.95
TC3	28° 02.268'N	0.5	52.4	6.8	751	19.9	47.5	9.8	122	18.4	32.4	40.8	2.68	7.87
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	56.6	7.3	816	25.3	55.8	9.5	116	18.9	32.7	43.3	2.83	7.75
	80° 34.852'W	1.0	51.1	6.5	801	33.4	61.7	13.9	120	19.4	32.4	19.4	1.27	7.79
		2.0	51.1	5.3	780	27.9	57.2	9.6	125	19.5	32.2	10.8	0.70	7.81
		2.5	45.7	6.1	809	25.3	56.0	9.2	127	19.6	32.2	8.8	0.58	7.83
		3.0	876	1.8	2350	271.8	266.2	9.9	137	19.6	31.4	4.6	0.30	7.24
TC5	28° 01.952'N	0.5	52.8	37.3	900	36.0	48.0	13.2	169	4.9	31.3	73.9	5.32	7.49
	80° 34.849'W	1.0	98.8	5.6	936	52.1	75.6	9.4	117	19.0	32.6	28.2	1.84	7.64
		1.5	202	4.4	1070	139.1	148.1	9.1	122	19.1	32.1	16.3	1.07	7.65
		2.0	575	3.1	1530	269.8	271.6	9.6	132	19.1	31.5	5.0	0.33	7.45
		2.5	699	3.4	1750	308.8	303.1	9.6	137	19.0	31.2	3.4	0.23	7.39

*Sonde

Appendix C5 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for August 26, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µM)	POC (%)	POC (mM)	PON (%)	PON (µM)
TC1	28° 02.416'N	0.5	5.5	4.8	20.0	0.73	0.93	10.3	0.7	1.19	26.4	0.121	5.0	19.6
	80° 34.576'W	1.75	13.0	7.9	20.0	1.85	1.71	14.5	0.5	2.02	13.0	0.141	3.1	28.8
TC2	28° 02.334'N	0.5	7.5	6.2	20.0	1.02	1.01	7.6	0.7	1.73	29.8	0.187	6.4	34.4
	80° 34.752'W	1.25	9.1	7.3	20.0	1.01	1.04	8.8	0.7	1.96	29.8	0.225	5.3	34.3
TC3	28° 02.268'N	0.5	9.1	6.1	20.0	0.77	1.00	4.7	0.8	2.36	33.4	0.254	5.9	38.4
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	11.0	8.8	20.0	0.73	0.83	4.3	0.9	3.35	35.4	0.325	6.5	51.2
	80° 34.852'W	1.0	10.1	8.8	20.0	0.54	0.89	4.7	0.9	2.82	30.5	0.257	6.2	44.9
		2.0	9.6	8.2	20.0	0.60	0.59	4.7	0.8	2.55	32.7	0.262	6.4	43.9
		2.5	9.2	7.6	20.0	0.65	0.77	6.5	0.9	2.51	30.2	0.230	6.1	39.9
		3.0	6.8	10.7	20.0	0.78	0.56	4.6	0.8	1.76	36.6	0.208	5.9	28.7
TC5	28° 01.952'N	0.5	3.4	2.9	3.0	2.15	4.56	7.8	0.9	0.93	25.4	0.072	6.5	15.8
	80° 34.849'W	1.0	10.4	6.7	20.0	0.79	0.43	2.5	0.9	2.84	33.8	0.291	4.9	36.2
		1.5	7.3	8.5	20.0	0.67	0.74	2.6	0.9	2.23	31.9	0.195	6.9	36.1
		2.0	6.5	11.4	20.0	0.82	0.52	2.8	1.0	2.03	36.7	0.198	5.8	26.8
		2.5	5.6	15.7	20.0	0.67	0.47	2.6	1.0	1.80	38.4	0.178	6.2	24.6

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µg/L)	POC (%)	POC (mg/L)	PON (%)	PON (µg/L)
TC1	28° 02.416'N	0.5	5.5	4.8	20.0	0.73	0.93	10.3	0.7	36.9	26.4	1.5	5.0	275
	80° 34.576'W	1.75	13.0	7.9	20.0	1.85	1.71	14.5	0.5	62.4	13.0	1.7	3.1	403
TC2	28° 02.334'N	0.5	7.5	6.2	20.0	1.02	1.01	7.6	0.7	53.4	29.8	2.2	6.4	482
	80° 34.752'W	1.25	9.1	7.3	20.0	1.01	1.04	8.8	0.7	60.8	29.8	2.7	5.3	481
TC3	28° 02.268'N	0.5	9.1	6.1	20.0	0.77	1.00	4.7	0.8	72.9	33.4	3.0	5.9	538
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	11.0	8.8	20.0	0.73	0.83	4.3	0.9	103.7	35.4	3.9	6.5	717
	80° 34.852'W	1.0	10.1	8.8	20.0	0.54	0.89	4.7	0.9	87.2	30.5	3.1	6.2	629
		2.0	9.6	8.2	20.0	0.60	0.59	4.7	0.8	78.8	32.7	3.1	6.4	615
		2.5	9.2	7.6	20.0	0.65	0.77	6.5	0.9	77.9	30.2	2.8	6.1	559
		3.0	6.8	10.7	20.0	0.78	0.56	4.6	0.8	54.5	36.6	2.5	5.9	402
TC5	28° 01.952'N	0.5	3.4	2.9	3.0	2.15	4.56	7.8	0.9	28.9	25.4	0.9	6.5	221
	80° 34.849'W	1.0	10.4	6.7	20.0	0.79	0.43	2.5	0.9	88.0	33.8	3.5	4.9	507
		1.5	7.3	8.5	20.0	0.67	0.74	2.6	0.9	69.0	31.9	2.3	6.9	506
		2.0	6.5	11.4	20.0	0.82	0.52	2.8	1.0	62.8	36.7	2.4	5.8	375
		2.5	5.6	15.7	20.0	0.67	0.47	2.6	1.0	55.6	38.4	2.1	6.2	345

* Refractometer

Appendix C6. Concentrations of dissolved and particulate parameters for Stations 1-5 for September 9, 2015.

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Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.421'N	0.5	2.6	0.41	42.6	0.45	1.08	0.91	150	16.6	29.6	76.8	5.34	7.92
	80° 34.575'W	1.75	3.4	0.35	46.5	0.76	1.37	0.70	139	17.6	30.0	59.8	4.10	7.88
TC2	28° 02.337'N	0.5	3.5	1.28	51.0	0.91	1.32	0.95	140	16.4	29.5	61.9	4.31	7.83
	80° 34.749'W	1.25	2.9	0.42	42.1	0.74	1.35	0.72	121	17.0	29.9	72.8	5.03	7.94
TC3	28° 02.271'N	0.5	3.5	2.11	48.0	0.79	1.31	0.93	141	11.2	29.4	62.9	4.52	7.44
	80° 34.831'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	4.0	1.78	44.4	0.70	1.24	0.88	139	11.8	29.3	62.9	4.51	7.35
	80° 34.853'W	1.0	2.7	0.35	41.5	0.61	1.27	0.82	142	16.9	30.0	64.3	4.44	7.76
		2.0	4.6	0.42	44.9	0.99	1.68	0.82	142	17.4	30.1	48.6	3.33	7.76
		2.5	4.8	0.42	49.4	1.30	2.29	0.84	147	17.7	30.2	30.7	2.10	7.68
		3.0	64.7	0.22	115	8.72	8.80	0.92	158	17.8	30.3	15.5	1.06	7.60
TC5	28° 01.952'N	0.5	5.6	5.82	56.3	1.35	1.28	1.34	118	0.6	28.3	64.6	5.01	7.31
	80° 34.849'W	1.0	7.1	5.15	55.8	1.49	1.45	1.43	121	1.0	28.3	63.5	4.92	7.18
		1.5	12.8	0.85	55.2	2.10	2.40	0.78	142	17.3	30.4	35.8	2.45	7.30
		2.0	10.0	0.40	47.6	1.69	2.15	0.72	148	17.7	30.4	27.5	1.87	7.57
		2.5	34.2	0.35	77.7	5.73	5.59	0.81	150	17.8	30.4	16.5	1.13	7.55

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.421'N	0.5	36.0	5.8	597	13.9	33.5	11.0	150	16.6	29.6	76.8	5.34	7.92
	80° 34.575'W	1.75	47.3	4.9	652	23.6	42.4	8.4	139	17.6	30.0	59.8	4.10	7.88
TC2	28° 02.337'N	0.5	48.9	17.9	715	28.0	40.9	11.4	140	16.4	29.5	61.9	4.31	7.83
	80° 34.749'W	1.25	40.3	5.9	590	22.9	41.9	8.6	121	17.0	29.9	72.8	5.03	7.94
TC3	28° 02.271'N	0.5	49.4	29.6	672	24.5	40.6	11.2	141	11.2	29.4	62.9	4.52	7.44
	80° 34.831'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	56.3	25.0	623	21.6	38.4	10.6	139	11.8	29.3	62.9	4.51	7.35
	80° 34.853'W	1.0	37.4	4.9	582	18.8	39.3	9.9	142	16.9	30.0	64.3	4.44	7.76
		2.0	64.3	5.9	629	30.6	52.1	9.8	142	17.4	30.1	48.6	3.33	7.76
		2.5	67.0	5.9	692	40.2	70.8	10.1	147	17.7	30.2	30.7	2.10	7.68
		3.0	906	3.1	1620	270.0	272.6	11.0	158	17.8	30.3	15.5	1.06	7.60
TC5	28° 01.952'N	0.5	79.1	81.6	789	41.8	39.6	16.1	118	0.6	28.3	64.6	5.01	7.31
	80° 34.849'W	1.0	99.3	72.2	782	46.0	44.8	17.2	121	1.0	28.3	63.5	4.92	7.18
		1.5	180	11.9	773	64.9	74.4	9.4	142	17.3	30.4	35.8	2.45	7.30
		2.0	140	5.6	666	52.4	66.5	8.7	148	17.7	30.4	27.5	1.87	7.57
		2.5	479	4.9	1090	177.4	173.1	9.7	150	17.8	30.4	16.5	1.13	7.55

*Sonde

Appendix C6 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for September 9, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µM)	POC (%)	POC (mM)	PON (%)	PON (µM)
TC1	28° 02.421'N	0.5	5.7	3.3	16.5	0.46	1.02	5.3	0.8	1.52	28.8	0.136	6.2	24.9
	80° 34.575'W	1.75	6.5	4.7	18.0	0.40	1.09	4.3	0.9	1.82	26.9	0.147	6.1	28.5
TC2	28° 02.337'N	0.5	6.6	5.4	10.0	1.16	2.81	5.7	0.9	1.91	25.9	0.143	5.0	23.7
	80° 34.749'W	1.25	8.6	5.1	17.5	0.83	1.45	8.4	0.8	2.13	27.7	0.198	5.3	32.5
TC3	28° 02.271'N	0.5	7.5	5.4	12.0	0.82	2.21	4.5	0.9	2.26	28.0	0.176	5.5	29.6
	80° 34.831'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	10.8	6.2	14.0	0.57	1.66	3.8	1.1	3.66	36.4	0.328	6.1	47.1
	80° 34.853'W	1.0	10.1	5.2	18.0	0.42	0.79	3.2	1.1	3.46	32.6	0.274	6.5	46.9
		2.0	8.3	5.5	18.5	0.59	0.96	4.4	1.0	2.66	30.6	0.212	6.7	39.8
		2.5	7.7	4.9	18.5	0.42	0.89	3.9	1.0	2.37	35.6	0.229	8.1	44.6
		3.0	8.3	28.9	19.0	0.43	0.40	2.4	0.7	1.97	28.7	0.197	6.4	37.8
TC5	28° 01.952'N	0.5	4.3	3.6	<1.0	2.56	6.96	10.1	0.7	0.94	18.7	0.067	5.6	17.3
	80° 34.849'W	1.0	4.4	3.4	<1.0	2.90	7.29	9.1	0.7	0.93	17.6	0.064	3.1	9.7
		1.5	6.3	4.1	17.0	0.99	2.53	6.2	0.9	1.90	31.2	0.163	7.1	31.7
		2.0	4.9	4.4	18.0	1.01	1.85	5.2	0.9	1.41	31.4	0.128	7.6	26.6
		2.5	7.6	5.9	19.0	0.61	1.70	3.7	1.2	2.86	29.7	0.187	5.7	30.8

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µg/L)	POC (%)	POC (mg/L)	PON (%)	PON (µg/L)
TC1	28° 02.421'N	0.5	5.7	3.3	16.5	0.46	1.02	5.3	0.8	47.0	28.8	1.6	6.2	348
	80° 34.575'W	1.75	6.5	4.7	18.0	0.40	1.09	4.3	0.9	56.3	26.9	1.8	6.1	399
TC2	28° 02.337'N	0.5	6.6	5.4	10.0	1.16	2.81	5.7	0.9	59.1	25.9	1.7	5.0	332
	80° 34.749'W	1.25	8.6	5.1	17.5	0.83	1.45	8.4	0.8	66.1	27.7	2.4	5.3	455
TC3	28° 02.271'N	0.5	7.5	5.4	12.0	0.82	2.21	4.5	0.9	70.1	28.0	2.1	5.5	414
	80° 34.831'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	10.8	6.2	14.0	0.57	1.66	3.8	1.1	113.5	36.4	3.9	6.1	659
	80° 34.853'W	1.0	10.1	5.2	18.0	0.42	0.79	3.2	1.1	107.2	32.6	3.3	6.5	657
		2.0	8.3	5.5	18.5	0.59	0.96	4.4	1.0	82.4	30.6	2.5	6.7	557
		2.5	7.7	4.9	18.5	0.42	0.89	3.9	1.0	73.4	35.6	2.7	8.1	626
		3.0	8.3	28.9	19.0	0.43	0.40	2.4	0.7	61.2	28.7	2.4	6.4	529
TC5	28° 01.952'N	0.5	4.3	3.6	<1.0	2.56	6.96	###	0.7	29.0	18.7	0.8	5.6	242
	80° 34.849'W	1.0	4.4	3.4	<1.0	2.90	7.29	9.1	0.7	28.8	17.6	0.8	3.1	135
		1.5	6.3	4.1	17.0	0.99	2.53	6.2	0.9	58.9	31.2	2.0	7.1	445
		2.0	4.9	4.4	18.0	1.01	1.85	5.2	0.9	43.7	31.4	1.5	7.6	373
		2.5	7.6	5.9	19.0	0.61	1.70	3.7	1.2	88.5	29.7	2.2	5.7	431

* Refractometer

Appendix C7. Concentrations of dissolved and particulate parameters for Stations 1-5 for October 14, 2015.

Brevard County: Turkey Creek, October 14, 2015

Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (μM)	Nitrate + Nitrite (μM)	ΣN (μM)	Phosphate (μM)	ΣP (μM)	DOC (mM)	Alkalinity (mg-CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.417'N	0.5	2.5	0.57	44.3	1.07	1.84	0.90	128	16.4	26.0	67.5	4.99	7.92
	80° 34.584'W	1.75	2.5	0.46	41.8	1.17	1.90	0.83	129	17.0	26.3	68.8	5.05	8.07
TC2	28° 02.333'N	0.5	2.5	0.58	44.8	1.24	2.06	0.78	122	16.4	26.1	48.4	3.58	7.80
	80° 34.748'W	1.25	2.5	0.51	40.9	1.49	2.25	0.78	131	16.9	26.0	49.8	3.67	7.91
TC3	28° 02.268'N	0.5	2.5	0.46	44.6	1.38	2.16	0.83	130	16.2	26.4	44.2	3.25	7.77
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	2.1	0.41	41.8	1.38	2.17	0.79	119	16.0	26.3	49.0	3.61	7.54
	80° 34.853'W	1.0	2.3	0.53	43.4	1.41	2.24	0.79	131	16.9	26.3	49.9	3.66	7.78
		2.0	2.1	0.46	47.3	1.86	2.62	0.76	135	17.2	26.7	38.7	2.82	7.87
		2.5	5.2	0.48	43.3	2.51	3.37	0.84	121	17.5	27.0	23.5	1.69	7.78
		3.0	46.1	0.54	93.9	7.58	7.80	0.85	133	17.8	27.2	12.1	0.87	7.63
TC5	28° 01.955'N	0.5	5.6	3.37	59.1	1.65	1.65	1.34	150	3.4	25.5	58.4	4.69	7.46
	80° 34.854'W	1.0	3.6	0.42	46.5	2.08	2.74	0.84	132	16.9	27.2	46.8	3.38	7.36
		2.0	2.7	0.49	43.4	1.98	2.62	0.84	128	17.4	27.2	25.6	1.84	7.67
		2.5	5.6	0.45	45.3	2.73	3.33	0.81	129	17.6	27.4	12.2	0.88	7.67
		3.0	8.1	5.91	46.7	3.01	3.79	0.76	122	17.6	27.3	8.4	0.60	7.67

*Sonde

Brevard County: Turkey Creek, October 14, 2015

Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (μg-N/L)	Nitrate + Nitrite (μg-N/L)	ΣN (μg-N/L)	Phosphate (μg-P/L)	ΣP (μg-P/L)	DOC (mg/L)	Alkalinity (mg CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.417'N	0.5	35.7	8.0	621	33.2	57.0	10.8	128	16.4	26.0	67.5	4.99	7.92
	80° 34.584'W	1.75	34.3	6.5	586	36.1	58.8	10.0	129	17.0	26.3	68.8	5.05	8.07
TC2	28° 02.333'N	0.5	34.3	8.1	627	38.3	63.7	9.4	122	16.4	26.1	48.4	3.58	7.80
	80° 34.748'W	1.25	34.3	7.1	573	46.1	69.5	9.4	131	16.9	26.0	49.8	3.67	7.91
TC3	28° 02.268'N	0.5	34.3	6.5	624	42.9	66.9	10.0	130	16.2	26.4	44.2	3.25	7.77
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	28.9	5.7	585	42.9	67.1	9.5	119	16.0	26.3	49.0	3.61	7.54
	80° 34.853'W	1.0	31.7	7.4	608	43.5	69.3	9.5	131	16.9	26.3	49.9	3.66	7.78
		2.0	28.9	6.5	663	57.8	81.2	9.1	135	17.2	26.7	38.7	2.82	7.87
		2.5	72.8	6.7	607	77.8	104.3	10.1	121	17.5	27.0	23.5	1.69	7.78
		3.0	647	7.6	1320	234.7	241.4	10.2	133	17.8	27.2	12.1	0.87	7.63
TC5	28° 01.955'N	0.5	78.3	47.2	828	51.0	51.1	16.1	150	3.4	25.5	58.4	4.69	7.46
	80° 34.854'W	1.0	50.9	5.9	652	64.5	84.9	10.1	132	16.9	27.2	46.8	3.38	7.36
		2.0	37.2	6.9	608	61.3	81.0	10.1	128	17.4	27.2	25.6	1.84	7.67
		2.5	78.3	6.4	635	84.6	103.2	9.7	129	17.6	27.4	12.2	0.88	7.67
		3.0	114	82.8	654	93.3	117.5	9.1	122	17.6	27.3	8.4	0.60	7.67

*Sonde

Appendix C7 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for October 14, 2015.

Brevard County: Turkey Creek, October 14, 2015

Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µM)	POC (%)	POC (mM)	PON (%)	PON (µM)
TC1	28° 02.417'N	0.5	8.4	3.7	17.0	0.73	0.59	4.6	0.8	2.16	35.7	0.250	5.5	33.0
	80° 34.584'W	1.75	10.5	4.2	18.0	0.61	0.62	4.2	0.8	2.84	33.0	0.288	5.1	38.1
TC2	28° 02.333'N	0.5	9.8	3.9	17.0	0.61	0.76	4.1	0.8	2.52	33.5	0.273	5.2	36.3
	80° 34.748'W	1.25	10.7	4.2	18.0	0.88	1.00	5.5	0.8	2.76	32.0	0.284	5.0	38.1
TC3	28° 02.268'N	0.5	9.9	4.4	17.0	0.82	1.06	3.9	0.9	2.82	35.1	0.290	5.5	38.9
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	9.8	4.4	18.0	0.77	0.82	4.6	0.8	2.56	34.3	0.280	5.3	37.1
	80° 34.853'W	1.0	9.7	4.4	18.0	0.91	0.83	4.5	0.8	2.41	33.4	0.270	5.1	35.4
		2.0	8.8	5.0	19.0	0.89	1.18	5.4	0.9	2.46	33.6	0.245	5.9	36.9
		2.5	10.8	6.5	19.0	0.40	0.60	2.7	1.0	3.44	32.4	0.290	5.7	43.8
		3.0	8.3	27.4	20.0	0.30	0.43	2.4	0.8	2.02	30.8	0.214	5.3	31.5
TC5	28° 01.955'N	0.5	2.7	4.6	3.0	1.86	7.55	6.6	1.0	0.89	23.3	0.052	3.3	6.3
	80° 34.854'W	1.0	6.8	4.1	18.0	0.61	1.24	4.2	0.9	1.94	39.2	0.223	7.3	35.7
		2.0	8.5	5.4	19.0	0.49	0.74	3.8	0.9	2.58	37.2	0.263	6.7	40.6
		2.5	7.5	5.2	19.0	0.36	0.68	2.9	1.0	2.41	35.4	0.220	6.2	33.0
		3.0	7.4	5.5	19.0	0.37	0.70	2.7	1.1	2.63	33.9	0.209	6.0	31.7

*Refractometer

Brevard County: Turkey Creek, October 14, 2015

Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µg/L)	POC (%)	POC (mg/L)	PON (%)	PON (µg/L)
TC1	28° 02.417'N	0.5	8.4	3.7	17.0	0.73	0.59	4.6	0.8	66.9	35.7	3.0	5.5	463
	80° 34.584'W	1.75	10.5	4.2	18.0	0.61	0.62	4.2	0.8	88.0	33.0	3.5	5.1	534
TC2	28° 02.333'N	0.5	9.8	3.9	17.0	0.61	0.76	4.1	0.8	78.2	33.5	3.3	5.2	508
	80° 34.748'W	1.25	10.7	4.2	18.0	0.88	1.00	5.5	0.8	85.4	32.0	3.4	5.0	534
TC3	28° 02.268'N	0.5	9.9	4.4	17.0	0.82	1.06	3.9	0.9	87.3	35.1	3.5	5.5	546
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	9.8	4.4	18.0	0.77	0.82	4.6	0.8	79.4	34.3	3.4	5.3	519
	80° 34.853'W	1.0	9.7	4.4	18.0	0.91	0.83	4.5	0.8	74.8	33.4	3.2	5.1	495
		2.0	8.8	5.0	19.0	0.89	1.18	5.4	0.9	76.3	33.6	2.9	5.9	518
		2.5	10.8	6.5	19.0	0.40	0.60	2.7	1.0	106.5	32.4	3.5	5.7	613
		3.0	8.3	27.4	20.0	0.30	0.43	2.4	0.8	62.5	30.8	2.6	5.3	442
TC5	28° 01.955'N	0.5	2.7	4.6	3.0	1.86	7.55	6.6	1.0	27.5	23.3	0.6	3.3	88.9
	80° 34.854'W	1.0	6.8	4.1	18.0	0.61	1.24	4.2	0.9	60.2	39.2	2.7	7.3	500
		2.0	8.5	5.4	19.0	0.49	0.74	3.8	0.9	79.9	37.2	3.2	6.7	570
		2.5	7.5	5.2	19.0	0.36	0.68	2.9	1.0	74.6	35.4	2.6	6.2	462
		3.0	7.4	5.5	19.0	0.37	0.70	2.7	1.1	81.5	33.9	2.5	6.0	444

* Refractometer

Appendix C8. Concentrations of dissolved and particulate parameters for Stations 1-5 for November 23, 2015.

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Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-$CaCO_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.420'N	0.5	2.6	1.87	58.9	0.13		1.27	147	17.2	22.9	83.4	6.50	7.90
	80° 34.575'W	1.75	3.3	1.00	60.4	0.17		1.07	135	18.2	23.2	80.4	6.18	7.97
TC2	28° 02.335'N	0.5	2.7	2.08	57.1	0.29		1.23	141	17.1	22.9	74.2	5.78	7.81
	80° 34.747'W	1.5	2.8	1.17	59.5	0.10		0.97	138	17.9	23.4	76.2	5.85	8.00
TC3	28° 02.270'N	0.5	2.8	1.45	59.6	0.17		1.03	133	15.8	23.7	7.7	72.80	5.63
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.148'N	0.5	2.9	1.49	59.0	0.24		0.96	129	13.2	23.7	68.4	5.37	7.44
	80° 34.854'W	1.0	4.1	1.03	61.9	0.18		1.06	132	18.3	24.2	65.2	4.93	7.74
		2.0	5.0	1.24	67.0	0.49		1.01	143	18.5	24.4	52.9	3.98	7.85
		2.5	7.4	1.03	74.7	1.18		1.12	151	18.5	24.5	47.9	3.60	7.85
		3.2	9.9	0.83	87.3	1.76		0.98	146	18.6	24.7	40.1	3.00	7.80
TC5	28° 01.950'N	0.5	4.1	5.34	47.6	1.30		1.02	152	4.2	22.7	69.5	5.86	7.62
	80° 34.852'W	1.0	7.2	1.83	71.5	1.27		1.07	143	14.7	24.8	59.9	4.57	7.39
		2.0	8.7	1.00	75.9	1.48		0.95	133	18.8	25.0	45.6	3.38	7.72
		2.5	11.1	0.83	78.6	2.55		0.96	151	19.0	25.1	29.0	2.14	7.68
		2.8	12.8	7.91	82.7	3.25		0.93	136	19.0	25.1	21.1	1.56	7.66

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg $CaCO_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.420'N	0.5	36.0	26.2	825	3.9	0.0	15.2	147	17.2	22.9	83.4	6.50	7.90
	80° 34.575'W	1.75	45.6	14.0	846	5.2	0.0	12.8	135	18.2	23.2	80.4	6.18	7.97
TC2	28° 02.335'N	0.5	38.4	29.1	800	9.0	0.0	14.8	141	17.1	22.9	74.2	5.78	7.81
	80° 34.747'W	1.5	39.6	16.4	833	3.0	0.0	11.7	138	17.9	23.4	76.2	5.85	8.00
TC3	28° 02.270'N	0.5	39.0	20.3	835	5.2	0.0	12.4	133	15.8	23.7	7.7	72.80	5.63
	80° 34.829'W	-	-	-	-	-	-		-	-	-	-	-	-
TC4	28° 02.148'N	0.5	40.2	20.8	827	7.4	0.0	11.5	129	13.2	23.7	68.4	5.37	7.44
	80° 34.854'W	1.0	57.6	14.5	867	5.5	0.0	12.7	132	18.3	24.2	65.2	4.93	7.74
		2.0	69.6	17.4	939	15.1	0.0	12.1	143	18.5	24.4	52.9	3.98	7.85
		2.5	103	14.5	1050	36.4	0.0	13.5	151	18.5	24.5	47.9	3.60	7.85
		3.2	139	11.6	1220	54.5	0.0	11.8	146	18.6	24.7	40.1	3.00	7.80
TC5	28° 01.950'N	0.5	57.6	74.8	667	40.2	0.0	12.3	152	4.2	22.7	69.5	5.86	7.62
	80° 34.852'W	1.0	101	25.7	1000	39.3	0.0	12.9	143	14.7	24.8	59.9	4.57	7.39
		2.0	121	14.0	1060	45.9	0.0	11.4	133	18.8	25.0	45.6	3.38	7.72
		2.5	156	11.6	1100	79.1	0.0	11.5	151	19.0	25.1	29.0	2.14	7.68
		2.8	179	110.8	1160	100.7	0.0	11.2	136	19.0	25.1	21.1	1.56	7.66

*Sonde

Appendix C8 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for November 23, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µM)	POC (%)	POC (mM)	PON (%)	PON (µM)
TC1	28° 02.420'N	0.5	10.9	6.5	17.0	2.00	2.12	15.0	0.5	1.89	20.9	0.189	4.5	34.9
	80° 34.575'W	1.75	18.5	9.9	19.5	3.13	2.58	16.8	0.4	2.33	15.8	0.243	3.2	42.2
TC2	28° 02.335'N	0.5	14.3	6.1	15.0	2.25	2.43	14.9	0.5	2.17	17.3	0.206	3.4	34.6
	80° 34.747'W	1.5	42.5	19.7	18.5	2.85	2.96	17.4	0.3	3.98	13.0	0.460	2.2	66.8
TC3	28° 02.270'N	0.5	14.2	5.8	18.0	1.48	1.64	10.8	0.5	2.16	17.5	0.207	3.6	36.6
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.148'N	0.5	12.0	6.0	18.0	1.68	1.64	11.2	0.7	2.68	27.2	0.272	5.4	46.4
	80° 34.854'W	1.0	13.4	6.2	19.0	1.79	1.86	13.0	0.5	2.34	21.3	0.238	4.3	41.2
		2.0	12.6	6.4	19.0	1.97	2.16	14.1	0.5	2.12	20.7	0.218	4.3	38.8
		2.5	11.1	6.0	19.0	2.24	2.05	14.8	0.6	2.09	20.9	0.194	4.4	35.0
		3.2	10.4	5.8	20.0	1.43	1.97	14.2	0.6	2.08	21.9	0.190	4.4	32.7
TC5	28° 01.950'N	0.5	2.6	2.2	2.0	2.63	5.41	9.1	0.7	0.55	22.0	0.048	4.7	8.8
	80° 34.852'W	1.0	8.4	4.5	17.0	1.41	1.88	7.9	0.8	2.26	31.2	0.219	6.6	39.8
		2.0	8.0	4.4	20.0	1.76	1.90	11.8	0.7	1.81	25.2	0.168	5.1	29.2
		2.5	5.0	3.3	20.0	1.38	1.81	9.6	0.9	1.50	28.2	0.117	5.9	21.0
		2.8	5.8	3.8	20.0	1.21	1.42	8.7	0.8	1.49	23.5	0.114	5.1	21.3

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µg/L)	POC (%)	POC (mg/L)	PON (%)	PON (µg/L)
TC1	28° 02.420'N	0.5	10.9	6.5	17.0	2.00	2.12	15.0	0.5	58.6	20.9	2.3	4.5	488
	80° 34.575'W	1.75	18.5	9.9	19.5	3.13	2.58	16.8	0.4	72.1	15.8	2.9	3.2	591
TC2	28° 02.335'N	0.5	14.3	6.1	15.0	2.25	2.43	14.9	0.5	67.1	17.3	2.5	3.4	485
	80° 34.747'W	1.5	42.5	19.7	18.5	2.85	2.96	17.4	0.3	123.3	13.0	5.5	2.2	935
TC3	28° 02.270'N	0.5	14.2	5.8	18.0	1.48	1.64	10.8	0.5	66.9	17.5	2.5	3.6	512
	80° 34.829'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.148'N	0.5	12.0	6.0	18.0	1.68	1.64	11.2	0.7	83.0	27.2	3.3	5.4	650
	80° 34.854'W	1.0	13.4	6.2	19.0	1.79	1.86	13.0	0.5	72.5	21.3	2.9	4.3	577
		2.0	12.6	6.4	19.0	1.97	2.16	14.1	0.5	65.8	20.7	2.6	4.3	544
		2.5	11.1	6.0	19.0	2.24	2.05	14.8	0.6	64.7	20.9	2.3	4.4	491
		3.2	10.4	5.8	20.0	1.43	1.97	14.2	0.6	64.6	21.9	2.3	4.4	458
TC5	28° 01.950'N	0.5	2.6	2.2	2.0	2.63	5.41	9.1	0.7	17.1	22.0	0.6	4.7	123
	80° 34.852'W	1.0	8.4	4.5	17.0	1.41	1.88	7.9	0.8	70.1	31.2	2.6	6.6	557
		2.0	8.0	4.4	20.0	1.76	1.90	11.8	0.7	56.1	25.2	2.0	5.1	408
		2.5	5.0	3.3	20.0	1.38	1.81	9.6	0.9	46.4	28.2	1.4	5.9	294
		2.8	5.8	3.8	20.0	1.21	1.42	8.7	0.8	46.2	23.5	1.4	5.1	298

* Refractometer

Appendix C9. Concentrations of dissolved and particulate parameters for Stations 1-5 for December 14, 2015.

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Table 1. Dissolved parameters in molar units.

Station	Location	Water Depth (m)	Ammonium (µM)	Nitrate + Nitrite (µM)	ΣN (µM)	Phosphate (µM)	ΣP (µM)	DOC (mM)	Alkalinity (mg-CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.419'N	0.5	5.7	0.82	68.4	0.03	0.55	1.42	133	18.1	22.8	94.2	7.32	8.23
	80° 34.585'W	2.0	7.1	0.84	69.9	0.08	0.58	1.22	125	19.0	22.8	99.8	7.71	8.33
TC2	28° 02.335'N	0.5	6.5	1.37	68.3	0.08	0.63	1.12	131	14.9	23.1	88.2	6.94	8.05
	80° 34.753'W	1.5	7.2	0.92	68.0	0.07	0.66	1.07	122	18.7	22.8	93.8	7.25	8.31
TC3	28° 02.268'N	0.5	6.8	1.07	67.6	0.12	0.64	1.07	128	16.7	23.1	88.1	6.84	8.14
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	7.4	0.81	70.4	0.27	0.76	1.04	138	16.8	23.2	87.3	6.78	7.92
	80° 34.852'W	1.0	10.1	0.90	72.6	0.11	0.68	1.02	126	18.1	23.1	88.4	6.82	8.12
		2.0	13.3	0.96	79.0	0.31	0.96	1.16	127	18.4	23.0	89.0	6.87	8.25
		2.5	20.2	1.56	96.5	0.65	1.28	1.15	132	18.6	22.8	84.5	6.53	8.18
		3.0	35.1	1.65	118	2.03	2.46	1.15	131	18.7	22.8	72.7	5.63	8.07
TC5	28° 01.952'N	0.5	6.6	6.44	60.8	0.77	1.00	1.05	147	3.4	22.7	80.5	6.81	7.57
	80° 34.854'W	1.0	14.7	2.73	82.9	0.56	0.98	1.11	136	16.4	23.1	84.9	6.62	7.59
		2.0	19.8	1.92	93.3	1.07	1.44	1.17	133	18.6	22.7	85.2	6.60	8.02
		2.5	26.7	2.25	99.8	1.77	2.06	1.11	130	18.7	22.6	82.5	6.40	8.03
		2.8	25.9	2.29	101	1.78	2.16	1.12	129	18.7	22.6	79.4	6.16	8.02

*Sonde

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Table 2. Dissolved parameters in g/L.

Station	Location	Water Depth (m)	Ammonium (µg-N/L)	Nitrate + Nitrite (µg-N/L)	ΣN (µg-N/L)	Phosphate (µg-P/L)	ΣP (µg-P/L)	DOC (mg/L)	Alkalinity (mg CaCO$_3$/L)	Salinity*	Temp.* (°C)	DO* (%)	DO* (mg/L)	pH*
TC1	28° 02.419'N	0.5	79.3	11.5	959	1.1	17.0	17.0	133	18.1	22.8	94.2	7.32	8.23
	80° 34.585'W	2.0	99.0	11.8	979	2.4	17.8	14.7	125	19.0	22.8	99.8	7.71	8.33
TC2	28° 02.335'N	0.5	91.7	19.2	957	2.4	19.4	13.4	131	14.9	23.1	88.2	6.94	8.05
	80° 34.753'W	1.5	101	12.9	953	2.0	20.3	12.8	122	18.7	22.8	93.8	7.25	8.31
TC3	28° 02.268'N	0.5	94.8	15.0	947	3.6	20.0	12.8	128	16.7	23.1	88.1	6.84	8.14
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	103	11.3	986	8.4	23.6	12.5	138	16.8	23.2	87.3	6.78	7.92
	80° 34.852'W	1.0	142	12.6	1020	3.3	21.2	12.3	126	18.1	23.1	88.4	6.82	8.12
		2.0	186	13.4	1110	9.7	29.7	13.9	127	18.4	23.0	89.0	6.87	8.25
		2.5	283	21.9	1350	20.3	39.6	13.8	132	18.6	22.8	84.5	6.53	8.18
		3.0	492	23.1	1650	62.8	76.1	13.8	131	18.7	22.8	72.7	5.63	8.07
TC5	28° 01.952'N	0.5	92.4	90.2	850	23.8	30.9	12.6	147	3.4	22.7	80.5	6.81	7.57
	80° 34.854'W	1.0	205	38.2	1160	17.4	30.2	13.3	136	16.4	23.1	84.9	6.62	7.59
		2.0	277	27.0	1310	33.0	44.6	14.0	133	18.6	22.7	85.2	6.60	8.02
		2.5	374	31.5	1400	54.8	63.7	13.3	130	18.7	22.6	82.5	6.40	8.03
		2.8	363	32.1	1420	55.2	66.8	13.4	129	18.7	22.6	79.4	6.16	8.02

*Sonde

Appendix C9 (continued). Concentrations of dissolved and particulate parameters for Stations 1-5 for December 14, 2015.

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Table 3. Particulate parameters in molar units.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µM)	POC (%)	POC (mM)	PON (%)	PON (µM)
TC1	28° 02.419'N	0.5	6.5	2.3	19.0	1.69	1.65	18.3	0.4	0.78	15.2	0.082	3.4	15.7
	80° 34.585'W	2.0	13.3	6.1	20.0	2.17	2.06	20.1	0.3	1.08	12.7	0.141	2.3	21.9
TC2	28° 02.335'N	0.5	9.7	3.6	19.0	2.18	2.12	19.0	0.3	0.84	14.0	0.113	2.6	18.0
	80° 34.753'W	1.5	16.1	6.0	20.0	2.12	2.43	19.0	0.2	1.25	12.4	0.167	2.1	24.2
TC3	28° 02.268'N	0.5	7.6	3.4	19.0	2.10	1.97	18.4	0.3	0.64	15.2	0.096	3.1	16.6
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	8.3	4.5	19.0	2.00	2.05	18.6	0.3	0.72	17.1	0.118	3.4	20.1
	80° 34.852'W	1.0	11.0	5.0	19.5	1.90	1.98	20.0	0.3	0.96	15.7	0.143	2.9	22.7
		2.0	17.1	8.0	20.0	1.76	2.12	22.3	0.3	1.38	14.3	0.204	2.4	29.3
		2.5	17.8	8.1	20.0	2.10	2.22	21.9	0.2	1.33	15.9	0.236	2.7	34.4
		3.0	45.0	22.7	20.0	1.21	1.70	22.4	0.2	2.91	14.2	0.532	2.3	73.9
TC5	28° 01.952'N	0.5	2.0	2.5	2.0	2.38	8.21	12.1	0.7	0.44	20.3	0.033	6.1	8.6
	80° 34.854'W	1.0	5.9	2.8	18.0	1.47	2.13	19.3	0.4	0.67	19.9	0.098	4.4	18.7
		2.0	18.2	8.1	20.0	1.66	1.82	20.8	0.3	1.53	15.8	0.240	2.7	35.1
		2.5	15.2	6.7	20.0	1.22	1.84	22.9	0.3	1.37	17.0	0.215	3.0	32.5
		2.8	15.3	8.1	20.0	1.28	1.81	22.6	0.3	1.33	16.9	0.215	2.9	31.6

*Refractometer

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Table 4. Particulate parameters in g/L.

Station	Location	Water Depth (m)	TSS (mg/L)	Turbidity (NTU)	Salinity*	Al (%)	Fe (%)	Si (%)	ΣP (%)	ΣP (µg/L)	POC (%)	POC (mg/L)	PON (%)	PON (µg/L)
TC1	28° 02.419'N	0.5	6.5	2.3	19.0	1.69	1.65	18.3	0.4	24.0	15.2	1.0	3.4	221
	80° 34.585'W	2.0	13.3	6.1	20.0	2.17	2.06	20.1	0.3	33.3	12.7	1.7	2.3	307
TC2	28° 02.335'N	0.5	9.7	3.6	19.0	2.18	2.12	19.0	0.3	26.2	14.0	1.4	2.6	252
	80° 34.753'W	1.5	16.1	6.0	20.0	2.12	2.43	19.0	0.2	38.8	12.4	2.0	2.1	339
TC3	28° 02.268'N	0.5	7.6	3.4	19.0	2.10	1.97	18.4	0.3	19.8	15.2	1.2	3.1	232
	80° 34.832'W	-	-	-	-	-	-	-	-	-	-	-	-	-
TC4	28° 02.147'N	0.5	8.3	4.5	19.0	2.00	2.05	18.6	0.3	22.4	17.1	1.4	3.4	282
	80° 34.852'W	1.0	11.0	5.0	19.5	1.90	1.98	20.0	0.3	29.6	15.7	1.7	2.9	318
		2.0	17.1	8.0	20.0	1.76	2.12	22.3	0.3	42.8	14.3	2.4	2.4	411
		2.5	17.8	8.1	20.0	2.10	2.22	21.9	0.2	41.0	15.9	2.8	2.7	482
		3.0	45.0	22.7	20.0	1.21	1.70	22.4	0.2	90.0	14.2	6.4	2.3	1040
TC5	28° 01.952'N	0.5	2.0	2.5	2.0	2.38	8.21	12.1	0.7	13.6	20.3	0.4	6.1	120
	80° 34.854'W	1.0	5.9	2.8	18.0	1.47	2.13	19.3	0.4	20.8	19.9	1.2	4.4	261
		2.0	18.2	8.1	20.0	1.66	1.82	20.8	0.3	47.4	15.8	2.9	2.7	492
		2.5	15.2	6.7	20.0	1.22	1.84	22.9	0.3	42.4	17.0	2.6	3.0	455
		2.8	15.3	8.1	20.0	1.28	1.81	22.6	0.3	41.2	16.9	2.6	2.9	442

* Refractometer

Appendix D: Abstract accepted for Oral Presentation at Ocean Sciences 2016

On behalf of the Program Committee, I am pleased to inform you that the abstract listed below was accepted for presentation at the 2016 Ocean Sciences Meeting in New Orleans, Louisiana. New this year the meeting will begin with a Keynote address by the Honorable Dr. Jane Lubchenco and Icebreaker reception on **Sunday, 21 February** and conclude at **6:00 PM on 26 February**, with a closing poster session and refreshments.

Abstract ID: 92968
Abstract Title: Physical, chemical and biological controls of nutrient fluxes from fine-grained, organic-rich sediments in the Indian River Lagoon, Florida
Final Paper Number: MG33A-06
Presentation Type: Oral
Session Date and Time: Wednesday, February 24, 2016; 2:00 PM - 4:00 PM
Presentation Length: 3:15 PM - 3:30 PM
Session Number and Title: MG33A: Physical and Biogeochemical Processes at the Sediment-Water Interface in Estuaries, Coastal Oceans, and Shelf Seas II
Location: Ernest N. Morial Convention Center; 231-232

Link to Abstract and Ocean Sciences 2016 websitehttps://agu.confex.com/agu/os16/meetingapp.cgi/Paper/92968

Physical, chemical and biological controls of nutrient fluxes from fine-grained, organic-rich sediments in the Indian River Lagoon, Florida

Austin L. Fox, John H. Trefry, Robert P. Trocine, Stacey L. Fox

Releases and biogeochemical controls of dissolved nitrogen and phosphorus from fine-grained, organic-rich sediments in the Indian River Lagoon, Florida, were determined using (1) interstitial water chemistry, (2) laboratory incubations and experiments and (3) *in situ* chambers. Fluxes of nitrogen, essentially all as ammonium ions, and phosphorus, essentially all as orthophosphate ions, averaged 2000 ± 1000 and 150 ± 90 μmol/m^2/day, respectively. This internal recycling of ammonium and phosphate from fine-grained, organic-rich sediments that compose at least 10% of the sediments throughout the northern lagoon total 300 metric tons/yr and 50 metric tons/yr, respectively, and were greater than external inputs to this system. Ammonium fluxes varied spatially in response to physical and chemical differences in sediment composition. Seasonal and experimental changes in temperature resulted in a >50% differences in fluxes of ammonium and phosphate. High fluxes of dissolved sulfide supported dense mats of sulfur-oxidizing bacteria that provided stability to an otherwise unconsolidated fluff layer; this negative feedback loop reduced the net flux of nitrogen and phosphorus into the overlying water.

Chapter 4 Movement Measurements of Muck and Fluidized Mud at Dredge Sites

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4.1. Summary

Muck is typically greater than 75% water by weight (Trefry et al., 1987) and like water, it moves as fluid mud (Mehta et al., 1994) when disturbed by wind waves and currents. The purpose of measuring muck and fluidized mud movement is to provide management information that can be applied to calculate the mass of moving particulate material just above the bottom. This moving dense fluid is a “carrier” of nutrients. Data concerning the magnitude of moving muck and fluid mud in terms of transport fluxes in bottom waters can be used in calibration of sediment and water quality models.

Muck movement and fluxes measured from sonde deployments in Palm Bay and Turkey Creek closely match the magnitude of fluxes reported in previous studies (Mehta et al., 1994; Maglio et al., 2016; Bostater and Rotkiske, 2015). The moving muck and fluid mud collected within the *in-situ* sondes is in agreement with the definitions used in previous research (Trefry et al., 1987; Teeter et al., 1992; Teeter, 1994; McAnally et al., 2007). At the mouth of Palm Bay, the measurements of moving fluid mud and muck suggest a net westward (upstream) flow and accumulation of moving fluid mud in the southwestern area of Palm Bay (east of US1). This was verified by sludge judge measurements muck depths greater than 3 m. Stokes drift velocity (Craik, 2005) concerning residual upstream bottom transport also supports this westward (upstream) movement of particulates in the bottom boundary layer. The Stokes drift velocity in Palm Bay would be westward due to westward propagating wind driven gravity waves when the wind blows from east to west. Stokes drift theory in shallow bottom waters suggests that moving fluid mud and muck from outer Palm Bay will thus likely contribute to buildup of muck in the deep dredged area east of US1.

Particulates moving into the sondes located in the moving lutocline and nepheloid layers include estuarine flocs (colloidal aggregates). These fine grain flocs were clearly observable in optical and acoustic imagery. The irregular size of these floc aggregates was quantitatively analyzed and described. The magnitude of the floc material collected by the sondes within the moving fluid mud is similar to prior research in the Indian River Lagoon (Bostater and Rotkiske, 2016. Image analysis of flocs indicated predominant effective diameters of 0.1 mm to 10.2 mm. Mean cross-sectional floc diameter was 2.77 mm (2770 µm) ± 2.44 mm SD with a *median* floc effective cross-sectional area of ~30 mm^2. These particulates do not settle according to Stoke’s law for individual particle settling. Stokes settling law applies only for laminar flows and spherical particles.

Area wide station analysis utilizing all flux density sonde results indicate different magnitudes of material moving (1) west of the railroad bridge, (2) east of US1 and within Palm Bay, and (3) at the mouth of Palm Bay and nearby Indian River Lagoon. Station sonde fluxes at the mouth of Palm Bay were greater than 1200 g m^{-2} day^{-1}. A net upstream flux (towards Palm Bay and west of US1) in the lower 0.5 meter water column transect across the mouth of Palm Bay was measured. The total dry weight moving muck collected across a transect of six stations at the mouth of Palm Bay indicated a net upstream movement 93,000 g day^{-1} (~34,000 kg yr^{-1}). This net upstream result is also consistent with a Stokes drift towards US1 during the sampling period.

Area wide GIS spatial analysis demonstrates that sonde data processed in a gridded manner could be applied in modeling water quality and sediments. The gridded state variables include transport fluxes of particulate organic matter, particulate inorganic matter, particulate organic nitrogen, particulate organic phosphorus and particulate organic carbon movement. The data from this project estimated nutrient transport fluxes within the moving muck by utilizing muck-nutrient relations developed by Trefry, 2015.

The pre-dredging data developed can be used to assess the efficacy of future dredging in terms of muck movement reduction (MMR) by comparing the magnitude of moving muck (1) before dredging, (2) during dredging and (3) after dredging. This procedure has been used in a previous dredging study in the Indian River Lagoon (Maglio et al., 2016; Bostater and Rotkiske, 2015; Rotkiske and Bostater, 2016) to estimate the reduction in moving muck after dredging. In summary, data derived from the sondes can provide important sediment flux (mass transport) of sediments in the bottom boundary layer and the moving lutocline for future bottom sediment forecast modeling.

4.2 Approach

4.2.1 Conceptual Framework, Definitions, Methods

Improving our scientific understanding of estuaries occurs through research, advances in techniques, instrumentation and methods used by scientists (Schubel, 1986). The research reported here concerns direct observation of moving muck and fluidized mud at a dredge site in response to recommendations made by the American Society of Civil Engineers, Task Committee on Management of Fluid Mud (McAnally et al., 2007, I & II). Fluid mud is most often associated with a lutocline and forms in near-bottom aquatic habitats. This mud is a high concentration aqueous suspension of fine sediment and flocs. This fluff and fluidized muck has been defined using site specific density. It is defined as to flow as a density current and is most often associated with navigation and related dredging activities. However, fluid mud is now described as being "ubiquitous" in inland waterways. The fluidization and liquefaction of muck and mud are caused by pore water pressure oscillations due to water waves and associated water surface height amplitude changes. Individual particles are then entrained (Kato and Philips, 1969) within the moving lutocline, and overlying nephelometric water column layers. As noted by the ASCE Task Force, past measurement techniques are characterized as being indirect or surrogate measures, *extremely* unreliable, *not* universally applicable, slow, and limited by calibration requirements. They report that new field instruments, techniques and methods development are needed (Waters, 1987; Hydraulics Research Ltd., 1990) and specifically needed is the characterization of fluid mud by temporally averaging the fluid mud sediment fluxes in channels and ports (McAnally et al., 2007).

The research reported below addresses the above recommendations and the approach used makes use of newly developed passive probes or sondes. By definition a sonde is a device that measures a physical property. The conceptual framework used to guide this research concerning fluid mud sediment flux (see Figure 4.1) was previously developed by Mehta et al., 1994 and used during a recent Florida Inland Navigation District dredging project (Bostater and Rotkiske, 2015).

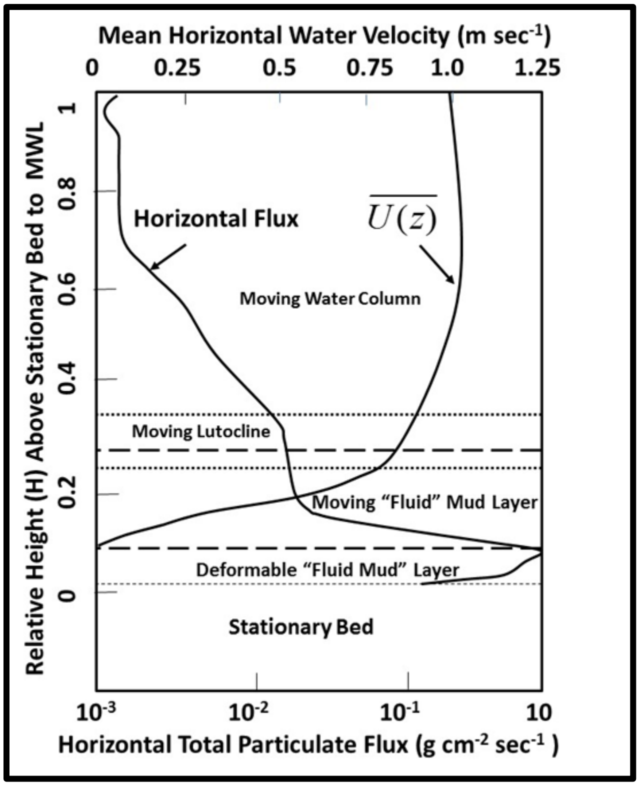


Figure 4.1 Conceptual diagram of the bottom water column based upon previous observations and mathematical models (modified after Mehta, Lee and Li, 1994 and reproduced from Bostater and Rotkiske, 2015).

During the Turkey Creek pre-dredge 2015 research, horizontal measurements of the fluid mud horizontal flux were made within the moving fluid mud layer and moving lutocline. Measurements are time averaged through long term deployments as recommended by McAnally et al., 2009. Vertical fluxes of fluid mud measure upwelling (resuspended) and/or downwelling (depositional) particulate fluxes as reported by Bostater and Yang, 2014 and noted by Di Toro, 2001. The concepts behind directional sediment flux measurements used in this research were also described by Anderson, 1992 where he reports on short or long time interval, directional sediment movement monitoring arrays. These arrays utilize positioning collecting tubes, orifices, funnels, and baffles (that help minimize the effects of turbulence) while measuring large volumes, rate, and the vector (direction and magnitude) of sediment movement carried by currents in remote and inaccessible locations. Sediment flux methods and fluid-mud interactions with water surface wave energy dissipation are topics of research sponsored by the US Office of Naval Research, Coastal Geosciences (Hsu, 2016; Dalrymple, 2006). Bostater and Yang, 2014 described and demonstrated new methods for observations of spectral wave energy in shallow Indian River Lagoon waters and reported on new instrumentation used in this research project for measuring the movement (flux density) of fluid mud and muck.

Published reviews of methodologies and comparisons of reported sediment sampling methods (Gray and Gartner, 2009; Bostater and Rotkiske, 2015; Bostater and Rotkiske, 2016) describe the method type, benefits, and limitations of existing techniques. In general methods have been developed for measuring concentrations of particulate matter and colloidal aggregates, but none were developed for directly measuring the vertical and horizontal fluxes (movement) of fluid mud and muck. Indirect measurement techniques are considered “surrogate” methods and do not conserve mass flux within a control volume since they are typically instantaneous point measurements. It has been reported that measurements of high concentrations of suspended matter using optical backscatter sensors yield noisy calibrations when compared to filtration based techniques. As clearly stated by Bianchi (2007) *in-situ* investigations of mobile fluid muds within the bottom boundary layer are not possible with conventional equipment using submersible pumps and samplers, CTD, OBS (optical backscattering sensors) and ADPs (acoustic Doppler profilers), since these instruments are too coarse. These systems use only “point” sampling resolutions. Such systems do not allow the reliable calculations of volume mass flux in a conservation of mass form necessary to estimate moving fluid muds necessary for hydrodynamic and scalar substance modeling studies in estuaries. The new method and protocol (Bostater and Rotkiske, 2016) used and described below utilizes direct methods for estimating sediment flux density and has been previously tested and reported.

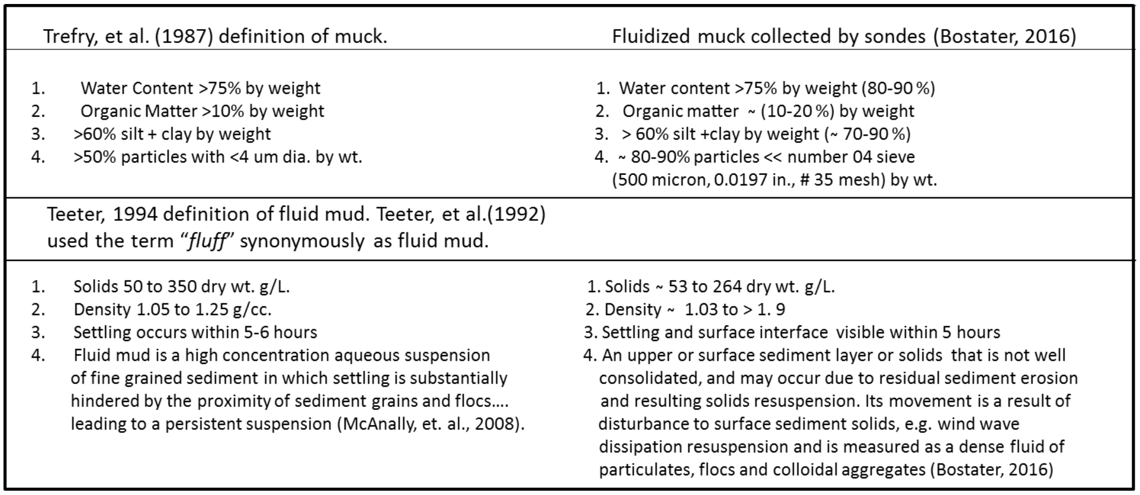
An essential component of muck removal management and Indian River Lagoon (IRL) restoration is to scientifically understand the movement or “flux” (g m^{-2} day^{-1}) of the material before, during and after dredging activities This approach allows one to determine the efficacy of the dredging. The purpose of measuring muck and fluidized mud movement is also to provide management information that can be applied to calculate the mass of moving material just above the bottom, as well as re-suspended & settled material (especially at newly dredged locations). This moving material is a “carrier” of nutrients and its understanding will contribute to greater understanding of water quality restoration and management in any modeling framework. The approach is intended to define efficacy of restoration dredging at or near dredged waterways in terms of muck movement reduction (MMR). The goal of this project was (1) to measure ***in-situ*** movement (horizontal and vertical) at transects and stations at Palm Bay and Turkey Creek, (2) to collect water samples at the stations and transects and (3) to utilize acoustic and optical floc imaging using the published methods of Bostater and Rotkiske, 2015; Bostater and Yang, 2014.

The above introduction has presented information necessary to help understand the context of this research project from (1) a research perspective and (2) the context of this study from a management perspective.

The conceptual framework and methods for this pre-dredge project were also successfully applied in a Florida Inland Navigation Dredging project in the Indian River Lagoon and reported in Maglio et al., 2016. The sondes and results described by Bostater and Rotkiske, 2015 and Bostater and Rotkiske, 2016 using the sondes shown in Bostater and Yang, 2014 have been shown to measure total particulate matter as: fine sand 500-62 µm, silts 62-4 µm and clays 4-0.24 µm (as defined by Newcombe, 1996 and the American Geophysical Union's Subcommittee on Sediment Technology). At stations in the Indian River Lagoon selected sonde sample analyses indicated particles collected were ~80-90% and less than a number 04 sieve (500 micron, 0.0197 in., # 35 mesh) by weight. After rinsing and final settling (~ 5 to 6 hr.) the moving fluid mud particulate matter is greater than 75 % water content and approximately 10-20% organic matter by weight based upon loss on ignition analysis (105° C drying followed by placement in a furnace at 550° C) as described by Bostater and Rotkiske, 2015. Since the material is greater than 75% water it is considered a non-Newtonian fluid that moves within the lutocline.

The sondes collect moving particles and small floc aggregate particles (after floc disaggregation) with settling velocities ranging from less than 26 to 53 mm sec^{-1} for fine sands and 3 to 0.044 mm sec^{-1} for silts and less than 0.011 mm sec^{-1} for clays based upon the particle characterization information provided by Cooke, et al., 1993. Definitions of fluid mud/muck in this research are also presented in Table 1 (reproduced from Bostater and Rotkiske, 2016).

Table 4.1 Published definitions of fluid mud and muck collected within the sondes (reproduced from Bostater and Rotkiske, 2016).



Trefry, et al. (1987) definition of muck.	Fluidized muck collected by sondes (Bostater, 2016)
1. Water Content >75% by weight	1. Water content >75% by weight (80-90 %)
2. Organic Matter >10% by weight	2. Organic matter ~ (10-20 %) by weight
3. >60% silt + clay by weight	3. > 60% silt +clay by weight (~ 70-90 %)
4. >50% particles with <4 um dia. by wt.	4. ~ 80-90% particles << number 04 sieve (500 micron, 0.0197 in., # 35 mesh) by wt.
Teeter, 1994 definition of fluid mud. Teeter, et al.(1992) used the term "*fluff*" synonymously as fluid mud.	
1. Solids 50 to 350 dry wt. g/L.	1. Solids ~ 53 to 264 dry wt. g/L.
2. Density 1.05 to 1.25 g/cc.	2. Density ~ 1.03 to > 1. 9
3. Settling occurs within 5-6 hours	3. Settling and surface interface visible within 5 hours
4. Fluid mud is a high concentration aqueous suspension of fine grained sediment in which settling is substantially hindered by the proximity of sediment grains and flocs…. leading to a persistent suspension (McAnally, et. al., 2008).	4. An upper or surface sediment layer or solids that is not well consolidated, and may occur due to residual sediment erosion and resulting solids resuspension. Its movement is a result of disturbance to surface sediment solids, e.g. wind wave dissipation resuspension and is measured as a dense fluid of particulates, flocs and colloidal aggregates (Bostater, 2016)

The sondes use *direct passive sensing* and the measurement technique yields a direct measurement of the mean flux (g m^{-2} t^{-1}) where the mass of the total moving particulate matter is calculated in the laboratory. The area (m^2) is based upon the cross-sectional area of the sonde wherein particles enter a fixed control volume. Particles moving into the volume of the sonde have momentum and after entrainment across and through the control surface, momentum is lost due to turbulent dissipation and the particulate matter falls to the lower portion of the control volume. The horizontal sondes are inexpensive and made of PVC fittings that can be anchored to the bottom. The vertical sondes are a type of trap that is based upon larger and similar designs currently used in monitoring fluxes of marine particles and marine snow or flocs (see Bostater and Rotkiske, 2015 for a review). The unit of measurement calculated from these sondes is a time and space averaged mean mass flux density. The sondes essentially measure the total particulate deposition within a control volume.

In ocean and environmental engineering as well as marine science, this depositional flux (mass per unit area per time) is typically calculated from “point measurements “ of the product of velocity U (L/T) and concentration C (M/L^3) or UC, where U=characteristic velocity scale, L=characteristic length scale, T=characteristic time scale, M=characteristic mass. However these point measurements are very noisy. By averaging this product over a time period and space (using a cross-sectional area) one obtains what is called an estimate of the mass transport T_m = $\overline{AU_A C_A}$, where A=cross sectional area, U_A=cross sectional averaged velocity and C_A=cross sectional averaged concentration (Bostater and Ambrose, ASTM, 1981) and is a standard method used in modeling fate and mass transport (T_m) of chemicals and materials. In this case the total mass transport (T_m) represents the resulting mean horizontal or vertical deposition of particulate matter transported into a sonde control volume V (L^3). The above value of the mass transport (T_m) can also be expressed as a time derivative or d(M(t))/dt, where the mass in the sonde volume is $M(t) = V \cdot C(t)$. With a constant control volume with a mass input rate (here the mass input of particles into the sonde volume) the time rate change of mass input rate in the sonde is also given by d(VC(t))/dt = M. This change in mass input rate is also known as a source term M. This relation is also known as a mass balance equation. In the case of the sondes the volume of the sondes are constant and the above can be rewritten as V d(C(t))/dt = W. Thus the mass input rate or flux into the sondes are a function of the integral of d(C(t))/dt where dt = Δt is the deployment time and $\int dc(t)$ represents the time integrated input or accumulation of particulate matter in a sonde. This mass input into a sonde is a function of the variable concentration of particles deposited during a deployment period across the fixed sonde cross sectional area and a variable velocity or flow rate.

In summary, with the above definitions, one can note that the sondes passively collect moving fluid mud and muck as a flux of particulate matter during a deployment period Δt.

After the sondes are retrieved laboratory methods are used to analyze the total solids (fluid mud) collected within the sondes. First, the water and solids removed from the sondes are allowed to settle in the laboratory for 24 hrs. The settled sample residue is double rinsed with deionized water to remove dissolved salts. Sample preservation is not practical according to EPA method 160.3 (Total Residue, STORET NO. 00500). The residue is placed into a pre-weighed porcelain evaporating dish and water is decanted using a vacuum tube and/or a syringe or similar device.

The residue wet volume and wet weight is then measured. Wet density (mg ml^{-1}) is calculated and recorded. Samples are then heated to 105^o C until water is evaporated (24 hours is required due to the large quantity of moving fluid mud captured). Final dried residue is weighed and dry total weight of residue (mg) recorded for each sample. Dry weight flux (mass m^{-2} time^{-1}) is calculated based upon sonde deployment time and the cross-sectional area of the sonde. The dried residue within the evaporating dish is placed in a muffle furnace at 550^o C +/- 50^o C for one hour. The evaporating dish is then immediately covered, cooled to just above room temperature and re-weighed, and the result is used in the calculation of % loss on ignition (% LOI) in order to provide an estimate of organic matter of the fluid mud collected in a sonde. Linear relations between % LOI and nutrients in the particulate matter (TPN, TPN, and TPC) are then calculated as proposed by Di Toro, 2006 using the relations obtained by Trefry, 2015. Although not calculated, nutrients associated with moving inorganic particulates within the moving fluid mud can thus be estimated to determine nutrients in the moving fluid mud and muck. Sonde mass nutrient fluxes are then calculated using % LOI and the organic weight of each sample. Additional information concerning the above procedures is described in Standard Methods for the Examination of Water & Wastewater (15th ed.) methods 209, A, D, E and ASTM standards C1603-10, STP148E-EB, STP148D-EB and D5907-13.

Triplicate horizontal and duplicate vertical sonde deployments have provided estimates of precision using recommendations published by EPA, 1984. Duplicate and triplicate measurements were made in October 2015. The passive sonde *in-situ* fluid mud flux measurements are a *direct measurement technique*. A review of direct and indirect fluid mud movement and flux methods (Bostater and Rotkiske, 2015) indicates that this protocol (Bostater and Rotkiske, 2016) is the only published *direct method* available for analysis of fluid mud movement or mass flux density (mg cm^{-2} sec^{-1}) measured in the field.

Directional fluxes of fluid mud are obtained by deploying the horizontal sondes in different directions (E, W, N, S) and the vertical fluxes (depositional and resuspended) are also made by using vertical sonde deployments. The horizontal passive sensing sondes are deployed ~15 to 20 cm off the bottom and have a ~10 cm diameter cross-sectional opening. They are typically placed in E-W and N-S directions or parallel and perpendicular to a waterway. The vertical depositional (settling) and resuspension (upwelling) sondes are placed in pairs near the bottom (~10 cm above). A duplicate pair is also placed 50 cm above the bottom. Thus the lower 0.5 m of the bottom region is sampled. This deployment procedure results in 8 flux measurements to be made at a station location. The heights used were based upon the Hillsboro Bay, Florida, fluidization depths, lutocline and moving lutocline height and model predictions reported by Mehta, et al., 1994) under the influence of water surface wave amplitudes of 2-4 cm. These heights also coincide with waves on lutoclines imaged by acoustic sensors reported by Traykovski, et al., 2000. These are assumed to be representative of conditions in Turkey Creek based upon recent research reported in Bostater and Rotkiske, 2015 in the Indian River Lagoon. The sonde typical deployment period is on the order of 12-17 hours although longer periods (such as over the duration of a wind and/or rainstorm event) can be made. The horizontal systems can be constructed in various sizes.

The above sonde methods and approach of analysis has been previously used and results reported in Maglio, et al., 2016. An example result from this study is shown in Figure 4.2 below. The figure shows that muck movement reduction (MMR) occurred at transect 4 (upper right) when pre-dredging, during dredging and post-dredging measurements were compared. The data collected during year one at the Turkey Creek stations will be available to make similar comparisons to during dredging and post-dredging research results to quantify muck movement reduction (MMR).

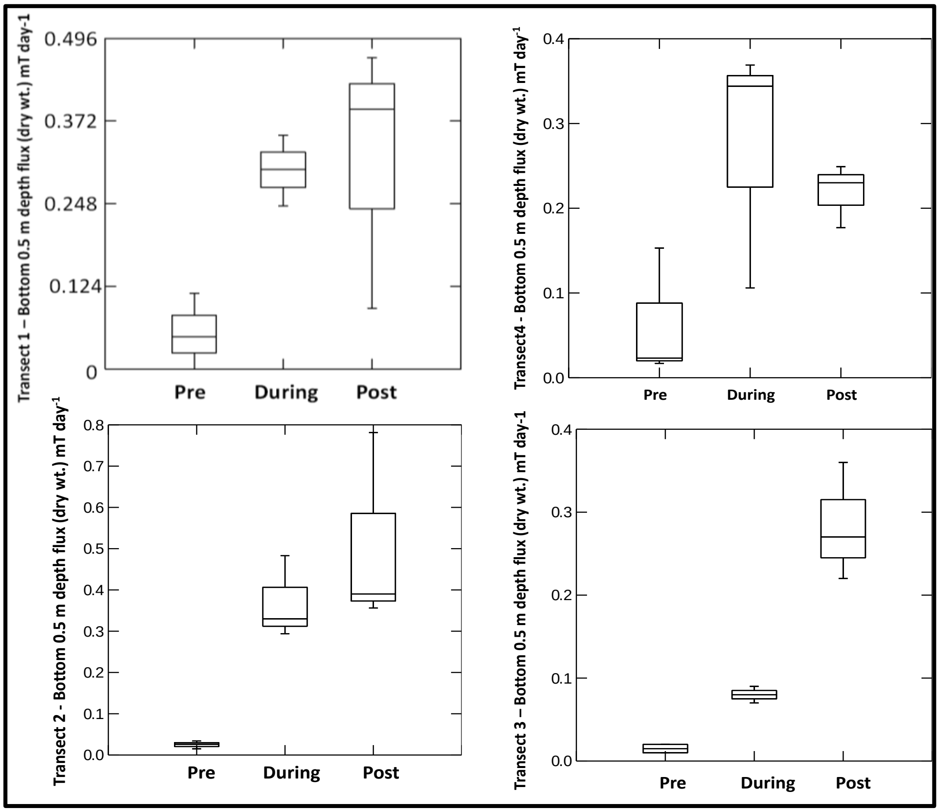


Figure 4.2 Fluxes in metric tons per day (*mT* day^{-1}) at locations indicate the fluid mud movement for pre-dredge, during dredging and post dredging conditions obtained from a recent Florida Inland Navigation District dredging project. Results for transect 4 (upper right) indicates muck movement reduction (MMR) occurred during the study near Sebastian Florida during 2015.

Station Selections in Turkey Creek were based upon stratified random sampling and used to determine where the sondes were deployed during (March thru October) 2015 (pre-dredging) as shown in Figure 4.3. Three stations were selected west (upstream) of the Turkey Creek railroad bridge (TCB1 thru TCB3), eight stations were located east of Turkey creek at the mouth (TC1 thru TC6) and two stations were located outside of Turkey Creek (TCOUT1N and TCOUT1S) and eight stations in Turkey Creek east of the US1 bridge. Stations TCP1 thru TCP4 were located near docks/piers around the north and northwest perimeter of Turkey Creek and east of US1 road. Stations TCB4 thru TCB7 were located east of the US1 bridge and on either side of the boating channel within Turkey Creek.

The rationale for the station locations included the desire to have stations (1) outside of Turkey Creek, (2) stations east of US 1 but within Turkey Creek and (3) stations west of the railroad bridge. In addition, shallow perimeter stations in the vicinity of the north and northwest shore were desired since these are in the Turkey Creek area where biological sampling occurred during year 2015. Stations TCB4 thru TCB7 were selected to be in the vicinity of the boating/waterway channel within Turkey Creek east of US1. A second method was used to compare the sonde method at station TCB6. In addition, stations TCB1 thru TCB3 were sampled twice during the pre-dredge sampling. During the sampling period in October, duplicate vertical flux deployments and triplicate horizontal flux deployments were made following EPA, 1984 recommendations. Overall, the stations were selected in order to perform (1) pre-dredging, (2) during dredging, and (3) post dredging comparisons for assessing muck movement reduction (MMR) as shown in Figure 4.3.

Figure 4.3 Pre-dredge fluidized muck and mud sample locations during 2015. Stations were selected using stratified random sampling in order to insure stations were located (**1**) west of the railroad bridge, (**2**) in the main bay of Turkey Creek and (**3**) near the mouth of Turkey Creek. Georeferenced satellite image courtesy Digital Globe.

4.3 Results and Discussion

4.3.1 Sonde Station Deployment Results

Sonde deployments occurred March 5-6, April 10-11, May 14-15 and October 1-3, 2015. Deployment periods ranged from approximately 12 to 39 hours. The sondes were deployed at the end of a day and retrieved during the following morning. At each station the horizontal mud movement probes (up to 4 directions – east, west, north, south) and four vertical probes (2 measuring settling and 2 measuring upwelling (resuspension) were placed at stations during the deployment period. Results are presented below for movement of fluid mud and muck as a dry weight flux, organic matter flux, as well as associated carbon, nitrogen and phosphorus flux estimated from the sondes located within the bottom 0.5 m lutocline and nepheloid water column.

The laboratory analysis of sonde deployments located west of the railroad bridge (TCB1, TCB2, TCB3) indicated a greater westward (upstream) movement of fluidized muck and greater deposition (settling) than resuspension or upwelling (see Figure 4.4 and Figure 4.5). The calculations shown in these figures indicated the mass flux in terms of (mass per unit area per unit time) by extrapolating the deployment time measurements to an annual basis based upon the sonde cross-sectional area. Each bar in the Figure 4.4 represents the total amount of material collected during a deployment in the specified direction. Thus, n=2 for each station. The values shown in Figures 4.4 and 4.5 represent the actual dry weight of mud and muck trapped and then extrapolated to an annual flux at the stations. The sondes were located within the lower 0.5 water column.

Calculations from the deployments at stations outside and east of Palm Bay (TCOUT1N and TCOUT1S) suggest greater particle settling than resuspension - *however* the horizontal muck movement is greater by an order of magnitude. This suggests the mud and muck may not be accumulating outside of Palm Bay. The sludge judge (push pole) measurements made at stations during pre and post sonde deployments confirmed little or no mud at the 2 stations located outside of Palm Bay in the Indian River Lagoon. These results are expected due to the shallow depths and influence of the wind the wind and associated broad fetch of the IRL.

Horizontal and vertical probes were deployed at 6 locations across the mouth of Palm Bay (TC1, TC2, TC3, TC4, TC5 and TC6). Results from 5 stations are shown in Figures 4.4 and 4.5. Results suggest greater resuspension than deposition at the mouth of Palm Bay and greater westward movement towards Palm Bay of the fluidized muck and mud.

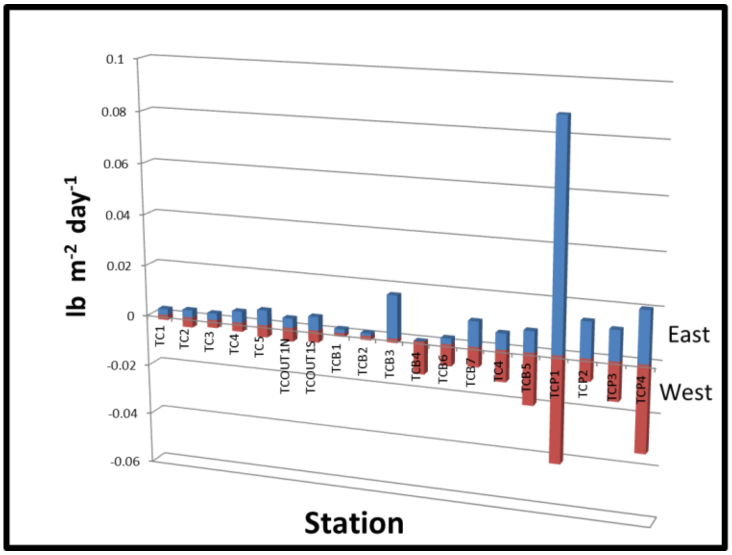


Figure 4.4 Pre-dredge sonde sediment mass flux station results extrapolated in terms of lbs. m^{-2} day^{-1} for 2015 Turkey Creek samples using the east (blue) and west (red) directional horizontal sondes.

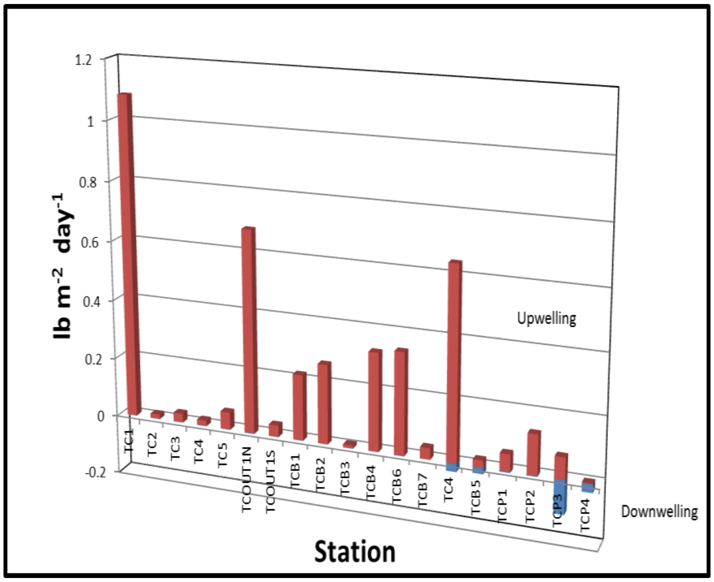


Figure 4.5 Measured sonde fluid mud mass flux results extrapolated in terms of lbs. m^{-2} day^{-1} for 2015 Turkey Creek pre-dredging stations from the red upwelling (resuspension) and downwelling (depositional) sondes. Values shown represent combined surface and bottom probe measurements.

The transect data from all six stations at the mouth of Turkey Creek were combined to estimate the relative order of magnitude of fluid mud movement in the lower 0.5 - meter bottom layer within the lutocline and near bottom nepheloid layer. The depth was selected since the sondes were placed within the bottom water depth layer depicted in Figure 4.6.

On a dry weight basis, the sonde results suggest that ~ 75,000 thousand lbs. yr^{-1} (~ 93 kg day^{-1}) dry weight fluid mud and muck moves across the mouth of Turkey Creek in the lower 0.5 m depth bottom layer at the mouth of Turkey Creek. Figure 4.6 below depicts this concept of fluid mud and muck movement at a cross sectional area (*vertical slice*) at the mouth of Turkey Creek.

Figure 4.6 Conceptual bottom lutocline and nepheloid layer (0.5 m deep) through which fluid mud and muck movement was measured using the sondes. The horizontal and vertical sonde measurements allow one to extrapolate the mass movement or flux density – lbs. per year moving through an idealized bottom cross-sectional area (*vertical slice*) as depicted above.

The above pre-dredging results can form the basis to determine the muck movement reduction after dredging at the mouth of Turkey Creek. As originally proposed, comparisons of the results from the sondes and another method were made. The station used for the comparison (TCB6) was located near the southern shoreline and channel marker as indicated in Figure 4-3. The second method utilized a flat horizontal sonde that can accumulate both settled fluidized muck and horizontal fluidized muck. The trap with a white optically calibrated inner target allows material to accumulate on and within the probe. The results are reported in total mass per unit time trapped within and on the surface of the sonde or probe. The difference between the 2 methods developed for estimating the fluidized muck movement in the east and westward directions along the channel and shoreline was less than one order of magnitude.

Subsurface imaging of the particulate material shows the sondes measure particle movement (Bostater and Rotkiske, 2015). Imaging was used to collect video sequences at stations TCB6 and station TCP2. Visual inspection by a diver and video imagery indicated the fluidized particulates entering the sondes are predominantly in the form of flocs and colloidal assemblages – before they settle and break with the sonde control volume.

Figure 4.7 is an image snapshot from a video sequence at station TCP2 along the north western shore of Palm Bay east of US1 in 1.5 to 2-m water depth. Sludge judge (push pole) measurements made before and after deployments at this station indicated muck thickness on the order of 0.5 m. The flocs and colloidal assemblages also settled on top of the sonde and just inside the sonde. The entrance to the westward facing sonde is seen in the image. The fluidized mud and muck move into the sonde in the form of flocs and colloidal assemblages before settling within where they break inside the sonde. After breaking, the flocs are visually indistinguishable from fluid mud and muck.

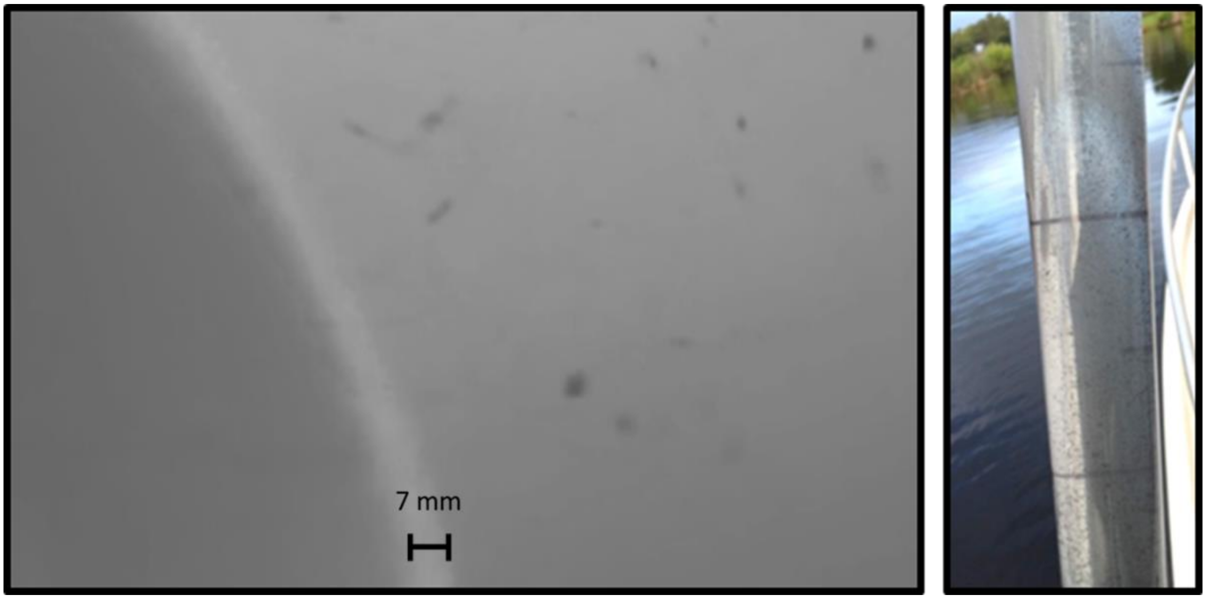


Figure 4.7 Subsurface image (left) from station TCP2 at ≈10 cm above the bottom. Large colloidal assemblages and flocs were identifiable in the water just outside the horizontal sonde. The right image shows flocs and colloidal aggregates in clear near bottom water collected at station TCB1.

Figure 4.8 indicates locations of the three stations west of the railroad bridge in Turkey Creek. During October the three stations were instrumented (TCB1, TCB2, TCB3) from October 1 thru October 3.

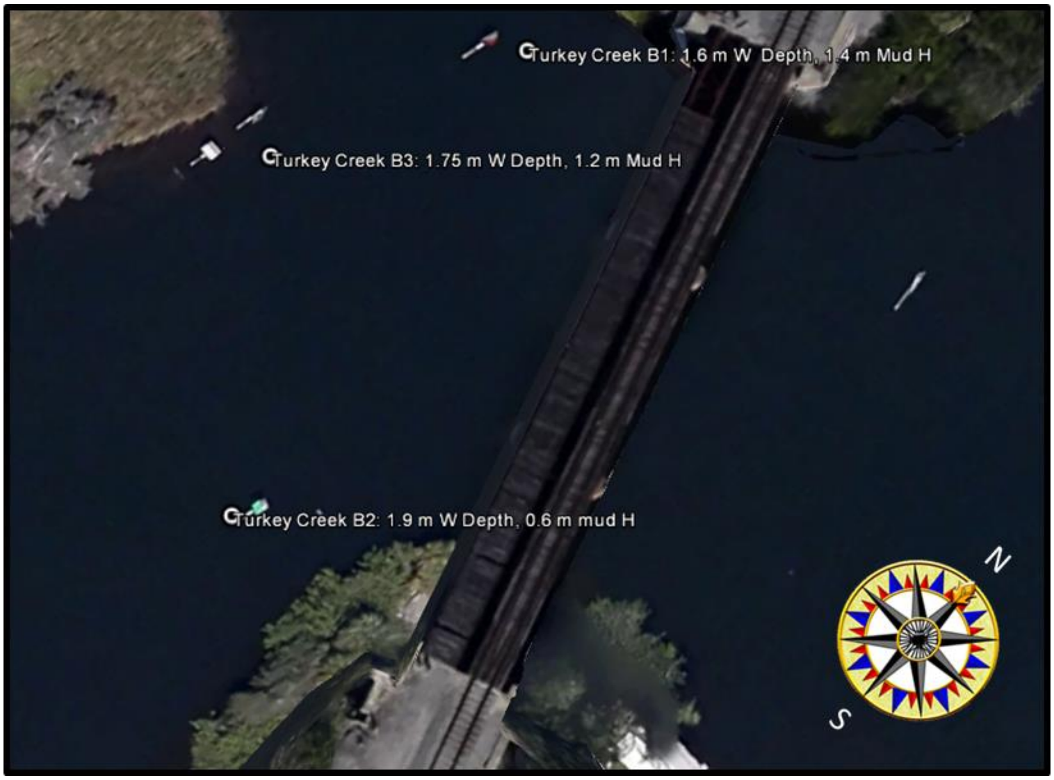


Figure 4.8 Stations TB1, TB2 and TB3 station locations in Turkey Creek west of the railroad bridge.

Triplicate deployments were made at the above three stations using westward facing sondes. The triplicate results for the percent loss on ignition (% LOI) analyses from the 3 stations are shown in Figure 4.9. The westward facing sonde results at station TCB1 and TCB2 indicate excellent results with standard deviation of the triplicate deployment results at TCB1 and TCB2 of 1.58 and 2.21 percent respectively and standard error of the mean of 0.91 and 1.28 % respectively. Station TCB3 results indicate greater variability. The westward facing sondes may have been influenced by deployment to close to the nearby island that blocked the downstream flow of particulates. Pooled station results for the eastward facing sondes are shown in Figure 4.9 and indicated higher organic matter content within the moving fluid mud moving upstream (west of the railroad bridge).

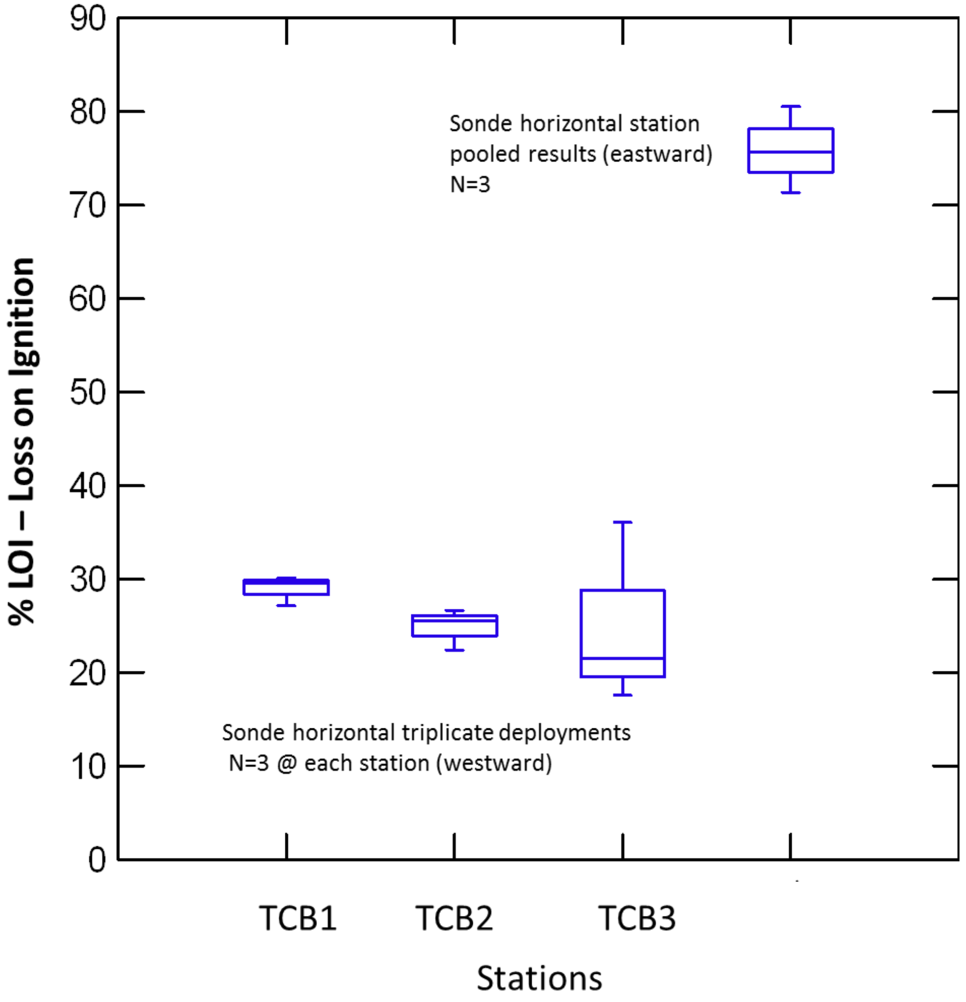


Figure 4.9 Station horizontal sonde (westward facing) triplicate (n=3) deployment results for percent loss on ignition (% LOI) and eastward facing sondes with single deployments at each station (n=1) were pooled giving N=3. The above data represent % LOI results from a total of 12 horizontal sondes simultaneously deployed during October 1-3, 2015.

Figure 4.9 above shows the October 1-3 results for % LOI from station TCB1 and TCB2 for the westward facing (downstream flux) sondes. The triplicate result with a coefficient of variability of 0.05 and 0.09 indicate good reproducibility and precision of the horizontal sonde method for % LOI. Station TCB3 results (shown in Figure 4.9) were influenced by close proximity to an island as shown in Figure 4.8 and the coefficient of variability was 0.38 at this station.

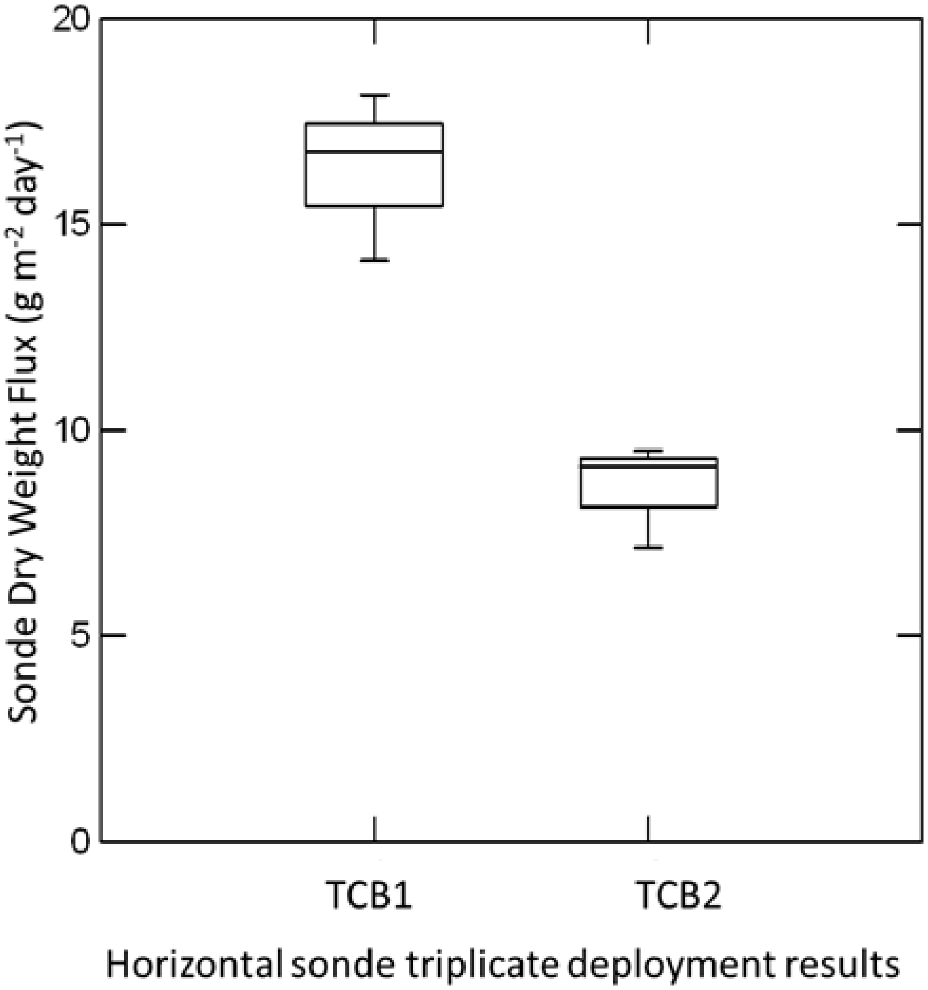
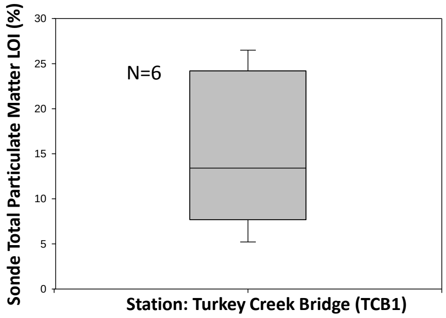


Figure 4.10 Sonde downstream flux direct measurements (g m^{-2} day^{-1}) based upon triplicate deployment results for Turkey Creek stations TCB1 and TCB2, west of the railroad bridge. These results suggest the sonde method has good reproducibility based upon the simultaneous deployments yielding a coefficient of variability of 0.125 and 0.147.

Analysis was performed using information collected from two stations in order to demonstrate how sonde data from this research project can be related to (1) monitoring results by Trefry, 2015 and (2) utilized in water quality modeling activities. Neither of these research efforts measures the ambient movement of fluid mud and muck that is greater than 75% water (Trefry, 1978). Figure 4.11 thru 4.13 shows two stations TCB1 and TCP1 where sampling was conducted for estimation of fluid mud fluxes.

At each station horizontal probes (up to 4 directions) and four vertical probes (2 measuring settling and 2 measuring upwelling or suspension were placed at stations during a 12-17 hour deployment period. Muck movement can be reported in terms of a mass flux (e.g. g m^{-2} day^{-1}) dry weight. The laboratory analysis of samples collected by the sonde provide an estimate of % loss of ignition (% LOI) by drying the total particulate matter captured at 105° C followed by placement of the material in a furnace at 550° C as described in Standard Methods For Examination of Water & Wastewater, 1980. Figure 4.11 thru Figure 4.13 show results of the LOI for the 2 stations mentioned above, along with ancillary data collected at each station.



Loss on Ignition %

	LOI % TCB1
N of Cases	6
Minimum	5.220
Maximum	26.502
Arithmetic Mean	15.080
Standard Deviation	8.418

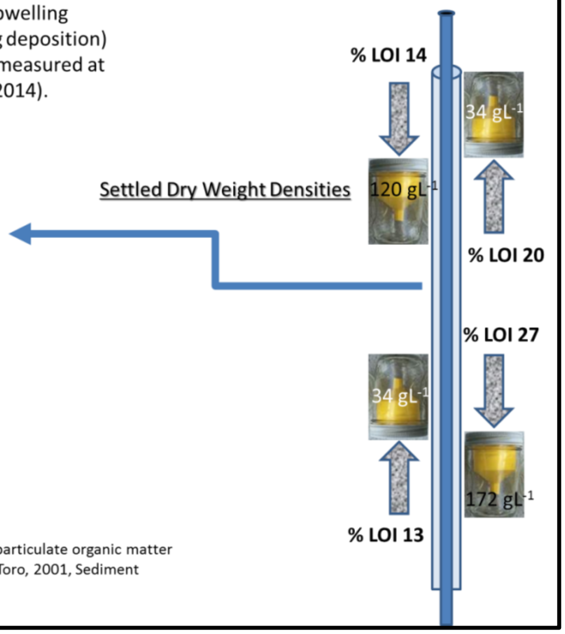
Sonde Total Particulate Matter Dry Weight **Density:** **$\overline{X}$ = 61 gL^{-1} (43-82)**
Water Temp 29.5^0 C
Mud Bottom
Muck Depth: 20 cm
Water Depth: 1.2 m
Horizontal Deployment Orientation: **2** - Upstream, Downstream
Deposition (settling) sondes: **2**
Resuspension (upwelling sondes): **2**
Horizontal Water Velocity: ~ 5 cm/sec
Deployment ΔT: 17 hours

Figure 4.11 Percent LOI results at station TCB1 from horizontal and vertical sondes.

4 Sondes deployed to sample upwelling (resuspended) and downwelling deposition) fluxes of fluidized mud & muck measured at each station (Bostater & Yang , 2014).

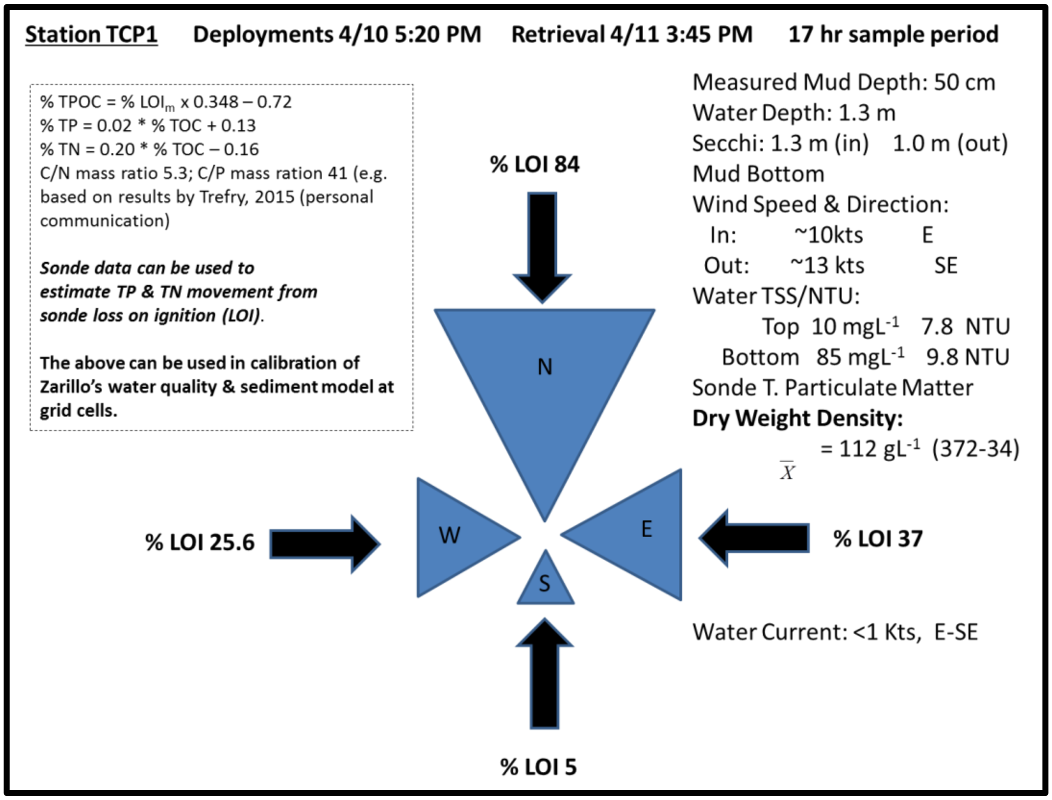
STATION TCP1 4/10-11 2015

% TPOC = % LOI x 0.348 – 0.72
% TP = 0.02 * % TOC + 0.13
% TN = 0.20 * % TOC – 0.16
C/N mass ratio ~5.3
C/P mass ration ~41
(e.g. based on Trefry, 2015 (personal communication Palm Bay data)



Approach of using %LOI for estimating particulate organic matter fluxes and deposition modified after DiToro, 2001, Sediment Flux Modeling, Wiley, 624 pp.

Figure 4.12 Station TCP1 % loss on ignition (LOI) results from the depositional and resuspension sondes described by Bostater & Yang, 2014. Organic matter was greater in the bottom depositional sonde. The % loss on ignition data is used in this report to estimate particulate nutrients captured within the fluid mud using the results of Trefry, 2015.


Station TCP1 **Deployments 4/10 5:20 PM** **Retrieval 4/11 3:45 PM** **17 hr sample period**

% TPOC = % LOI_m x 0.348 – 0.72
% TP = 0.02 * % TOC + 0.13
% TN = 0.20 * % TOC – 0.16
C/N mass ratio 5.3; C/P mass ration 41 (e.g. based on results by Trefry, 2015 (personal communication)

Sonde data can be used to estimate TP & TN movement from sonde loss on ignition (LOI).

The above can be used in calibration of Zarillo's water quality & sediment model at grid cells.

Measured Mud Depth: 50 cm
Water Depth: 1.3 m
Secchi: 1.3 m (in) 1.0 m (out)
Mud Bottom
Wind Speed & Direction:
In: ~10kts E
Out: ~13 kts SE
Water TSS/NTU:
Top 10 mgL^{-1} 7.8 NTU
Bottom 85 mgL^{-1} 9.8 NTU
Sonde T. Particulate Matter
Dry Weight Density:
$\overline{X}$ = 112 gL^{-1} (372-34)

Water Current: <1 Kts, E-SE

Figure 4.13 Station TCP1 % loss on ignition (LOI) results from the horizontal sondes described developed by Bostater & Yang, 2014. The results depicted above indicates the percent organic matter was different based upon the directional movement of the fluid mud, with the greatest organic matter content from material moving from the north and indicated by the size of the blue triangle.

Using a modification of the methodology originally proposed by Di Toro (2001), relations between % LOI, total particulate organic (% TPOC), total particulate phosphorus (% TP), and total particulate nitrogen (% TN) can be used to estimate the depositional fluxes and horizontal fluxes if the particulate matter fluxes from the sondes are available. Research by Trefry, 2015 has developed relations for estimating the % total particulate carbon, % total particulate nitrogen and % total particulate phosphorus based upon the % LOI of muck. Thus, the sonde data collected can be used to estimate not only the fluid mud fluxes but also the associated carbon, phosphorus and nitrogen fluxes associated with the particulate moving fluid mud using the sonde data. These results demonstrate the use of data from this research task for providing information on bottom boundary layer particulate nutrient flux *movement* in Turkey Creek for use in water quality modeling activities. For example, Figure 4.14 shows the results of calculations using data collected from station TCP1 where the sonde fluid mud results and the Trefry, 2015 relations (indicated in figure 4.13) can be combined in order to calculate nutrient depositional fluxes over idealized model lower grid layers. This example calculation is meant to demonstrate how the sonde flux data, muck nutrient relations and water quality modeling of Turkey Creek can be combined for model calibration purposes.

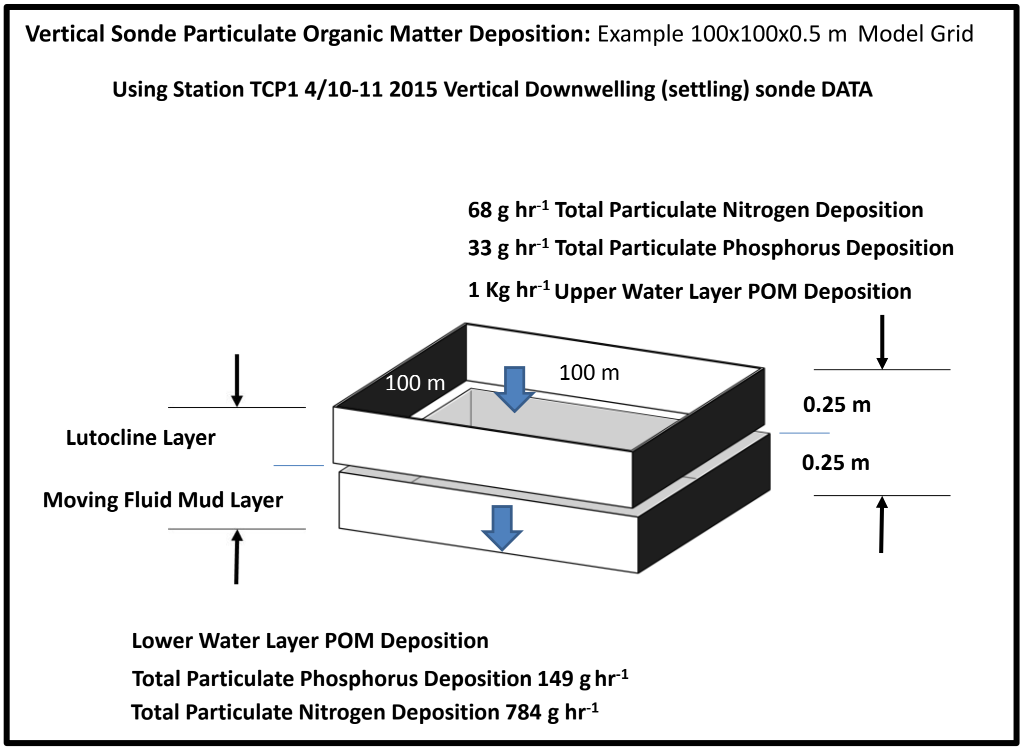


Figure 4.14 Schematic showing results of combining sonde depositional % LOI and Trefry, 2015 nutrient relations for estimating nutrient deposition per hectare for use in water quality model calibrations.

Stations were instrumented just west of the railroad bridge (TCB1, TCB2, TCB3) from October 1 thru October 3. These were instrumented in response to possible upstream water releases in anticipation of an approaching tropical storm. High flows however *did not* occur during the deployment period. Figure 4.15 shows the provisional flows from the upstream USGS gauging station.

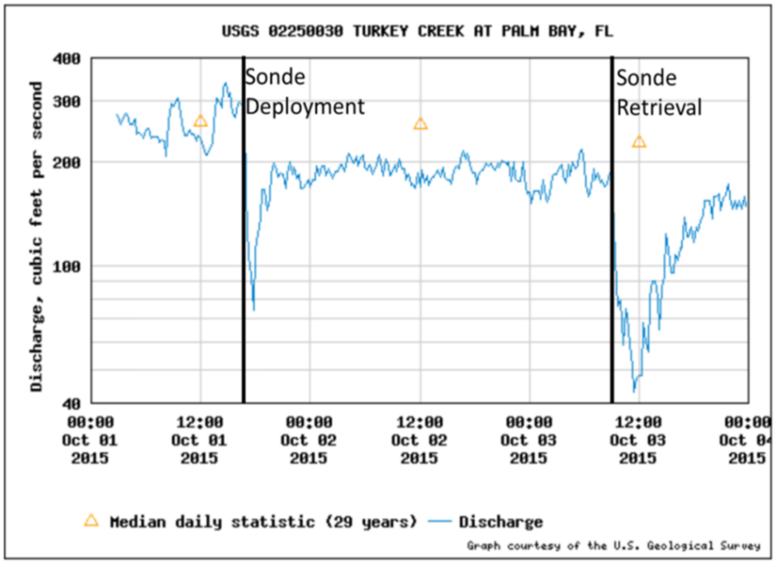


Figure 4.15 Discharge time series during the October, 2015 deployment period.

Freshwater inflow was actually at a minimum during the instrument deployment and retrieval period from 10/1 to 10/3. During this pre-dredging sampling period a total of 36 sondes were deployed (12 horizontal and 24 vertical sondes) during approximately a 39-hour deployment period. At these stations, muck depth was measured using a sludge judge (muck pole) constructed of clear PVC pipe. Comparison of the water and mud/muck depths between the May and October, 2015 sampling periods is also shown in Table 4.2. Precision estimated from this technique is reported in the QA/QC section of this subtask report. A review of the USGS provisional discharge data earlier in September showed that a large release of water actually occurred mid-September and may have caused the changes in the muck depths and water depths.

Station	Depth (m)	Muck (m)
TCB1	1.6/2.55	1.4/0.97
TCB2	1.9 /2.7	0.6/0.75
TCB3	1.75/1.3	1.2/0.5

Table 4.2 Comparison between the May-October (May/October) water "depth" and "muck" depths at stations west of the railroad bridge in Turkey Creek. Muck depths and water depths measured with a sludge judge indicates observed muck depths changed between May and October sampling dates indicating muck depth changes.

4.3.2 Optical and Acoustic Sampling at Selected Stations

Water clarity at the 3 stations was greater than expected with 1 secchi meter depth at all stations on October 1 and October 3. However the bottom 0.5 meter water layer was extremely clear (see Figure 4.16 (right), but with many flocs and colloidal aggregates as shown below. Bottom water salinity at these stations was in the 10-12 psu range and surface waters were around 2 psu. A diver reported a strong thermocline at the 1 m depth. The unique clarity of the bottom layer water at station TCB1 on October 3, 2015 is shown in Figure 4.16 (right) within the bottom 0.5 meter water collected within a clear PVC sludge judge.

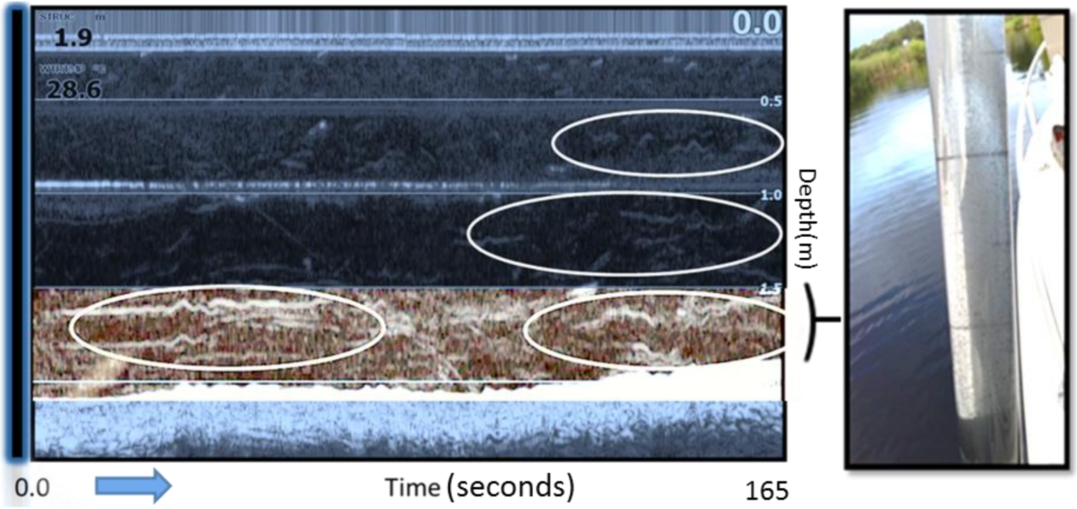


Figure 4.16 Clear bottom layer water at station TCB1 (right) collected with the sludge judge. Subsurface nephelometric layers are visible as wavelike features in the image (left) below the secchi depth in the fixed station acoustic echogram image (left) taken from a 0.0-165 sec time recording. The water depth was ~1.9 m and water temperature 28.6 ^{o}C.

A fixed location, time continuous acoustic fan beam image (Figure 4.16) acquired at station TCB1 indicated oscillating internal nephelometric layers passing through the acoustic (455 MHz) fan beam within the lutocline. The surface of the moving lutocline indicated passing waves as water moved through the fixed station acoustic fan beam.

Similar acoustic backscatter imaging results have been reported by Traykovski et al. 2000 above fluid mud flows and within a moving lutocline. Similar waves in resuspended sediment and nepheloid layers induced by internal solitary waves have also been reported in acoustic echograms and models as shown in Bourgault, et al., 2014.

Analysis of floc movements and sizes were conducted at station TCB1 using imaging methods described by Bostater and Rotkiske, 2015. *In-situ* imaging of large underwater flocs has also been reported by Eisma et al., 1990 and Manning et al., 2011. At TCB1, Lagrangian movement of the water was measured. Triplicate measurements indicated movement between 30-31 cm sec^{-1}. Image analysis of flocs and colloidal assemblages indicated predominate size range of 0.1 mm to 10.2 mm effective diameter. Mean cross-sectional floc diameter was 2.77 mm (2770 µm) ± 2.44 mm SD with a median floc effective cross-sectional area of 30 mm^2. Image analysis of the *in-situ* flocs and colloidal aggregates in the bottom 20-30 cm water column layer provided estimates of the colloidal aggregate sizes in terms of an effective cross-sectional area (mm^2) frequency distribution as shown in Figure 4.17. The size frequency distribution follows an exponential distribution as determined by application of the KS nonparametric test (P<0.001).

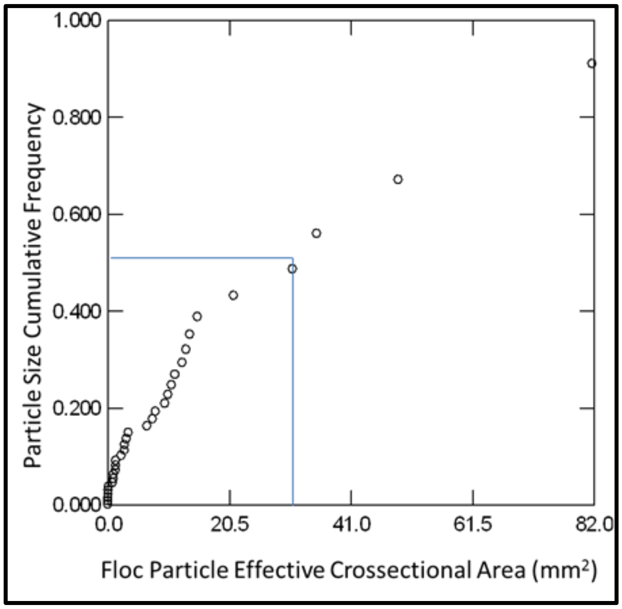


Figure 4.17 Station TCB1 floc size (cross-sectional area) determined from image analysis using the methods reported by Bostater and Rotkiske, 2015. Median floc sizes were near 30 mm^2. These dominate sizes are in the 2,000-3,000 micron range and are the equivalent size range of US Screen Mesh numbers ≈ 6-12.

An example image from a 3 channel "*multispectral"* floc camera system was acquired at station TCB1 as shown in Figure 4.18 below. As noted, the flocs that dominated the particles in the clear high salinity bottom water layer were not spherical in shape and thus settling or vertical deposition rates do not follow terminal gravitational settling based upon spherical Stokes estimation as discussed in Bostater and Rotkiske, 2015. When the floc and colloidal assemblages enter and settle within the sondes they are broken (like snowflakes) and their size and form are not distinguishable from collected fluid mud and muck outside the sonde. These fragile mineral and biogenic aggregates are broken by Niskin bottles and sampling with pumps. Thus they are not typically observed using common water sampling methods (Gibbs and Konwar, 1983).

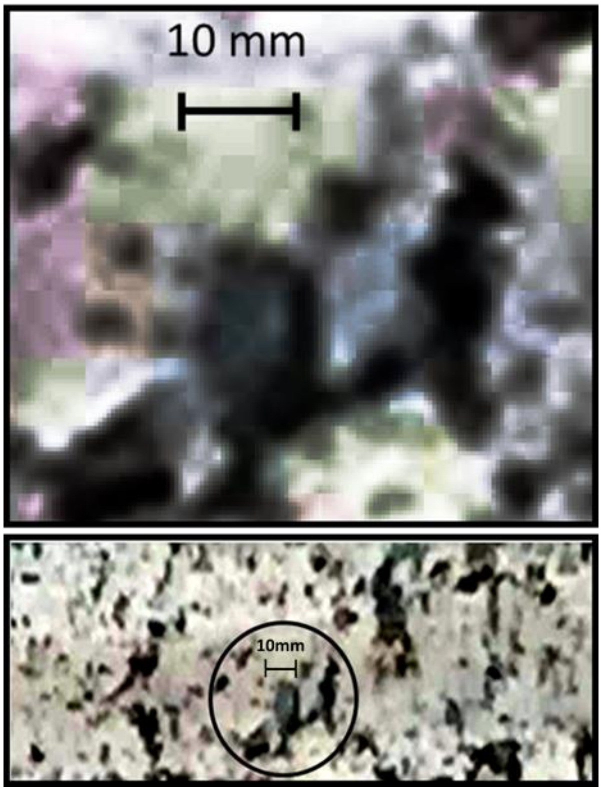


Figure 4.18 Multispectral 3 channel image (lower) and the zoomed multispectral sub-image (top) of colloidal aggregates and flocs taken from a multispectral 3 channel image (lower). Measurements were obtained at station TCB1 in Turkey Creek west of the railroad bridge (N 28.032076, W -80.682458338) on October 3, 2015 using the methods described in Bostater and Yang, 2014, and Bostater and Rotkiske, 2015.

4.3.3 Wide Area Sonde Data Analyses Results

The pre-dredge sonde deployment results during 2015 have been compared with respect to total non-directional moving particulates in the lutocline (dry weight) extrapolated to grams m^2 day^{-1} from the following areas: (1) stations at the mouth and just outside of Palm Bay (n=52), (2) stations west of the railroad bridge (n=52), and (3) stations east of US1 within Palm Bay (n=54). The distribution of the measured dry weight fluxes are indicated in Figure 4.19. The variability is greater at stations East of US1 within the bay as shown in the figure below. The pooled station results will be available to consider the efficacy of dredging in terms of muck movement reduction (MMR) as shown in Figure 4.2. The data used in Figure 4.19 suggest the fluid mud movement measurement distributions are non-normal. Kruskal-Wallis p test for analysis of variance for n=164 cases and the three grouping categories indicated p-values <0.001, suggesting the centers of the three station grouped distributions are different. Kolmogorov-Smirnov two sample test probabilities were 0.001 or less and suggest the distributions are different from each other. Box plots and interquartile ranges have been used to help identify outliers as described by Goic et al. 2013; Frigge et al. 1989; Iglewicz and Hoaglin, 1993.

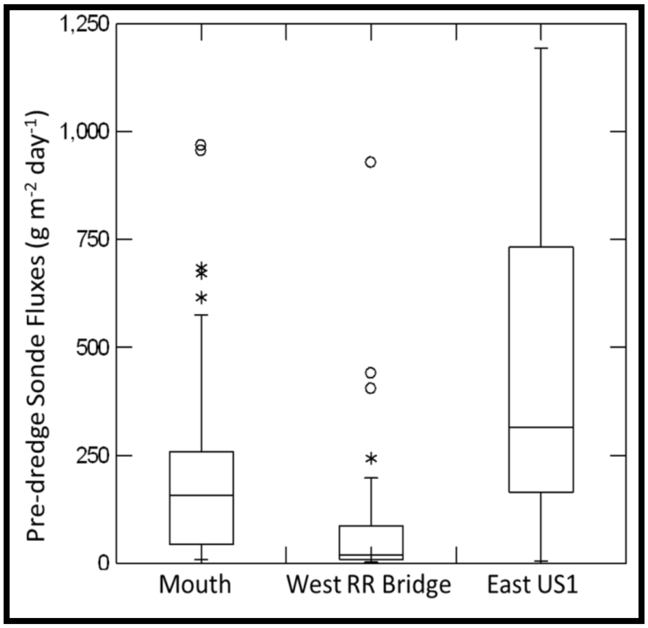


Figure 4.19 Sonde total non-directional moving particulates in the lutocline (dry weight) extrapolated to grams m^2 day^{-1} from (1) stations at the *mouth* and just outside of Palm Bay (n=52), (2) stations *west of the railroad bridge* (n=52), and (3) stations *east of US1* within Palm Bay (n=54).

Pooled area results suggest the area moving fluid mud fluxes are different ($P < 0.001$) using the Kolmogorov-Smirnov two sample test. The above total fluxes or fluid mud results will be available for evaluating muck movement reduction (MMR) using the future dredging and post dredging results.

Area wide characterization of subsurface sediment media with different grain size characteristics has been previously studied using GIS techniques. Specifically, Nobre and Sykes, 1992 have demonstrated a power Bayesian kriging technique for mapping subsurface data. The methodology (Bostater and Rotkiske, 2016) maps data in a manner where observational data prevails close to observed stations, but minimizing mapped result errors using variograms and associated variance reduction methods. This technique was applied to develop subsurface fluid mud movement (fluxes) using spatial contours and grids for the Turkey Creek data. Resulting geospatial results are shown in Figures 4.20, 4.21, 4.22, 4.23 and 4.24. Use of this method reduces predicted variable kriging variances by 2-3 orders of magnitude by utilizing Bessel correlation functions of the first kind and Hankel transformations. By using power variograms methods and correlation methods, one can reduce predicted error variance due to automated detection of potential outliers. Figure 4.19 and Figure 4.20 show the subsurface continuous fluid mud movement using the above methodology in order to predict the geospatial subsurface bottom layer distribution of moving fluid mud and muck in Turkey Creek for particulate organic dry weight material and total dry weight fluxes collected. Gridded data in Figures 4.21 thru 4.24 represents georeferenced 6.5 m^2 gridded data used to create the color pixel flux maps. Gridded data are used for overlaying with airborne and satellite imagery and to coincide with model grid sizes.

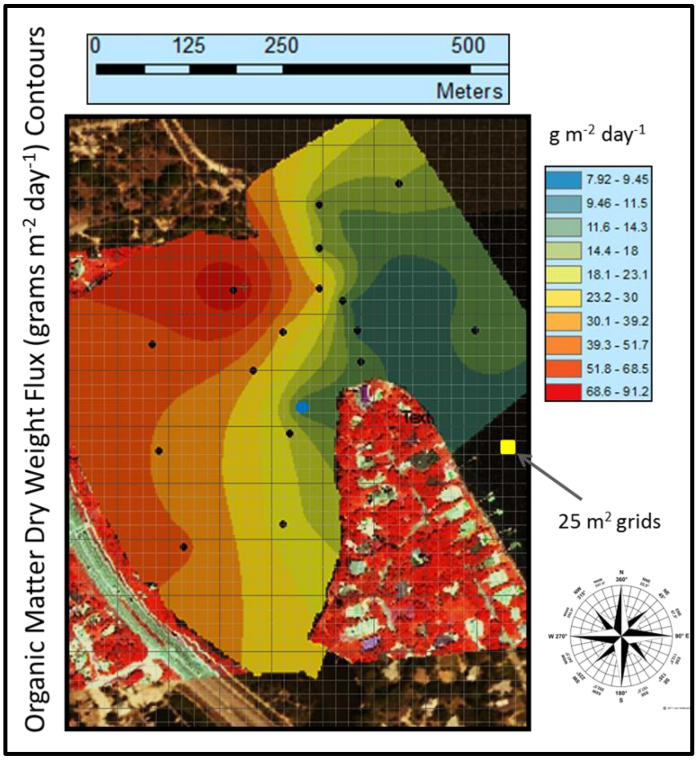


Figure 4.20 Gridded and color contoured map of the moving (total non-directional particulate organic matter) dry weight flux (g m^{-2} day^{-1}) in the lower 0.5-meter water column based upon horizontal and vertical sonde data from stations east of US 1 and at the mouth of Turkey Creek are shown. A spatial grid of ~25 m^2 is overlaid on gridded image. Subsurface characterization is based upon utilizing Bayesian kriging power semivariogram methods (Nobre and Sykes, 1992).

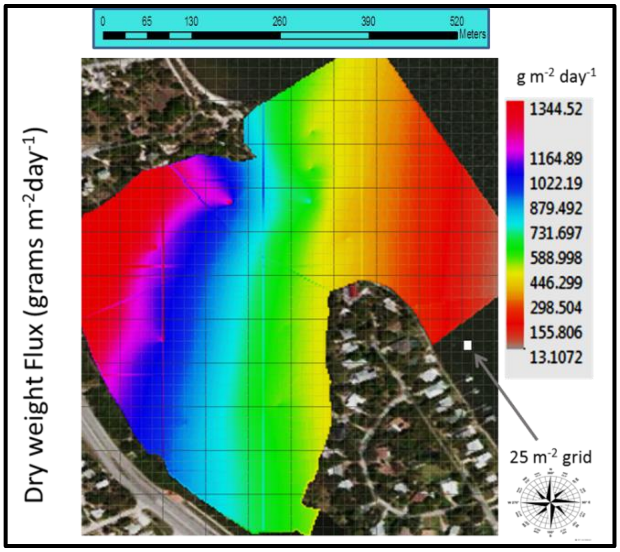


Figure 4.21 Georeferenced map of estimated total particulate matter (dry weight) flux (g m^{-2} day^{-1}) moving in the lower 0.5 meter water column based upon horizontal and vertical sonde data from stations east of US 1 and at the mouth of Turkey Creek. A spatial grid of ~25 m^2 is overlaid on the 6.2 m^2 gridded image. Subsurface characterization utilizes Bayesian kriging power semivariogram methods (Nobre and Sykes, 1992).

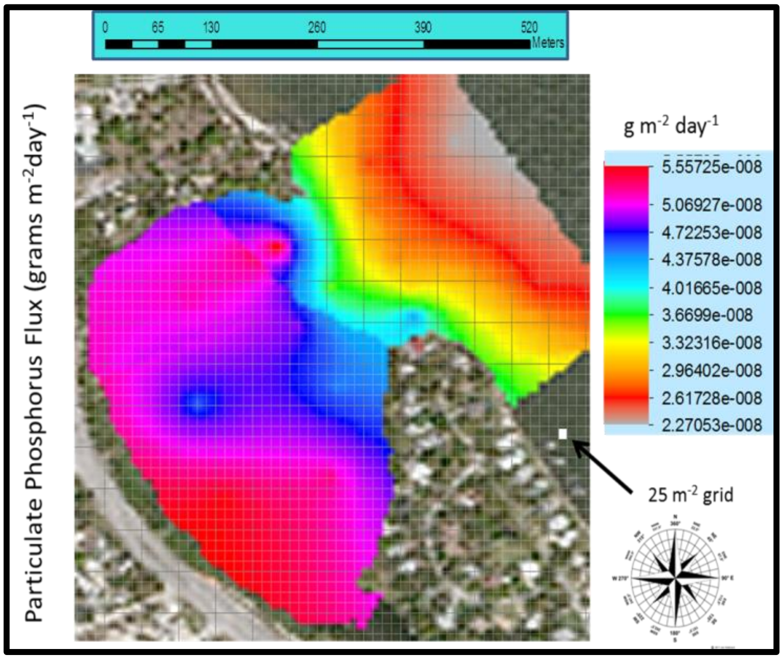


Figure 4.22 Georeferenced map of estimated particulate phosphorus flux (g m^{-2} day^{-1}) moving in the lower 0.5 meter water column based upon total horizontal and vertical sonde data from stations east of US 1 and at the mouth of Turkey Creek. A spatial grid of ~25 m^2 is overlaid on the 6.2 m^2 gridded image. Subsurface characterization utilizes Bayesian kriging power semivariogram methods (Nobre and Sykes, 1992).

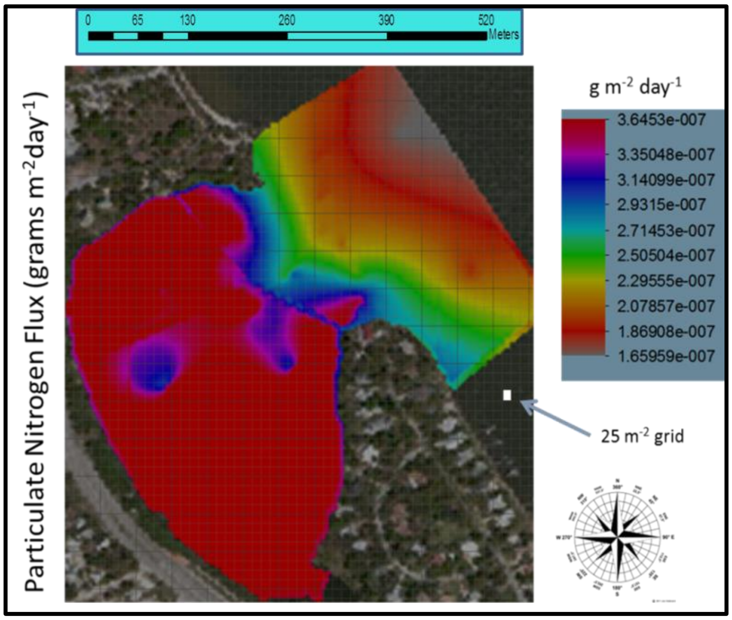


Figure 4.23 Gridded and contoured georeferenced map of estimated particulate nitrogen flux (g m^{-2} day^{-1}) moving in the lower 0.5-m water column based upon total horizontal and vertical sonde data from stations east of US 1 and at the mouth of Turkey Creek. A spatial grid of ~25 m^{2} is overlaid on the 6.2 m^{2} gridded image. Subsurface characterization utilizes Bayesian kriging power semivariogram methods (Nobre and Sykes, 1992).

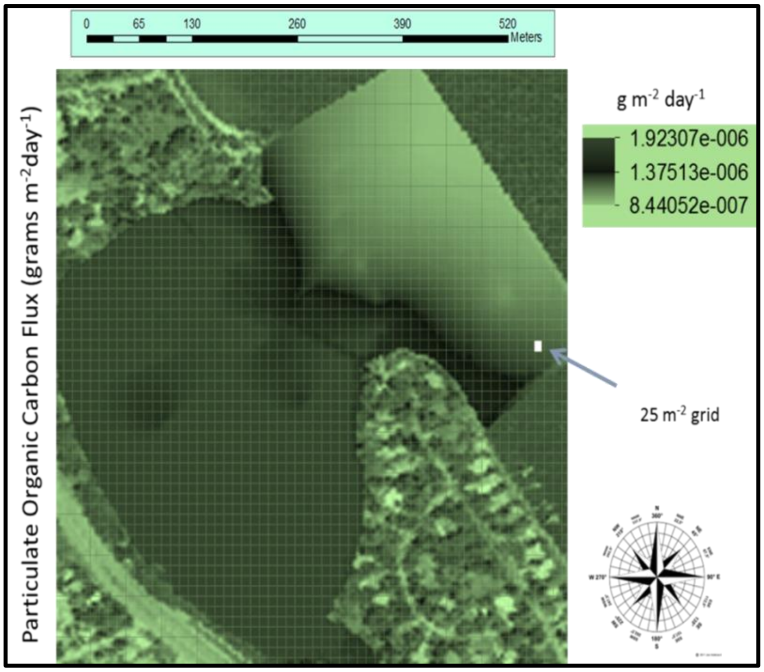


Figure 4.24 Gridded and contoured georeferenced map of estimated particulate organic carbon flux (g m^{-2} day^{-1}) moving in the lower 0.5-m water column based upon total horizontal and vertical sonde data from stations east of US 1 and at the mouth of Turkey Creek. A spatial grid of ~25 m^{2} is overlaid on the 6.2 m^{2} gridded image. Subsurface characterization utilizes Bayesian kriging power semivariogram methods (Nobre and Sykes, 1992).

A high spatial resolution multispectral 3 channel airborne image of Palm Bay collected during January, 2015 is shown Figure 4.25. The image has been analyzed to discriminate or extract subsurface bottom reflectance features using remote sensing methods (Bostater, 2006, 2008, 2012). The effective pixel size or ground sampling distance (GSD) is ≈ 6 cm^2, and in general matches the gridded data sizes shown above. The inset in the image shows the top of the channel markers subsurface features in greater detail.

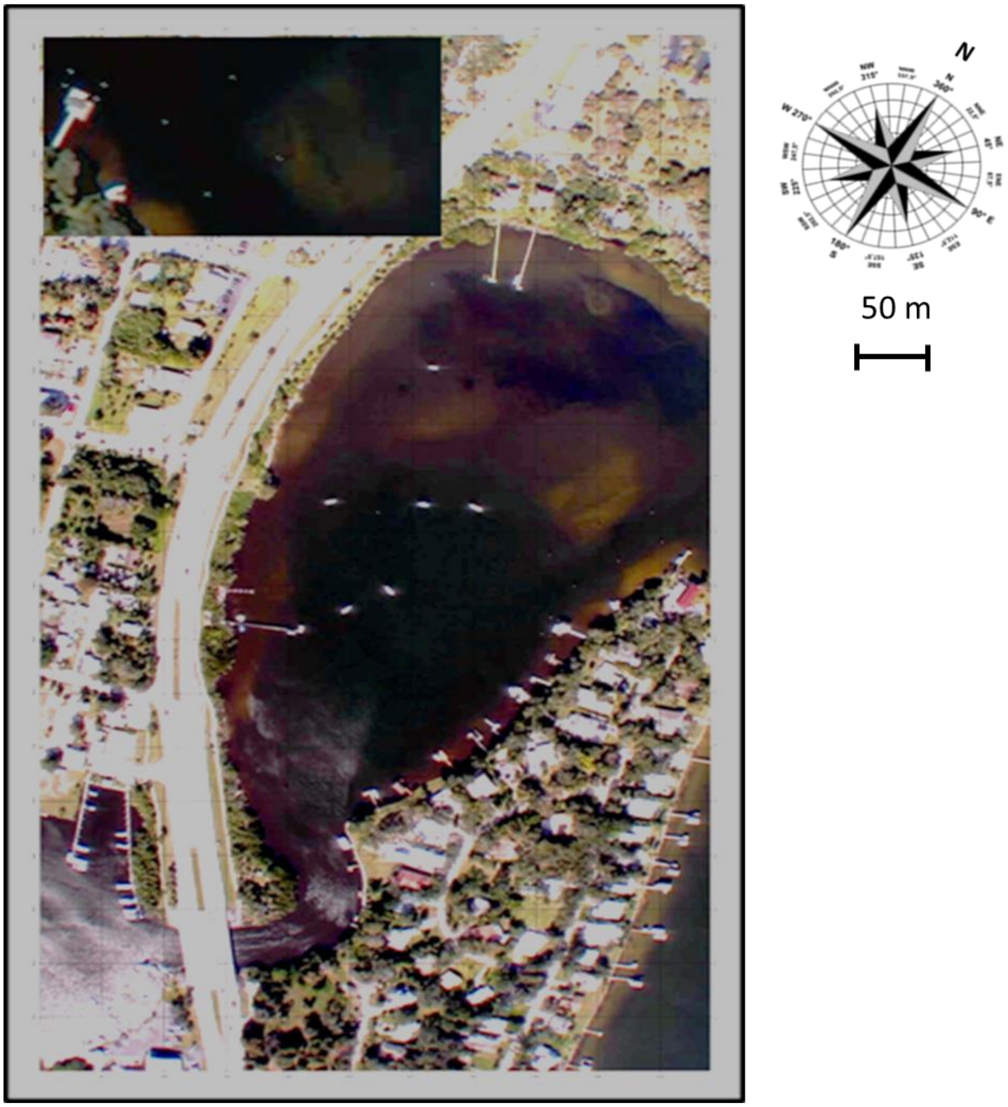
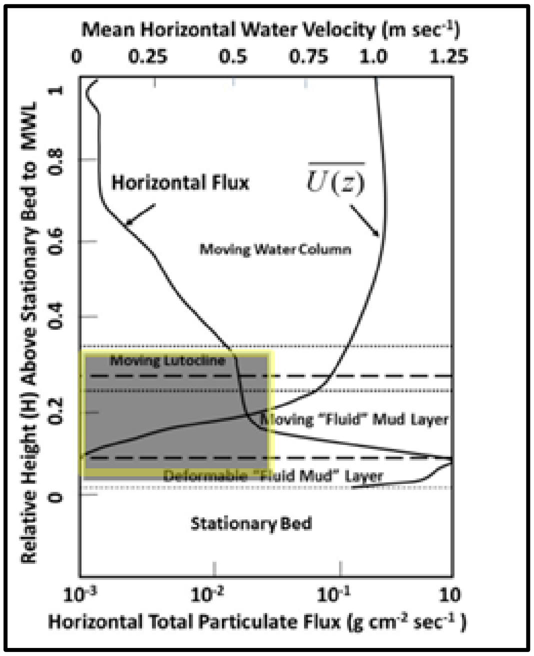


Figure 4.25 A high spatial resolution airborne multispectral (3 band) image of Turkey Creek with a GSD of approximately 6 cm^2. The image has been processed for detecting subsurface bottom features and bottom reflectance using the methods published and described by Bostater, 2006, 2008, 2012. Only the lower left area of the water surface is influenced by sun glint. The zoomed inset in the upper left shows the detail in the high spatial resolution airborne imagery.

Section 4.4 Conclusions

- The fluxes measured from sonde deployments closely match the magnitude of fluxes shown in Figure 4.1 and reproduced below. The grey area represents the range of fluxes observed in Turkey Creek during the 2015 research period. Thus fluxes are within the range of previous research results by Mehta et al., 1994 and Bostater and Rotkiske, 2015. This indicates the new sonde methodology is capturing the moving fluid mud in the lutocline.



- The muck and fluid mud collected by the sondes are in agreement with the quantitative definitions published by previous research (Mehta, et al. 1994; Teeter 1992, 1994; McAnally, et al. 2007). The area outline within the yellow box indicates the range of particulate fluxes measured during this project (~ 1 x 10^{-3} to 0.49 g cm^{-2} sec^{-1}).

- The total horizontal movement of fluid mud and muck collected by the passive sonde method suggests a net westward flow and moving fluid mud may accumulate and settle in the western areas of Palm Bay (east of US1). This was verified by sludge judge measurements near station TCP4 where *in-situ* muck depth was greater than 3 m.

- Solids moving in the bottom lutocline and nepheloid layers into the sondes include flocs and colloidal aggregates. These fine grain aggregates were clearly observable in optical and acoustic imagery. Image analysis of flocs and colloidal assemblages indicated predominate sizes ranged from 0.1 mm to 10.2 mm effective diameter. Mean cross-sectional floc diameter was 2.77 mm (2770 µm) ± 2.44 mm SD with a *median* floc effective cross-sectional area of 30 mm^2. The size distribution does not follow the *normal* distribution. These particulates do no settle according to Stokes settling velocities. In essence, a substantial transport pathway of particulate matter within the moving lutocline is via flocs and colloidal aggregates.

- Area wide station analysis results utilizing all flux density sonde results shown in Figure 19, suggests a significantly different magnitude of material moving (1) west of the railroad bridge, (2) east of US1 and (3) at the mouth and outside of Palm Bay. Fluxes greater than 1200 g m^2 day^1 were observed with a net flux towards US1 (the western area of Palm Bay). Overall, it appears that Palm Bay may be acting like a muck sink. Both the IRL and Turkey Creek (west of the railroad bridge) appear to be acting as sources of muck.

- Area wide GIS spatial analysis demonstrates that the sonde data can be processed in gridded manner (see Figures 4.20 thru 4.24) that may be readily utilized in water quality and sediment modeling state variables - particulate organic matter, particulate inorganic matter, particulate organic nitrogen, particulate organic phosphorus and organic carbon fluxes.

- On a dry weight basis, total moving muck collected at a transect of six stations across the mouth of Palm Bay indicates 93,151g m^{-2} day^{-1} (dry weight) or 0.75 million lbs. m^{-2} yr^{-1} of muck moves across the mouth of Palm Bay within the lutocline (the lower 0.5-m water column) as depicted in Figure 4.6. The net westward flux was towards the western area of Palm Bay (east of US1) during the sampling period.

- Although dredge permit delays caused no dredging to occur this research period, the data developed can be used assess the efficacy of dredging in terms of muck movement reduction (MMR) similar to previous research conducted for the Florida Inland Navigation District and depicted in Figure 4.2.

- Area wide data derived from the sondes can provide model calibration sediment movement and mass transport data in the bottom boundary layer and the moving lutocline.

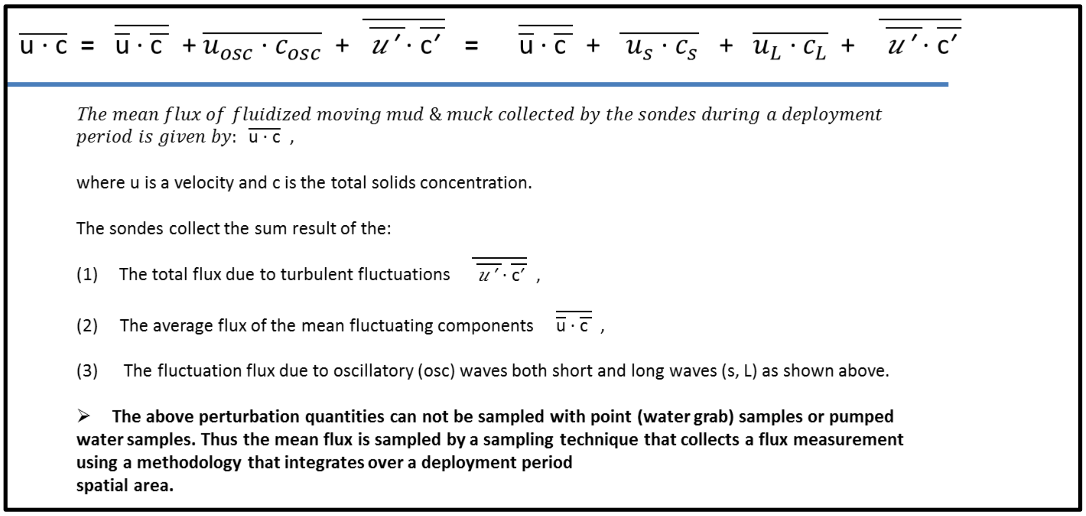
4.5 Quality Assurance Plan for Task 4

A. Project Purpose and intended use of data

The statement of work provided to Brevard County contains information on the purpose and intended use of the data collected in Task 4. In general, the purpose of Task 4 was to collect research data to assess the movement of fluid mud and muck. The scope of work described the probes and sondes to be deployed in order to assess muck movement reduction (MMR) during the pre-dredge, during dredging, and post dredging sampling. Efficacy of the dredging could be inferred by analysis of sonde data in terms of total non-directional flux density (mass per unit area per unit time) – fluid mud and muck movement.

B. Brief historical overview and literature search

Bostater and Yang, 2014; Bostater and Rotkiske, 2015 and Maglio et al., 2016 previously described the sondes (vertical & horizontal). They reviewed existing and historical aquatic methods that might be considered for indirect (surrogate) and direct measurements of fluid mud movement in terms of mass flux density (mass per unit are per unit time). The scientific methods and approaches reported in Bostater and Rotkiske, 2015, presented and compared (1) different operating principles of over 20 different specific samplers, probes and sensor systems applicable to sampling of fluid mud and bottom sediment characteristics, (2) the methodologies were compared as being optical, acoustical or direct and (3) the benefit and limitations of the various methods (particularly bedload type samplers). Only cylindrical sediment traps were noted as being capable of measuring vertical flux density, and that these were used around the world in different configurations by researchers. No horizontal traps were reported in the literature. The review also indicated no *direct* methods had been developed and reported in the open scientific literature for horizontal and directional fluid mud movements. Only one technique that incorporated directional measurement method has been published in the form of a US patent (Anderson, 1992) but the patent did not address or mention the ability to measure time and spatially averaged horizontal *fluxes* of particulates using the invention. Figure 4.5.1 below summarizes the theoretical operational basis and field sampling approach of the mass conserving sondes.



$$\overline{u\cdot c} = \overline{\overline{u}\cdot\overline{c}} + \overline{u_{osc}\cdot c_{osc}} + \overline{\overline{u'\cdot c'}} = \overline{\overline{u}\cdot\overline{c}} + \overline{u_s\cdot c_s} + \overline{u_L\cdot c_L} + \overline{\overline{u'\cdot c'}}$$

The mean flux of fluidized moving mud & muck collected by the sondes during a deployment period is given by: $\overline{u\cdot c}$,

where u is a velocity and c is the total solids concentration.

The sondes collect the sum result of the:

(1) The total flux due to turbulent fluctuations $\overline{\overline{u'\cdot c'}}$,

(2) The average flux of the mean fluctuating components $\overline{\overline{u}\cdot\overline{c}}$,

(3) The fluctuation flux due to oscillatory (osc) waves both short and long waves (s, L) as shown above.

➢ **The above perturbation quantities can not be sampled with point (water grab) samples or pumped water samples. Thus the mean flux is sampled by a sampling technique that collects a flux measurement using a methodology that integrates over a deployment period spatial area.**

Figure 4.5.1 Operation of the sondes or probes is based upon perturbation theory that indicates the sondes automatically perform a time and spatial averaging collection method to collect moving fluidized mud. The method allows one to capture particulate matter fluctuations where turbulence, water wave effects, variations in flux fluctuations due to mean river flow, fluctuating concentrations and velocities dominate instantaneous measurement systems in use today (from Bostater & Rotkiske, 2016).

Instantaneous water sample sampling (grab samples) or pumped samples cannot capture the variability of fluxes of substances in waters nor can grab sample results or pumped samples be used to calculate the conservation of mass in time and space that the sondes capture and which point sampling techniques cannot estimate. Maglio, et al., 2016 reported on the use and results to estimate muck movement reduction in Florida waters during a recent dredging project using the sondes and methods proposed for and accepted for use in this project. This research and the sonde operational theory follow the recommendations of the American Society of Civil Engineers (ASCE), Task Committee on Management of Fluid Mud, 2007 concerning the need to develop methods to measure fluid mud using temporal and spatial averaging techniques. No prior US EPA standard method or American Society of Testing and Materials (ASTM) is known to exist concerning direct or indirect (surrogate) horizontal fluid mud movement or flux density (mass L^{-2} T^{-1}) in aquatic systems.

C. Statement of anticipated results of the research project

The intended use of the data collected in this research is to help assess the benefits of muck dredging in the Indian River Lagoon as part of needed environmental remediation due to impacts of muck on the water quality and biotic populations in the Indian River Lagoon. The expected outcome of the research is to document through research data the reduction in the amount of moving fluid mud and muck after dredging has been completed. The concept of muck movement reduction (MMR) was recently developed for a dredging project in the Sebastian Inlet region and Intracoastal Waterway near Wabasso, Florida. The research demonstrated the ability of the sondes to document muck movement reduction at coastal waterway transects where research monitoring occurred during 2015 (Weaver et al., 2015; Maglio et al., 2016; Bostater and Rotkiske, 2015). Similar to the above referenced dredging project, this research task makes use of stratified random sampling for selection of stations and transects where sonde deployments occur. In addition, stratified random sampling is used to determine when sampling will occur during a selected day. Use of stratified random sampling design for *in-situ* sampling is intended to remove bias in results that could be attributed to sampling in time and space or locations.

D. Description of work to be conducted, including the types of analyses to be performed to monitor the effectiveness of the research

Field Sampling:

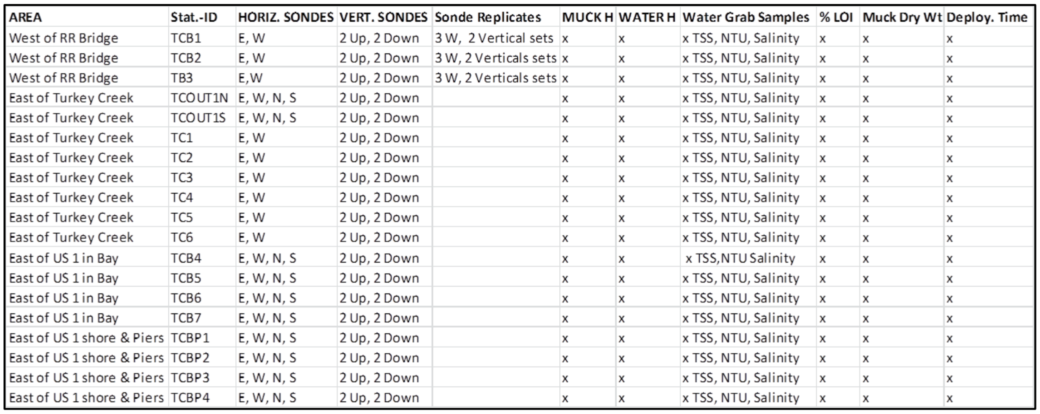
- *Sampling Plan Design and Rationale*

The *in-situ* station sampling design rationale makes use of a stratified random sampling of locations that allows the (1) use of sondes located along transects, (2) stations in the vicinity of shorelines and (3) stations outside the bay (west of the mouth of the bay and upstream of the railroad bridge). This approach allows for the analysis of pre-dredge, during dredging, and post dredging sonde measurements of fluid mud movement in terms of - mass per unit area per unit time.

- *Location of each sampling point for the project and link each point to the sampling methods, analysis, indicators, populations to be measured or investigated and frequency.*

The map Figure 4.2 shows the location of each sampling point. At each location deployments of the sondes are made. At each location 2 or 4 horizontal directional sondes are deployed. Two along the transect at the mouth of the Turkey Creek measuring inflow and outflow (east-west directions) and two at the 3 stations west of the railroad bridge in Turkey Creek for measuring upstream and downstream (east-west directions). Horizontal sondes deployments at all other stations were in the North, South, East, and West orientation.

Table 4.5.1 Description of samples collected during 2015 at each station.



AREA	Stat.-ID	HORIZ. SONDES	VERT. SONDES	Sonde Replicates	MUCK H	WATER H	Water Grab Samples	% LOI	Muck Dry Wt	Deploy. Time
West of RR Bridge	TCB1	E, W	2 Up, 2 Down	3 W, 2 Vertical sets	x	x	x TSS, NTU, Salinity	x	x	x
West of RR Bridge	TCB2	E, W	2 Up, 2 Down	3 W, 2 Verticals sets	x	x	x TSS, NTU, Salinity	x	x	x
West of RR Bridge	TB3	E,W	2 Up, 2 Down	3 W, 2 Verticals sets	x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TCOUT1N	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TCOUT1S	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TC1	E, W	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TC2	E, W	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TC3	E, W	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TC4	E, W	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TC5	E, W	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of Turkey Creek	TC6	E, W	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 in Bay	TCB4	E, W, N, S	2 Up, 2 Down		x	x	x TSS,NTU Salinity	x	x	x
East of US 1 in Bay	TCB5	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 in Bay	TCB6	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 in Bay	TCB7	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 shore & Piers	TCBP1	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 shore & Piers	TCBP2	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 shore & Piers	TCBP3	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x
East of US 1 shore & Piers	TCBP4	E, W, N, S	2 Up, 2 Down		x	x	x TSS, NTU, Salinity	x	x	x

All of the above stations were selected as being relevant to the purpose and intent of the project. The key parameters necessary to estimate muck movement reduction project goal are derived from the deployment of the vertical sondes and horizontal sondes. Key parameters essential for calculation of direction fluxes (mass m^{-2} t^{-1}) of fluid mud & muck passively moving into each directional horizontal or vertical sonde (depositional, resuspended matter are: (1) deployment time (HH.MM), (2) dry weight (grams), (3) calculation of % loss on ignition (estimation of organic content of the fluid mud and after ignition in a muffle furnace). All other parameters collected are provided as ancillary background information such as depths and water grab samples (salinity, NTU, TSS). Water grab sample results at each station are not used in the calculation of moving fluid mud & muck fluxes. As noted above either 2 or 4 horizontal sondes are deployed and one set of four vertical sondes are deployed at each station. The deployment design allows the estimation of muck movement reduction as reported in Maglio, et al., 2016 using the methods for direct measurement of fluid mud & muck flux in Bostater & Rotkiske, 2015.

- *Map of the sampling point locations*

The Table below gives the general area, station ID name and latitude longitude information. Stations are relevant for calculation of moving fluid mud flux at the following areas: (1) just west of the railroad bridge, (2) with the bay (east of US 1), and (3) at or near the mouth of Palm Bay.

Table 4.5.2 Station locations (latitude longitude decimal degrees), station ID and region.

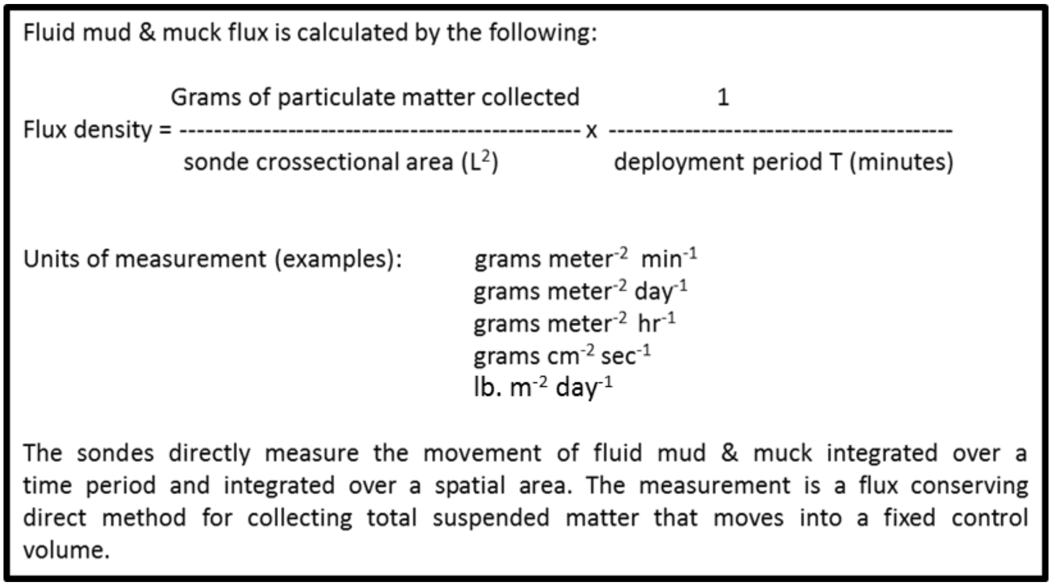
West of RR Bridge	TCB1	28.032073	-80.582459
West of RR Bridge	TCB2	28.031683	-80.582319
West of RR Bridge	TCB3	28.031876	-80.582534
East of Turkey Creek	TCOUT1N	28.040005	-80.578327
East of Turkey Creek	TCOUT1S	28.038344	-80.57742
East of Turkey Creek	TC1	28.037996	-80.578788
East of Turkey Creek	TC2	28.038338	-80.578826
East of Turkey Creek	TC3	28.038671	-80.579005
East of Turkey Creek	TC4	28.038813	-80.579285
East of Turkey Creek	TC5	28.039262	-80.579292
East of Turkey Creek	TC6	28.03976	-80.579288
East of US 1 in Bay	TCB4	28.036151	-80.57972
East of US 1 in Bay	TCB5	28.037894	-80.580077
East of US 1 in Bay	TCB6	28.037183	-80.579645
East of US 1 in Bay	TCB7	28.038323	-80.579714
East of US 1 along shore & Piers	TCBP1	28.038801	-80.580306
East of US 1 along shore & Piers	TCBP2	28.038189	-80.581279
East of US 1 along shore & Piers	TCBP3	28.036987	-80.581195
East of US 1 along shore & Piers	TCBP4	28.035898	-80.5809

Figure 4.5.2 Map of stations for Task 4 and as described in the above table.

Laboratory Analysis

- Previously published references concerning the sondes, field and laboratory analyses are provided in Bostater and Rotkiske, 2015 and Weaver, et al., 2015. Images of the sondes are published in Bostater and Yang, 2014. Data derived from the devices are independent of any time dependent calibration or standards. The volumes of the sondes are essential the same. The cross-sectional sonde openings (areas) are fixed and identical and only vary depending upon whether the sonde is a vertical or horizontal type. Pre-deployment requires capping as the sonde enters the water. After they are attached to the bottom, caps are removed. A cap is reinserted before sonde retrieval. This insures no mud enters the sonde during the deployment and recovery process.

- Calculations for estimating the moving fluid mud flux after laboratory analyses are complete is described in Figure 4.5.3 below. The instruments and methodology is described in Bostater and Yang, 2014; Bostater and Rotkiske, 2015 and Weaver et al., 2015.



Fluid mud & muck flux is calculated by the following:

$$\text{Flux density} = \frac{\text{Grams of particulate matter collected}}{\text{sonde crossectional area } (L^2)} \times \frac{1}{\text{deployment period T (minutes)}}$$

Units of measurement (examples):

grams meter^{-2} min^{-1}
grams meter^{-2} day^{-1}
grams meter^{-2} hr^{-1}
grams cm^{-2} sec^{-1}
lb. m^{-2} day^{-1}

The sondes directly measure the movement of fluid mud & muck integrated over a time period and integrated over a spatial area. The measurement is a flux conserving direct method for collecting total suspended matter that moves into a fixed control volume.

Figure 4.5.3 Method for calculating the moving fluid mud flux density for the horizontal and vertical sondes. The cross-sectional area for the vertical sondes is 20.261 cm^2 and the cross-sectional area for the horizontal sondes is 81.073 cm^2 (based upon ANSI approved NEIKO Model 01412A Digital Caliper, 0.02 mm Accuracy, 0.01 Digital Resolution).

At each station horizontal probes (up to 4 directions) and four vertical probes (2 measuring settling and 2 measuring upwelling or suspension are deployed at stations for ≈12-40 hours. In order to assess the muck movement, results are reported in terms of a mass flux (e.g. mg m^{-2} yr^{-1}) dry weight (following drying at 105°C. The laboratory analysis of probe deployments also result in an estimate of % loss of ignition (LOI) based upon drying the total particulate matter captured in the sondes at 105°C (Equatherm Environmental Oven) followed by placement of the material in a furnace (Thermodyne SYBRON Type 4800 furnace) at 550° C) as described in Standard Methods For Examination of Water & Wastewater, 1980. Water grab samples are analyzed in the lab for conductivity, temperature and salinity using a calibrated YSI Model 33 (daily calibrated using LaMotte salinity standards). Total water suspended solids are filtered using Millipore nucleopore MF filters with nominal 0.45 micron pore size membrane filters followed by drying in a desiccator using the methods recommended in Standard Methods, 1980; EPA, 1983 and Grasshoff et al., 1976. These results are not needed to calculate fluxes and are collected as background data useful interpretation and modeling.

Water and total solids (fluid mud) are transferred from sondes by pouring from the horizontal sondes into 1 gallon plastic containers with marked lids with station ID, and material is transferred (within 1-2 hours from collection) to the lab for settling and processing. Water is removed in 24 hours and material settled again in the laboratory for 12 hours. Settled sample residue is rinsed and settled again for 12 hrs. Rinsing with deionized water removes dissolved salts that would influence weight of the particulate matter captured. Sample preservation is not practical according to EPA 1983, method 160.3 (Total Residue, STORET NO. 00500) and Greenberg, et al., 1980 (Standard Methods for Analysis of Water & Wastewater, 14th ed.). Settled fluid mud that has been placed into a pre-weighed porcelain evaporating dish is decanted using a vacuum tube and/or a syringe or similar device and volume and weight recorded for wet weight measurement and volume.

All distilled and deionized water used in the decanting process derived from a Barnstead F-Stream III glass still following by carbon activated filtering.

Filter pads are dried in a desiccator using Drierite desiccant, 8 mesh size (CAS 7778-18-9 and CAS7646-79-9) for 48 hours.

The sonde residue wet volume and wet weights are measured using an open balance, Olhaus Pioneer and Sartorius M prove model with 0.001 g digital scale). Scales are calibrated between measurements and at the beginning of daily use. Scale calibrations make use of TROEMNER calibration standards that follow ISO/IEC standard 17025 and ASTM class 4 standards for balance calibration standards (Certification No. 872685A).

Sonde wet density (mg ml^{-1}) is also calculated and recorded and is an ancillary measurement. Porcelain evaporating dishes are heated at 103-105° C until water is removed (one hour or more).

Dried residue is weighed and dry weight total residue (mg) recorded for each sample. Dry weight flux (g m^{-2} $time^{-1}$) is calculated based upon sonde deployment time and cross-sectional area of the sonde. Dried residue within in an evaporating dish is placed in a muffle furnace at 550^{o} C +/- 50^{o} C for one hour. Evaporating dish is then immediately covered, cooled to just above room temperature and weighed and recorded as oven weight for calculation of % loss on ignition (% LOI) using the same balances in order to provide an estimate of organic matter of the fluid mud flux collected in a sonde. Linear relations between % LOI and nutrients in the particulate matter (TPN, TPN, and TPC) are then calculated as proposed by Di Toro, 2001 using the relations obtained by Trefry (personal communication, 2015). Sonde nutrient fluxes are then calculated using % LOI and the dry weight for each sonde sample. Additional information concerning the relevant procedures are prescribed in Standard Methods for the Examination of Water & Wastewater (Greenberg, et al., 1980), Method 208A, ASTM D1888-1978, ASTM D1069-66, ASTM D509-13 (standard test methods for particulate, nonfilterable solids or residue in water). Triplicate horizontal and duplicate vertical sonde deployments have provided estimates of precision of % LOI and sonde dry weight fluxes and analyzed per guidance from EPA, 1984.

The passive sonde *in-situ* fluid mud flux measurements are a direct measurement technique. A review of direct and indirect fluid mud movement and flux methods is reported in Bostater and Rotkiske, 2015. No other direct method has been reported in any published literature for analysis of field based moving fluid mud, muck or particulate matter flux collected within a moving lutocline. No correction factors are thus used to correct for laboratory or field measurement bias.

E. **Quality Control and Measures (per EPA, 1984)**

Accuracy and precision of methods were examined during the study of the push pole measurements of station muck measurements using the push pole or sludge judge technique and the sondes fluid mass flux density. The figure below indicates muck depth changes at stations. During October, three closely space stations east of the railroad bridge in Turkey Creek, yielded measurements (n=6) the mean was 0.765 m, a range of 1.33 m, a standard deviation ± 0.481 m, and a coefficient of variation (CV) of 0.628. The precision (the closeness of data values to each other) estimated as relative standard deviation (standard deviation/mean x 100%) for the October transect (stations TCB1-3) muck depth data is thus 63%. Previous work (Weaver, et al., 2015) shows similar results for muck depth precision using a push pole or sludge judge (1.5 inch diameter clear PVC pipe) and similar replicate sampling technique.

EPA (1984) suggests the use of the sample coefficient of variation (CV – an index of precision and reliability of a measurement system (see Liu, 2012) as a method to address precision of physical measurements. EPA suggested (1984) data quality variability documentation is the purpose of a quality assessment program when considering physical measurement methods and the capability of a measurement system. Boxplots are used to help identify potential outliers (Frigge, Hoaglin and Iglewicz, 1989; Goic et al., 2013; Iglewicz and Hoaglin, 1993).

Figure 4.5.4 shown below and the results above make use of *collocated samples* (multiple measurements at a point in space and time) and replicates (duplicates and triplicates). Measurements are made immediately before and after sonde deployments for precision evaluation using the sludge judge (push pole method) method as described above.

Precision and reliability estimates based upon triplicate deployments at stations TCB1, TCB2 and TCB3 are shown in the Tables 4.5.3 through Table 4.5.5 below. Organic matter content in terms of % loss on ignition results precision results were 0.05 to 0.09 (coefficient f variation) at 2 stations for horizontal sonde flux triplicate results at stations TCB1 and TCB2 as shown in Table 4.5.3. The % loss on ignition (ash weight or organic matter) suggests good reproducibility between stations and a pooled coefficient of variability of 0.136 or 13.6 %. The % LOI and sonde flux measurements used to calculate the flux of carbon, nitrogen and phosphorus in the moving fluid mud collected within the sondes are described in Figures 4.12 and 4.13.

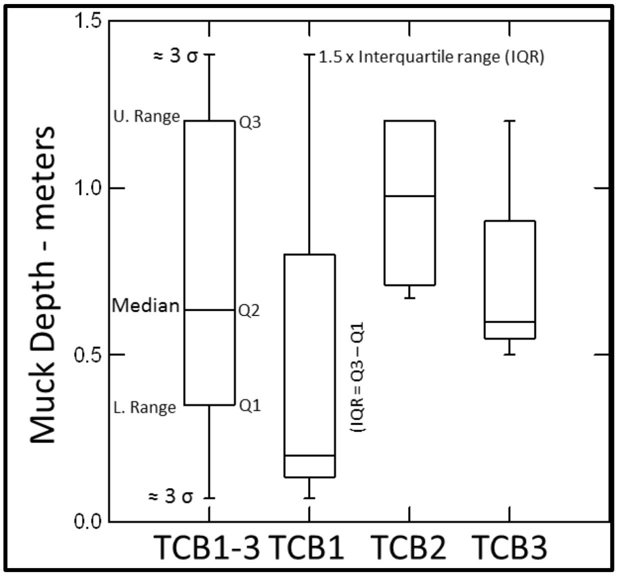
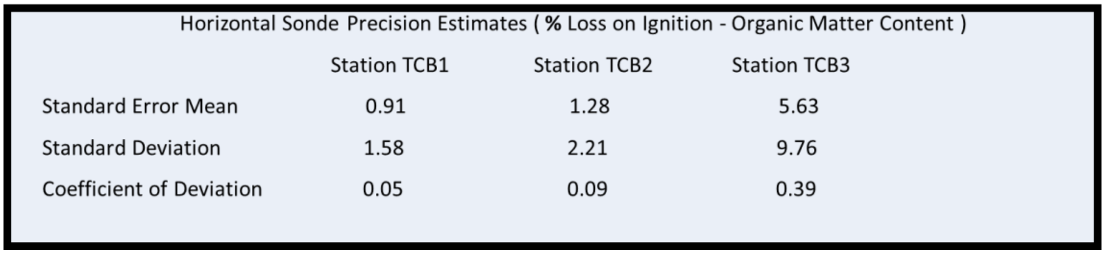


Figure 4.5.4 Muck depth (m) variability at stations TCB1 thru TCB3 during April and October Deployments. Total observations n=12 (n=4 at each station). The October pooled mean precision using the coefficient of variation (CV x 100) was 89% using the sludge judge or push pole technique. This measure of reliability is considered typical of this method for measuring muck depth.

Table 4.5.4 shows results from triplicate deployments at two stations with a pooled (average) variation of coefficient of 0.195 (19.5 %) for total particulate nitrogen. Similar quality control analyses were applied to the total dry weight horizontal and vertical sonde fluxes results from the two stations where triplicate deployments were made and is shown in Table 4.5.5 and Table 4.5.6 below.

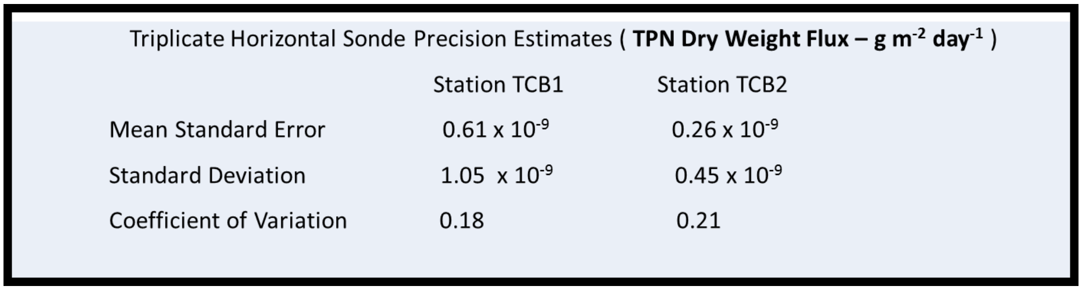
Table 4.5.3 Triplicate deployment results at three stations for % loss of ignition (% organic matter) within sonde moving fluid mud.



Horizontal Sonde Precision Estimates (**%** Loss on Ignition - Organic Matter Content)

	Station TCB1	Station TCB2	Station TCB3
Standard Error Mean	0.91	1.28	5.63
Standard Deviation	1.58	2.21	9.76
Coefficient of Deviation	0.05	0.09	0.39

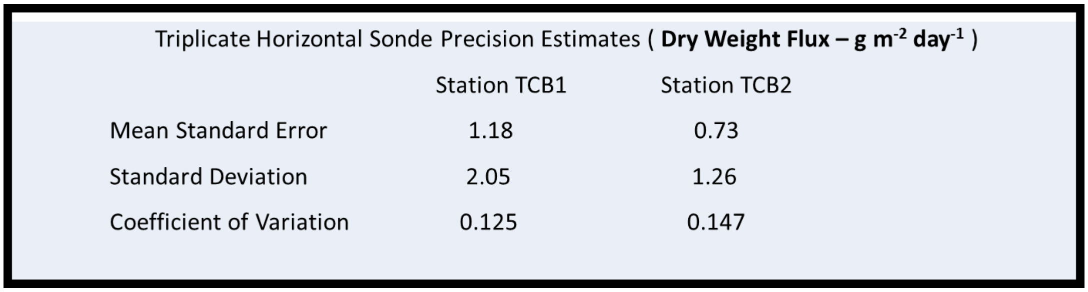
Table 4.5.4 Triplicate deployment results from two stations for moving horizontal sonde fluid mud flux measurements in g m $^{-2}$ day^{-1}of total organic particulate nitrogen.



Triplicate Horizontal Sonde Precision Estimates (**TPN Dry Weight Flux – g m^{-2} day^{-1}**)

	Station TCB1	Station TCB2
Mean Standard Error	0.61×10^{-9}	0.26×10^{-9}
Standard Deviation	1.05×10^{-9}	0.45×10^{-9}
Coefficient of Variation	0.18	0.21

Table 4.5.5 Triplicate deployment results from two stations for horizontal sonde moving fluid mud flux dry weight measurements in g m $^{-2}$ day^{-1}.



Triplicate Horizontal Sonde Precision Estimates (**Dry Weight Flux – g m^{-2} day^{-1}**)

	Station TCB1	Station TCB2
Mean Standard Error	1.18	0.73
Standard Deviation	2.05	1.26
Coefficient of Variation	0.125	0.147

Table 4.5.6 Pooled station duplicate deployment results (TCB1 and TCB2) for vertical sonde particulate flux precision estimates.

Vertical Sonde Dry Weight Flux Precision Estimates (g m^{-2} min^{-1})				
	Bottom Deposition	**Top Deposition**	**Bottom Resuspension**	**Top Resuspension**
Std. Mean Error	**± 0.016**	**± 0.032**	**± 0.0002**	**± 0.002**
Std. Deviation	**± 0.031**	**± 0.064**	**± 0.003**	**± 0.004**
Coeff. Of Variation	**0.87**	**1.41**	**0.85**	**0.76**

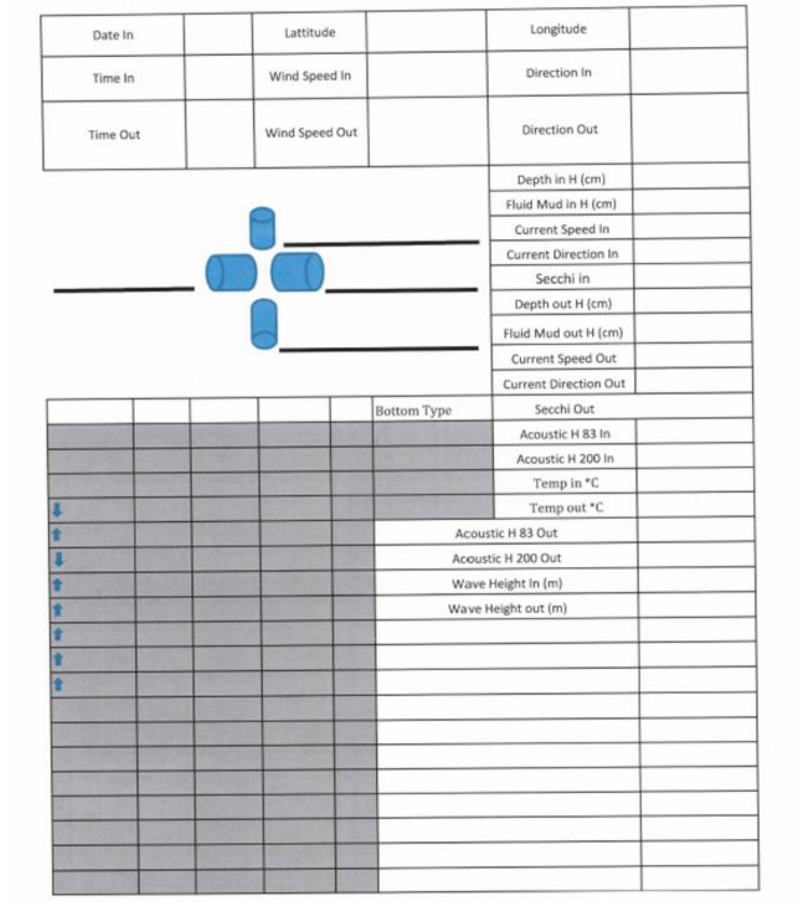
Table 4.5.6 shows quality control results in terms of precision estimates for vertical sonde measurements of depositional and resuspended total particulate matter collected at stations TCB1 and TCB2. Total samples (n=4) collected for each of the top and bottom sondes indicate lower precision. These results support prior research suggesting vertical probes, traps and sonde methods result in less reliable estimates of settling and resuspension of particulate matter (Di Toro, 2001).

Quality control estimates obtained from duplicate and triplicate sonde deployments as described above are the only known information available for any indirect or direct method related to measurements of moving fluid mud or muck flux density. Evaluation of the above suggests similar procedures need to be conducted at other stations within the sampling design being used in order to help insure quality indicators are available for Task 4 sonde data.

Task 4 endpoint analyses - data analysis products and interpretation will be based on the documentation of muck movement reduction (MMR) as presented in Figure 4.2 and as reported in Bostater and Rotkiske, 2015, 2016; Weaver et al., 2015, and Maglio et al., 2016.

F. Documentation and Records

Field sampling documentation utilizes field data sheets used to document sampling dates and ancillary data collected at each station. The form used is shown in Figure 4.5.5 and was specifically designed and used in a prior dredging research study where the sondes were deployed and is being used in this research. Station positions were determined using WAAS grade differential GPS receivers. Sheets are placed within a special aluminum page holding notebook in the field to help insure log sheets remain dry in the event of rain and during use. All field records are stored in the Environmental Optics & Remote Sensing Lab, Building 407, on the FIT Campus. All sample records are locked and only available to the PI and working lab and field assistants. Detailed results from sample analyses brought into the lab are recorded in bound notebooks. Selected information is recorded with different weights and volumes necessary for parameter calculations and tracked through the sample processing and data entry process until stored with original field data sheets. Any field or lab deviation or anomaly is recorded on the field sheets and in the bound notebooks and initialized by the PI. Sample bottles and containers are marked in the field as to station ID using waterproof pens/markers on the caps of the containers.



Date In		Lattitude		Longitude	
Time In		Wind Speed In		Direction In	
Time Out		Wind Speed Out		Direction Out	

Depth in H (cm)	
Fluid Mud in H (cm)	
Current Speed In	
Current Direction In	
Secchi in	
Depth out H (cm)	
Fluid Mud out H (cm)	
Current Speed Out	
Current Direction Out	
Bottom Type	
Secchi Out	
Acoustic H 83 In	
Acoustic H 200 In	
Temp in °C	
Temp out °C	
Acoustic H 83 Out	
Acoustic H 200 Out	
Wave Height In (m)	
Wave Height out (m)	

Figure 4.5.5 Example of a field sampling log sheet used to record sonde deployments at each station and any field related information.

Field data are entered into a Microsoft Excel spreadsheet and calculations performed within the project sheets. The spreadsheet is copied and stored on multiple computers and digital storage devices to insure no loss of information may occur due to computer software or hardware problems. Data backups occur monthly. Data analysis is performed using SYSTAT statistical software, ArcGIS geographical information system software, and ENVI image processing software. Monthly reports and quarterly reports utilize the above software. MS Word and PowerPoint are used to produce reports. Data entry is verified from data sheets and lab notebooks.

G. Training Required For The Project

To date the Principal Investigator has personally trained assistants in the proper deployment of the sondes and their recovery, with special attention given to the insertion and removal of caps in the horizontal sondes to insure no fluid mud or muck enters the sondes during the deployment and retrieval process in the field.

Data Appendices

Appendix I – sonde derived data.
Appendix II – background data.

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Appendix 1

Name	stb	Lattitutde	Longitude	Date Time In	Date Time Out	Organic Dry Weight (g)	Inorganic Dry Weight (g)	Predicted TPOC (%) Eq. Used (% Organic-0.72)/2.88	Organic Carbon Mass Flux Over Sonde g/(m2 day)	Organic Carbon Mass Flux Over Sonde g/(cm2 s)	Predicted % TPN	Predicted % TPP	Nitrogen Mass Flux Over Sonde (g/m^{2}day)	Nitrogen Mass Flux Over Sonde (g/cm^{2}s)	Phosphorous Mass Flux Over Sonde (g/m^{2}day)	Phosphorous Mass Flux Over Sonde (g/cm^{2}s)	TPN+TPP+TPC (g)	Organic Matter Ash WT. (g)	Inorganic Matter WT.(g)	% Inorganic Matter	% Organic Matter
Out Of The Mouth	TC1E	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.367	0.554	13.58611	5.02E-07	5.81E-16	2.557222	0.401722	9.45E-08	1.09E-16	1.48E-08	1.72E-17	0.06072	0.367	0.554	60.15201	39.84799
Into The Mouth	TC1W	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.168	0.566	7.697321	1.3E-07	1.51E-16	1.379464	0.283946	2.33E-08	2.7E-17	4.8E-09	5.56E-18	0.015726	0.168	0.566	77.11172	22.88828
Settling Bottom	TC1SB	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.054	0.118	10.65116	2.32E-07	2.68E-16	1.970233	0.343023	4.29E-08	4.96E-17	7.46E-09	8.64E-18	0.007001	0.054	0.118	68.60465	31.39535
Settling Top	TC1ST	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.027	0.05	11.92532	1.3E-07	1.5E-16	2.225065	0.368506	2.42E-08	2.8E-17	4.01E-09	4.64E-18	0.00392	0.027	0.05	64.93506	35.06494
Upwelling Bottom	TC1UB	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	1.621	0.025	33.94485	2.22E-05	2.57E-14	6.62897	0.808897	4.33E-06	5.01E-15	5.28E-07	6.11E-16	0.670814	1.621	0.025	1.518834	98.48117
Upwelling Top	TC1UT	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.037	1.63	0.520679	7.76E-09	8.98E-18		0.140414			2.09E-09	2.42E-18	0.000224	0.037	1.63	97.78044	2.219556
Out Of The Mouth	TC2E	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.342	0.788	10.25885	3.53E-07	4.09E-16	1.89177	0.335177	6.51E-08	7.54E-17	1.15E-08	1.34E-17	0.042701	0.342	0.788	69.73451	30.26549
Into The Mouth	TC2W	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.386	1.109	8.715069	3.39E-07	3.92E-16	1.583014	0.304301	6.15E-08	7.12E-17	1.18E-08	1.37E-17	0.040925	0.386	1.109	74.1806	25.8194
Settling Bottom	TC2SB	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.072	0.141	11.48709	3.33E-07	3.86E-16	2.137418	0.359742	6.2E-08	7.18E-17	1.04E-08	1.21E-17	0.010069	0.072	0.141	66.19718	33.80282
Settling Top	TC2ST	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.036	0.079	10.61957	1.54E-07	1.78E-16	1.963913	0.342391	2.85E-08	3.3E-17	4.97E-09	5.75E-18	0.004653	0.036	0.079	68.69565	31.30435
Upwelling Bottom	TC2UB	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.037	0.008	28.29938	4.22E-07	4.88E-16	5.499877	0.695988	8.2E-08	9.49E-17	1.04E-08	1.2E-17	0.012763	0.037	0.008	17.77778	82.22222
Upwelling Top	TC2UT	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.015	0	34.47222	2.08E-07	2.41E-16	6.734444	0.819444	4.07E-08	4.71E-17	4.95E-09	5.73E-18	0.006304	0.015	0	0	100
Out Of The Mouth	TC3E	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.39	1.218	8.171434	2.03E-07	2.35E-16	1.474287	0.293429	3.66E-08	4.23E-17	7.28E-09	8.42E-18	0.038763	0.39	1.218	75.74627	24.25373
Into The Mouth	TC3W	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.554	1.321	10.00926	3.53E-07	4.08E-16	1.841852	0.330185	6.49E-08	7.51E-17	1.16E-08	1.35E-17	0.067484	0.554	1.321	70.45333	29.54667
Settling Bottom	TC3SB	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.076	0.22	8.665165	1.68E-07	1.94E-16	1.573033	0.303303	3.04E-08	3.52E-17	5.86E-09	6.79E-18	0.008012	0.076	0.22	74.32432	25.67568
Settling Top	TC3ST	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.027	0.082	8.350917	5.74E-08	6.64E-17	1.510183	0.297018	1.04E-08	1.2E-17	2.04E-09	2.36E-18	0.002743	0.027	0.082	75.22936	24.77064
Upwelling Bottom	TC3UB	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.014	0.021	13.63889	4.86E-08	5.62E-17	2.567778	0.402778	9.15E-09	1.06E-17	1.43E-09	1.66E-18	0.002325	0.014	0.021	60	40
Upwelling Top	TC3UT	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.02	0.033	12.85273	6.54E-08	7.57E-17	2.410545	0.387055	1.23E-08	1.42E-17	1.97E-09	2.28E-18	0.00313	0.02	0.033	62.26415	37.73585
Out Of The Mouth	TC4E	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.684	1.094	13.10771	8.62E-07	9.98E-16	2.461541	0.392154	1.62E-07	1.87E-16	2.58E-08	2.98E-17	0.109176	0.684	1.094	61.52981	38.47019
Into The Mouth	TC4W	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.398	1.02	9.49573	3.63E-07	4.21E-16	1.739146	0.319915	6.65E-08	7.7E-17	1.22E-08	1.42E-17	0.045988	0.398	1.02	71.9323	28.0677
Settling Bottom	TC4SB	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.201	0.462	10.27665	7.95E-07	9.2E-16	1.895329	0.335533	1.47E-07	1.7E-16	2.59E-08	3E-17	0.02514	0.201	0.462	69.68326	30.31674
Settling Top	TC4ST	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.043	0.027	21.07937	3.49E-07	4.04E-16	4.055873	0.551587	6.71E-08	7.77E-17	9.12E-09	1.06E-17	0.011045	0.043	0.027	38.57143	61.42857
Upwelling Bottom	TC4UB	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.031	0.001	33.38715	3.98E-07	4.61E-16	6.517431	0.797743	7.77E-08	9E-17	9.51E-09	1.1E-17	0.012618	0.031	1E-03	3.125	96.875
Upwelling Top	TC4UT	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.024	0.005	28.48563	2.63E-07	3.04E-16	5.537126	0.699713	5.11E-08	5.92E-17	6.46E-09	7.48E-18	0.008333	0.024	0.005	17.24138	82.75862
Out Of The Mouth	TC5E	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.093	2.154	1.187101	1.12E-08	1.29E-17	0.07742	0.153742	7.28E-10	8.43E-19	1.45E-09	1.67E-18	0.001319	0.093	2.154	95.86115	4.138852
Into The Mouth	TC5W	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.488	1.313	9.158353	4.52E-07	5.23E-16	1.671671	0.313167	8.25E-08	9.55E-17	1.55E-08	1.79E-17	0.054379	0.488	1.313	72.90394	27.09606
Settling Bottom	TC5SB	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.069	0.238	7.554017	2.11E-07	2.44E-16	1.350803	0.28108	3.77E-08	4.36E-17	7.85E-09	9.08E-18	0.006338	0.069	0.238	77.52443	22.47557
Settling Top	TC5ST	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.041	0.217	5.267873	8.74E-08	1.01E-16	0.893575	0.235357	1.48E-08	1.72E-17	3.9E-09	4.52E-18	0.002623	0.041	0.217	84.10853	15.89147
Upwelling Bottom	TC5UB	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.023	0.029	15.10791	1.41E-07	1.63E-16	2.861581	0.432158	2.66E-08	3.08E-17	4.02E-09	4.65E-18	0.004232	0.023	0.029	55.76923	44.23077
Upwelling Top	TC5UT	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.025	0.037	13.7509	1.39E-07	1.61E-16	2.590179	0.405018	2.62E-08	3.03E-17	4.1E-09	4.74E-18	0.004187	0.025	0.037	59.67742	40.32258
Out Of The Mouth	TC6E	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.245	1.003	6.566462	1.65E-07	1.91E-16	1.153292	0.261329	2.89E-08	3.35E-17	6.55E-09	7.59E-18	0.019554	0.245	1.003	80.36859	19.63141
Into The Mouth	TC6W	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.265	1.058	6.704942	1.82E-07	2.11E-16	1.180988	0.264099	3.2E-08	3.71E-17	7.16E-09	8.29E-18	0.021598	0.265	1.058	79.96977	20.03023
Settling Bottom	TC6SB	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.071	0.143	11.26999	3.28E-07	3.79E-16	2.093998	0.3554	6.09E-08	7.05E-17	1.03E-08	1.2E-17	0.009741	0.071	0.143	66.82243	33.17757
Settling Top	TC6ST	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.041	0.063	13.43857	2.26E-07	2.61E-16	2.527714	0.398771	4.24E-08	4.91E-17	6.7E-09	7.75E-18	0.00671	0.041	0.063	60.57692	39.42308
Upwelling Bottom	TC6UB	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.035	0.074	10.89934	1.56E-07	1.81E-16	2.019867	0.347987	2.9E-08	3.35E-17	4.99E-09	5.77E-18	0.004644	0.035	0.074	67.88991	32.11009
Upwelling Top	TC6UT	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.024	0.043	12.18781	1.2E-07	1.39E-16	2.277562	0.373756	2.24E-08	2.59E-17	3.67E-09	4.25E-18	0.003561	0.024	0.043	64.1791	35.8209
North	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.204	1.845	3.206971	7.83E-08	9.07E-17	0.481394	0.194139	1.18E-08	1.36E-17	4.74E-09	5.49E-18	0.00792	0.204	1.845	90.04392	9.956076
South	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.144	0.974	4.222272	7.28E-08	8.43E-17	0.684454	0.214445	1.18E-08	1.37E-17	3.7E-09	4.28E-18	0.007374	0.144	0.974	87.11986	12.88014
Out Of The Mouth	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.278	0.927	7.760604	2.58E-07	2.99E-16	1.392121	0.285212	4.63E-08	5.36E-17	9.5E-09	1.1E-17	0.026237	0.278	0.927	76.92946	23.07054
Into The Mouth	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.208	1.514	3.94409	9.82E-08	1.14E-16	0.628818	0.208882	1.57E-08	1.81E-17	5.2E-09	6.02E-18	0.009946	0.208	1.514	87.92102	12.07898
Settling Bottom	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.119	0.854	3.996603	2.28E-07	2.64E-16	0.639321	0.209932	3.65E-08	4.22E-17	1.2E-08	1.39E-17	0.005767	0.119	0.854	87.76978	12.23022
Settling Top	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.016	0.118	3.895937	2.99E-08	3.46E-17	0.619187	0.207919	4.75E-09	5.49E-18	1.59E-09	1.85E-18	0.000756	0.016	0.118	88.0597	11.9403
Upwelling Bottom	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.009	0.883	0.100336	4.33E-10	5.01E-19		0.132007			5.69E-10	6.59E-19	8.32E-06	0.009	0.883	98.99103	1.008969
Upwelling Top	TCOUT1	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.037	0.011	26.51505	4.7E-07	5.44E-16	5.143009	0.660301	9.12E-08	1.06E-16	1.17E-08	1.35E-17	0.011958	0.037	0.011	22.91667	77.08333
North	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.233	1.256	5.183363	1.45E-07	1.68E-16	0.876673	0.233667	2.46E-08	2.84E-17	6.55E-09	7.58E-18	0.014664	0.233	1.256	84.35191	15.64809
South	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.164	1.291	3.663708	7.23E-08	8.37E-17	0.572742	0.203274	1.13E-08	1.31E-17	4.01E-09	4.64E-18	0.007281	0.164	1.291	88.72852	11.27148
Out Of The Mouth	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.195	1.235	4.484848	1.05E-07	1.22E-16	0.73697	0.219697	1.73E-08	2E-17	5.16E-09	5.97E-18	0.010611	0.195	1.235	86.36364	13.63636
Into The Mouth	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.173	1.11	4.431952	9.23E-08	1.07E-16	0.72639	0.218639	1.51E-08	1.75E-17	4.55E-09	5.27E-18	0.009302	0.173	1.11	86.51598	13.48402
Settling Bottom	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.039	0.395	2.8702	5.39E-08	6.24E-17	0.41404	0.187404	7.78E-09	9E-18	3.52E-09	4.07E-18	0.001354	0.039	0.395	91.01382	8.986175
Settling Top	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.084	0.12	14.04739	5.68E-07	6.58E-16	2.649477	0.410948	1.07E-07	1.24E-16	1.66E-08	1.92E-17	0.014371	0.084	0.12	58.82353	41.17647
Upwelling Bottom	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.007	0.016	10.31763	3.48E-08	4.03E-17	1.903527	0.336353	6.42E-09	7.43E-18	1.13E-09	1.31E-18	0.000879	0.007	0.016	69.56522	30.43478
Upwelling Top	TCOUT1	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.034	0.015	23.84297	3.9E-07	4.52E-16	4.608594	0.606859	7.55E-08	8.73E-17	9.94E-09	1.15E-17	0.00988	0.034	0.015	30.61224	69.38776
Out Of The Mouth	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.116	0.379	7.886925	1.11E-07	1.28E-16	1.417385	0.287738	1.99E-08	2.3E-17	4.04E-09	4.67E-18	0.011127	0.116	0.379	76.56566	23.43434
Into The Mouth	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.065	0.357	5.09821	4.01E-08	4.64E-17	0.859642	0.231964	6.76E-09	7.82E-18	1.82E-09	2.11E-18	0.004023	0.065	0.357	84.59716	15.40284
Settling Bottom	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.075	0.208	8.952002	3.25E-07	3.76E-16	1.6304	0.30904	5.92E-08	6.85E-17	1.12E-08	1.3E-17	0.008169	0.075	0.208	73.49823	26.50177
Settling Top	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.009	0.097	2.698113	1.18E-08	1.36E-17	0.379623	0.183962	1.65E-09	1.91E-18	8.01E-10	9.27E-19	0.000294	0.009	0.097	91.50943	8.490566
Upwelling Bottom	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.032	0.248	3.718254	5.76E-08	6.66E-17	0.583651	0.204365	9.04E-09	1.05E-17	3.16E-09	3.66E-18	0.001442	0.032	0.248	88.57143	11.42857
Upwelling Top	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.047		181.0772	4.12E-06	4.77E-15	36.05543	3.751543	8.2E-07	9.49E-16	8.53E-08	9.87E-17	0.103816	0.047			
Out Of The Mouth	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.047	0.271	4.881901	2.77E-08	3.21E-17	0.81638	0.227638	4.64E-09	5.37E-18	1.29E-09	1.5E-18	0.002785	0.047	0.271	85.22013	14.77987
Into The Mouth	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.129	0.377	8.602108	1.34E-07	1.55E-16	1.560422	0.302042	2.43E-08	2.82E-17	4.71E-09	5.45E-18	0.013499	0.129	0.377	74.50593	25.49407
Settling Bottom	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.041	0.034	18.73148	3.72E-07	4.3E-16	3.586296	0.50463	7.11E-08	8.23E-17	1E-08	1.16E-17	0.009357	0.041	0.034	45.33333	54.66667
Settling Top	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.098	0.048	23.0567	1.09E-06	1.27E-15	4.451339	0.591134	2.11E-07	2.44E-16	2.8E-08	3.24E-17	0.027537	0.098	0.048	32.87671	67.12329
Upwelling Bottom	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.059	0.014	27.81317	7.94E-07	9.19E-16	5.402633	0.686263	1.54E-07	1.79E-16	1.96E-08	2.27E-17	0.020002	0.059	0.014	19.17808	80.82192
Out Of The Mouth	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	5.061	0.291	32.5843	1.98E-05	2.3E-14	6.35686	0.781686	3.87E-06	4.48E-15	4.76E-07	5.51E-16	2.010373	5.061	0.291	5.43722	94.56278
Into The Mouth	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	0.136	0.376	8.97309	1.47E-07	1.7E-16	1.634618	0.309462	2.68E-08	3.1E-17	5.06E-09	5.86E-18	0.014847	0.136	0.376	73.4375	26.5625
Settling Bottom	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	1.071	0.773	19.91676	1.03E-05	1.19E-14	3.823351	0.528335	1.97E-06	2.28E-15	2.72E-07	3.15E-16	0.259915	1.071	0.773	41.91974	58.08026
Settling Top	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	0.032	0.318	2.924603	4.51E-08	5.22E-17	0.424921	0.188492	6.55E-09	7.58E-18	2.9E-09	3.36E-18	0.001132	0.032	0.318	90.85714	9.142857
Upwelling Top	TCB3	28.036151	-80.5797	4/10/2015 15:15	4/11/2015 8:20	0	0.006		0	0		0.125	0	0	0	0	0	0	0.006	100	0
Into The Mouth	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.784	3.164	6.645193	6.49E-07	7.51E-16	1.169039	0.262904	1.14E-07	1.32E-16	2.57E-08	2.97E-17	0.063325	0.784	3.164	80.14184	19.85816
Settling Bottom	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.384	1.033	9.159551	4.38E-07	5.07E-16	1.67191	0.313191	8E-08	9.26E-17	1.5E-08	1.73E-17	0.042795	0.384	1.033	72.90049	27.09951
Settling Top	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.053	0.156	8.555157	2.26E-07	2.62E-16	1.551031	0.301103	4.1E-08	4.74E-17	7.96E-09	9.21E-18	0.005516	0.053	0.156	74.64115	25.35885
Upwelling Bottom	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.121	0.171	14.13832	8.53E-07	9.87E-16	2.667664	0.412766	1.61E-07	1.86E-16	2.49E-08	2.88E-17	0.020835	0.121	0.171	58.56164	41.43836
Upwelling Top	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.95	0.049	32.76913	1.55E-05	1.8E-14	6.393826	0.785383	3.03E-06	3.5E-15	3.72E-07	4.31E-16	0.379509	0.95	0.049	4.904905	95.0951
Out Of The Mouth	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.156	0.565	7.262714	1.36E-07	1.58E-16	1.292543	0.275254	2.43E-08	2.81E-17	5.17E-09	5.98E-18	0.013776	0.156	0.565	78.36338	21.63662
Into The Mouth	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.284	2.413	3.406326	1.16E-07	1.35E-16	0.521265	0.198127	1.78E-08	2.06E-17	6.77E-09	7.84E-18	0.011717	0.284	2.413	89.46978	10.53022
Settling Bottom	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.042	0.389	3.133604	6.34E-08	7.33E-17	0.466721	0.192672	9.44E-09	1.09E-17	3.9E-09	4.51E-18	0.001593	0.042	0.389	90.25522	9.74478
Settling Top	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.054	0.057	16.64189	4.33E-07	5.01E-16	3.168378	0.462838	8.24E-08	9.54E-17	1.2E-08	1.39E-17	0.010947	0.054	0.057	51.35135	48.64865
Upwelling Bottom	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.072	0.344	5.759615	2E-07	2.31E-16	0.991923	0.245192	3.44E-08	3.98E-17	8.5E-09	9.84E-18	0.005038	0.072	0.344	82.69231	17.30769
Upwelling Top	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.798	0.707	18.16085	6.98E-06	8.08E-15	3.472171	0.493217	1.33E-06	1.54E-15	1.9E-07	2.19E-16	0.176567	0.798	0.707	46.97674	53.02326
Out Of The Mouth	TCB7	28.038323	-80.5797	4/10/2015 15:40	4/11/2015 9:30	0.525	2.76	5.299214	3.21E-07	3.71E-16	0.899843	0.235984	5.45E-08	6.3E-17	1.43E-08	1.65E-17	0.033784	0.525	2.76	84.01826	15.98174
Into The Mouth	TCB7	28.038323	-80.5797	4/10/2015 15:40	4/11/2015 9:30	0.434	2.141	5.602211	2.8E-07	3.24E-16	0.960442	0.242044	4.81E-08	5.56E-17	1.21E-08	1.4E-17	0.029532	0.434	2.141	83.14563	16.85437
Upwelling Top	TCB7	28.038323	-80.5797	4/10/2015 15:40	4/11/2015 9:30	0.015	0.044	8.577684	1.48E-08	1.72E-17	1.555537	0.301554	2.69E-09	3.11E-18	5.21E-10	6.04E-19	0.001565	0.015	0.044	74.57627	25.42373

Appendix 1 (continued)

Name	stb	Lattitutde	Longitude	Date Time In	Date Time Out	Organic Dry Weight (g)	Inorganic Dry Weight (g)	Predicted TPOC (%) Eq. Used (% Organic-0.72)/2.88	Organic Carbon Mass Flux Over Sonde g/(m2 day)	Organic Carbon Mass Flux Over Sonde g/(cm2 s)	Predicted % TPN	Predicted % TPP	Nitrogen Mass Flux Over Sonde (g/m^2day)	Nitrogen Mass Flux Over Sonde (g/cm^2s)	Phosphorous Mass Flux Over Sonde (g/m^2day)	Phosphorous Mass Flux Over Sonde (g/cm^2s)	TPN+TPP +TPC (g)	Organic Matter Ash WT. (g)	Inorganic Matter WT.(g)	% Inorganic Matter	% Organic Matter
Out Of The Mouth	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.328	1.69	5.393652	2.13E-07	2.46E-16	0.91873	0.237873	3.63E-08	4.2E-17	9.39E-09	1.09E-17	0.021485	0.328	1.69	83.74628	16.25372
Into The Mouth	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.784	3.164	6.645193	6.27E-07	7.26E-16	1.169039	0.262904	1.1E-07	1.28E-16	2.48E-08	2.87E-17	0.063325	0.784	3.164	80.14184	19.85816
Settling Bottom	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.085	0.744	3.31018	1.35E-07	1.57E-16	0.502036	0.196204	2.05E-08	2.38E-17	8.03E-09	9.29E-18	0.003407	0.085	0.744	89.74668	10.25332
Settling Top	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.009	0.097	2.698113	1.17E-08	1.35E-17	0.379623	0.183962	1.65E-09	1.9E-18	7.97E-10	9.23E-19	0.000294	0.009	0.097	91.50943	8.490566
Upwelling Bottom	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.218	16.891	0.192425	2.02E-08	2.34E-17		0.133848			1.41E-08	1.63E-17	0.000446	0.218	16.89	98.72582	1.274183
Upwelling Top	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.06	0.547	3.18218	9.19E-08	1.06E-16	0.476436	0.193644	1.38E-08	1.59E-17	5.59E-09	6.48E-18	0.002311	0.06	0.547	90.11532	9.884679
North +	TCB5N	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	7.031	0.329	32.9201	1.96E-05	2.27E-14	6.42402	0.788402	3.83E-06	4.43E-15	4.7E-07	5.44E-16	2.821718	7.031	0.329	4.470109	95.52989
South-	TCB5S	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.385	0.999	9.409	3.07E-07	3.55E-16	1.7218	0.31818	5.62E-08	6.5E-17	1.04E-08	1.2E-17	0.044079	0.385	0.999	72.18208	27.81792
East +	TCB5E	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.164	0.773	5.827315	3.24E-07	3.75E-16	1.005463	0.246546	5.59E-08	6.47E-17	1.37E-08	1.59E-17	0.01161	0.164	0.773	82.49733	17.50267
West -	TCB5W	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.551	1.75	8.064622	1.51E-06	1.74E-15	1.452924	0.291292	2.72E-07	3.14E-16	5.44E-08	6.3E-17	0.054047	0.551	1.75	76.05389	23.94611
Settling Bottom	TCB5 Se	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.236	1.263	5.216607	4.18E-07	4.83E-16	0.883321	0.234332	7.07E-08	8.18E-17	1.88E-08	2.17E-17	0.014949	0.236	1.263	84.25617	15.74383
Settling Top	TCB 5 Se	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.034	2.287	0.258641	2.98E-09	3.45E-18		0.135173			1.56E-09	1.8E-18	9.71E-05	0.034	2.287	98.53511	1.464886
Upwelling Bottom	TCB 5Up	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.021	0.098	5.877451	4.19E-08	4.85E-17	1.01549	0.247549	7.23E-09	8.37E-18	1.76E-09	2.04E-18	0.0015	0.021	0.098	82.35294	17.64706
Upwelling Top	TCB5 Up	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0	0.025		0	0		0.125	0	0	0	0	0	0	0.025	100	0
North	TCP1 N	28.038801	-80.5803	5/14/15 5:20 PM	5/15/2015 15:45	6.041	1.196	28.73396	1.59E-05	1.84E-14	5.586793	0.704679	3.1E-06	3.58E-15	3.9E-07	4.52E-16	2.115887	6.041	1.196	16.52618	83.47382
South	TCP1S	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	1	17.955	1.581824	1.45E-07	1.68E-16	0.156365	0.161636	1.43E-08	1.66E-17	1.48E-08	1.72E-17	0.018998	1	17.96	94.72435	5.275653
East	TCP1 E	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	3.399	5.822	12.54914	1.57E-05	1.81E-14	2.349827	0.380983	2.93E-06	3.39E-15	4.75E-07	5.5E-16	0.519365	3.399	5.822	63.13849	36.86151
West	TCP1W	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	1.121	3.26	8.634641	3.55E-06	4.11E-15	1.566928	0.302693	6.45E-07	7.46E-16	1.25E-07	1.44E-16	0.117753	1.121	3.26	74.41223	25.58777
Settling Top	TCP1 Se	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.042	0.269	4.439175	6.84E-08	7.92E-17	0.727835	0.218783	1.12E-08	1.3E-17	3.37E-09	3.9E-18	0.002262	0.042	0.269	86.49518	13.50482
Settling Bottom	TCP1 Se	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	1.015	4.833	5.776514	2.15E-06	2.49E-15	0.995303	0.24553	3.71E-07	4.29E-16	9.15E-08	1.06E-16	0.071226	1.015	4.833	82.64364	17.35636
Upwelling Bottom	TCP1 Up	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.017	0.067	6.777116	4.23E-08	4.89E-17	1.195423	0.265542	7.46E-09	8.63E-18	1.66E-09	1.92E-18	0.0014	0.017	0.067	79.7619	20.2381
Upwelling Top	TCP1 Up	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.01	0.027	9.134384	3.35E-08	3.88E-17	1.666877	0.312688	6.12E-09	7.08E-18	1.15E-09	1.33E-18	0.001111	0.01	0.027	72.97297	27.02703
North	TCP2N	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	1.462	0.611	24.23813	3.39E-06	3.92E-15	4.687626	0.614763	6.55E-07	7.58E-16	8.59E-08	9.95E-17	0.431882	1.462	0.611	29.47419	70.52581
South	TCP2S	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	1.232	4.588	7.100134	8.36E-07	9.68E-16	1.260027	0.272003	1.48E-07	1.72E-16	3.2E-08	3.71E-17	0.106348	1.232	4.588	78.83162	21.16838
Settling Top	TCP2E	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.296	1.109	7.065144	8E-07	9.26E-16	1.253029	0.271303	1.42E-07	1.64E-16	3.07E-08	3.56E-17	0.025425	0.296	1.109	78.93238	21.06762
West	TCP2W	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.861	0.004	34.31166	1.13E-05	1.31E-14	6.702331	0.816233	2.21E-06	2.56E-15	2.69E-07	3.11E-16	0.360158	0.861	0.004	0.462428	99.53757
Settling Bottom	TCP2 Se	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.091	13.362					0.129697			4.52E-09	5.23E-18	.	0.091	13.36	99.32357	0.676429
Settling Top	TCP2 Se	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.022	0.129	4.808867	4.05E-08	4.68E-17	0.801773	0.226177	6.75E-09	7.81E-18	1.9E-09	2.2E-18	0.001284	0.022	0.129	85.43046	14.56954
Upwelling Down	TCP2 Up	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.002	0.162	0.173442	1.33E-10	1.54E-19		0.133469			1.02E-10	1.18E-19	.	0.002	0.162	98.78049	1.219512
Upwelling Top	TCP2 Up	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.425	0.096	28.07427	4.57E-06	5.28E-15	5.454854	0.691485	8.87E-07	1.03E-15	1.12E-07	1.3E-16	0.145438	0.425	0.096	18.4261	81.5739
North	TCP3N	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.764	0.17	28.15233	2.08E-06	2.41E-15	5.470466	0.693047	4.04E-07	4.68E-16	5.12E-08	5.93E-17	0.262173	0.764	0.17	18.20128	81.79872
South	TCP3S	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.007	2.282					0.127124			8.61E-11	9.96E-20		0.007	2.282	99.69419	0.30581
East	TCP3E	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.205	0.973	5.792492	4.6E-07	5.32E-16	0.998498	0.24585	7.92E-08	9.17E-17	1.95E-08	2.26E-17	0.014426	0.205	0.973	82.59762	17.40238
West	TCP3W	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.276	1.226	6.130382	6.55E-07	7.58E-16	1.066076	0.252608	1.14E-07	1.32E-16	2.7E-08	3.12E-17	0.020559	0.276	1.226	81.6245	18.3755
Settling Bottom	TCP3 Se	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.188	1.953	2.798939	2.04E-07	2.36E-16	0.399788	0.185979	2.91E-08	3.37E-17	1.35E-08	1.57E-17	0.006363	0.188	1.953	91.21906	8.780943
Settling Top	TCP3 Se	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.315	10.008	0.809527	9.87E-08	1.14E-16	0.001905	0.146191	2.32E-10	2.69E-19	1.78E-08	2.06E-17	0.003017	0.315	10.01	96.94856	3.051439
Upwelling Bottom	TCP3 Up	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.173	1.754	2.867252	1.92E-07	2.22E-16	0.41345	0.187345	2.77E-08	3.2E-17	1.25E-08	1.45E-17	0.006	0.173	1.754	91.02231	8.977686
Upwelling Top	TCP 3 Up	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0	0.008		0	0		0.125	0	0	0	0	0	0	0.008	100	0
North	TCD4N	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	1.606	0.447	26.91215	4.82E-06	5.57E-15	5.22243	0.668243	9.35E-07	1.08E-15	1.2E-07	1.38E-16	0.526813	1.606	0.447	21.77302	78.22698
South	TCP4S	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.611	1.754	8.720519	5.94E-07	6.87E-16	1.584104	0.30441	1.08E-07	1.25E-16	2.07E-08	2.4E-17	0.064821	0.611	1.754	74.1649	25.8351
East	TCP4 E	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.486	1.262	9.40389	2.04E-06	2.36E-15	1.720778	0.318078	3.73E-07	4.32E-16	6.89E-08	7.98E-17	0.055612	0.486	1.262	72.1968	27.8032
West	TCP4W	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.751	2.169	8.68027	2.91E-06	3.36E-15	1.576054	0.303605	5.28E-07	6.11E-16	1.02E-07	1.18E-16	0.079305	0.751	2.169	74.28082	25.71918
Upwelling Top	TCP4 Up	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.006	0.014	10.16667	2.72E-08	3.15E-17	1.873333	0.333333	5.01E-09	5.8E-18	8.92E-10	1.03E-18	0.000742	0.006	0.014	70	30
Sett Top	TCP4 Se	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.072	0.337	5.862469	1.88E-07	2.18E-16	1.012494	0.247249	3.25E-08	3.76E-17	7.94E-09	9.19E-18	0.005128	0.072	0.337	82.39609	17.60391
Upwelling Bottom	TCP4 Up	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.697	3.281	5.833808	1.81E-06	2.1E-15	1.006762	0.246676	3.13E-07	3.62E-16	7.67E-08	8.87E-17	0.049398	0.697	3.281	82.47863	17.52137
Sett Bott	TCP4 Se	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.735	0.609	18.73872	6.14E-06	7.11E-15	3.587743	0.504774	1.18E-06	1.36E-15	1.65E-07	1.91E-16	0.16781	0.735	0.609	45.3125	54.6875
Large Square	Large Sq	28.03748	-80.5795	5/14/15 7:18 PM	5/15/2015 13:45	7.947	11.578	13.88252	6.81E-07	7.88E-16	2.616504	0.40765	1.28E-07	1.49E-16	2E-08	2.32E-17	1.343574	7.947	11.58	59.29834	40.70166
Out Of The Mouth	TCB1E	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.181	0.058	26.04591	2.48E-07	2.88E-16	5.049182	0.650918	4.82E-08	5.58E-17	6.21E-09	7.19E-18	0.05746	0.181	0.058	24.26778	75.73222
Into The Mouth	TCB1W	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.06	0.161	9.176848	2.9E-08	3.36E-17	1.67537	0.313537	5.3E-09	6.13E-18	9.92E-10	1.15E-18	0.006699	0.06	0.161	72.85068	27.14932
Into The Mouth	TCB1W	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.055	0.131	10.01732	2.9E-08	3.36E-17	1.843465	0.330346	5.34E-09	6.19E-18	9.58E-10	1.11E-18	0.006705	0.055	0.131	70.43011	29.56989
Into The Mouth	TCB1W	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.072	0.167	10.21025	3.88E-08	4.49E-17	1.88205	0.334205	7.14E-09	8.27E-18	1.27E-09	1.47E-18	0.008947	0.072	0.167	69.87448	30.12552
Settling Bottom	TCB1SB	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.053	0.284	5.210765	5.83E-08	6.74E-17	0.882153	0.234215	9.86E-09	1.14E-17	2.62E-09	3.03E-18	0.003353	0.053	0.284	84.273	15.727
Settling Top	TCB1ST	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.016	0.068	6.363757	2.15E-08	2.49E-17	1.112751	0.257275	3.76E-09	4.35E-18	8.68E-10	1E-18	0.001237	0.016	0.068	80.95238	19.04762
Settling Bottom	TCB1SB	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.015	0.037	9.766026	3.09E-08	3.58E-17	1.793205	0.325321	5.67E-09	6.57E-18	1.03E-09	1.19E-18	0.001783	0.015	0.037	71.15385	28.84615
Settling Top	TCB1ST	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.052	0.192	7.149818	7.84E-08	9.08E-17	1.269964	0.272996	1.39E-08	1.61E-17	2.99E-09	3.47E-18	0.00452	0.052	0.192	78.68852	21.31148
Upwelling Bottom	TCB1UB	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.003	0.017	4.958333	3.14E-09	3.63E-18	0.831667	0.229167	5.26E-10	6.09E-19	1.45E-10	1.68E-19	0.000181	0.003	0.017	85	15
Upwelling Top	TCB1UT	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.006	0.002	25.79167	3.26E-08	3.78E-17	4.998333	0.645833	6.33E-09	7.32E-18	8.17E-10	9.46E-19	0.001886	0.006	0.002	25	75
Upwelling Bottom	TCB1UB	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.003	0.01	7.762821	4.91E-09	5.69E-18	1.392564	0.285256	8.81E-10	1.02E-18	1.81E-10	2.09E-19	0.000283	0.003	0.01	76.92308	23.07692
Upwelling Top	TCB1UT	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.001	0.016	1.792484	3.78E-10	4.38E-19	0.198497	0.16585	4.19E-11	4.85E-20	3.5E-11	4.05E-20	2.16E-05	1E-03	0.016	94.11765	5.882353
Out Of The Mouth	TCB2E	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.122	0.049	24.52258	1.58E-07	1.83E-16	4.744516	0.620452	3.05E-08	3.53E-17	3.99E-09	4.62E-18	0.036463	0.122	0.049	28.65497	71.34503
Into The Mouth	TCB2W	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.024	0.07	8.615248	1.09E-08	1.26E-17	1.56305	0.302305	1.98E-09	2.29E-18	3.83E-10	4.43E-19	0.002515	0.024	0.07	74.46809	25.53191
Into The Mouth	TCB2W	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.028	0.097	7.527778	1.11E-08	1.29E-17	1.345556	0.280556	1.99E-09	2.3E-18	4.14E-10	4.8E-19	0.002563	0.028	0.097	77.6	22.4
Into The Mouth	TCB2W	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.032	0.088	9.009259	1.52E-08	1.76E-17	1.641852	0.310185	2.77E-09	3.21E-18	5.24E-10	6.06E-19	0.003508	0.032	0.088	73.33333	26.66667
Settling Bottom	TCB2SB	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.031	0.015	23.14976	1.51E-07	1.75E-16	4.469952	0.592995	2.93E-08	3.39E-17	3.88E-09	4.49E-18	0.008746	0.031	0.015	32.6087	67.3913
Settling Top	TCB2ST	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.052	0.013	27.52778	3.02E-07	3.5E-16	5.345556	0.680556	5.87E-08	6.79E-17	7.47E-09	8.65E-18	0.017448	0.052	0.013	20	80
Settling Bottom	TCB2SB	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.035	0.008	28.01227	2.07E-07	2.4E-16	5.442455	0.690245	4.02E-08	4.65E-17	5.1E-09	5.9E-18	0.011951	0.035	0.008	18.60465	81.39535
Settling Top	TCB2ST	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.023	0.004	29.32819	1.42E-07	1.65E-16	5.705638	0.716564	2.77E-08	3.21E-17	3.48E-09	4.03E-18	0.008223	0.023	0.004	14.81481	85.18519
Upwelling Bottom	TCB2UB	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.007	0.012	12.5424	1.85E-08	2.15E-17	2.34848	0.380848	3.47E-09	4.02E-18	5.63E-10	6.51E-19	0.001069	0.007	0.012	63.15789	36.84211
Upwelling Top	TCB2UT	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.002	0.032	1.792484	7.57E-10	8.76E-19	0.198497	0.16585	8.38E-11	9.7E-20	7E-11	8.1E-20	4.31E-05	0.002	0.032	94.11765	5.882353
Upwelling Bottom	TCB2UB	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.001	0.02	1.403439	2.96E-10	3.43E-19	0.120688	0.158069	2.55E-11	2.95E-20	3.34E-11	3.86E-20	1.68E-05	1E-03	0.02	95.2381	4.761905
Upwelling Top	TCB2UT	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	0.006	0.064	2.72619	3.45E-09	4E-18	0.385238	0.184524	4.88E-10	5.65E-19	2.34E-10	2.71E-19	0.000198	0.006	0.064	91.42857	8.571429
Out Of The Mouth	TCB3E	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.091	0.022	27.71214	1.33E-07	1.54E-16	5.382429	0.684243	2.59E-08	2.99E-17	3.29E-09	3.81E-18	0.030739	0.091	0.022	19.46903	80.53097
Into The Mouth	TCB3W	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.268	0.98	7.206375	1.02E-07	1.18E-16	1.281275	0.274127	1.81E-08	2.1E-17	3.88E-09	4.49E-18	0.023482	0.268	0.98	78.52564	21.47436
Into The Mouth	TCB3W	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.035	0.062	12.27864	2.27E-08	2.63E-17	2.295727	0.375573	4.24E-09	4.91E-18	6.94E-10	8.04E-19	0.005232	0.035	0.062	63.91753	36.08247
Into The Mouth	TCB3W	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.447	2.096	5.853356	1.38E-07	1.6E-16	1.010671	0.247067	2.39E-08	2.76E-17	5.83E-09	6.75E-18	0.031787	0.447	2.096	82.42234	17.57766
Settling Bottom	TCB3SB	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.176	1.267	3.985004	1.48E-07	1.72E-16	0.637001	0.2097	2.37E-08	2.74E-17	7.8E-09	9.03E-18	0.008504	0.176	1.267	87.80319	12.19681
Settling Top	TCB3ST	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.042	0.099	10.09279	8.96E-08	1.04E-16	1.858558	0.331856	1.65E-08	1.91E-17	2.95E-09	3.41E-18	0.005159	0.042	0.099	70.21277	29.78723
Settling Bottom	TCB3SB	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.118	1.208	2.839911	7.08E-08	8.2E-17	0.407982	0.186798	1.02E-08	1.18E-17	4.66E-09	5.39E-18	0.004053	0.118	1.208	91.10106	8.898944
Settling Top	TCB3ST	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.029	0.016	22.12654	1.36E-07	1.57E-16	4.265309	0.572531	2.61E-08	3.03E-17	3.51E-09	4.06E-18	0.00782	0.029	0.016	35.55556	64.44444
Upwelling Bottom	TCB3UB	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.028	0.068	9.877315	5.85E-08	6.77E-17	1.815463	0.327546	1.07E-08	1.24E-17	1.94E-09	2.24E-18	0.003366	0.028	0.068	70.83333	29.16667
Upwelling Top	TCB3UT	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.034	0.009	27.20478	1.96E-07	2.26E-16	5.280956	0.674096	3.8E-08	4.39E-17	4.84E-09	5.61E-18	0.011274	0.034	0.009	20.93023	79.06977
Upwelling Bottom	TCB3UB	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.023	0.01	23.95034	1.16E-07	1.35E-16	4.630067	0.609007	2.25E-08	2.61E-17	2.96E-09	3.43E-18	0.006714	0.023	0.01	30.30303	69.69697
Upwelling Top	TCB3UT	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.003	0.035	2.491228	1.58E-09	1.83E-18	0.338246	0.179825	2.14E-10	2.48E-19	1.14E-10	1.32E-19	9.03E-05	0.003	0.035	92.10526	7.894737

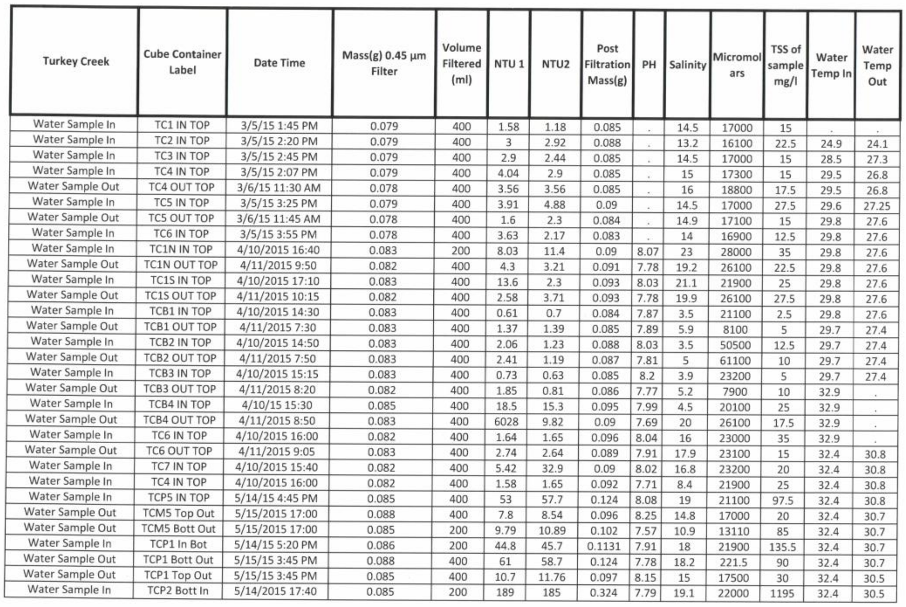
Appendix I – continued

Name	stb	Lattitutde	Longitude	Date Time In	Date Time Out	Dry Weight Flux Over Sonde g/(cm^2 s)	Conversion of Dry Weight Flux Over Sonde g/(m^2 day)	Conversion of Dry Weight Flux Over Sonde kg/(m^2 yr)	Conversion of Dry Weight Flux Over Sonde lbs/(m^2 yr)	Organic Weight Flux Over Sonde g/(cm^2 min)	Organic Weight Flux Over Sonde g/(cm^2 s)	Conversion of Organic Weight Flux Over Sonde g/(m^2 min)	Conversion of Organic Weight Flux Over Sonde g/(m^2 day)	Conversion of Organic Weight Flux Over Sonde kg/(m^2 yr)	Conversion of Organic Weight Flux Over Sonde lbs/(m^2 yr)	Inorganic Weight Flux Over Sonde g/(cm^2 min)	Inorganic Weight Flux Over Sonde g/(cm^2 s)	Conversion of Inorganic Weight Flux Over Sonde	Conversion of inorganic Weight Flux Over Sonde g/(m^2 day)	Conversion of inorganic Weight Flux Over Sonde kg/(m^2 yr)	Conversion of inorganic Weight Flux Over Sonde lbs/(m^2 yr)	Organic Weight lbs/(yr m^3)
Out Of The Mouth	TC1E	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.00055641	133.53951352	48.74192243	107.45754474	0.00000370	0.00022172	0.03695334	53.21281375	19.423	42.820	0.00000558	0.00033469	0.056	80.327	29.319	64.638	10.48514
Into The Mouth	TC1W	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.00044344	106.42562750	38.84535404	85.63934619	0.00000169	0.00010150	0.01691597	24.35899921	8.891	19.601	0.00000570	0.00034194	0.057	82.067	29.954	66.038	8.356237
Settling Bottom	TC1S	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.00041580	99.79159721	36.42393298	80.30102656	0.00000218	0.00013054	0.02175689	31.32992005	11.435	25.211	0.00000475	0.00028526	0.048	68.462	24.989	55.090	31.38459
Settling Top	TC1S	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.00018614	44.67414526	16.30606302	35.94871538	0.00000109	0.00006527	0.01087844	15.66496003	5.718	12.605	0.00000201	0.00012087	0.020	29.009	10.588	23.343	14.05008
Upwelling Bottom	TC1U	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.00397909	954.98237793	348.56856794	768.46214951	0.00006531	0.00391866	0.65310957	940.47778531	343.274	756.790	0.00000101	0.00006044	0.010	14.505	5.294	11.672	300.3432
Upwelling Top	TC1U	28.037996	-80.5788	3/5/15 1:45 PM	3/6/15 10:10 AM	0.00402986	967.16623572	353.01567604	778.26634461	0.00000149	0.00008944	0.01490750	21.46679707	7.835	17.274	0.00006567	0.00394041	0.657	945.699	345.180	760.992	304.1751
Out Of The Mouth	TC2E	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.00068268	163.84326849	59.80279300	131.84259018	0.00000344	0.00020662	0.03443609	49.58796268	18.100	39.903	0.00000793	0.00047606	0.079	114.255	41.703	91.940	12.86451
Into The Mouth	TC2W	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.00090319	216.76609415	79.11962436	174.42891356	0.00000389	0.00023320	0.03886646	55.96770056	20.428	45.036	0.00001117	0.00066999	0.112	160.798	58.691	129.392	17.01986
Settling Bottom	TC2S	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.00051491	123.57912910	45.10638212	99.44255033	0.00000290	0.00017406	0.02900919	41.77322674	15.247	33.614	0.00000568	0.00034086	0.057	81.806	29.859	65.828	38.8658
Settling Top	TC2S	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.00027800	66.72112604	24.35321100	53.68963985	0.00000145	0.00008703	0.01450459	20.88661337	7.624	16.807	0.00000318	0.00019098	0.032	45.835	16.730	36.882	20.98388
Upwelling Bottom	TC2U	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.00010878	26.10826671	9.52951735	21.00898951	0.00000149	0.00008944	0.01490750	21.46679707	7.835	17.274	0.00000032	0.00001934	0.003	4.641	1.694	3.735	8.211085
Upwelling Top	TC2U	28.038338	-80.5788	3/5/15 2:20 PM	3/6/15 10:45 AM	0.00003626	8.70275557	3.17650578	7.00299650	0.00000060	0.00003626	0.00604358	8.70275557	3.177	7.003	0.00000000	0.00000000	0.000	0.000	0.000	0.000	2.737028
Out Of The Mouth	TC3E	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.00061342	147.22127099	53.73576391	118.46708062	0.00000248	0.00014878	0.02479629	35.70665155	13.033	28.733	0.00000774	0.00046464	0.077	111.515	40.703	89.734	11.5594
Into The Mouth	TC3W	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.00071528	171.66659397	62.65830680	138.13792050	0.00000352	0.00021134	0.03522344	50.72175630	18.513	40.815	0.00000840	0.00050394	0.084	120.945	44.145	97.323	13.47877
Settling Bottom	TC3S	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.00045184	108.44052130	39.58079027	87.26070556	0.00000193	0.00011601	0.01933530	27.84283655	10.163	22.405	0.00000560	0.00033582	0.056	80.598	29.418	64.856	34.10469
Settling Top	TC3S	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.00016639	39.93248926	14.57535858	32.13316522	0.00000069	0.00004121	0.00686912	9.89153404	3.610	7.960	0.00000209	0.00012517	0.021	30.041	10.965	24.174	12.55882
Upwelling Bottom	TC3U	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.00005343	12.82235894	4.68016101	10.31798883	0.00000036	0.00002137	0.00356177	5.12894358	1.872	4.127	0.00000053	0.00003206	0.005	7.693	2.808	6.191	4.032649
Upwelling Top	TC3U	28.038671	-80.579	3/5/15 2:45 PM	3/6/15 11:05 PM	0.00008090	19.41671496	7.08710096	15.62438309	0.00000051	0.00003053	0.00508824	7.32706225	2.674	5.896	0.00000084	0.00005037	0.008	12.090	4.413	9.728	6.106583
Out Of The Mouth	TC4E	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.00102560	246.14518719	89.84299332	198.06989533	0.00000658	0.00039455	0.06575870	94.69252420	34.563	76.198	0.00001052	0.00063105	0.105	151.453	55.280	121.872	19.32662
Into The Mouth	TC4W	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.00081795	196.30701655	71.65206104	157.96575454	0.00000383	0.00022958	0.03826310	55.09886642	20.111	44.337	0.00000981	0.00058837	0.098	141.208	51.541	113.628	15.41347
Settling Bottom	TC4S	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.00153030	367.27256458	134.05448607	295.53955231	0.00000773	0.00046394	0.07732297	111.34507614	40.641	89.598	0.00001777	0.00106636	0.178	255.927	93.414	205.942	115.5077
Settling Top	TC4S	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.00016157	38.77689219	14.15356565	31.20327098	0.00000165	0.00009925	0.01654173	23.82009092	8.694	19.168	0.00000104	0.00006232	0.010	14.957	5.459	12.036	12.19538
Upwelling Bottom	TC4U	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.00007386	17.72657929	6.47020144	14.26435245	0.00000119	0.00007155	0.01192543	17.17262368	6.268	13.819	0.00000004	0.00000231	0.000	0.554	0.202	0.446	5.575033
Upwelling Top	TC4U	28.038813	-80.5793	3/5/15 2:07 PM	3/6/15 11:30 AM	0.00006694	16.06471248	5.86362005	12.92706941	0.00000092	0.00005540	0.00923259	13.29493446	4.853	10.698	0.00000019	0.00001154	0.002	2.770	1.011	2.229	5.052373
Out Of The Mouth	TC5E	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.00136307	327.13686693	119.40495643	263.24286789	0.00000094	0.00005642	0.00940258	13.53971011	4.942	10.895	0.00002178	0.00130665	0.218	313.597	114.463	252.348	25.68586
Into The Mouth	TC5W	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.00109252	262.20449370	95.70464020	210.99261463	0.00000493	0.00029603	0.04933825	71.04708103	25.932	57.171	0.00001327	0.00079649	0.133	191.157	69.772	153.822	20.58755
Settling Bottom	TC5S	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.00074519	178.84638258	65.27892964	143.91540489	0.00000279	0.00016749	0.02791441	40.19674397	14.672	32.346	0.00000963	0.00057771	0.096	138.650	50.607	111.570	56.24743
Settling Top	TC5S	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.00062625	150.30086874	54.85981709	120.94519369	0.00000166	0.00009952	0.01658682	23.88502178	8.718	19.220	0.00000878	0.00052673	0.088	126.416	46.142	101.725	47.26982
Upwelling Bottom	TC5U	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.00012622	30.29319835	11.05701740	24.37655067	0.00000093	0.00005583	0.00930480	13.39891466	4.891	10.782	0.00000117	0.00007039	0.012	16.894	6.166	13.595	9.527251
Upwelling Top	TC5U	28.039262	-80.5793	3/5/15 3:25 PM	3/6/15 11:45 AM	0.00015050	36.11881342	13.18336690	29.06434887	0.00000101	0.00006068	0.01011392	14.56403767	5.316	11.719	0.00000150	0.00008981	0.015	21.555	7.867	17.345	11.35941
Out Of The Mouth	TC6E	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.00076648	183.95592764	67.14391359	148.02699069	0.00000251	0.00015047	0.02507857	36.11314285	13.181	29.060	0.00001027	0.00061601	0.103	147.843	53.963	118.967	14.4437
Into The Mouth	TC6W	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.00081255	195.01097136	71.17900455	156.92284349	0.00000271	0.00016275	0.02712580	39.06115451	14.257	31.432	0.00001083	0.00064979	0.108	155.950	56.922	125.491	15.31171
Settling Bottom	TC6S	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.00052592	126.22004829	46.07031762	101.56766435	0.00000291	0.00017449	0.02908107	41.87674499	15.285	33.698	0.00000586	0.00035143	0.059	84.343	30.785	67.870	39.69637
Settling Top	TC6S	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.00025559	61.34058421	22.38931324	49.35998641	0.00000168	0.00010076	0.01679330	24.18234570	8.827	19.459	0.00000258	0.00015483	0.026	37.158	13.563	29.901	19.2917
Upwelling Bottom	TC6U	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.00026787	64.28965076	23.46572253	51.73306268	0.00000143	0.00008601	0.01433574	20.64346584	7.535	16.612	0.00000303	0.00018186	0.030	43.646	15.931	35.122	20.21918
Upwelling Top	TC6U	28.03976	-80.5793	3/5/15 3:55 PM	3/6/15 12:00 PM	0.00016466	39.51749175	14.42388449	31.79922201	0.00000098	0.00005898	0.00983022	14.15551943	5.167	11.391	0.00000176	0.00010567	0.018	25.362	9.257	20.408	12.4283
North	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00147224	353.33851705	128.96855872	284.32700183	0.00000244	0.00014658	0.02442962	35.17865177	12.840	28.308	0.00002209	0.00132567	0.221	318.160	116.128	256.019	27.74313
South	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00080330	192.79280725	70.36937465	155.13791510	0.00000172	0.00010347	0.01724444	24.83198948	9.064	19.982	0.00001166	0.00069984	0.117	167.961	61.306	135.156	15.13754
Out Of The Mouth	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00086581	207.79546756	75.84534566	167.21036467	0.00000333	0.00019975	0.03329134	47.93953526	17.498	38.576	0.00001110	0.00066607	0.111	159.856	58.347	128.634	16.31551
Into The Mouth	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00123729	296.94920759	108.38646077	238.95124312	0.00000249	0.00014945	0.02490863	35.86842926	13.092	28.863	0.00001813	0.00108784	0.181	261.081	95.294	210.088	23.31561
Settling Bottom	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00279747	671.39365264	245.05868321	540.26191624	0.00000570	0.00034214	0.05702284	82.11289277	29.971	66.075	0.00004092	0.00245534	0.409	589.281	215.087	474.187	211.1542
Settling Top	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00038526	92.46325740	33.74908895	74.40400491	0.00000077	0.00004600	0.00766694	11.04038894	4.030	8.884	0.00000565	0.00033926	0.057	81.423	29.719	65.520	29.07982
Upwelling Bottom	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00256459	615.50168361	224.65811452	495.28636104	0.00000043	0.00002588	0.00431265	6.21021878	2.267	4.997	0.00004231	0.00253871	0.423	609.291	222.391	490.289	193.5761
Upwelling Top	TCOU	28.040005	-80.5783	4/10/2015 16:40	4/11/2015 9:50	0.00013800	33.12116683	12.08922589	26.65218086	0.00000177	0.00010638	0.01772979	25.53089943	9.319	20.544	0.00000053	0.00003163	0.005	7.590	2.770	6.108	10.41665
North	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00107509	258.02220402	94.17810447	207.62717942	0.00000280	0.00016823	0.02803857	40.37553629	14.737	32.490	0.00001511	0.00090686	0.151	217.647	79.441	175.137	20.25917
South	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00105054	252.13049486	92.02763062	202.88619614	0.00000197	0.00011841	0.01973530	28.41883241	10.373	22.868	0.00001554	0.00093213	0.155	223.712	81.655	180.018	19.79657
Out Of The Mouth	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00103249	247.79835577	90.44639986	199.40017902	0.00000235	0.00014079	0.02346575	33.79068488	12.334	27.191	0.00001486	0.00089170	0.149	214.008	78.113	172.209	19.45642
Into The Mouth	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00092636	222.32537794	81.14876295	178.90239838	0.00000208	0.00012491	0.02081834	29.97840248	10.942	24.123	0.00001336	0.00080145	0.134	192.347	70.207	154.779	17.45636
Settling Bottom	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00125388	300.93138205	109.83995445	242.15564816	0.00000188	0.00011268	0.01877932	27.04222097	9.870	21.761	0.00001902	0.00114120	0.190	273.889	99.970	220.395	94.64332
Settling Top	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00058938	141.45161737	51.62984034	113.82431388	0.00000404	0.00024269	0.04044777	58.24478362	21.259	46.869	0.00000578	0.00034670	0.058	83.207	30.370	66.955	44.48672
Upwelling Bottom	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00006645	15.94797647	5.82101141	12.83313343	0.00000034	0.00002022	0.00337065	4.85373197	1.772	3.906	0.00000077	0.00004623	0.008	11.094	4.049	8.927	5.01566
Upwelling Top	TCOU	28.038344	-80.5774	4/10/2015 17:10	4/11/2015 10:15	0.00014157	33.97612378	12.40128518	27.34015382	0.00000164	0.00009823	0.01637171	23.57526956	8.605	18.971	0.00000072	0.00004334	0.007	10.401	3.796	8.369	10.68554
Out Of The Mouth	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.00035915	86.19682624	31.46184158	69.36148761	0.00000140	0.00008417	0.01402754	20.19966029	7.373	16.254	0.00000458	0.00027499	0.046	65.997	24.089	53.107	6.767929
Into The Mouth	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.00030619	73.48497106	26.82201444	59.13241974	0.00000079	0.00004716	0.00786026	11.31877516	4.131	9.108	0.00000432	0.00025903	0.043	62.166	22.691	50.024	5.769831
Settling Bottom	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.00082163	197.19135865	71.97484591	158.67737336	0.00000363	0.00021775	0.03629111	52.25919399	19.075	42.052	0.00001006	0.00060388	0.101	144.932	52.900	116.625	15.4829
Settling Top	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.00030775	73.85966084	26.95877621	59.43392783	0.00000044	0.00002613	0.00435493	6.27110328	2.289	5.046	0.00000469	0.00028162	0.047	67.589	24.670	54.388	5.79925
Upwelling Bottom	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.00081292	195.10099089	71.21186168	156.99528106	0.00000155	0.00009291	0.01548421	22.29725610	8.138	17.942	0.00001200	0.00072002	0.120	172.804	63.073	139.053	61.35952
Upwelling Top	TCB1	28.032076	-80.5825	4/10/2015 14:30	4/11/2015 7:30	0.00002613	6.27110328	2.28895270	5.04627689	0.00000227	0.00013645	0.02274243	32.74909490	11.953	26.353	-0.00000184	-0.00011032	-0.018	-26.478	-9.664	-21.307	1.97227
Out Of The Mouth	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.00023073	55.37493080	20.21184974	44.55950113	0.00000057	0.00003410	0.00568357	8.18434512	2.987	6.586	0.00000328	0.00019663	0.033	47.191	17.225	37.974	4.347882
Into The Mouth	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.00036713	88.11231127	32.16099361	70.90285400	0.00000156	0.00009360	0.01559959	22.46341532	8.199	18.076	0.00000456	0.00027354	0.046	65.649	23.962	52.827	6.918328
Settling Bottom	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.00021775	52.25919399	19.07460581	42.05230743	0.00000198	0.00011903	0.01983914	28.56835938	10.427	22.989	0.00000165	0.00009871	0.016	23.691	8.647	19.064	4.103243
Settling Top	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.00042388	101.73123096	37.13189930	81.86182513	0.00000474	0.00028452	0.04742038	68.28534681	24.924	54.948	0.00000232	0.00013936	0.023	33.446	12.208	26.913	7.987647
Upwelling Bottom	TCB2	28.03168	-80.5823	4/10/2015 14:50	4/11/2015 7:50	0.00021194	50.86561548	18.56594965	40.93091256	0.00000285	0.00017129	0.02854900	41.11056594	15.005	33.081	0.00000068	0.00004065	0.007	9.755	3.561	7.850	15.9973
Out Of The Mouth	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	0.00386427	927.42433573	338.50988254	746.28654415	0.00006090	0.00365416	0.60902655	876.99823676	320.104	705.709	0.00000350	0.00021011	0.035	50.426	18.406	40.577	72.81872
Into The Mouth	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	0.00036968	88.72220850	32.38360610	71.39363053	0.00000164	0.00009820	0.01636586	23.56683663	8.602	18.964	0.00000452	0.00027148	0.045	65.155	23.782	52.430	6.966215
Settling Bottom	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	0.00532755	1278.61167857	466.69326268	1028.88252350	0.00005157	0.00309425	0.51570902	742.62099119	271.057	597.578	0.00003722	0.00223329	0.372	535.991	195.637	431.305	100.3929
Settling Top	TCB3	28.031876	-0.58253	4/10/2015 15:15	4/11/2015 8:20	0.00101119	242.68659843	88.58060843	195.28681303	0.00000154	0.00009245	0.01540867	22.18848900	8.099	17.855	0.00001531	0.00091874	0.153	220.498	80.482	177.432	19.05506
Upwelling Top	TCB3	28.036151	-80.5797	4/10/2015 15:15	4/11/2015 8:20	0.00001733	4.16034169	1.51852472	3.34777394	0.00000000	0.00000000	0.00000000	0.00000000	0.000	0.000	0.00000029	0.00001733	0.003	4.160	1.519	3.348	1.308433
Into The Mouth	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.00295132	708.31786841	258.53602197	569.97436212	0.00000977	0.00058608	0.09767977	140.65886749	51.340	113.186	0.00003942	0.00236525	0.394	567.659	207.196	456.788	55.6151
Settling Bottom	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.00105928	254.22655003	92.79269076	204.57286503	0.00000478	0.00028706	0.04784315	68.89413918	25.146	55.438	0.00001287	0.00077222	0.129	185.332	67.646	149.135	19.96115
Settling Top	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.00062517	150.04195252	54.76531267	120.73684710	0.00000264	0.00015854	0.02642286	38.04891619	13.888	30.617	0.00000778	0.00046664	0.078	111.993	40.877	90.119	11.78087
Upwelling Bottom	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.00087345	209.62799108	76.51421674	168.68497299	0.00000603	0.00036194	0.06032388	86.86639356	31.706	69.900	0.00000853	0.00051151	0.085	122.762	44.808	98.785	65.92828
Upwelling Top	TCB4	28.036151	-80.5797	4/10/2015	4/11/2015 8:50	0.00298828	717.18617496	261.77295386	577.11057539	0.00004736	0.00284170	0.47361727	682.00887509	248.933	548.804	0.00000244	0.00014657	0.024	35.177	12.840	28.307	225.556
Out Of The Mouth	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.00052058	124.9388913	45.60269531	100.5367336	1.87726E-06	0.00011264	0.018772603	27.0325479	9.86688	21.75275	6.79905E-06	0.00040794	0.068	97.90634	35.73582	78.78399	9.809846
Into The Mouth	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.00194730	467.3511647	170.5831751	376.0715265	3.41758E-06	0.00020505	0.034175764	49.21310003	17.96278	39.60115	2.90374E-05	0.00174224	0.29	418.1381	152.6204	336.4704	36.69508
Settling Bottom	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.00124521	298.8512112	109.0806921	240.4817612	2.02239E-06	0.00012134	0.020223883	29.12239181	10.62967	23.43442	1.87312E-05	0.00112387	0.187	269.7288	98.45102	217.0473	23.46495
Settling Top	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.00032069	76.96632122	28.09270724	61.93381785	2.60021E-06	0.00015601	0.026002136	37.44307519	13.66672	30.12997	2.74467E-06	0.00016468	0.027	39.52325	14.42598	31.80385	6.043176
Upwelling Bottom	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.00120188	288.450357	105.2843803	232.1123263	3.46695E-06	0.00020802	0.034669514	49.92410025	18.2223	40.17329	1.65643E-05	0.00099386	0.166	238.5263	87.06208	191.939	90.71802
Upwelling Top	TCB6	28.037183	-80.5796	4/10/2015 16:00	4/11/2015 9:05	0.00434813	1043.552373	380.8966162	839.733296	3.84254E-05	0.00230552	0.384253781	553.3254444	201.9638	445.2539	3.40435E-05	0.00204261	0.34	490.2269	178.9328	394.4794	328.1986
Out Of The Mouth	TCB7	28.038323	-80.5797	4/10/2015 15:40	4/11/2015 9:30	0.00227210	545.3029467	199.0355755	438.798332	6.05201E-06	0.00036312	0.060520051	87.14887275	31.80934	70.12759	3.18163E-05	0.00190898	0.318	458.1541	167.2262	368.6707	42.81564
Into The Mouth	TCB7	28.038323	-80.5797	4/10/2015 15:40	4/11/2015 9:30	0.00178102	427.4444711	156.017232	343.9591187	5.00299E-06	0.00030018	0.050029908	72.04306814	26.29572	57.97214	2.46807E-05	0.00148084	0.247	355.4014	129.7215	285.987	33.56172
Upwelling Top	TCB7	28.038323	-80.5797	4/10/2015 15:40	4/11/2015 9:30	0.00004081	9.793873319	3.574763761	7.88100505	1.72914E-07	0.00001037	0.001729144	2.489967793	0.908838	2.003645	5.07216E-07	0.00003043	0.005	7.303906	2.665926	5.87736	

Appendix I – continued

Name	stb	Lattitutde	Longitude	Date Time In	Date Time Out	Dry Weight Flux Over Sonde g/(cm^2 s)	Conversion of Dry Weight Flux Over Sonde g/(m^2 day)	Conversion of Dry Weight Flux Over Sonde kg/(m^2 yr)	Conversion of Dry Weight Flux Over Sonde lbs/(m^2 yr)	Organic Weight Flux Over Sonde g/(cm^2 min)	Organic Weight Flux Over Sonde g/(cm^2 s)	Conversion of Organic Weight Flux Over Sonde g/(m^2 min)	Conversion of Organic Weight Flux Over Sonde g/(m^2 day)	Conversion of Organic Weight Flux Over Sonde kg/(m^2 yr)	Conversion of Organic Weight Flux Over Sonde lbs/(m^2 yr)	Inorganic Weight Flux Over Sonde g/(cm^2 min)	Inorganic Weight Flux Over Sonde g/(cm^2 s)	Conversion of Inorganic Weight Flux Over Sonde	Conversion of inorganic Weight Flux Over Sonde g/(m^2 day)	Conversion of inorganic Weight Flux Over Sonde kg/(m^2 yr)	Conversion of inorganic Weight Flux Over Sonde lbs/(m^2 yr)	Organic Weight lbs/(yr m^3)
Out Of The Mouth	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.00145704	349.6902671	127.6369475	281.3913016	3.94706E-06	0.00023682	0.039470601	56.83766482	20.74575	45.73654	2.0337E-05	0.00122022	0.203	292.8526	106.8912	235.6548	27.45668
Into The Mouth	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.00285055	684.1314046	249.7079627	550.5118229	9.43444E-06	0.00056607	0.094344362	135.8558818	49.5874	109.3215	3.80747E-05	0.00228448	0.381	548.2755	200.1206	441.1903	53.71605
Settling Bottom	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.00239509	574.8205431	209.8094982	462.5507657	4.09293E-06	0.00024558	0.040929287	58.9381739	21.51243	47.4268	3.58252E-05	0.00214951	0.358	515.8824	188.2971	415.124	45.13327
Settling Top	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.00030625	73.49936981	26.82726998	59.14400623	4.33369E-07	0.00002600	0.004333689	6.240512531	2.277787	5.021661	4.67075E-06	0.00028025	0.047	67.25886	24.54948	54.12235	5.770961
Upwelling Bottom	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.04943006	11863.21432	4330.073227	9546.177383	1.04972E-05	0.00062983	0.104971584	151.1590813	55.17306	121.6358	0.000813337	0.04880023	8.133	11712.06	4274.9	9424.542	3730.997
Upwelling Top	TC4	28.038813	-80.5793	4/10/2015 16:00	4/11/2015 9:05	0.00175370	420.8879007	153.6240838	338.68313	2.88913E-06	0.00017335	0.028891262	41.60341687	15.18525	33.47774	2.63392E-05	0.00158035	0.263	379.2845	138.4388	305.2054	
North +	TCB5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00374360	898.4648047	327.9396537	722.9831786	5.96043E-05	0.00357626	0.596043369	858.3024514	313.2804	690.665	2.78905E-06	0.00016734	0.028	40.16235	14.65926	32.31813	70.5449
South-	TCB5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00070396	168.950447	61.66691315	135.9522716	3.26378E-06	0.00019583	0.032637846	46.99849862	17.15445	37.81909	8.46889E-06	0.00050813	0.085	121.9519	44.51246	98.13318	13.26551
East +	TCB5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00190707	457.6971552	167.0594617	368.303068	5.56314E-06	0.00033379	0.055631399	80.10921393	29.23986	64.46286	2.62214E-05	0.00157328	0.262	377.5879	137.8196	303.8402	35.93708
West -	TCB5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00468321	1123.971349	410.2495424	904.4454211	1.86908E-05	0.00112145	0.186907931	269.14742	98.23881	216.5795	5.93628E-05	0.00356177	0.594	854.8239	312.0107	687.8659	88.25103
Settling Bottom	TCB5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00305091	732.2177542	267.2594803	589.2062956	8.00549E-06	0.00048033	0.080054939	115.2791127	42.07688	92.76363	4.2843E-05	0.00257058	0.428	616.9386	225.1826	496.4427	230.2835
Settling Top	TCB 5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00472392	1133.740765	413.8153794	912.3067459	1.15333E-06	0.00006920	0.011533339	16.60800777	6.061923	13.36425	7.75787E-05	0.00465472	0.776	1117.133	407.7535	898.9425	356.563
Upwelling Bottom	TCB 5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00024220	58.12802718	21.21672992	46.77488271	7.12353E-07	0.00004274	0.007123533	10.25788715	3.744129	8.254391	3.32432E-06	0.00019946	0.033	47.87014	17.4726	38.52049	18.28134
Upwelling Top	TCB5	28.037894	-80.5801	5/14/15 4:45 PM	5/15/2015 17:00	0.00005088	12.21177042	4.457296202	9.826656031	0	0.00000000	0	0	0	0	8.4804E-07	0.00005088	0.008	12.21177	4.457296	9.826656	3.840618
North	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/2015 15:45	0.00398209	955.7020918	348.8312635	769.0412941	5.54001E-05	0.00332400	0.554000692	797.7609972	291.1828	641.9481	1.09681E-05	0.00065809	0.11	157.9411	57.6485	127.0932	75.03901
South	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.01042981	2503.155057	913.6515959	2014.256975	9.17068E-06	0.00055024	0.091706786	132.0577714	48.20109	106.2652	0.00016466	0.00987957	1.647	2371.097	865.4505	1907.992	196.5406
East	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.02030234	4872.561768	1778.485045	3920.88836	0.000124729	0.00748375	1.247291618	1796.099929	655.5765	1445.299	0.000213643	0.01281859	2.136	3076.462	1122.909	2475.59	382.5797
West	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.00964587	2315.00847	844.9780917	1862.857814	4.1136E-05	0.00246816	0.411360372	592.3589352	216.211	476.6637	0.000119628	0.00717771	1.196	1722.65	628.7671	1386.194	181.7679
Settling Top	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.00068474	164.338652	59.98360797	132.241219	1.54123E-06	0.00009247	0.015412253	22.19364432	8.10068	17.85894	9.87118E-06	0.00059227	0.099	142.145	51.88293	114.3823	51.68473
Settling Bottom	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.01287584	3090.200761	1127.923278	2486.645172	3.72463E-05	0.00223478	0.372462781	536.3464043	195.7664	431.5911	0.000177351	0.01064106	1.774	2553.854	932.1568	2055.054	971.8723
Upwelling Bottom	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.00018495	44.38728863	16.20136035	35.71788551	6.23829E-07	0.00003743	0.006238293	8.983141747	3.278847	7.22862	2.45862E-06	0.00014752	0.025	35.40415	12.92251	28.48927	13.95986
Upwelling Top	TCP1	28.038801	-80.5803	5/14/15 5:20 PM	5/15/15 3:45 PM	0.00008146	19.5515438	7.136313488	15.73287814	3.66958E-07	0.00002202	0.003669584	5.284201028	1.928733	4.252129	9.90788E-07	0.00005945	0.01	14.26734	5.20758	11.48075	6.148987
North	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00118928	285.4275174	104.1810438	229.6798858	1.39792E-05	0.00083875	0.13979171	201.3000629	73.47452	161.9836	5.84218E-06	0.00035053	0.058	84.12745	30.70652	67.69629	22.41096
South	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00333894	801.3449837	292.490919	644.8320963	1.178E-05	0.00070680	0.117799854	169.6317904	61.9156	136.5005	4.3869E-05	0.00263214	0.439	631.7132	230.5753	508.3316	62.91933
Settling Top	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00322535	774.0842471	282.5407502	622.8957289	1.13251E-05	0.00067950	0.11325076	163.081094	59.5246	131.2293	4.24308E-05	0.00254585	0.424	611.0032	223.0162	491.6665	60.77889
West	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00198571	476.5714404	173.9485757	383.4909648	3.29422E-05	0.00197653	0.329421973	474.3676418	173.1442	381.7176	1.53042E-07	0.00000918	0.002	2.203799	0.804386	1.773369	37.41903
Settling Bottom	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.03088302	7411.925535	2705.35282	5964.282022	3.4817E-06	0.00020890	0.034816957	50.13641743	18.29979	40.34414	0.000511235	0.03067412	5.112	7361.789	2687.053	5923.938	2331.06
Settling Top	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00034664	83.19339595	30.36558952	66.94466553	8.41729E-07	0.00005050	0.008417286	12.12089213	4.424126	9.753527	4.93559E-06	0.00029614	0.049	71.0725	25.94146	57.19114	26.16443
Upwelling Down	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00037648	90.3557413	32.97984557	72.70811356	7.65208E-08	0.00000459	0.000765208	1.101899284	0.402193	0.886684	6.19818E-06	0.00037189	0.062	89.25384	32.57765	71.82143	28.417
Upwelling Top	TCP2	28.038189	-80.5813	5/14/2015 17:40	5/15/2015 15:10	0.00119602	287.0447635	104.7713387	230.9812632	1.62607E-05	0.00097564	0.162606665	234.1535979	85.46606	188.4204	3.673E-06	0.00022038	0.037	52.89117	19.30528	42.56085	90.27596
North	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00054214	130.1136739	47.49149097	104.7008152	7.39106E-06	0.00044346	0.073910634	106.4313135	38.84743	85.64392	1.64461E-06	0.00009868	0.016	23.68236	8.644062	19.05689	10.21616
South	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00132865	318.8760166	116.3897461	256.5954669	6.77192E-08	0.00000406	0.000677192	0.975156014	0.355932	0.784696	2.20764E-05	0.00132459	0.221	317.9009	116.0338	255.8108	25.03724
East	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00273606	656.6541922	239.6787802	528.4012603	7.93566E-06	0.00047614	0.079356554	114.2734375	41.7098	91.95438	3.76653E-05	0.00225992	0.377	542.3808	197.969	436.4469	51.55862
West	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00348859	837.2619666	305.6006178	673.7340347	1.06841E-05	0.00064105	0.106841019	153.8510671	56.15564	123.802	4.74591E-05	0.00284755	0.475	683.4109	249.445	549.932	65.73943
Settling Bottom	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00497275	1193.460633	435.613131	960.3625622	7.27758E-06	0.00043665	0.072775766	104.7971037	38.25094	84.32889	7.56016E-05	0.00453610	0.756	1088.664	397.3622	876.0337	375.345
Settling Top	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.02397652	5754.364369	2100.342995	4630.463675	1.21938E-05	0.00073163	0.121938119	175.5908918	64.09068	141.2958	0.000387415	0.02324489	3.874	5578.773	2036.252	4489.168	1809.755
Upwelling Bottom	TCP3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00447571	1074.170313	392.0721641	864.3711617	6.69692E-06	0.00040182	0.066969189	96.43563264	35.19901	77.60052	6.78982E-05	0.00407389	0.679	977.7347	356.8732	786.7706	337.828
Upwelling Top	TCP 3	28.036987	-80.5812	5/14/2015 17:15	5/15/2015 14:30	0.00001858	4.45945122	1.627699695	3.588463567	0	0.00000000	0	0	0	0	3.09684E-07	0.00001858	0.003	4.459451	1.6277	3.588464	1.402503
North	TCD4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00137251	329.4030202	120.2321024	265.0664125	1.78946E-05	0.00107368	0.178945869	257.6820509	94.05395	207.3535	4.98062E-06	0.00029884	0.05	71.72097	26.17815	57.71295	25.86379
South	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00158110	379.4632941	138.5041023	305.349277	6.80797E-06	0.00040848	0.068079655	98.03470304	35.78267	78.88728	1.95437E-05	0.00117262	0.195	281.4286	102.7214	226.462	29.79438
East	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00467610	1122.265011	409.6267289	903.0723523	2.16684E-05	0.00130011	0.216684463	312.0256266	113.8894	251.083	5.62666E-05	0.00337600	0.563	810.2394	295.7374	651.9893	88.11705
West	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00781134	1874.721871	684.2734831	1508.564799	3.34835E-05	0.00200901	0.334835456	482.1630567	175.9895	387.9905	9.67055E-05	0.00580233	0.967	1392.559	508.284	1120.574	147.1978
Upwelling Top	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00005350	12.84056076	4.686804679	10.33263561	2.67512E-07	0.00001605	0.002675117	3.852168229	1.406041	3.099791	6.24194E-07	0.00003745	0.006	8.988393	3.280763	7.232845	4.038373
Sett Top	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00109412	262.5894676	95.84515568	211.3023982	3.21014E-06	0.00019261	0.032101402	46.22601875	16.8725	37.19749	1.50252E-05	0.00090151	0.15	216.3634	78.97266	174.1049	82.58474
Upwelling Bottom	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.01064161	2553.987536	932.2054506	2055.161223	3.10759E-05	0.00186456	0.310759405	447.4935426	163.3351	360.0924	0.000146284	0.00877706	1.463	2106.494	768.8703	1695.069	803.2325
Sett Bott	TCP4	28.035898	-80.5809	5/14/2015 19:18	5/15/2015 13:45	0.00359536	862.8856833	314.9532744	694.353113	3.27702E-05	0.00196621	0.327701811	471.8906081	172.2401	379.7244	2.71524E-05	0.00162915	0.272	390.9951	142.7132	314.6288	271.3787
Large Square	Large	28.03748	-80.5795	5/14/15 7:18 PM	5/15/2015 13:45	0.00072333	173.5999972	63.36399896	139.6937054	4.90681E-06	0.00029441	0.049068117	70.65808847	25.7902	56.85766	7.14874E-06	0.00042892	0.071	102.9419	37.5738	82.83604	54.59743
Out Of The Mouth	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	7.55887E-05	18.14129526	6.621572771	14.59806911	9.54084E-07	5.7245E-05	0.009540837	13.7388052	5.014664	11.05544	3.05728E-07	1.83437E-05	0.003	4.40249	1.606909	3.542628	1.424403
Into The Mouth	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	6.98959E-05	16.77500524	6.122876913	13.49863294	3.16271E-07	1.89763E-05	0.003162708	4.554300066	1.66232	3.664787	8.4866E-07	5.09196E-05	0.008	12.22071	4.460557	9.833846	1.317126
Into The Mouth	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	5.88264E-05	14.1183302	5.153190524	11.3608404	2.89915E-07	1.73949E-05	0.002899149	4.17477506	1.523793	3.359388	6.90525E-07	4.14315E-05	0.007	9.943555	3.629398	8.001452	1.108531
Into The Mouth	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	7.55887E-05	18.14129526	6.621572771	14.59806911	3.79525E-07	2.27715E-05	0.00379525	5.465160079	1.994783	4.397745	8.80287E-07	5.28172E-05	0.009	12.67614	4.626789	10.20032	1.424403
Settling Bottom	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.000426486	102.3565547	37.36014245	82.36501513	1.11789E-06	6.70734E-05	0.011178902	16.09761839	5.875631	12.95355	5.9902E-06	0.000359412	0.06	86.25894	31.48451	69.41147	32.19127
Settling Top	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.000106305	25.5132065	9.312320373	20.53015214	3.37476E-07	2.02486E-05	0.003374763	4.859658381	1.773775	3.910505	1.43427E-06	8.60565E-05	0.014	20.65355	7.538545	16.61965	8.023937
Settling Bottom	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	6.58079E-05	15.79388974	5.764769755	12.7091418	3.16384E-07	1.8983E-05	0.00316384	4.555929732	1.662914	3.666099	7.80414E-07	4.68248E-05	0.008	11.23796	4.101855	9.043043	4.967199
Settling Top	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	0.000308791	74.10979031	27.05007346	59.63520383	1.0968E-06	6.58079E-05	0.010967979	15.79388974	5.76477	12.70914	4.04972E-06	0.000242983	0.04	58.3159	21.2853	46.92606	23.30763
Upwelling Bottom	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	2.53107E-05	6.074572977	2.217219136	4.888131462	6.32768E-08	3.79661E-06	0.000632768	0.911185946	0.332583	0.73322	3.58569E-07	2.15141E-05	0.004	5.163387	1.884636	4.154912	1.910461
Upwelling Top	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	1.01243E-05	2.429829191	0.886887655	1.955252585	1.26554E-07	7.59322E-06	0.001265536	1.822371893	0.665166	1.466439	4.21845E-08	2.53107E-06	4E-04	0.607457	0.221722	0.488813	0.764185
Upwelling Bottom	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	1.6452E-05	3.948472435	1.441192439	3.17728545	6.32768E-08	3.79661E-06	0.000632768	0.911185946	0.332583	0.73322	2.10923E-07	1.26554E-05	0.002	3.037286	1.10861	2.444066	1.2418
Upwelling Top	TCB1	28.032073	-80.5825	10/1/2015 16:45	10/3/2015 7:45	2.15141E-05	5.16338703	1.884636266	4.154911742	2.10923E-08	1.26554E-06	0.000210923	0.303728649	0.110861	0.244407	3.37476E-07	2.02486E-05	0.003	4.859658	1.773775	3.910505	1.623892
Out Of The Mouth	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	5.41286E-05	12.99085849	4.741663347	10.45357827	6.43634E-07	3.8618E-05	0.006436342	9.268331785	3.382941	7.458108	2.58509E-07	1.55105E-05	0.003	3.722527	1.358722	2.99547	1.020005
Into The Mouth	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	2.97549E-05	7.14117367	2.60652839	5.746411447	1.26617E-07	7.59699E-06	0.001266166	1.823278384	0.665497	1.467169	3.69298E-07	2.21579E-05	0.004	5.317895	1.941032	4.279243	0.560705
Into The Mouth	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	3.95677E-05	9.496241583	3.466128178	7.641504584	1.47719E-07	8.86316E-06	0.001477193	2.127158115	0.776413	1.711697	5.11742E-07	3.07045E-05	0.005	7.369083	2.689715	5.929808	0.745618
Into The Mouth	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	3.7985E-05	9.116391919	3.327483051	7.335844401	1.68822E-07	1.01293E-05	0.001688221	2.431037845	0.887329	1.956225	4.64261E-07	2.78556E-05	0.005	6.685354	2.440154	5.379619	0.715793
Settling Bottom	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	5.82645E-05	13.98346953	5.103966378	11.25231973	6.5442E-07	3.92652E-05	0.006544196	9.423642509	3.43963	7.583085	3.16655E-07	1.89993E-05	0.003	4.559827	1.664337	3.669235	4.39782
Settling Top	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	8.23302E-05	19.75925042	7.212126404	15.90001701	1.09774E-06	6.58642E-05	0.010977361	15.80740034	5.769701	12.72001	2.74434E-07	1.6466E-05	0.003	3.95185	1.442425	3.180003	6.214311
Settling Bottom	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	5.44646E-05	13.07150413	4.771099006	10.51847279	7.38861E-07	4.43317E-05	0.007388609	10.63959638	3.883453	8.561548	1.68882E-07	1.01329E-05	0.002	2.431908	0.887646	1.956925	4.111005
Settling Top	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	3.41987E-05	8.207688637	2.995806352	6.60462245	4.85537E-07	2.91322E-05	0.004855371	6.991734765	2.551983	5.62616	8.44412E-08	5.06647E-06	8E-04	1.215954	0.443823	0.978463	2.581329
Upwelling Bottom	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	2.40658E-05	5.775780893	2.108160026	4.647697279	1.47772E-07	8.86633E-06	0.001477722	2.127919276	0.776691	1.71231	2.53324E-07	1.51994E-05	0.003	3.647862	1.331469	2.935388	1.816491
Upwelling Top	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	4.3065E-05	10.33560791	3.772496888	8.316931974	4.22206E-08	2.53324E-06	0.000422206	0.607976936	0.221912	0.489231	6.7553E-07	4.05318E-05	0.007	9.727631	3.550585	7.827701	3.250562
Upwelling Bottom	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	2.6599E-05	6.383757829	2.330071607	5.136928572	2.11103E-08	1.26662E-06	0.000211103	0.303988468	0.110956	0.244616	4.22206E-07	2.53324E-05	0.004	6.079769	2.219116	4.892313	2.0077
Upwelling Top	TCB2	28.031683	-80.5823	10/1/2015 17:30	10/3/2015 8:28	8.86633E-05	21.27919276	7.766905358	17.12309524	1.26662E-07	7.59971E-06	0.001266619	1.823930808	0.665735	1.467694	1.35106E-06	8.10636E-05	0.014	19.45526	7.101171	15.6554	6.692334
Out Of The Mouth	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	3.58151E-05	8.595631859	3.137405628	6.916795416	4.80705E-07	2.88423E-05	0.004807046	6.92214601	2.526583	5.570163	1.16214E-07	6.97286E-06	0.001	1.673486	0.610822	1.346633	0.674905
Into The Mouth	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.000395551	94.93228814	34.65028517	76.39080248	1.4157E-06	8.49421E-05	0.014157014	20.38610034	7.440927	16.40444	5.17682E-06	0.000310609	0.052	74.54619	27.20936	59.98637	7.453813
Into The Mouth	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	3.0744E-05	7.378551241	2.693171203	5.937426154	1.84886E-07	1.10932E-05	0.001848864	2.66236385	0.971763	2.14237	3.27513E-07	1.96508E-05	0.003	4.716187	1.721408	3.795056	0.579343
Into The Mouth	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.000805999	193.4397506	70.60550896	155.6585022	2.36126E-06	0.000141676	0.023612632	34.00218974	12.4108	27.36113	1.10721E-05	0.000664323	0.111	159.4376	58.19471	128.2974	15.18834
Settling Bottom	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.001830079	439.2189423	160.3149139	353.4338856	3.72019E-06	0.000223211	0.037201882	53.57070952	19.55331	43.10767	2.67811E-05	0.001606868	0.268	385.6482	140.7616	310.3262	138.1349
Settling Top	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.000178823	42.91744342	15.66486685	34.5351198	8.87772E-07	5.32663E-05	0.008877722	12.78391932	4.666131	10.28706	2.09261E-06	0.000125556	0.021	30.13352	10.99874	24.24806	13.49759
Settling Bottom	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.001681694	403.6065956	147.3164074	324.777084	2.49422E-06	0.000149653	0.024942171	35.9167257	13.1096	28.90173	2.5534E-05	0.001532041	0.255	367.6899	134.2068	295.8754	126.9348
Settling Top	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	5.70711E-05	13.69705641	4.99942559	11.02184674	6.12986E-07	3.67791E-05	0.006129855	8.82699191	3.221852	7.102968	3.38199E-07	2.02919E-05	0.003	4.870065	1.777574	3.918879	4.307743
Upwelling Bottom	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	0.000121752	29.22038701	10.66544126	23.51327305	5.91848E-07	3.55109E-05	0.005918481	8.522612878	3.110754	6.858038	1.43735E-06	8.62407E-05	0.014	20.69777	7.554688	16.65524	9.189851
Upwelling Top	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	5.45346E-05	13.08829835	4.777228897	10.53198689	7.18673E-07	4.31204E-05	0.007186727	10.34888707	3.777344	8.327618	1.90237E-07	1.14142E-05	0.002	2.739411	0.999885	2.204369	4.116287
Upwelling Bottom	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	4.18521E-05	10.04450804	3.666245433	8.082687612	4.86161E-07	2.91697E-05	0.00486161	7.000717722	2.555262	5.633388	2.11374E-07	1.26825E-05	0.002	3.04379	1.110983	2.449299	3.159011
Upwelling Top	TCB3	28.031876	-80.5825	10/1/2015 18:10	10/3/2015 9:05	4.81933E-05	11.56640319	4.221737165	9.30733725	6.34123E-08	3.80474E-06	0.000634123	0.913137094	0.333295	0.73479	7.3981E-07	4.43886E-05	0.007	10.65327	3.888442	8.572547	3.637649

Appendix II – Background Data



Turkey Creek	Cube Container Label	Date Time	Mass(g) 0.45 µm Filter	Volume Filtered (ml)	NTU 1	NTU2	Post Filtration Mass(g)	PH	Salinity	Micromolars	TSS of sample mg/l	Water Temp In	Water Temp Out
Water Sample In	TC1 IN TOP	3/5/15 1:45 PM	0.079	400	1.58	1.18	0.085	.	14.5	17000	15	.	.
Water Sample In	TC2 IN TOP	3/5/15 2:20 PM	0.079	400	3	2.92	0.088	.	13.2	16100	22.5	24.9	24.1
Water Sample In	TC3 IN TOP	3/5/15 2:45 PM	0.079	400	2.9	2.44	0.085	.	14.5	17000	15	28.5	27.3
Water Sample In	TC4 IN TOP	3/5/15 2:07 PM	0.079	400	4.04	2.9	0.085	.	15	17300	15	29.5	26.8
Water Sample Out	TC4 OUT TOP	3/6/15 11:30 AM	0.078	400	3.56	3.56	0.085	.	16	18800	17.5	29.5	26.8
Water Sample In	TC5 IN TOP	3/5/15 3:25 PM	0.079	400	3.91	4.88	0.09	.	14.5	17000	27.5	29.6	27.25
Water Sample Out	TC5 OUT TOP	3/6/15 11:45 AM	0.078	400	1.6	2.3	0.084	.	14.9	17100	15	29.8	27.6
Water Sample In	TC6 IN TOP	3/5/15 3:55 PM	0.078	400	3.63	2.17	0.083	.	14	16900	12.5	29.8	27.6
Water Sample In	TC1N IN TOP	4/10/2015 16:40	0.083	200	8.03	11.4	0.09	8.07	23	28000	35	29.8	27.6
Water Sample Out	TC1N OUT TOP	4/11/2015 9:50	0.082	400	4.3	3.21	0.091	7.78	19.2	26100	22.5	29.8	27.6
Water Sample In	TC1S IN TOP	4/10/2015 17:10	0.083	400	13.6	2.3	0.093	8.03	21.1	21900	25	29.8	27.6
Water Sample Out	TC1S OUT TOP	4/11/2015 10:15	0.082	400	2.58	3.71	0.093	7.78	19.9	26100	27.5	29.8	27.6
Water Sample In	TCB1 IN TOP	4/10/2015 14:30	0.083	400	0.61	0.7	0.084	7.87	3.5	21100	2.5	29.8	27.6
Water Sample Out	TCB1 OUT TOP	4/11/2015 7:30	0.083	400	1.37	1.39	0.085	7.89	5.9	8100	5	29.7	27.4
Water Sample In	TCB2 IN TOP	4/10/2015 14:50	0.083	400	2.06	1.23	0.088	8.03	3.5	50500	12.5	29.7	27.4
Water Sample Out	TCB2 OUT TOP	4/11/2015 7:50	0.083	400	2.41	1.19	0.087	7.81	5	61100	10	29.7	27.4
Water Sample In	TCB3 IN TOP	4/10/2015 15:15	0.083	400	0.73	0.63	0.085	8.2	3.9	23200	5	29.7	27.4
Water Sample Out	TCB3 OUT TOP	4/11/2015 8:20	0.082	400	1.85	0.81	0.086	7.77	5.2	7900	10	32.9	.
Water Sample In	TCB4 IN TOP	4/10/15 15:30	0.085	400	18.5	15.3	0.095	7.99	4.5	20100	25	32.9	.
Water Sample Out	TCB4 OUT TOP	4/11/2015 8:50	0.083	400	6028	9.82	0.09	7.69	20	26100	17.5	32.9	.
Water Sample In	TC6 IN TOP	4/10/2015 16:00	0.082	400	1.64	1.65	0.096	8.04	16	23000	35	32.9	.
Water Sample Out	TC6 OUT TOP	4/11/2015 9:05	0.083	400	2.74	2.64	0.089	7.91	17.9	23100	15	32.4	30.8
Water Sample In	TC7 IN TOP	4/10/2015 15:40	0.082	400	5.42	32.9	0.09	8.02	16.8	23200	20	32.4	30.8
Water Sample In	TC4 IN TOP	4/10/2015 16:00	0.082	400	1.58	1.65	0.092	7.71	8.4	21900	25	32.4	30.8
Water Sample In	TCP5 IN TOP	5/14/15 4:45 PM	0.085	400	53	57.7	0.124	8.08	19	21100	97.5	32.4	30.8
Water Sample Out	TCM5 Top Out	5/15/2015 17:00	0.088	400	7.8	8.54	0.096	8.25	14.8	17000	20	32.4	30.7
Water Sample Out	TCM5 Bott Out	5/15/2015 17:00	0.085	200	9.79	10.89	0.102	7.57	10.9	13110	85	32.4	30.7
Water Sample In	TCP1 In Bot	5/14/15 5:20 PM	0.086	200	44.8	45.7	0.1131	7.91	18	21900	135.5	32.4	30.7
Water Sample Out	TCP1 Bott Out	5/15/15 3:45 PM	0.088	400	61	58.7	0.124	7.78	18.2	221.5	90	32.4	30.7
Water Sample Out	TCP1 Top Out	5/15/15 3:45 PM	0.085	400	10.7	11.76	0.097	8.15	15	17500	30	32.4	30.5
Water Sample In	TCP2 Bott In	5/14/2015 17:40	0.085	200	189	185	0.324	7.79	19.1	22000	1195	32.4	30.5

Chapter 5. Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of the Indian River Lagoon

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5.1. Summary

A coupled hydrodynamic-water quality model of the Indian River Lagoon is designed as a tool for understanding the ecology, maintaining water quality goals, and forecasting the potential benefits of management strategies, including muck dredging. The overall goal is to integrate water quality and physical process data into the coupled model of the IRL for long-term calibrated and validated predictions of water quality. Questions to be answered include: 1) whether muck dredging will improve local water quality in the vicinity of Turkey Creek and other localities that are to be dredged over the next several years, 2) whether improved model guidance by measured *in situ* data and modeled watershed data will allow the relative effects of watershed inputs and nutrient flux from muck sediments to be resolved, 3) if muck dredging, either locally or regionally, can result in a lasting improvement of IRL water quality. Project tasks are aimed at evaluating the benefits of muck dredging in the north and central Indian River Lagoon, among other issues.

Model validation results show a good match between predicted and measured parameters such as salinity, temperature, water level, and dissolved oxygen. Model runs under various scenarios/cases were conducted to test potential water quality improvements that may result from muck dredging. Model Case 1 includes existing conditions with respect to watershed inputs, baseflows, and gauged freshwater flow into Turkey Creek from the C-1 control structure. Nutrient flux from the benthic boundary of Turkey Creek was set according to fluxes reported by Dr. John Trefry in Chapter 3 of this report. In the region surrounding Turkey Creek the flux was set to be equivalent to the IRL average. Model Case 2 assumed a 50% reduction in the ammonium-based nitrogen flux from muck sediment to the water column. Model results indicate a reduction of about 25% to 30% in total nitrogen concentration in the water column at the mouth of Turkey Creek after hypothetical reduction of ammonium flux based on muck removal. Model results also showed a detectable, but variable reduction of total nitrogen within 4 km of Turkey Creek entrance. A numerical (model) monitoring station in the IRL, 10 km to the south of Turkey Creek entrance, showed a detectible reduction in total nitrogen concentration for

the first half of a 2-year model run. Other water quality variables are also calculated including forms of phosphorus, dissolved oxygen, and several others. These model data along with values for nitrogen components are stored in model data archives for further analysis.

5.2 Introduction and Goals

The goal of this project is to deploy a full three-dimensional combined hydrodynamic and water quality model in the Indian River Lagoon to answer the following questions: 1) whether muck dredging will improve local water quality in the vicinity of Turkey Creek and other localities that are to be dredged over the next several years, 2) whether improved model guidance by measured *in situ* data and modeled watershed data will allow the relative effects of watershed inputs and nutrient flux from muck sediments to be resolved, 3) if muck dredging either locally or regionally can result in a lasting improvement of IRL water quality. The modeling effort consists of three major software platforms including a three dimensional hydrodynamic model, a water quality or eutrophication model, and a watershed model to provide inputs to the combined hydrodynamic and water quality models.

5.3 Methods

5.3.1. Hydrodynamic Model Overview

The model applied to meet the project objectives is the EPA supported Environmental Fluid Dynamics Code/Hydrodynamic and Eutrophication Three-Dimensional Model (EFDC/HEM3D). EFDC/HEM3D includes features and capabilities that make it superior and more applicable to shallow estuarine environments than other models. The project area extends from the Mosquito Lagoon into the main body of the IRL extending to Ft Pierce Inlet. EFDC/HEM3D was developed and refined at the Virginia Institute of Marine Science over the time period of 1988-1995 (Hamrick, 1992). This multi-parameter finite difference model represents estuarine flow and material transport in three dimensions and has been extensively applied to shallow estuarine environments in Florida and other coastal states. A few examples include the central Indian River Lagoon (Zarillo and Surak, 1994, Zarillo and Yuk, 1996); Long Slip Canal, Hudson River (Zarillo, 1999); Lake Jesup, FL (Zarillo, 2001); the Loxahatchee River Estuary in South Florida (Zarillo, 2004); Lake Worth, FL (Zarillo, 2003); the lower Savannah River, GA (Tetra Tech, 2005); the Peconic Estuary, Long Island New York (Tetra Tech, 2000); the York River, VA (Sisson et al., 1997), the German Wadden Sea (Zarillo, 1997).

The details of the EFDC's hydrodynamic scheme can be found in technical manuals and users guides published with support of the U.S. EPA (Tetra Tetra, 2000) and within publications by Hamrick (1992, 1994). Figure 5.1 shows a flow diagram of the various model components of the EFDC model. The EFDC model can be used to drive a number of external water quality models using internal linkage processing procedures described in Hamrick (1992).

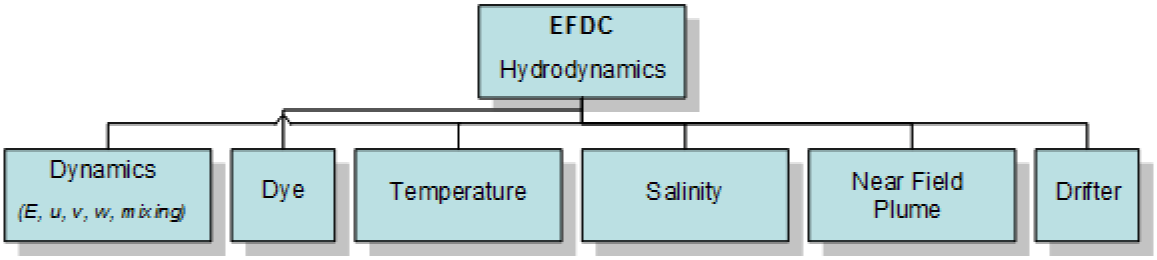

Figure 1. Flow diagram for the EFDC hydrodynamic and transport model. Drifter, dye, and near field plume calculations are driven by subroutines within the main body of the EFDC model.

5.3.2. Model Overview - Water Quality Calculations

The EFDC model can be directly coupled with the water quality model. The kinetic processes included in the HEM3D water quality model have been derived and updated from the Chesapeake Bay three-dimensional water quality model, CE-QUAL-ICM (Cerco and Cole, 1994). A detailed description of the water quality model is provided by Park et al. (1995) and Tetra Tech (2007). Table 5.1 lists the model's complete set of state variables. Figure 5.2 presents a schematic flow chart of interactions among water quality variables in EFDC/HEM3D. Earlier water quality models, such as WASP (Ambrose et al., 1993) used biochemical oxygen demand (BOD) to represent oxygen demanding organic material, whereas the HEM3D water quality model is carbon based. The algae species are represented in carbon units. The three organic carbon state variables play an equivalent role to BOD, including dissolved, labile particulate, and refractory particulate. Organic carbon, nitrogen and phosphorous can be represented by up to three reactive sub-classes, refractory particulate, labile particulate and labile dissolved. The use of the sub-classes allows a more realistic distribution of organic material by reactive classes when data are used to estimate distribution factors. The following brief sections discuss the role of each variable and summarize the kinetic interaction processes. The kinetic sources and sinks, as well as the external loads for each state variable, are fully described in Park et al. (1995). Kinetic processes include the exchange of fluxes at the sediment-water interface, including sediment oxygen demand. Formulations of these processes in the EFDC water quality model are also discussed in Park et al. (1995).

Table 5.1. List of water quality variables that can be calculated by the EFDC/HEM3D model.

(1) cyanobacteria **Bc**	(12) labile particulate organic nitrogen **LPON**
(2) diatom algae **Bd**	(13) dissolved organic nitrogen **DON**
(3) green algae **Bg**	(14) ammonia nitrogen **NH_4**
(4) refractory particulate organic carbon **RPOC**	(15) nitrate nitrogen **NO_3**
(5) labile particulate organic carbon **LPOC**	(16) particulate biogenic silica **SAP**
(6) dissolved organic carbon **DOC**	(17) dissolved available silica **SAD**
(7) refractory particulate org. phosphorus **RPOP**	(18) chemical oxygen demand **COD**
(8) labile particulate organic phosphorus	(19) dissolved oxygen **DO**
(9) dissolved organic phosphorus **DOP**	(20) total active metal **TAM**
(10) total phosphate **TP**	(21) fecal coliform bacteria **FCB**
(11) refractory particulate organic nitrogen **RPON**	

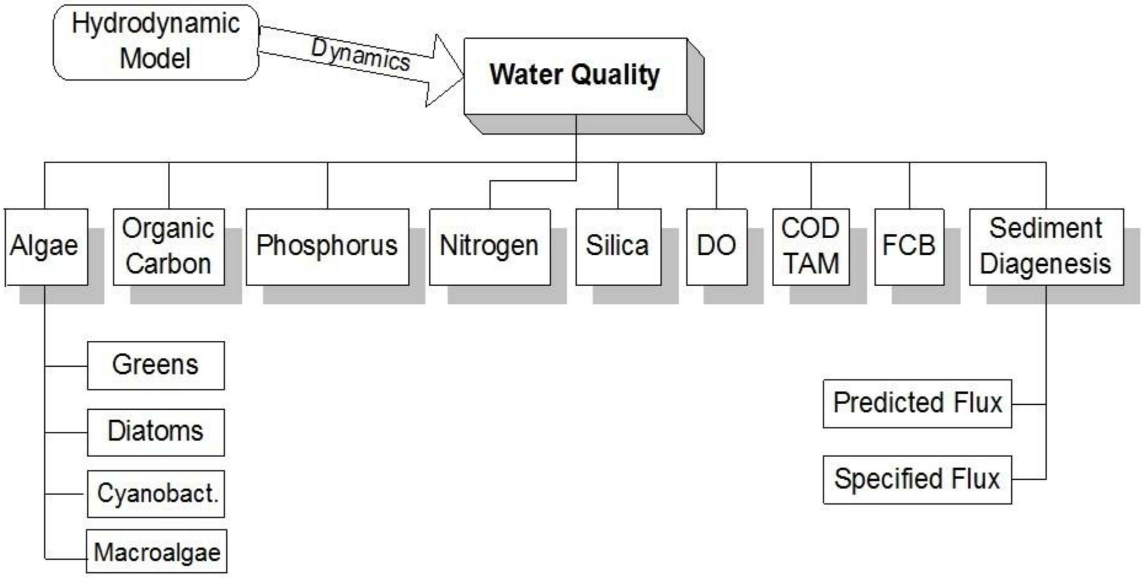

Figure 5 2. Flowchart for the water quality module of HEM3D.

Algae

Algae are grouped into four model classes: cyanobacteria, diatoms, greens, and stationary that can be differentiated in the model calculations. The grouping is based upon the distinctive characteristics of each class and upon the significant role the characteristics play in the ecosystem. Cyanobacteria, commonly called blue-green algae, are characterized by their abundance (as picoplankton) in saline water and by their bloom-forming characteristics in fresh water. Cyanobacteria are unique in that some species fix atmospheric nitrogen, although nitrogen fixers are not believed to be predominant in many river systems. Diatoms are distinguished by their requirement of silica as a nutrient to form cell walls. Diatoms are large algae characterized by high settling velocities. Settling of spring diatom blooms to the sediments may be a significant source of carbon for sediment oxygen demand. Algae that do not fall into the preceding two groups are lumped into the heading of green algae. Green algae settle at a rate intermediate between cyanobacteria and diatoms and are subject to greater grazing pressure than cyanobacteria. A stationary or non-transported algae variable is included in the model and has been used to simulate macroalgae. The stationary algae variable has the same kinetic formulation as the original algae groups, with the exception that it is not transported. The stationary algae group can also be used for various types of bottom substrate attached or floating periphyton.

Organic Carbon

Three organic carbon state variables are considered: dissolved, labile particulate, and refractory particulate. Labile and refractory distinctions are based upon the time scale of decomposition. Labile organic carbon decomposes on a time scale of days to weeks whereas refractory organic carbon requires more time, on the order of months to years. Labile organic carbon decomposes rapidly in the water column or the sediments. Refractory organic carbon decomposes slowly, primarily in the sediments, and may contribute to sediment oxygen demand years after deposition.

Nitrogen

Nitrogen is first divided into organic and mineral fractions. Organic nitrogen state variables are dissolved organic nitrogen, labile particulate organic nitrogen, and refractory particulate organic nitrogen. Two mineral nitrogen forms are considered: ammonium and nitrate. Both are utilized to satisfy algal nutrient requirements. The primary reason for distinguishing the two is that ammonium is oxidized by nitrifying bacteria into nitrate. This oxidation can be a significant sink of oxygen in the water column and sediments. An intermediate in the complete oxidation of ammonium, nitrite, also exists. Nitrite concentrations are usually much less than nitrate. Thus for modeling purposes, nitrite is combined with nitrate. Hence, the nitrate state variable actually represents the sum of nitrate plus nitrite.

Phosphorus

As with carbon and nitrogen, organic phosphorus is considered in three states: dissolved, labile particulate, and refractory particulate. Only a single mineral form, total phosphate, is considered. Total phosphate exists as several states within the model ecosystem: dissolved phosphate, phosphate sorbed and absorbed to inorganic solids, and phosphate incorporated in algal cells. Adjustable equilibrium partition coefficients are used to distribute the total among the three states.

Silica

Silica is divided into two state variables: available silica and particulate biogenic silica. Available silica is primarily dissolved and can be utilized by diatoms. Particulate biogenic silica cannot be utilized. In the model, particulate biogenic silica is produced through diatom mortality. Particulate biogenic silica undergoes dissolution to available silica or else settles to the bottom sediments.

Chemical Oxygen Demand

In the context of this study, chemical oxygen demand is the concentration of reduced substances that are oxidizable by inorganic means. The primary component of chemical oxygen demand is sulfide released from sediments. Oxidation of sulfide to sulfate may remove substantial quantities of dissolved oxygen from the water column.

Dissolved Oxygen

Dissolved oxygen is required for the existence of higher life forms. Oxygen availability determines the distribution of organisms and the flow of energy and nutrients in an ecosystem. Dissolved oxygen is a central component of the water quality model and is closely linked to the activity of other water quality constituents, low oxygen and anoxic conditions can result from excessive nutrient loading and eutrophication

Total Active Metals

Both phosphate and dissolved silica adsorb onto inorganic solids, primarily iron and manganese. Sorption and subsequent settling is one pathway for removal of phosphate and silica from the water column. Consequently, the concentration and transport of iron and manganese are represented in the model. However, limited data do not allow a complete treatment of iron and manganese chemistry. Rather, a single-state variable, total active metal is defined as the total concentration of metals that are active in phosphate and silica transport. Total active metal is partitioned between particulate and dissolved phases by an oxygen-dependent partition coefficient. Inorganic suspended solids can be used, in lieu of total active metal, as a sorption site for phosphate and silica. Inorganic suspended solids concentration can be provided by the sediment transport component of the EFDC modeling system.

5.3.3. Spatial Watershed Iterative Loading (SWIL) model

The Spatial Watershed Iterative Loading (SWIL) model is a custom ESRI ArcGIS toolset, providing a continuous monthly simulation of runoff (surface and baseflows) yielding robust representation of pollutant loadings and freshwater volumes to the IRL. SWIL was developed by Dr. Claudia Listopad of Applied Ecology, Inc. Details of model operation can be found in the SWIL Model Methodology Manual (Applied Ecology, Inc., 2015). The SWIL model was developed as part of this study to incorporate available watershed data into the TMDL process.

The SWIL model has been updated since the initial version was developed in 2012 (SWIL 1.0). By July 2014, SWIL 2.0 was released focusing on addressing initial FDEP comments, improving the ease of execution and reducing the overall processing time. SWIL 3.0, released in April 2015, focused on improving model calibration to the measured available gage data, which included a change in the methodology to derive baseflow volumes and loads. SWIL 3.0 also incorporated the newly released evapotranspiration (ET) raster datasets. For additional details on the changes included in the latter changes of SWIL, please review the Model Methodology Manual (Applied Ecology, Inc. 2015). SWIL 3.0 is applied in this study, but includes some spatial refinements to better fit the spatial coverage of the EFDC.HEM3D model grid. The SWILL model does not account for atmospheric inputs or point source loadings, which are handled by other components of the model.

5.3.4. Hydrodynamic and Water Quality Model Grid Generation

The model grid was designed as a theme in the ArcGIS software platform. A recent set of aerial images was used as a background over which a data layer was hand drawn to fit the model grid to shoreline boundaries and other morphologic features of the IRL system. Care was taken to include extensive marsh and mangrove areas as well as include the details of the numerous causeway-bridge combinations of the system. The EFDC/HEM3D model includes a separate grid generator computer code. Once a grid is visualized as a GIS layer, the grid generator uses an array of cell types and the x,y coordinates of the corner points of all water cells to produce model input files that numerically represent the model grid. A time consuming step in the grid generation process can be to digitize the water cell corner points. To speed this process, Applied Ecology, Inc. developed a digitizing tool that operates under ESRI ArcGIS 10.3. The hand drawn grid layer is opened by the tool and the coordinates of the cell corner points are digitized in order, row by row from the southwest corner of the grid to the northeast corner of the grid. The grid tool assigns I (row) and J (column) indices to each set of cell coordinates. The subscripted list of cell coordinates along with an ordered 2-dimensional array of cell types, and depth value inputs are then used by the grid generator to calculate an ordered list of cell dimensions (file dxdy.out) and a file specifying horizontal cell center coordinates and cell orientations (file lxly.out). These files are restated as input files, and along with control and boundary forcing information, are used to run both the hydrodynamic and water quality calculations.

The extent of the model domain allows an integrated evaluation of water quality interactions among the major basins of the IRL and incorporates all major areas of muck deposits. Figure 5.3 shows the geographic extent of the EFDC model grid from near Ponce de Leon Inlet on the north and Ft. Pierce Inlet on the south. The grid dimensions are stated in UTM metric coordinates and depth values are in the NAVD88 vertical datum. The details of the model grid in the Turkey Creek area of Brevard County are shown in Figure 5.4 At the time of this report the combined hydrodynamic and water quality model includes about 9,400 computational cells in the horizontal along with 5 vertical layers, each representing 20% of the water column.

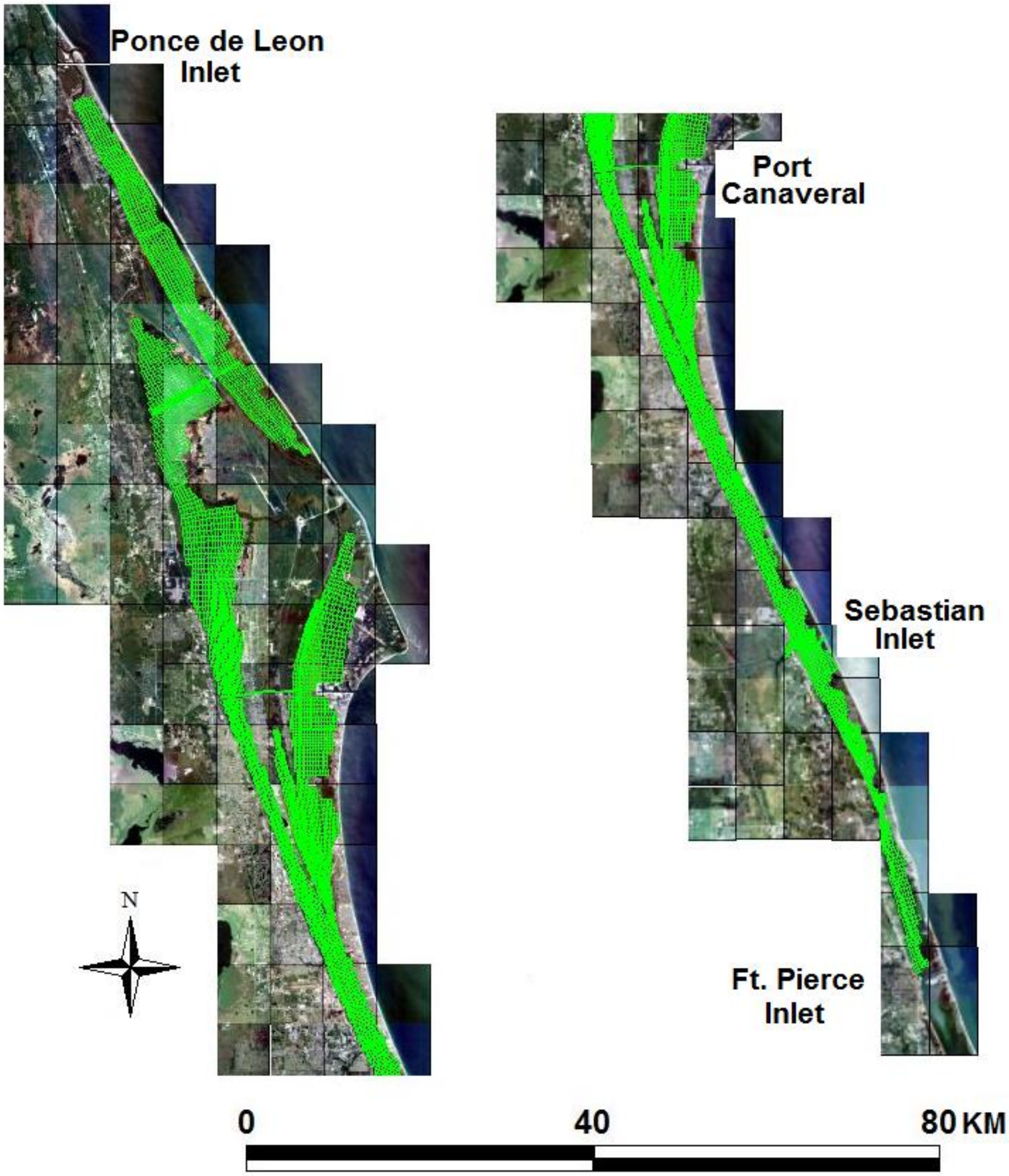

Figure 5.3. Extent of the model grid in two panels oriented north-south. Model grid contains about 9,400 computational water cells and 5 vertical layers, each representing 20% of the water column. Mode boundaries correspond with available time series of water level and salinity data.

Figure 5.4. Model grid in the Turkey Creek area.

5.3.5. Hydrodynamic Model Inputs

Data sets have been assembled from a wide range of sources and evaluated for use in the model. Figure 5.5 shows the distribution of monitoring stations managed by the SJRWMD. These data from stations include time series of water level, salinity, temperature, discharge and meteorological parameters. Water quality data at approximate monthly intervals are also available from the SJRWMD. These data have been assembled into a large ongoing database that can be used to extract data for model boundary conditions as well as for calibration.

Data in time series format are required to force the model at open boundaries. Other forcing includes surface water inflows and base flows from the watershed model that approximate groundwater influx. Data from meteorological stations maintained by the SJRWMD are used to setup air-sea interaction boundary conditions input to the hydrodynamic model. Table 5.2 lists the major input files used to run the hydrodynamics of EFDC and their function.

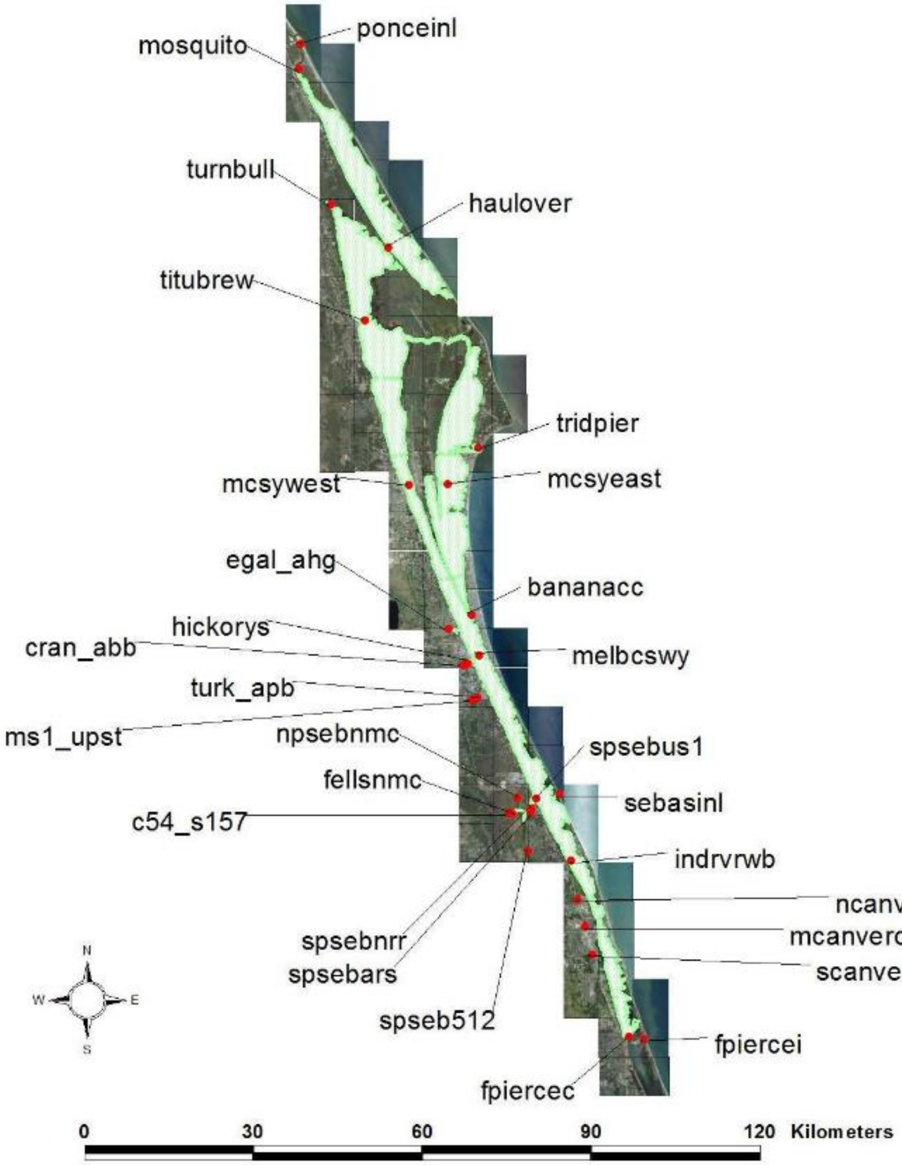

Figure 5.5. Long term IRL monitoring stations for freshwater, water level, salinity and water temperature.

Table 5.2. Hydrodynamic and transport input files

Input File	Description	Status
aser.inp	Atmospheric forcing time-series file.	Complete
cell.inp	Horizontal cell type identifier file.	Complete
dxdy.inp	File specifying horizontal grid spacing or metrics, depth, bottom elevation, bottom roughness and vegetation classes for either Cartesian or curvilinear orthogonal horizontal grids.	Complete
lxly.inp	File specifying horizontal cell center coordinates and cell orientations.	Complete
pser.inp	Water level time series	Complete
qser.inp	Volumetric source-sink time-series file. (inflow-outflow)	Complete
salt.inp	File with initial salinity distribution for cold start, salinity stratified flow simulations.	Complete
sser.inp	Salinity time-series file.	Complete
tser.inp	Temperature time-series file	Complete

For each of the time series files listed in Table 5.2, the complete available data record is loaded in the model boundary input file. For instance, Figure 5.6 shows the water level time series loaded into file pser.inp at the north open boundary of the model at north end of Mosquito Lagoon and the south boundary near Ft. Pierce Inlet (See Figure 5.5). Likewise Figure 5.7 shows salinity time series from these monitoring stations loaded into file sser.inp (Table 5.2). Although the data sets are of high quality, having been quality controlled levelled to NAVD88 with respect to water level, they are limited in time span. Thus to force the model outside of the 3-year periods from August 1997 through August 2000, other data sources or methods must be developed. As of February 2014 the water level time series open boundaries have been extended by about 6 months using tidal water level oscillation predicted using known tidal constituents established near the model boundaries from NOAA water level data. Predicted tide elevation time series are centered about a mean elevation of 0. To add a vertical datum and account for the low frequency, non-tidal sea level oscillations that propagate though the coastal ocean and into estuaries, low pass filtered water level data from the long term station at Trident Pier, Cape Canaveral and the Florida Tech Water level gauge at Sebastian Inlet are added to the constituent based water level record. Previous experience has shown that water level data by this method can result in good model calibration results (Zarillo et al., 2010).

However, to bring the model performance up to the present day and beyond, the model grid in year 2 of the project will be extended into the nearshore coastal ocean using combined tidal and low frequency water level data, and assuming full or near ocean salinity of about 33 to 35 psu.

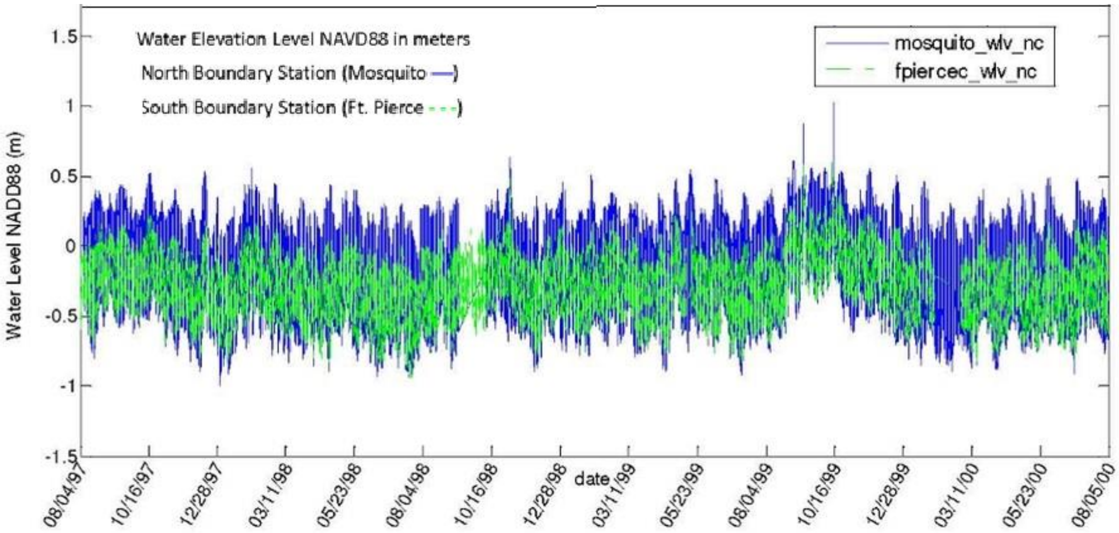

Figure 5.6. Water level time series applied in file to force north and south model boundaries. Annual highstand of sea level seen in October 1999 is included in model calibration (see Figure 5.12).

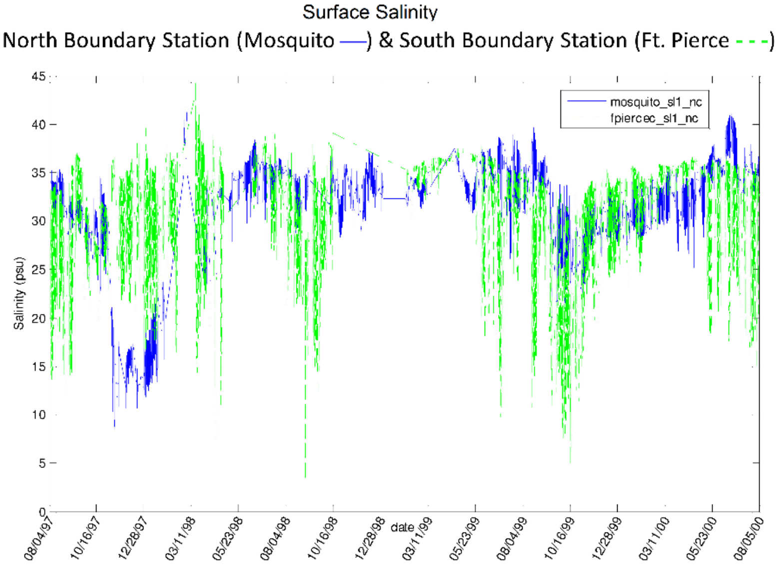

Figure 5.7. Surface salinity time series applied in model, along with near- bottom salinity data to force north and south model boundaries

5.3.6. Water Quality Model Setup

To activate the water quality calculations within EFDC/HEM3D, various input files are applied and controls set in the main input file (EFDC.INP). Table 5.4 lists the required files and their function within the model. Similar to the hydrodynamic portion of the model, water quality data to drive and calibrate the model are derived from existing historical sources, on-going data collection effort sponsored by the SJRWMD and the SWIL watershed model (Applied Ecology, 2015). Figure 5.5 shows the distribution of water quality monitoring stations maintained throughout the IRL system.

The water quality parameter concentrations and coefficients controlling the kinetics of the nutrient and sediment cycles initially have been set from a review of all available water quality data from the IRL. During the calibration process, kinetics and coefficients for each variable are adjusted where necessary. For example, kinetics constants and coefficients for the water column and sediment model input files are adjusted for model calibration and operation using information collected during year 1 of the project to determine the environmental impacts of muck dredging

Table 5.3. Summary of Major EFDC/HEM3D Water Quality Input Files

Model Input File	Description	Status
efdc.inp	Primary controlling input file for EFDC hydrodynamics and water quality transport options	Complete
wq3dwc.inp	Kinetics constants and coefficients for the water column	Operational pending input from IRLRI Team
wq3dsd.inp	Kinetics constants and coefficients for the sediment model	Operational pending input from IRLRI Team
cwqsr01-21.inp	Time-series tidal boundary conditions for water quality state variables 1-21	Complete
wqpsl.inp	Time-series river and point source loads for variables 1-21	Operational

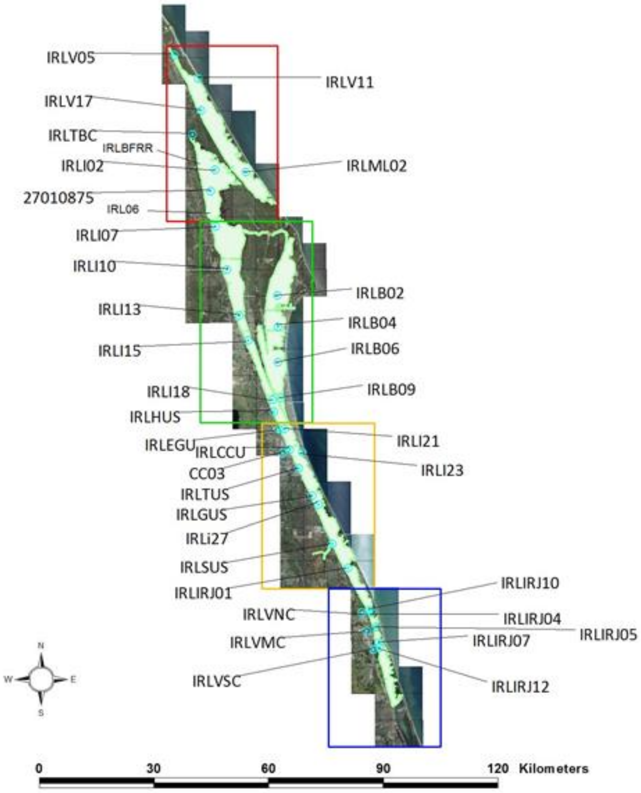

Figure 5.8. Location of water quality monitoring station maintained by the SJRWMD.

5.3.7. Watershed Inputs

Watershed inputs are assembled from the Spatial Watershed Iterative Loading (SWIL) Model developed by Applied Ecology, Inc. Figure 5.9 shows the watershed sub-basins linked to the IRL model. Time series of surface water flows, base flows, and major nutrient classes produced by the SWIL model are applied as inputs to model runs, along with freshwater inflows from major USGS gauging stations associated with water control structures connected to Turkey Creek and the Sebastian River. Surface water, baseflow, and USGS gauged flow data are placed in model input file qser.inp (see Table 5.2). At present there are no estimates of nutrient or sediment concentrations associated with the USGS gauged flows.

SWIL watershed model output is available as monthly loads of total phosphorus and total nitrogen from 1995 through 2011. Likewise, storm water runoff and baseflow volumes are provided as monthly volumes. Figure 5.10 shows an example of output from the SWIL water shed model from the Turkey Creek sub-basin.

Time series of water quality data from SWIL and from selected SJRWMD monitoring stations are specified as input to the EFDC/HEM3D model in file wqpsl.inp (see Table 5.3). In this file, time series of water quality data are linked to specific sets of water cells in the model grid that connect to the watershed sub-basins shown in Figure 5.11

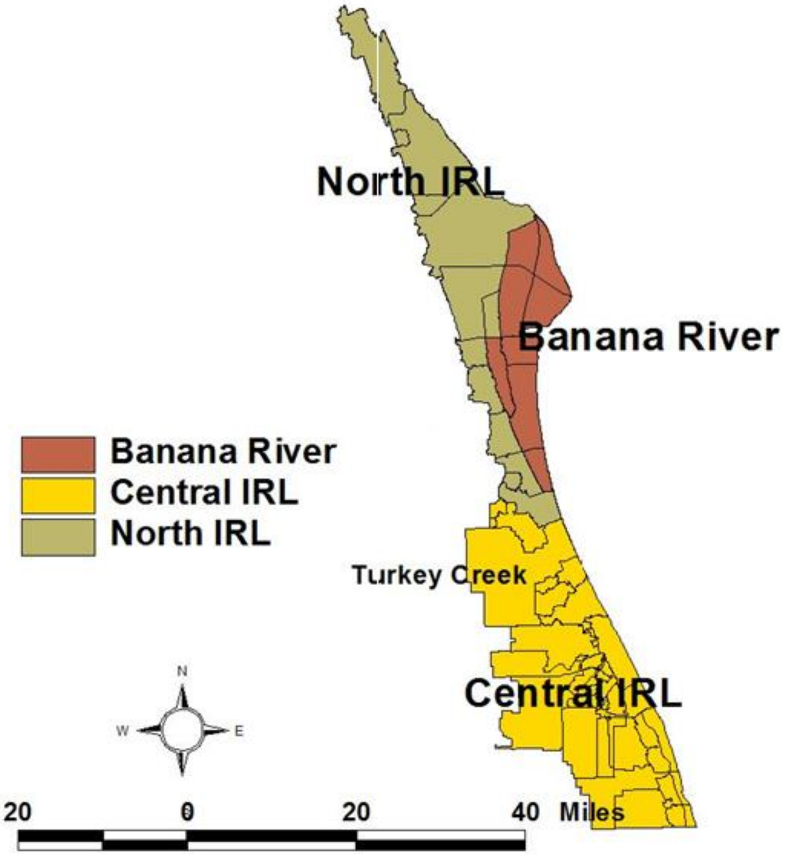

Figure 5.9. Boundaries of the watershed model sub-basin links to the IRL model. Barrier Island watersheds are not included.

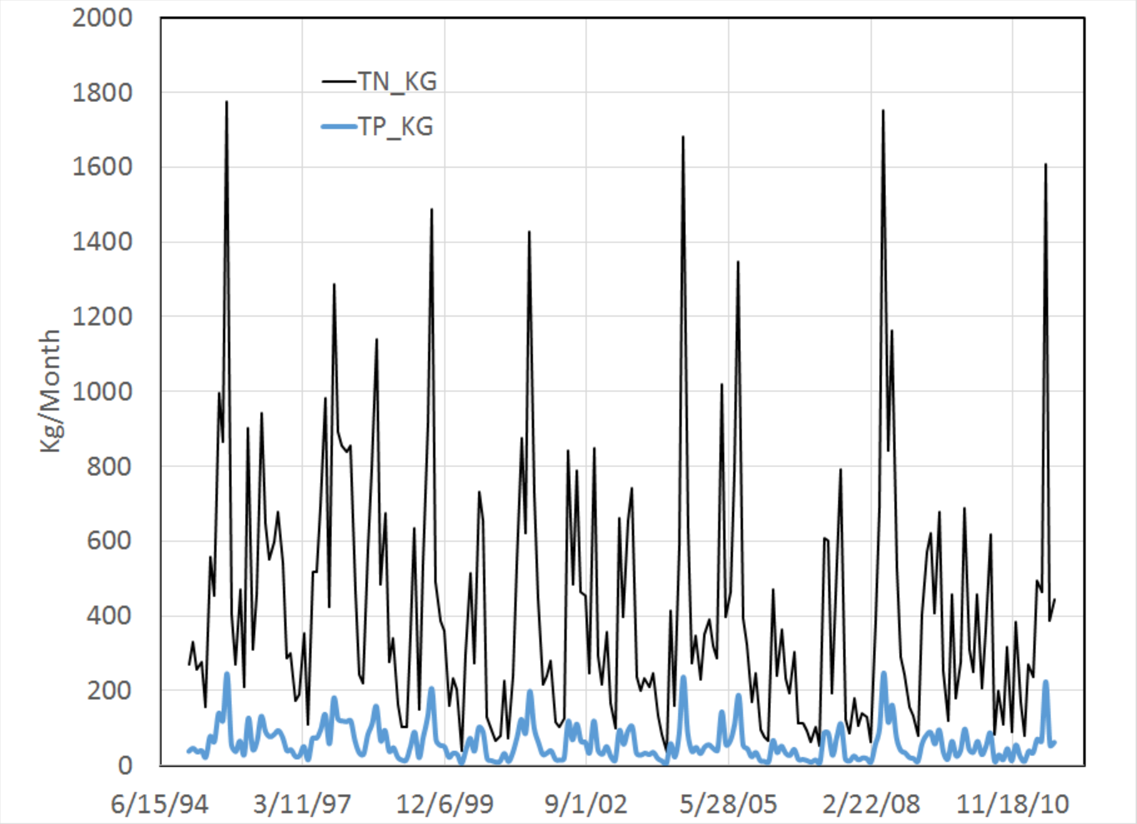

Figure 5.10. Example of total nitrogen and total phosphorus inputs to the EFDC/HEM3D model from the SWIL watershed model from 1994 to 2010. Inputs are received from the Turkey Creek sub-basin

5.3.8. Sediment Diagenesis Model Setup for Muck Assessment

The EFDC sediment diagenesis model is based on formulations modified from the Chesapeake Bay model and includes 27 state variables and fluxes (Table 5.4). This sub model is a key element in assessing the benefit of muck dredging. Three basic processes are included in the sediment sub model: depositional flux of particulate organic matter (POM) from water column, diagenesis (decay) of POM in sediments, and flux of substances produced by diagenesis. Benthic sediments are represented by two layers. The upper layer can be oxic or anoxic, whereas the lower layer is always anoxic. The diagenesis model is schematically represented in Figure 5.11.

Table 5.4. Sediment model state variables

(1) particulate organic carbon G1 class in layer 2	(15) nitrate nitrogen in layer 1
(2) particulate organic carbon G2 class in layer 2	(16) nitrate nitrogen in layer 2
(3) particulate organic carbonG3 class in layer 2	(17) phosphate phosphorus in layer 1
(4) particulate organic nitrogen G1 in layer 2	(18) phosphate phosphorus in layer 2
(5) particulate organic nitrogen G2 in G2layer 2	(19) available silica in layer 1
(6) particulate organic nitrogen G3 in layer 2	(20) available silica in layer 2
(7) particulate organic phosphorus G1 in layer 2	(21) ammonia nitrogen flux
(8) particulate organic phosphorus G2in layer 2	(22) nitrate nitrogen flux
(9) particulate organic phosphorus G3 in layer 2	(23) phosphate phosphorus flux
(10) particulate biogenic silica in layer 2	(24) silica flux
(11) sulfide/methane in layer 1	(25) sediment oxygen demand
(12) sulfide/methane in layer 2	(26) release of chemical oxygen demand
(13) ammonia nitrogen in layer 1	(27) sediment temperature
(14) ammonia nitrogen in layer 2	

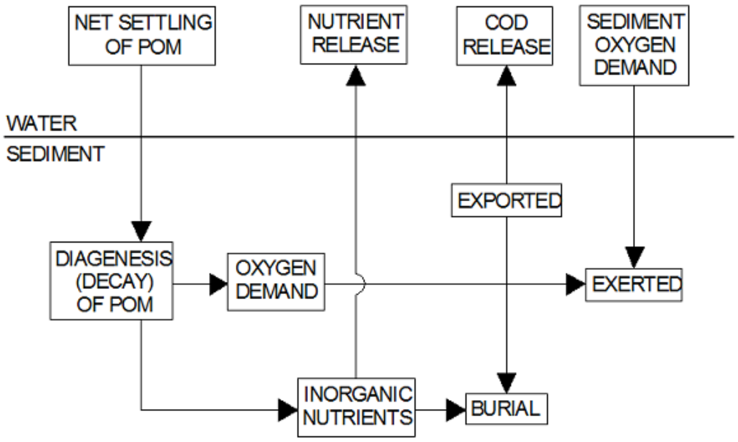

Figure 5.11. Sediment diagenesis schematic. Sub-bottom processs include two layers.

The kinetics of the sediment model are controlled within file wq3dsd.inp listed in Table 5.3. The recent data collected by Dr. Trefry's team and described in Chapter 2 of this report indicate high rates of loading of ammonium and phosphate to the water column by muck sediments (Trefry et al., 2015). The Trefry team is also performing laboratory experiments of nutrient flux from muck sediments sampled from the area of Turkey Creek to be dredged. Within the sediment diagenesis model, fluxes of these and other nutrients are accordingly specified for model runs to assess present conditions. In on-going model experiments described in a later section, nutrient fluxes from the bottom sediments are hypothetically adjusted to represent nutrient release after dredging of muck from Turkey Creek.

5.4 Results

5.4.1. Hydrodynamic Model Validation

To assure the accuracy of the model within the limitations of the observational data, model predicted data were compared with measured data over selected historical time periods. Below are example comparisons between predicted and model data

5.4.2. Calibration of Physical Processes

Figure 5.12 shows the comparison between predicted and measured water level data near the mouth of the Sebastian River for the historical 1999 calibration period. In this area, the tidal signal is damped due to the morphologic restrictions of Sebastian Inlet. However, the water level curve in Figure 5.12 shows a large low frequency oscillation over a range of about 40 cm along with shorter term spikes in water level due to local wind effects. Such lower frequency shifts in sea level are related to passing of weather systems and changes in Gulf Steam flux that have been correlated with variations in non-tidal sea level of up to 1 m on a seasonal time frame.

The water level record Figure 5.12 shows the typical seasonal shift in sea level that occurs between mid-July and mid-October each year. In 1999 sea level increased from a low of about -0.4m relative to NAVD88 to a persistent high stand at about +0.2m NAVD88. Shorter term events pushed sea level to above 0.5m for a day or two. At the end of October sea level usually undergoes a drop of about 0. 4m over a 2-week period, as demonstrated by the record in Figure 5.12. Although narrow and shallow inlets such as Ponce Inlet and Sebastian Inlet can damp the astronomical tides and severely reduce the tidal range of an interior location like the lower Sebastian River, low frequency sea shifts are readily transmitted through to the back barrier. By comparison, water level changes due to rainfall, freshwater inflows from water control structures and manipulation of mangrove impoundments are of secondary importance and local in extent.

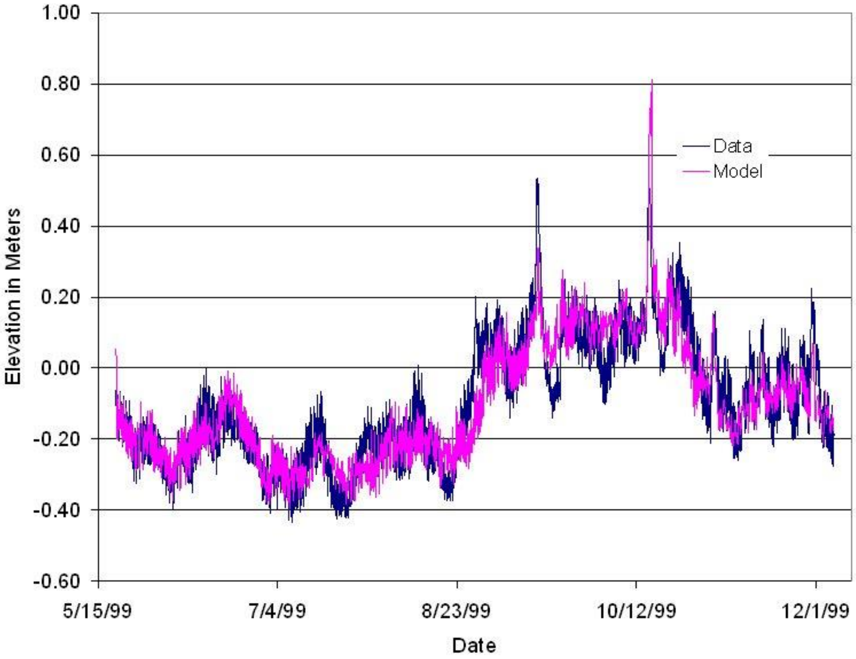

Figure 5.12. Model and measured water level comparison in the Sebastian River.

5.4.3. Calibration of Transport Processes

A number of transport processes are included in EFDC model code including salt and heat, sediment, and Lagrangian calculations for generic tracers that can be used for numerical flushing experiments. In this project, the IRL model is calibrated for salinity and water temperature with assumption that other transport processes that may be calculated will also have a similar verification level. Figure 5.13 is an example of a calibration model run for salinity calculations in the lower Sebastian River.

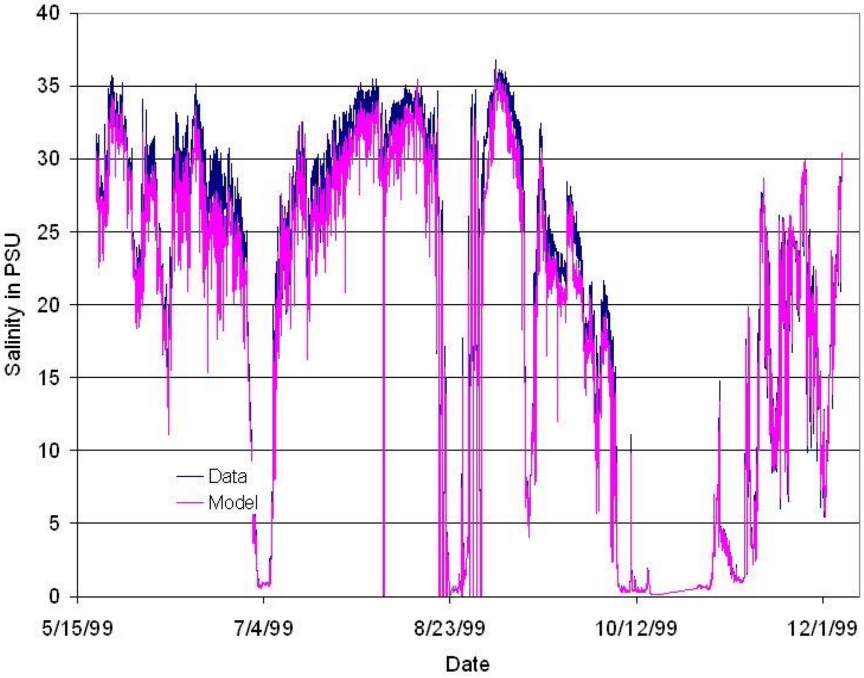

Figure 5.13. Comparison of measured and model salinity at the mouth of Sebastian River.

5.4.4. Calibration Statistics

The statistics applied to check the match between predicted water level, salinity and temperature at the lower Sebastian River calibration station included the root mean square error (RMSE) and the ratio between RMSE and the range (RANGE) of observed values of each variable during the calibration and validation periods. The RMSE/Range provides a comparison in a percentage format. The formulation of RMSE as shown below is the square root of the average squared differences between observed and predicted parameter values. In the formula

RMSE: $\sqrt{\sum (O-P)^2 / N}$,

Where O is the observed value, P is the predicted value and N is the number of observations.

The validation period is May to early December 1999, whereas the verification period is from January to early June 2000. Calibration adjustments to the model included incrementally adjusting the mean water elevation at the open boundaries of the model and local adjustments of a boundary roughness height to influence exchanges through the model open boundaries. Once adjustments are made for the calibration period model runs, no further changes are made in model parameter before performing data-model comparisons for the verification periods.

Table 5.5 lists data-model comparison for an initial calibration and subsequent verification period for water level, salinity and temperature in the lower Sebastian River. Based on the model validation results, the EFDC hydrodynamic predictions have good match with measured data. Further adjustments to model boundary conditions and controls will be made throughout the project to improve calibration. It is likely that some refinements and adjustments to the existing model grid will be made to better accommodate the footprint and magnitude of muck dredging project.

Table 5.5. Statistics of model-data comparisons in the lower Sebastian River for calibration and verification

	Calibration Period		Verification Period	
Parameter	RMSE	RMSE/Range	RMSE	RMSE/Range
Water level	0.08 m	7.7%	0.09 m	9.4%
Salinity surface	4.7 psu	16.6%	5.6 psu	17.3%
Salinity bottom	0.8 psu	4.8%	1.5 psu	4.1%
Temperature bottom	1.8 ^{o}C	8.2%	0.76 ^{o}C	4.2%%
Temperature surface	2.09 ^{o}C	10.9%	2.8 ^{o}C	15.7%

5.4.5. Water Quality Model Validation

Calibration and verification the EFDC/HEM3D water quality and eutrophication calculations are ongoing at the time of this writing. The Sediment Diagenesis Model is being adjusted and recalibrated for the flux of nutrients from muck sediments based on the work of John Trefry described in Chapter 3 of this report. New model runs are initiated and once complete, comparisons will be made between a suite of predicted and measured nutrient constituents, including forms of nitrogen, phosphorus, ammonia nitrogen and dissolved oxygen. However, even without detailed adjustment and calibration of the water quality and sediment sub-models, results have been encouraging. Dissolved oxygen (DO) levels are linked to the concentration and activity of other water quality components. Low oxygen and anoxic conditions are linked to excessive nutrient loading and eutrophication. Thus, a comparison of measured and predicted DO provides a guide to water quality model performance.

Figure 5.14 is an example of water quality model output for dissolved oxygen in the central IRL between Melbourne and Turkey Creek. Model output for a 1999 calibration period is compared to measured dissolved oxygen values. Predicted model values are shown for model layers 1 (lower) to layer 5 (upper). Superimposed on the longer term trend are daily oscillations that are characteristic of DO values. Similar to other water quality data DO values are collected at low spatial and temporal resolution. There are too few measured data to validate the model trends and variability.

When available, the measured data correspond well to the predicted data. Measured data are contained within the predicted data that are plotted in Figure 5.14 from model layer 1 (bottom) to model layer 5 (surface). Measured data that plot on the same date are likely to have been collected at more than one depth, one near-surface and one near-bottom. These multiple data points are captured by one of the model layers. Overall, the model results indicate that D.O. predictions are likely to be accurate and can be used to evaluate that aspect of water quality to help assess the efficacy of muck dredging in Turkey Creek and other areas.

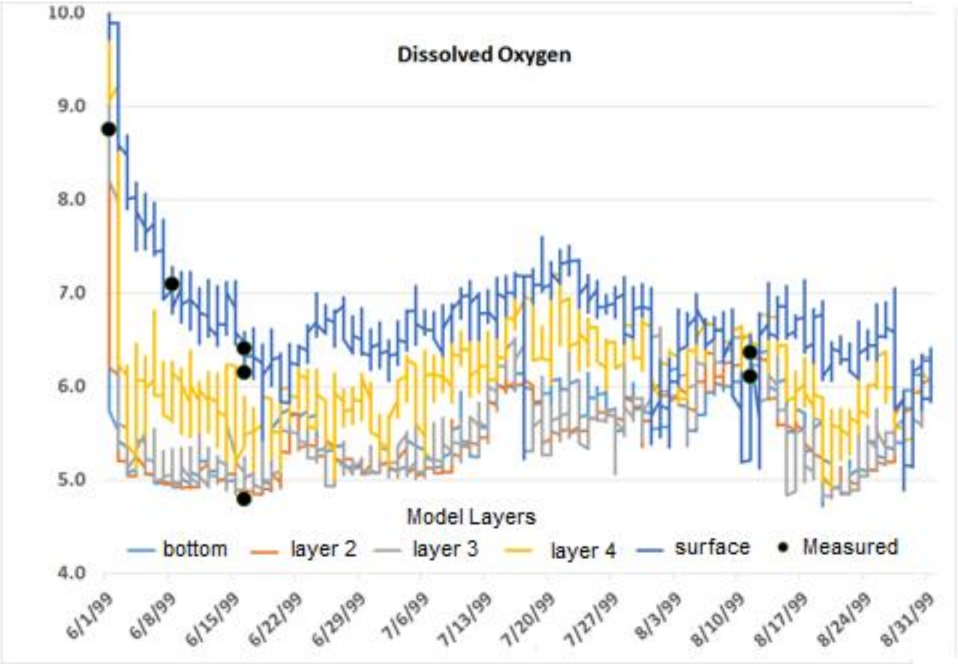

Figure 5.14. Comparison of measured and predicted dissolved oxygen values for a 1999 calibration period.

5.4.6. Model Simulations in the Central IRL

Calibration of the water quality model is ongoing. Further adjustments will be made based on analysis of muck nutrient dynamics discussed in Chapter 3. The coupled hydrodynamic and water quality model (HEFDC/HEM3D) driven by boundary conditions and watershed inputs is being tested for sensitivity to nutrient flux from muck sediments into the water column above. Model runs were setup to represent up to 3 years of real time in order to examine water quality conditions specific to the Turkey Creek and nearby area of the Indian River Lagoon. To accomplish this, sediment digenesis sub-domains were setup in the model to include the lower portion of Turkey Creek and about 10 square km of the central IRL, beyond the entrance of Turkey Creek. Two separate runs were launched. Model Case 1 includes existing conditions with respect to watershed inputs, baseflows, and gauged freshwater flow into Turkey Creek from the C-1 control structure. Nutrient flux from the benthic boundary of Turkey Creek was approximately set according to fluxes and reported by Dr. John Trefry and his research group in Chapter 3. The constituent being adjusted within the sediment diagenesis model is the flux of ammonium to the water column. It is reported that the equivalent of 15 metric tons annually per km^2 is being contributed to the water column from the interior of Turkey Creek (Chapter 3 of this report). This result compares to the IRL average of 8 metric tons annually per km^2, and a rate of 12 metric tons annually per km^2 for Eau Gallie Harbor to the north (Trefry, personal communication). Thus, for the existing model case, the sediment diagenesis subdomain that includes Turkey Creek was set to have a vertical ammonium flux equivalent to the nitrogen loading, but stated in g per m^2 per day. In the regional sediment diagenesis domain surrounding Turkey Creek the flux was set to be equivalent to the IRL average.

Model Case 2 assumes a 50% reduction in the ammonium-based nitrogen flux from muck sediment to the water column. This scenario was designed to test the sensitivity of the model to potentially large changes in nutrient contributions that may be associated with muck dredging within Turkey Creek, An additional model case involving a 90% reduction of ammonium based nitrogen flux from Turkey Creek (Case 3) has also been launched.

As of this report the model runs are still underway. Numerical model time step adjustments have been required to keep the model stable. Decreases in numerical time step have slowed the progress of model runs. However, as of this writing model runs are being converted to parallel processing to increase the speed of computations. It is expected that use of the Florida Tech Blue Marlin Beowulf cluster will substantially decrease computational time required for each run.

Figure 5.15 shows an example of a prediction from the initial run of Model Case 1, which approximates present pre-dredge nutrient loading conditions. The total P and N values were extracted from a numerical station approximately 5 km south of Turkey Creek entrance.

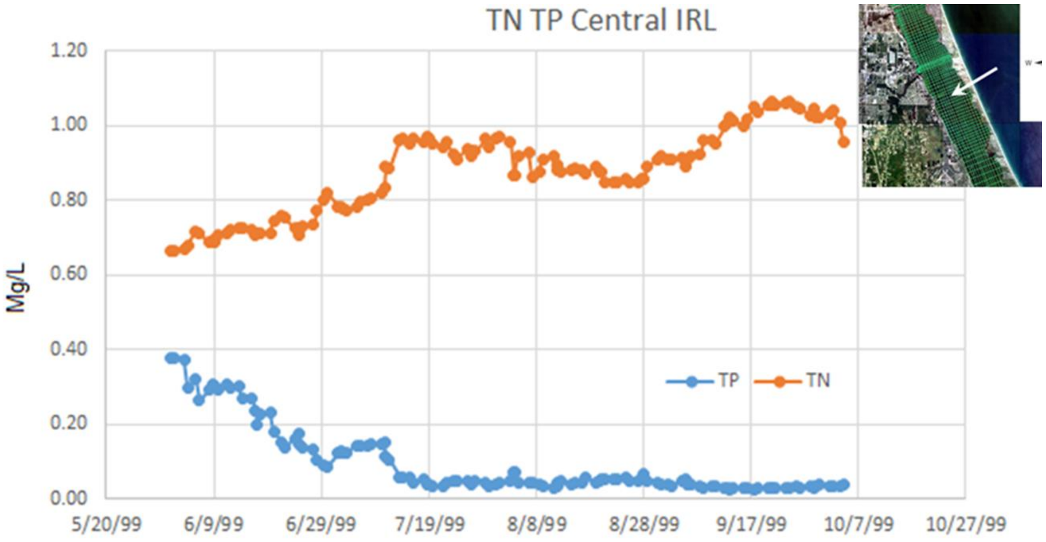

Figure 5.15. Five month time series of predicted total N and total P concentrations under pre-dredge conditions from a numerical observation station about 5 km south of Turkey Creek entrance

Figure 5.16 shows predicted total nitrogen values over a 20 month period at the entrance of Turkey Creek. Model results are shown for the case of existing nitrogen loading from ammonium flux and model Case 2 in which nitrogen loading from ammonium as specified in the controls of the EFDC sediment diagenesis model has been hypothetically reduced by 50%. Over the course of the 20-month simulation, predicted nitrogen concentrations in the water column, existing condition and hypothetical, are expected to track in parallel to each other; the existing condition showing the higher concentration during the simulation.

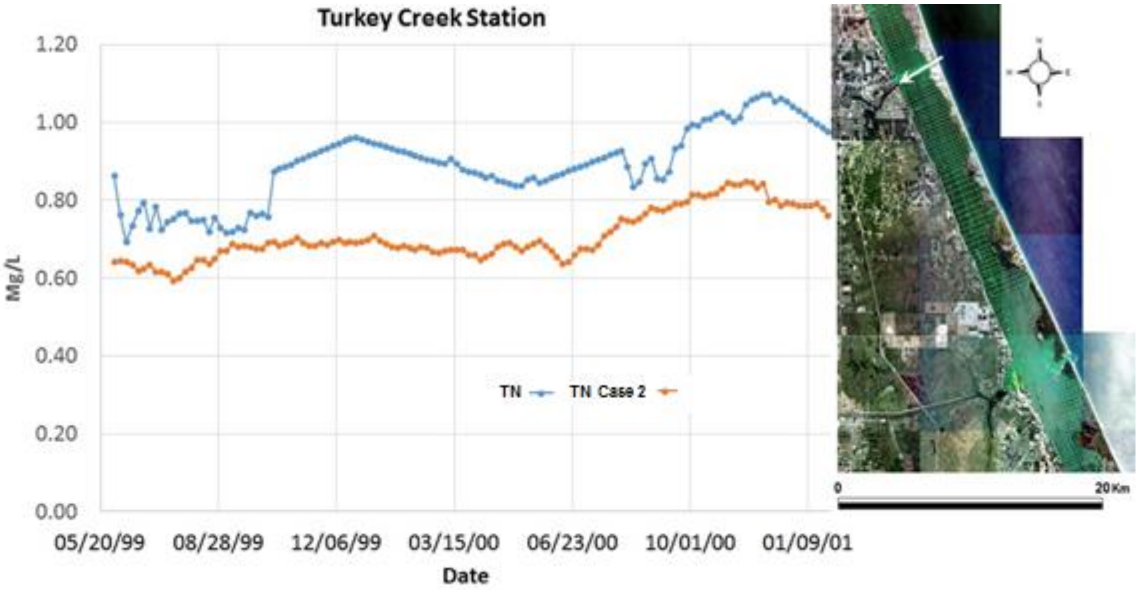

Figure 5.16. Prediction of total nitrogen concentrations over an approximate 20-month period at numerical observation station located in the entrance of Turkey Creek

Predicted total nitrogen values from a central lagoon location about 4 km north of Turkey Creek entrance are shown in Figure 5.17. The alternative is the same as represented in Figure 5.16. Nitrogen loading from ammonium flux to the water column is specified to be reduced by 50% in the sediment digenesis model. At this station about 4 km from Turkey entrance where ammonium flux is reduced to approximate results of dredging, the difference between the existing and reduced load case is not as marked. The predicted total nitrogen concentration for reduced ammonium flux remains slightly below concentration for the existing condition for the first half of the simulation. However, for the second half of the model run, predicted concentrations are on the average similar outside of some temporal variability. For the final few weeks of simulation, nitrogen concentrations for the existing case dropped slightly over 0.1 mg/L below those for the alternative case, before beginning to recover. There is a trend of a slight decrease in nitrogen concentration over about the first six months of the model run period.

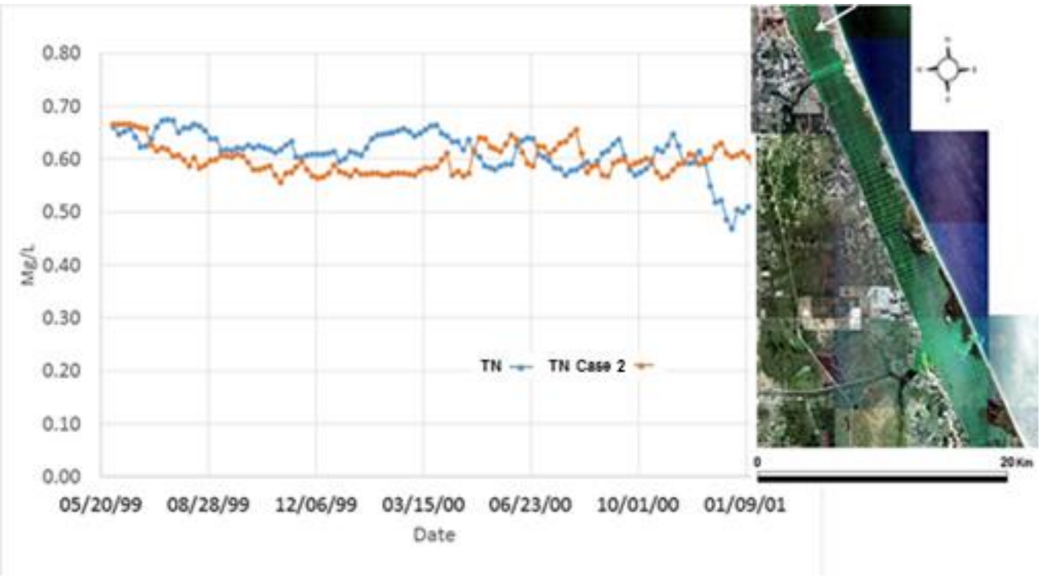

Figure 5.17. Prediction of total nitrogen concentrations over an approximate 20-month period at numerical observation station located about 4 km north of Turkey Creek entrance.

Figures 5.18 and 5.19 show predicted nitrogen values at numerical model stations located about 4 km and 10 km south of Turkey Creek entrance. The time series pattern predicted at the station 4 km south of Turkey Creek is similar to that shown in Figure 5.16 for the Creek entrance. Short time scale variations on the order of a few days are superimposed on longer-term trends. Variability is likely due to diurnal variations in wind, water temperature, along with slightly longer term synoptic variations in water level. There is a trend of slightly increasing concentration and an overall net increase of about 0.1 to 0.2 mg/L in total nitrogen concentration. Overall, the signature of the hypothetical reduction in ammonium based nitrogen flux within Turkey Creek entrance is modulated at the station 4 km south shown in Figure 5.18.

At the station 10 km south the pattern is different than those of stations closer to Turkey Creek entrance. Here, there is a net decrease in predicted nitrogen concentration of about 0.35 mg/L over the course of the model run, but included a period of stability in the middle of the simulation. A decrease in N concentration occurred at the beginning and end of the predicted time series. Predicted N concentration for the reduced ammonium case within Turkey Creek are below the existing case for the first 5 months of the simulation and then track closely with the existing case for the remainder of the simulation.

As model predictions continue and as more pre- and post-dredging nutrient data from Turkey Creek become available, model results will be examined within the larger context of other factors that influence nitrogen concentration in the central IRL.

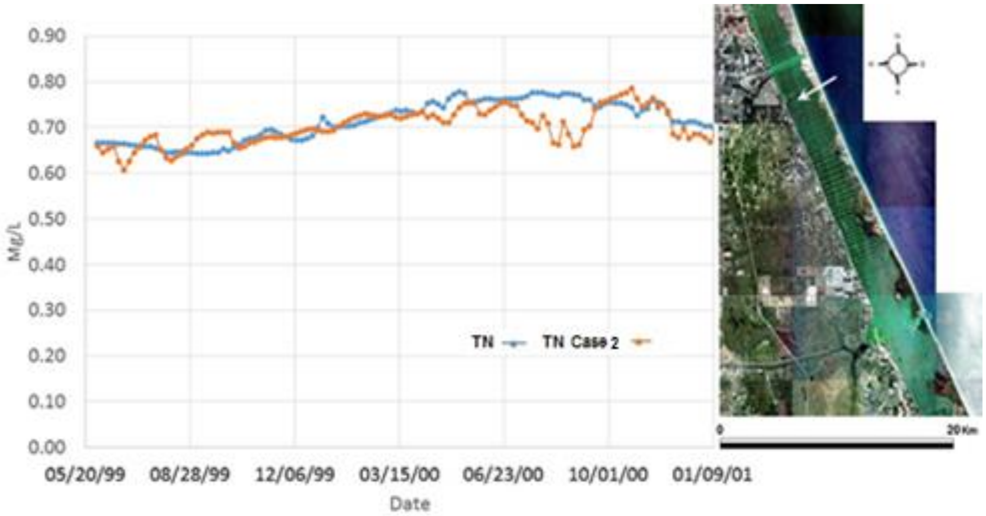

Figure 5.18. Prediction of total nitrogen concentrations over an approximate 20-month period at numerical observation station located about 4 km south of Turkey Creek entrance.

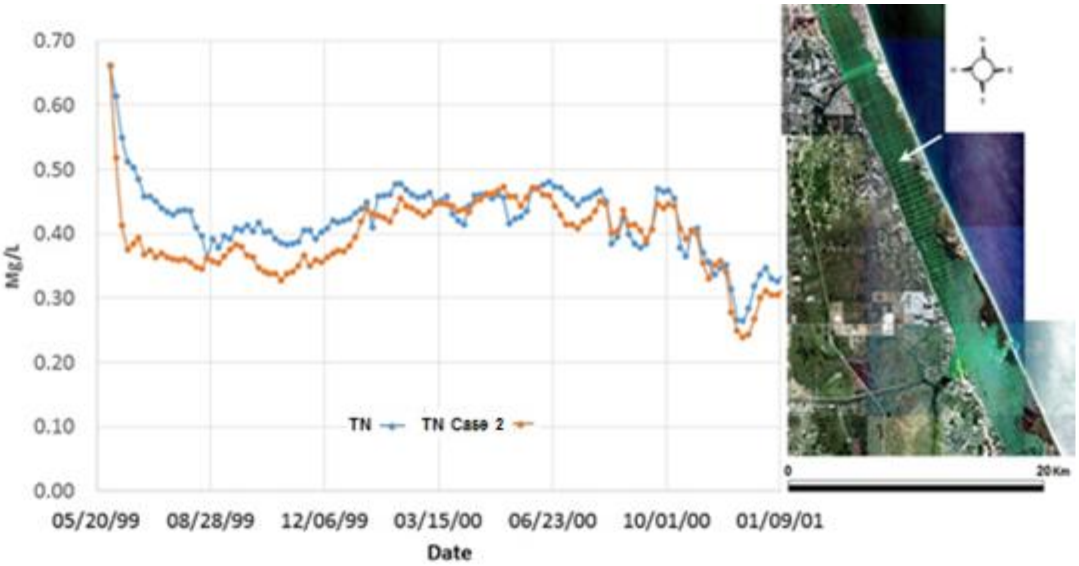

Figure 5.19. Prediction of total nitrogen concentrations over an approximate 20-month period at numerical observation station located about 10 km south of Turkey Creek entrance.

The ongoing prognostic model runs will examine longer term variability and trends of IRL water quality for existing conditions and hypothetical conditions in which the interaction of muck sediments with the water volume is adjusted for muck removal. The ongoing work by the IRLRI along with the body of historical data are critical to the operation of the EFDC/HEM3D model. With improved watershed and implementation of sediment transport calculations in year 2 of this project, the EFDC-HEM3D model could be driven into the future by using climatologic (characteristic) data developed from historical data and watershed modeling.

5.5 Project Quality Control

The quality of model predictions is ultimately demonstrated by the statistics provided from comparisons between measured and model data described under Section 5.4 of this report. The first year of this project was largely one of model setup and model validation, followed by initial model results. The model validation process will continue throughout the project as new data sets are added to the model boundaries and new water quality data are collected by the ongoing Florida Tech Environmental Muck Dredging Research Project that can be used for both calibration and boundary conditions.

Beyond the model validation process it is important to consider the measured data that support the model boundaries and calibration. There are two categories of measured data that need to be considered. For the model setup to date, much of the data are provided by the monitoring programs in the Indian River Lagoon Basin either sponsored by, or directly conducted by the SJRWMD. One data type is hydrologic data including water level and water discharge from tributaries and water control structures that connect with the IRL. These data are collected by the U.S. Geological Survey (USGS). The second, and equally important category is water quality data that can range from salinity and temperature measurements to a full pallet of nutrient constituents. Watershed inputs from the SWIL model should also be under quality control. The following sections address the quality control plans for the various model input data types

5.5.1. U.S. Geological Survey Hydrologic Data

The SJRWMD maintains a cooperative agreement with the USGS to maintain near real time observations of water level and surface water discharge within the IRL Basin. Historical and current stations maintained by the USGS are shown in Figure 5.5. The USGS has published a series of manuals on Techniques and Methods (TM) describing approved scientific and data-collection procedures and standard methods for planning and deploying monitoring stations (Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010). The material in the manuals is grouped under major subject headings called “books” and further subdivided into sections and chapters. For instance Chapter 7 of book 3, Section A (TM3-A7) covers all aspect of stage measurements at USGS gaging stations. Likewise Chapter 8 of book 3, Section 8 (TM3-A8) describes methodology for discharge measurements at USGS gaging stations. These and other USGS publications on hydrologic data collection can be found at http://water.usgs.gov/admin/memo/SW/. In addition to describing the methods of hydrologic data collection, the manuals include quality assurance and quality control sections that present discussion of accuracy requirements, sources of error, and error mitigation procedures, and equipment maintenance.

5.5.2. Quality Assurance for the SWIL Watershed model

Quality procedures for the SWIL watershed model are presented in an extensive technical document by Engineering Research & Design, Inc. (ERD, 2012). The EDR report deals with refinement of the SWIL model for application to TMDL calculations. SWIL model outputs are evaluated for accuracy by a comparison of measured versus model parameters. Calibration procedures are described in Section 4 of the ERD report.

5.5.3. Quality Assurance for SJRWMD water quality data

Quality assurance for water quality parameters is covered by the SJRWMD Field Standard Operating Procedures for Surface Water Sampling (FSOP). There is one standard document containing procedures for environmental sampling that is reviewed annually and revised as necessary (SJRWMD, 2015). The SJRWMD FSOP generally follows the Florida Department of Environmental Protection (FDEP) SOPs for field data activities.

Issues relating to quality assurance are distributed throughout the SJRWMD FSOP document. Among the many topics covered in the SJRWM FSOP are instrument maintenance, instrument calibration, field methods, and sample chain of command. A section is also provided on data review and assessment including procedures for internal and external audits of data sets. Within data review sections of the FSOP are descriptions of actions for data quality issues that may arise.

5.6 Conclusions

Modelling tasks completed include assembly of relevant hydrologic and water quality data, development of the model grid, coupling of the SWIL watershed model, model calibration, and several model production runs. Care was taken to add important details in the model grid including bridge-causeway structures, mangroves flats and wetlands, and narrow canals such as Haulover Canal. Freshwater inflows are also carefully added from stream flow data gages by the USGS and watershed runoff from the SWIL model that have been calibrated. These details insure that the distribution of freshwater inputs among the components of the IRL system are consistent with reality. Calibration and validation results show that both hydrodynamic and water quality model data match measured data within a limit of about 5 to 17% RMSE relative to the range of observations.

As of February 2016, model calibration for prediction of nutrient constituents such as nitrogen and phosphorus is continuing. However, calibration results thus far indicate that water quality model driven by the EFDC hydrodynamics coupled with the watershed model will provide accurate predictions relative to available dissolved oxygen and nutrient data. One indication of this is the good match between measured and model-predicted dissolved oxygen data. Dissolved oxygen levels are dependent on the levels of nutrients and the overall eutrophication process.

Model runs were focused on testing the sensitivity of the modeling scheme to the reduction of muck deposits at the mouth of Turkey Creek show that model is sensitive to potential variations in ammonium-based nitrogen flux to the water column. Model runs under various scenarios/cases were conducted to test potential water quality improvements that may result from muck dredging. Model Case 1 includes existing conditions with respect to watershed inputs, baseflows, and gauged freshwater flow into Turkey Creek from the C-1 control structure. Nutrient flux from the benthic boundary of Turkey Creek was set according to fluxes reported by Dr. John Trefry in Chapter 3 of this report. In the region surrounding Turkey Creek the flux was set to be equivalent to the IRL average. Model Case 2 assumed a 50% reduction in the ammonium-based nitrogen flux from muck sediment to the water column. Model results indicate a reduction of about 25% to 30% in total nitrogen concentration in the water column at the mouth of Turkey Creek after hypothetical reduction of ammonium flux based on muck removal. Model results also showed a detectible, but variable reduction of total nitrogen within 4 km of Turkey Creek entrance. A numerical (model) monitoring station in the IRL, 10 km to the south of Turkey Creek entrance, showed a detectible reduction in total nitrogen concentration for the first half of a 2-year model run. Other water quality variables are also calculated including forms of phosphorus, dissolved oxygen, and several others. These model data along with values for nitrogen components are stored in model data archives for further analysis

In the second year of the overall muck project, further details will be provided to guide the model, including measured nutrient flux from the benthic sediment of Turkey Creek once the muck removal is complete. In addition, the scope of work for year 2 includes setup of sediment transport calculations for sediment sizes in the silt and clay range. Sediment transport calculations, especially in the Turkey Creek area will be supported by sediment flux data being collected by other components of the overall project (Drs. Trefry and Bostater). Using longer term model runs, this calculation will provide an estimate of the return period for fine sediment constituent of muck sediment.

5.7 References

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