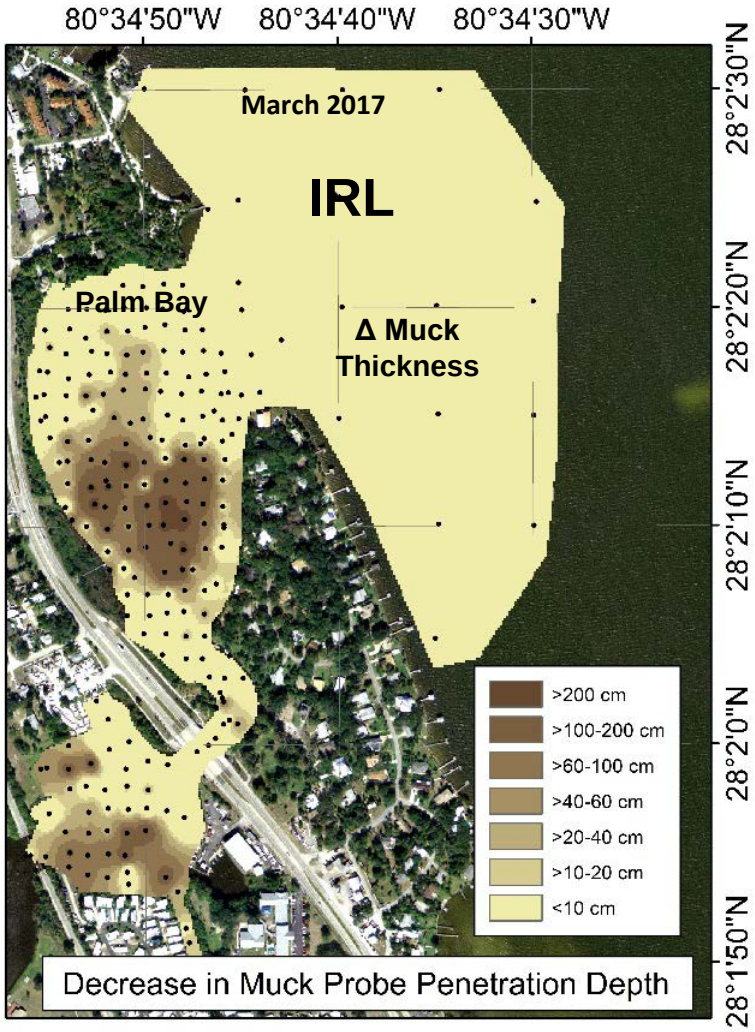
Impacts of Environmental Muck Dredging 2016-2017

Muck Dredging Research Project Management (Subtask 1)

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



John G. Windsor

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May 2019

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)

Impacts of Environmental Muck Dredging 2016-2017

Muck Dredging Research Project Management (Subtask 1)

Final Project Report Submitted to
Brevard County Natural Resources Management Department
2725 Judge Fran Jamieson Way, Building A, Room 219
Viera, Florida 32940
Funding provided by the Florida Legislature as part of
DEP Grant Agreement No. NS005 - Brevard County Muck Dredging

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Executive Summary

Nine interdisciplinary projects (Subtasks) 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 Dredging in the Indian River Lagoon, Part I: Seagrass Monitoring and Infaunal Surveys, (3) Biological Responses to Muck Dredging in the Indian River Lagoon, Part II: Fish Populations and Sea Grass Restoration, (4) Determining the Effectiveness of Muck Removal and the Impact of Upland Runoff on Water Quality in the Indian River Lagoon, (5) Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters, (6) Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites, (7) Wind and microclimate analysis for application to fetch limited wind wave growth analysis at IRL dredging locations, (8) Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants, and (9) Source to Slime Study in Indian River Lagoon. Executive summaries from all nine final project reports are included in this report. 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 facilitated the exchange of scientific findings among all the investigators and optimized the outcomes of these research investigations. In addition, the project management office engaged the public about muck dredging research through presentations open to the public and through social media. Environmental Muck Dredging research progress, reported through monthly meetings, written reports and public presentations, is summarized in this report.

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Acknowledgements

Funds for these investigations were provided by the Florida legislature as part of DEP Grant Agreement No. S0714 – Brevard County Muck Dredging.

Valuable guidance and feedback throughout these investigations were given by Matt Culver, Virginia Barker and Mike Mcgarry of the Brevard County Natural Resources Management Department. Other inputs throughout the year from external reviewers and comments on the draft final reports also improved the projects and the final reports. Those external reviewers included Robert Virnstein, Joel Steward and Charles Jacoby.

These studies are contributing to the effective restoration of the Indian River Lagoon System. The work would not have been brought to a successful conclusion without the dedication of my research colleagues. These principal investigators deserve my special thanks and include Charles R. Bostater, Austin L. Fox, Kevin B. Johnson, Steven M. Lazarus, Claudia Listopad, Jonathan Shenker, Leesa Souto, John H. Trefry, Robert J. Weaver, Thomas D. Waite, and Gary A. Zarillo.

Muck Dredging Research Project Management (Subtask 1)

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Summary

Nine interdisciplinary projects (Subtasks) 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 Dredging in the Indian River Lagoon, Part I. Seagrass Monitoring and Infaunal Surveys, (3) Biological Responses to Muck Dredging in the Indian River Lagoon, Part II: Fish Populations and Sea Grass Restoration, (4) Determining the Effectiveness of Muck Removal and the Impact of Upland Runoff on Water Quality in the Indian River Lagoon, (5) Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters, (6) Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites, (7) Wind and microclimate analysis for application to fetch limited wind wave growth analysis at IRL dredging locations, (8) Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants, and (9) Source to Slime Study in Indian River Lagoon. Executive summaries from each of the final reports are included in this report. 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 facilitated the exchange of scientific findings among all the investigators and optimized the outcomes of these research investigations. In addition, the project management office engaged the public about muck dredging research through presentations open to the public and through social media.

Introduction

In order to address serious water quality issues associated with muck sediment in the Indian River Lagoon, the Florida Legislature in the 2015 session directed $1.5 million 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 guide future muck removal efforts throughout the state. A list of each of the projects with are brief description are shown in Table 1.

Table 1. FIT EMD Year 2 Projects

1. *Muck Dredging Research Project Management*, John Windsor, PI. 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 Dredging in the Indian River Lagoon, Part I. Seagrass Monitoring and Infaunal Surveys,* Kevin Johnson, PI. Organic sediment pollution ("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. Muck has been removed from the Turkey Creek/Palm Bay region by dredging, and this dredging was completed during the first half of this phase of the monitoring (EMD2, the second year of legislated funding for *environmental muck dredging* in the IRL). Biological monitoring (infauna and seagrasses) has been conducted during pre-dredge and post-dredge ecological conditions to confirm whether or not recovery or enhancement of the ecosystem has occurred. Sampling areas proximal to planned dredging sites, as well as away from those sites at thriving areas, allow interpretations to be more conclusive on the driving forces behind observed changes. The project report details 2016-2017 benthic biological monitoring in Turkey Creek (City of Palm Bay, Brevard County) and the adjacent IRL targeted for environmental muck dredging.

3. *Biological Responses to Muck Dredging in the Indian River Lagoon, Part II: Fish Populations and Sea Grass Restoration,* Jonathan Shenker, PI. Muck at the bottom of the Indian River Lagoon (IRL) creates an inhospitable environment for plants and animals. As muck is removed from the IRL through environmental dredging efforts, it is essential that we determine if the removal efforts affect the biota of the region. This study summarizes the monitoring of fish and macroinvertebrate populations in the Turkey Creek region that was dredged in 2016, and in nearby Indian River Lagoon control regions. It also includes a comparison of the Turkey Creek fish data with that of the broader IRL populations sampled by the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program from 2010 to 2016.

4. *Determining the Effectiveness of Muck Removal and the Impact of Upland Runoff on Water Quality in the Indian River Lagoon, Florida,* John H. Trefry, PI. (Also presented in this Year 2 Subtask 4 report are results from a project implemented with the first year of legislative funding, Year 1 Subtask 6)
    a. *Subtask 4A Determining the Effectiveness of Muck Removal on Sediment and Water Quality in the Indian River Lagoon, Florida (Subtask 4a).* Austin L. Fox, John H. Trefry, Robert P. Trocine, Stacey L. Fox, and Jessica E. Voelker, Florida Institute of Technology, Melbourne, Florida 32901 Removal of fine-grained, organic-rich sediments is an integral part of restoring the Indian River Lagoon (IRL) to a healthy ecosystem. This sediment, often referred to as IRL muck, is a concern because it can increase turbidity, consume oxygen, create an inhospitable

Table 1. FIT EMD Year 2 Projects (Continued)

benthic habitat and is an internal source of dissolved nitrogen (N) and phosphorus (P) that diffuse from muck into the lagoon. Dredging is an effective method for removing large reservoirs of muck with associated N and P; however, there are challenges to dredging and few data were available to quantify the efficacy of environmental dredging in the IRL. The goals of the study were to track changes in (1) the distribution and composition of the muck, (2) benthic fluxes of N and P from muck to the overlying water column and (3) sediment and water quality.

b. *Subtask 4B Inputs of Nitrogen and Phosphorus from Major Tributaries to Indian River Lagoon (Subtask 4b)* John H. Trefry, Austin L. Fox, Robert P. Trocine, Stacey L. Fox, Jessica E. Voelker, and Katherine M. Beckett. Muck removal and control of nutrient inputs are important components of the restoration of the Indian River Lagoon (IRL). Successful management plans for controlling muck and nutrients in the IRL require continuing assessment of external and internal inputs of substances that are precursors to algal blooms and future muck deposits. Runoff from large drainage basins in the IRL provide one major pathway for external inputs. Atmospheric inputs and direct runoff from hundreds of outfalls along the lagoon also are important external sources. The main source of internal inputs is fluxes of nutrients from IRL muck. More detailed composition data for tributaries to the IRL during regular and storm flow are among the much needed baseline information. The goal for the first year of this study was to obtain and interpret composition data for selected dissolved and particulate chemicals, including nitrogen (N) and phosphorus (P), from major tributaries to the IRL. Surveys were carried out during (1) non-storm flow from December 2015 to February 2017 (15 months) and (2) nine storm events. Our sampling locations, all of which have active U.S. Geological Survey (USGS) flow gauges, are as follows: St. Sebastian River at the South Prong (SA), St. Sebastian River system in the Fellsmere Canal (SB), Turkey Creek (TC), Crane Creek (CC) and the Eau Gallie River (EG).

5. *Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters,* Gary Zarillo, PI. This project integrates water quality and hydrologic, and hydrodynamic process data into a model of the Indian River Lagoon (IRL) for long-term calibrated and validated predictions of water quality. The overall goal was to combine model simulations with measured data to assess the impact of muck dredging on local and regional water quality. Questions addressed include: 1) to determine 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) to determine whether improved model calibration 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, and 3) to determine if muck dredging either locally or regionally can result in a lasting improvement of IRL water quality.

Table 1. FIT EMD Year 2 Projects (Continued)

6. *Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites,* Charles Bostater, PI. Moving fluid mud and muck samples were collected in Palm Bay and Turkey Creek from March 2015 through March 2017. Samples collected pre-dredging, during dredging and post dredging conditions are collected to help assess the environmental benefits of muck dredging. The goal was to determine if moving muck reduction occurred after dredging. Reducing moving fluidized mud after dredging is considered to be a positive benefit of the environmental dredging.

7. *Wind and microclimate analysis for application to fetch limited wind wave growth analysis at IRL dredging locations,* Steven Lazarus, PI. This study provided an empirical description of the IRL wind field (and its variability) for modeling purposes. An algorithm was developed that relates airport meteorological station data to site-specific (lagoon) wind measurements. In part, this allows airport station data to be used in the calibration and verification of the Zarillo hydrodynamic/sediment transport model in lieu of costly, site-specific wind measurements. In support of this effort, we conducted 1) a detailed wind microclimate analysis of the Palm Bay dredge site and, 2) a wind-related site characterization for three National Weather Service locations. The meteorological role as it relates to (IRL) muck intersects a broad range of environmental related issues including re-suspension, erosion, transport (i.e., advection), turbulent mixing, runoff (hydrology), algal blooms, etc.

8. *Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants.* Robert J. Weaver PI, Thomas D. Waite, PI. The focus of this project was to 1) implement the design and construction of a suction head for fine sediment dredging and 2) treat the dredged canal slurry mixture in a mobile treatment trailer system. The slurry treatment included both laboratory and field testing of chemical treatment. The mobile solids removal/treatment system consists of a prototype suction head, a treatment trailer, and a deployment pontoon boat. Ferrate testing in the field confirmed the laboratory results, which showed that ferrate treatment reduced the solids and nutrients levels.

9. *Source to Slime Study in Indian River Lagoon,* Leesa Souto, PI. Groundwater nutrient concentrations were examined in one residential community with onsite sewage treatment and disposal systems (septic tanks), one with sewer service, and one with sewer service that also received reclaimed water for irrigation. Groundwater nitrogen concentrations in the three communities were compared with those in a natural area to refine models developed to identify and allocate nutrient source contributions to the Indian River Lagoon.

Nine executive summaries from each of the FIT EMD Year 2 Final Project reports are reproduced starting on Page 11 of this report.

Approach

Each of the nine projects was coordinated through the project management office. Regular meetings of the Florida Institute of Technology Environmental Muck Dredging (FIT-EMD) research principal investigators facilitated the exchange of scientific findings among all the investigators. Results of field and lab work as well as logistics discussions were shared with all interested parties. The project management office assembled and distributed written monthly, quarterly and final project reports and updated Brevard County Natural Resources Management Department on research findings by sending email updates, holding monthly scientific roundtable discussions with interested agencies and organizations, conducting quarterly scientific presentations and project review meetings, and obtaining and incorporating peer review by external scientists. In addition, the project office engaged the public about muck dredging research through presentations open to the public and through social media applications.

Results

Project design and research updates were discussed at monthly and quarterly meetings throughout the year. Representatives from Brevard County Natural Resources Management Department, FDEP, SJRWMD and HBOI at FAU received progress reports. Anyone who had requested regular updates was added to the list. In addition to monthly discussion of results, logistics and sampling strategies a few other noteworthy items are shown with the monthly meeting dates in Table 2. External scientific review is important for the ongoing work. An external review panel provided comments, criticisms and recommendations for all projects. At least three independent reviewers offered comments throughout the year, including reviews of current research direction as well as future proposed efforts.

In addition to coordinating the research efforts, reaching out to the local stakeholders was important to explain the impacts of IRL muck and the potential benefits associated with muck removal in the overall context of IRL restoration. Presenting research results is an important component of informing stakeholders. Research presentations by the FIT EMD Year 2 Principal Investigators are summarized in Table 3. Twitter and Facebook continue to be used to share 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. An important element captured from all research and dredging activities to date is “What Lessons Are We Learning?” Recommendations informed by FIT EMD research are being implemented in Indian River Lagoon restoration efforts. These 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.

Table 2 FIT Environmental Muck Dredging Research 2015 Monthly Meetings. In addition to monthly discussion of results, logistics and sampling strategies a few other noteworthy items are presented with each monthly meeting date below.

- July 13, 2016 The Notice to Proceed was received in May 2016. All agreed that written monthly reports would be brief summaries of progress since the last report to which PowerPoint presentation slides used during the monthly meetings would be attached. Quarterly reports be more detailed in data presentation and interpretation.

- July 11, 2016 Progress on continuation projects and the introduction of new projects were presented by PIs.

- August 8, 2016 Quality Assurance Plans for seven of the nine tasks were submitted to Brevard County on August 1, 2016. A significant effort by the team was required to prepare the plans. At least four of the FIT-EMD PIs contributed to reviewing and commenting on the Save Our Lagoon Plan. They also attended the SOL Project Plan presentation at the Brevard County Commission meeting on August 9, 2016.

- September 12, 2016 The dredging schedule was updated for the Turkey Creek project. The Mims boat ramp dredging project and the Sykes Creek dredging project were discussed. Comments on previously submitted proposals for Impacts of Environmental Muck Dredging Year 3 Projects were given by County staff. At the request of several PIs, the date for the oral presentation of revised project proposals to Brevard County staff and external reviewers was changed to October 13, 2016 at the Natural Resources Management Office in Viera. Services of external reviewers have been procured. The revised proposals in a quad chart format were distributed to County staff and external reviewers on September 29, 2016.

- October 10, 2016 The monthly meeting between Florida Institute of Technology Environmental Muck Dredging Year 2 (FIT-EMD Y2) Principal Investigators and Brevard County was postponed due to Hurricane Matthew impacts. Progress on continuation and new projects was summarized in the written monthly report. Also due to Hurricane Matthew the oral presentation of revised project proposals for Year 3 of Environmental Muck Dredging research to Brevard County staff and external reviewers was moved from October 13, 2016 to November 22, 2016 at the Natural Resources Management Office in Viera.

- November 22, 2016 Due to Hurricane Matthew impacts oral presentation of revised project proposals for Year 3 of Environmental Muck Dredging research to Brevard County staff and external reviewers was moved from October 13, 2016 to November 22, 2016 at the Natural Resources Management Office in Viera. Services of external reviewers were procured. After the presentations reviewer comments and suggested revisions were provided to PIs. Feedback from FDEP on previously submitted QA Plans was distributed to the PIs just after Thanksgiving break. Where necessary PIs responded (through Brevard County) to FDEP and/or revised QA Plans.

- December 12, 2016 An alternative monthly meeting format was agreed to by County staff and the PIs. Each month a few of the projects would be discussed in greater detail with an emphasis on collaboration between projects. For this month, Dr. Trefry and Dr. Johnson led the discussions for their collaborations, and graduating students, Katherine Beckett and Angelica Zamora-Duran, from their labs shared some of their MS work. Investigations of pre-, during and post dredging effects in Turkey Creek are dependent upon the completion of dredging. At this point it appears that Turkey Creek dredging will be completed during January 2017. Year 2 second quarter progress reports (December 1, 2016) were distributed to external reviewers in mid-December.

- January 9, 2017 Lengthy discussions for the modeling group included presentations by Dr. Zarillo and Dr. Lazarus. Progress on upstream removal of muck was led by Dr. Weaver and Dr. Waite. Ferrate treatment of dredged material was also a lengthy discussion. Dredging in Turkey Creek is now over. Measuring the effects of dredging post-dredging is now underway. Year 2 second quarter progress reports (December 1, 2016) were reviewed by two external reviewers. Reviewer comments were distributed to the principal investigators, who will address reviewer comments in the final reports for year 2. Revised quality assurance plans for all tasks were submitted to Brevard County staff with the monthly report.

Table 2 FIT Environmental Muck Dredging Research 2015 Monthly Meetings. In addition to monthly discussion of results, logistics and sampling strategies a few other noteworthy items are presented with each monthly meeting date below. *(Continued)*

- February 13, 2017 Dr. Bostater discussed progress on muck movement near the mouth of and at an upstream location in Turkey Creek. Dr. Souto and Dr. Listopad updated the group on progress in identifying upstream sources contributing to muck formation. Seeking volunteers to allow wells to be dug in their yards is a challenge. Dr. Shenker discussed recent fish collections and the difficulties with Gracillaria and towing fish nets. He also discussed his collaborations with a transplanting sea grass project.

- March 13, 2017 Chemical investigation results were presented by Dr. Trefry and Dr. Fox. Modeling discussions continued and were led by Dr. Zarillo and Dr. Listopad. At the end of the meeting Dr. Weaver presented a short update on removing muck sediments upstream in Turkey Creek. County staff agreed that final reports for Year 2 investigations may be submitted separately by subtask. Year 3 projects proposals that were accepted for funding required SOW submission to the County.

- April 10, 2017 The monthly meeting with County staff was cancelled due to schedule conflicts. Monthly progress was addressed in a written report. Environmental Muck Dredging projects acceptable for Year 3 funding have submitted Scopes of Work to the County for contract approval and execution. A collaborative University effort, through the Indian River Lagoon Research Institute, developed the following projects to help better manage future muck removal efforts throughout the state: Muck Dredging Research Project Management, John Windsor, PI, ($98,500), Muck Removal Efficiency plus Biological and Chemical Responses/Improvements after Muck Dredging, Kevin Johnson, Jon Shenker and John Trefry, Co-PIs, ($358,600), Trends for Inputs of Muck Components from Rivers, Creeks and Outfalls to the Indian River Lagoon, John Trefry and Austin Fox, Co-PIs ($204,550), Lagoon-Wide Application of the Quick-Flux Technique to Determine Sediment N and P Fluxes, Austin L. Fox and John H. Trefry, Co-PIs ($193,850), Optimizing Selection of Sites for Environmental Dredging in the Indian River Lagoon System, John H. Trefry and Kevin B. Johnson, PIs ($190,950), Sediment & Water Quality Modeling for Nutrients, Muck and Water Clarity Scenario Assessments, Gary A. Zarillo and Claudia Listopad, Co-PIs ($169,000)

- May 8, 2017 In preparation for final report submission, each PI shared a short summary of key findings that would be included in their draft final report. Purchase orders are in place for external reviews.

- June 12. 2017 Dr. Johnson discussed recent developments in biological investigations, including the potential development of an index relating IRL muck characteristics to species diversity associated with the muck. This work is part of the Year 3 effort and is not included in the draft final report submitted by Dr. Johnson in June. Dr. Lazarus gave a preview of his draft final report, highlighting key conclusions. His draft final report has also been submitted for review. At the end of the meeting Dr. Weaver presented a short update on removing muck sediments upstream in Turkey Creek. Dr. Shenker also provided a brief update of his fishery and seagrass work. Approved FIT EMD Year 3 projects are awaiting Notices to Proceed.

- July 10, 2017 Dr. Souto discussed recent well drilling efforts in the Turkey Creek basin to better understand sources of nutrients to Turkey Creek and the Indian River Lagoon. Dr. Listopad, filling in for Dr. Zarillo, updated us on the most recent water quality model development updates, including the updates to the SWIL model. Dr. Trefry presented some thoughts on the role of tributary contributions to muck, including stormwater and baseflow. The final report on this topic was submitted and is under review. Dr. Fox gave us a preview of some very recent efforts throughout the IRL to rapidly assess the flux of nutrients from sediments, all part of the Year 3 effort. Projects recommended for Year 3 funding received Notices to Proceed during July. The first monthly report for these new projects will be for the month of August and delivered to Brevard County early in September.

Table 3. FIT Environmental Muck Dredging Related Research Presentations

May 11, 2016 Running Amuck: Our Six-Decade Legacy to the Indian River Lagoon, FAU Harbor Branch Oceanographic Institute, Ft. Pierce, Florida; Dr. John Trefry. Video available online at https://www.youtube.com/watch?v=BxjjOappyN8

June 11, 2016 Removing Muck, Indian River Lagoon Summit, Space Coast League of Cities, Melbourne, Florida; Dr. John Windsor

June 13, 2016 Managing Water Quality in Indian River Lagoon: A Historical Perspective. Marine Resources Council Teachers Workshop, Melbourne, Florida; Dr. John Windsor

June 16, 2016 Removing Muck, Brevard Marine Advisory Council, Viera, Florida; Dr. John Windsor

June 2016 Fluid Mud Sondes & Acoustic Imaging Methods for Coastal Dredging, Charles R. Bostater, Jr. and Tyler Rotkiske, Marine & Environmental Optics Lab, College of Engineering, Florida Institute of Technology, Melbourne, Florida USA. Proceedings of the Twenty-sixth (2016) International Ocean and Polar Engineering Conference, Rhodes, Greece, June 26-July 1, 2016.

August 9, 2016 Save Our Indian River Lagoon Project Plan, Brevard County Commission, Viera, Florida; Four FIT EMD PIs commented on Save Our Indian River Lagoon Project Plan.

August 9, 2016 Impacts of Environmental Muck Dredging on Indian River Lagoon, Brevard County Board of County Commissioners Meeting, Viera, Florida; Dr. John Windsor

August 29, 2016 Overview of the IRL water quality issues with a focus on muck removal, nutrient reduction, and restoration as well as increasing flushing in the IRL, 6th Grade AG Class at Ocean Breeze Elementary, Indian Harbour Beach, Florida; Dr. Robert Weaver.

Jessica Voelker (M.S. student) received a $2000 cash scholarship from the Florida Stormwater Association (FSA) Educational Foundation for her research on nitrogen speciation in this creeks study. She will attend the FSA annual meeting and present results from her study.

September 30, 2016 The following list of presentations was from a technical conference called: **From Science to Solutions**, Indian River Lagoon Research Institute TechCon 2016, Melbourne, Florida, organized by Dr. Robert Weaver.

- Three-dimensional hydrologic and water quality model of the Indian River Lagoon, Gary Zarillo, Florida Institute of Technology; Claudia Listopad, Applied Ecology, Inc.
- Biological monitoring associated with environmental dredging in a tributary creek of the Indian River Lagoon, Daniel Hope, Tony Cox, Angelica Zamora-Duran and Kevin. B. Johnson, Florida Institute of Technology
- Ferrate (FeO_4^{2-}) treatment of dredged muck residuals for nutrient removal, T.D. Waite, Florida Institute of Technology
- Environmental muck dredging in Turkey Creek, John H. Trefry, Austin L. Fox, Robert P. Trocine, Stacey L. Fox, Jessica E. Voelker and Katherine M. Beckett, Florida Institute of Technology
- Fish Abundance and Diversity around the Turkey Creek Muck Removal Site, J. Shenker, J. King, A. Cianciotto and J. Renner, Florida Institute of Technology
- Responses of Benthic Community Recruitment to Ecosystem Change, Kody Lieberman and Hannah Briant, Florida Institute of Technology
- Living Shoreline Design, Carmen Glasser, Ashly Allen, Nathan Bonanno and Robert J. Weaver, Florida Institute of Technology
- Progress on Muck Removal and Treatment, Leigh Provost, Kyle Tseka and Robert J. Weaver, Florida Institute of Technology

Table 3. Table 3. FIT Environmental Muck Dredging Related Research Presentations *(Continued)*

October 26, 2016 Environmental Muck Dredging: One Component of "Save Our Lagoon", John H. Trefry, Austin L. Fox, Robert P. Trocine, Stacey L. Fox, Jessica E. Voelker, Katherine M. Beckett, Save Our Lagoon public information session, Gleason Auditorium, Melbourne, Florida; Dr. John Trefry.

November, 2016 All of the following peer reviewed presentations were delivered at the **American Water Resources Association 2016 Annual Water Resources Conference**, November 13-17, 2016, Orlando, Florida

- Classifying 'Muck' in the Indian River Lagoon, Florida, Based on Biological, Chemical and Physical Characteristics - Katherine Beckett, Florida Institute of Technology, Melbourne, FL (co-authors: J. Voelker, A. Fox, S. Fox, R. Trocine, J. Trefry)
- Chemical Forms of Nitrogen in Varied Florida Watersheds - Jessica Voelker, Florida Institute of Technology, Melbourne, FL (co-authors: S. Fox, A. Fox, K. Beckett, R. Trocine, J. Trefry)
- Reporting the Health of the Indian River Lagoon - Leesa Souto, Marine Resources Council, Palm Bay, FL (co-authors: C. Listopad, S.S. Housley)
- Applying Differences in Biogeochemically-controlled Fluxes of Nitrogen and Phosphorus from Indian River Lagoon Sediments to Management Decisions about Dredging - Austin Fox, Florida Institute of Technology, Melbourne, FL (co-authors: J.H. Trefry, R.P. Trocine, S L. Fox)
- Identifying Potential Top-Down Control of Harmful Algae Among Zooplankton of the Indian River Lagoon Estuary - L. Holly Sweat, Department of Marine & Environmental Systems Florida Institute of Technology, Melbourne, FL (co-authors: S. Badylak, C.A. Jacoby, K.B. Johnson, H.G. Kolb, X. Ma, E.J. Phlips, S. So, B. Stelling)
- Using Site-Specific Watershed Loading Models to Inform Management Decisions at the Local Level: Case Studies Across the Indian River Lagoon Watershed - Claudia Listopad, Applied Ecology, Inc., Indian Harbour Beach, FL (co-author: E. Elevand)

December 2016 Four Florida Institute of Technology M.S. Theses, supported by FIT Environmental Muck Dredging, were successfully defended:

- Voelker, Jessica E. (2016) Chemical Forms of Nitrogen in Runoff from Diverse Florida Watersheds. M.S. Thesis, Florida Institute of Technology.
- Beckett, Katherine M. (2016) Categorizing "Muck" in the Indian River Lagoon, Florida, Based on Chemical, Physical and Biological Characteristics. M.S. Thesis, Florida Institute of Technology.
- Hope, Daniel (2016) The Tolerance of Benthic Infauna to Fine-Grained Organic Rich Sediments in A Shallow Subtropic Estuary. M.S. Thesis, Florida Institute of Technology.
- Zamora-Duran, Angelica (2016) Benthic Foraminifera as Bioindicators of Environmental Conditions in the Indian River Lagoon, Florida. M.S. Thesis, Florida Institute of Technology.

February 9, 2017 Research Presentations by Project Investigators delivered at the **Indian River Lagoon Symposium 2017: An Estuary in Peril**, Johnson Education Center, FAU Harbor Branch, Ft. Pierce, Florida:

- Benthic Foraminiferal Distributions in the Indian River Lagoon and the Influence of Environmental Factors Angelica Zamora-Duran, Anthony Cox, Daniel Hope, and Kevin B. Johnson Florida Institute of Technology, Melbourne, FL

- Removal of Nutrients from Dredged Muck Residuals Utilizing High-Valence Iron (FeO_4^{2-}), Thomas D. Waite, Florida Institute of Technology, Melbourne, FL

- The Role of Biotic and Environmental Factors in Spatial and Temporal Variability of Indian River Lagoon Copepod Communities, H.G. Kolb[1], L.H. Sweat[1], X. Ma[1], C. Jacoby[2], and K.B. Johnson[1] ; [1] Florida Institute of Technology, Melbourne, FL; [2] St. John's River Water Management District, Palatka, FL

- Selective Avoidance by Copepods Grazing on Bloom-Forming Algal Species in the Indian River Lagoon Xiao Ma, Kevin B. Johnson, L. Holly Sweat, and Hannah G. Kolb Florida Institute of Technology, Melbourne, FL

Table 3. FIT Environmental Muck Dredging Related Research Presentations *(Continued)*

- Laboratory Scale Modeling of Living Shorelines to Determine Design Parameters, Ashley Allen[1], Nathan Bonanno[1], Robert J. Weaver[1], Jacob Zehnder[2], Jody B. Palmer[2], Samantha Anderson[2], and Virginia Barker[3] ; [1] Florida Institute of Technology, Melbourne, FL; [2] Brevard Zoo, Melbourne, FL; [3] Brevard County Natural Resources Management, Melbourne, FL

- A Tale of Two Ports: Comparing Distributions of Microbes and Macrofoulers from Indian River Lagoon Inlets, L. Holly Sweat and Kevin B. Johnson, Florida Institute of Technology, Melbourne, FL

February 15, 2017 Ongoing Indian River Lagoon Research at FIT: Restoration, Hurricanes, Flushing and Dredging, Emeritus Professors Organization, Florida Institute of Technology, Melbourne, Florida; Dr. Robert Weaver

February 20, 2017 "Running Amuck: A Six-Decade Legacy to the Indian River Lagoon" with an emphasis on ongoing dredging projects, Banana River Sail and Power Squadron, Merritt Island, Florida; Dr. John Trefry

March 17, 2017 State Funded Muck Research at Florida Institute of Technology, Save Our Indian River Lagoon Citizen Oversight Committee, Brevard County Government Center, March 17, 2017; Dr. John Windsor.

June, 2017 Florida Tech assists the Marine Resources Council and Brevard County Natural Resources Department with Muck Finders program. FIT scientists Austin Fox and John Trefry helped train more than 20 citizen volunteers to carry out muck surveys in the Indian River Lagoon. They explained the significance of the muck issue to lagoon restoration and then helped train teams of volunteers. Each team has a (1) boat driver, (2) data recorder and (3) muck pole prober. The program is a joint activity of Marine Resources Council, Brevard County Natural Resources Department and FIT. The teams obtained water depths and muck thicknesses in the Banana River Lagoon in the area (1) from the southern tip of Merritt Island to Mathers Bridge and (2) in Newfound Harbor. Very few data are available for these important areas of the lagoon. The resulting data is being incorporated into the EMD projects.

July 19, 2017 The Department of Ocean Engineering and Sciences at Florida Institute of Technology held their annual student research symposium. Undergraduate student research presentations related to ongoing efforts by principal investigators in muck research investigations included:

- The correlation of benthic infauna with Indian River Lagoon sediment quality in May 2017. Abdulrahman Al-Naama (Advisor Dr. Kevin B. Johnson)
- The development of a benthic infaunal community following muck dredging in Turkey Creek. Melissa Rivera (Advisor Dr. Kevin B. Johnson)
- Spatial and spectral resolutions of remote sensing imagers for shallow waters. Charles Morrisette (Advisor Dr. Charles Bostater)
- Temporal and spatial changes in water clarity in the Indian River Lagoon and adjacent creeks. Devin McAllister (Advisor Dr. Charles Bostater)
- An analysis of surface and bottom reflectance in a shallow water estuary using hyperspectral and multispectral imagery. Samin Aziz (Advisor Dr. Charles Bostater)

Impacts of Environmental Muck Dredging 2015-2016 at Florida Institute of Technology Year 2 Final Report - Titles and Executive Summaries

In order to address serious water quality issues associated with muck sediment in the Indian River Lagoon, the Florida Legislature in the 2015 session directed 1.5 million dollars through Brevard County to the Florida Institute of Technology (Year 2 Projects) to investigate the effects of environmental muck dredging in the Indian River Lagoon. A collaborative University effort, through the Indian River Lagoon Research Institute, developed the following projects to help better manage future muck removal efforts throughout the state:

1. Muck Dredging Research Project Management, John Windsor, PI, ($94,500)
2. Biological Responses to Muck Dredging in the Indian River Lagoon, Part I. Seagrass Monitoring and Infaunal Surveys, Kevin Johnson, PI, ($168,200)
3. Biological Responses to Muck Dredging in the Indian River Lagoon, Part II: Fish Populations and Sea Grass Restoration, Jonathan Shenker, PI ($83,204)
4. Determining the Effectiveness of Muck Removal and the Impact of Upland Runoff on Water Quality in the Indian River Lagoon, Florida, John H. Trefry, PI ($406,350) (Also presented in this Year 2 Task 4 report is progress on a project implemented with the first year of legislative funding, Year 1 Task 1/subtask 6, $54,900)
5. Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters, Gary Zarillo, PI, ($130,000)
6. Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites, Charles Bostater, PI, ($80,784)
7. Wind and microclimate analysis for application to fetch limited wind wave growth analysis at IRL dredging locations, Steven Lazarus, PI ($86,106)
8. Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants. Robert J. Weaver PI, Thomas D. Waite, PI ($299,500)
9. Source to Slime Study in Indian River Lagoon, Leesa Souto, PI, ($149,334)

Muck Dredging Research Project Management (Subtask 1)

John G. Windsor
Florida Institute of Technology, Melbourne, FL 32901
June 2019

Executive Summary

Nine interdisciplinary projects (Subtasks) 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 Dredging in the Indian River Lagoon, Part I: Seagrass Monitoring and Infaunal Surveys, (3) Biological Responses to Muck Dredging in the Indian River Lagoon, Part II: Fish Populations and Sea Grass Restoration, (4) Determining the Effectiveness of Muck Removal and the Impact of Upland Runoff on Water Quality in the Indian River Lagoon, (5) Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters, (6) Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites, (7) Wind and microclimate analysis for application to fetch limited wind wave growth analysis at IRL dredging locations, (8) Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants, and (9) Source to Slime Study in Indian River Lagoon. Executive summaries from all nine final project reports are included in this report. 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 facilitated the exchange of scientific findings among all the investigators and optimized the outcomes of these research investigations. In addition, the project management office engaged the public about muck dredging research through presentations open to the public and through social media. Environmental Muck Dredging research progress, reported through monthly meetings, written reports and public presentations, is summarized in this report.

Biological Responses to Muck Dredging in the Indian River Lagoon: Seagrass Monitoring and Infaunal Surveys (Subtask 2)

Kevin Johnson
Florida Institute of Technology, Melbourne, Florida 32901
September 2017

Executive Summary

Organic sediment pollution ("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. Muck has been removed from the Turkey Creek/Palm Bay region by dredging, and this dredging was completed during the first half of this phase of the monitoring (the second year of legislated funding for *environmental muck dredging* in the IRL). Biological monitoring (infauna and seagrasses) has been conducted during pre-dredge and post-dredge ecological conditions to confirm whether or not recovery or enhancement of the ecosystem has occurred. Sampling areas proximal to planned dredging sites, as well as away from those sites at thriving areas, allows interpretations to be more conclusive on the driving forces behind observed changes. This report details 2016-2017 benthic biological monitoring in Turkey Creek (City of Palm Bay, Brevard County) and the adjacent IRL targeted for environmental muck dredging.

Infauna data were collected monthly, and seagrass/drift algae data every other month, through the duration of this study (May 2016-April 2017). Data have been collected and analyzed on the occurrence of seagrasses (*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. 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. 2017 has seen lesser amounts of drift algae in the IRL proper, but winter and spring 2017 showed large amounts of drift algae within Turkey Creek not seen in the previous year. There is no statistically distinguishable dredging signal in the abundance of seagrasses and drift algae before and after dredging. Rather, the small population changes observed in these communities are more likely tied to simple seasonal changes, with winter months having the least growth and some die-back of photosynthetic organisms.

The abundances and distributions of 63 species of invertebrate benthic infauna were determined via surface sediment grabs. Sediments were evaluated for 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. Infaunal diversity and abundance are greater in cleaner sediments with relatively low FGORS scores.

Comparisons were made between before and after dredging. Dredged muck sites showed some increase in infaunal diversity, richness, and abundances in the months following dredging, and those increases continued up through June 2017. Dredged sites of intermediate FGORS, on the other hand, showed a decrease in these same metrics. For seagrasses, drift algae, and infauna, a longer period of recovery and adjustment are likely required in order to document the more permanent effects of environmental dredging in Turkey Creek.

Biological Responses to Muck Dredging in the Indian River Lagoon: Fish Monitoring Surveys and Seagrass Transplanting Surveys (Subtask 3)

Jonathan Shenker
Florida Institute of Technology, Melbourne, FL 32901
March 2018

Executive Summary

Muck at the bottom of the Indian River Lagoon (IRL) creates an inhospitable environment for plants and animals. As muck is removed from the IRL through environmental dredging efforts, it is essential that we determine if the removal efforts affect the biota of the region. This report summarizes the monitoring of fish and macroinvertebrate populations in the Turkey Creek region that was dredged in 2016, and in nearby Indian River Lagoon control regions. It also includes a comparison of the Turkey Creek fish data with that of the broader IRL populations sampled by the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program from 2010 to 2016.

Biological data on fish populations have been collected monthly through the duration of this study, beginning in April 2015 and continuing to July 2017. This report primarily presents the data collected during 2016, with comparisons to the 2015 data and an initial analysis of data from the first quarter of 2017.

Turkey Creek is a dynamic environment that undergoes major shifts in salinity in association with rainfall events and experienced a major stranding of drift algae following an extended period of strong winds. The removal of muck in 2016 altered the configuration and nutrient dynamics of the deeper portions of the mouth of Turkey Creek. Despite the significant environmental variation and muck removal activities, the habitat supports an abundant and diverse assemblage of fishes.

The composition of the fish assemblage within Turkey Creek changed rapidly as pelagic schooling species, such as the numerically dominant anchovies, mullets and herrings, moved into and out of the region. The species composition and abundance of demersal juvenile fishes changed more slowly, reflecting seasonal patterns in reproduction and growth that vary among species.

The most abundant demersal juveniles were mojarras (*Eucinostomus* spp. and *Diapterus* spp.), which showed strong seasonal patterns in abundance, and consumed invertebrate prey that typically inhabit sandy or non-muck sediments. Juvenile *Eucinostomus* spp. were the only taxon that showed up in high densities along the shoreline inside the mouth of Turkey Creek in fall 2016, after the conclusion of muck dredging. Continued sampling through 2017 will help determine how spring/summer-recruiting juvenile *Eucinostomus* spp. and *Diapterus* spp. utilize the post-dredging region.

Although juvenile *Eucinostomus* spp. were the only demersal fishes to increase in abundance in fall 2016 after the completion of dredging, other taxa were far more variable in temporal and spatial patterns of abundance. These other species include the juvenile drums, which are some of the most important fishery species that utilize the Turkey Creek region. Juvenile red drum were

most abundant in fall and winter, and juvenile sea trout in summer. These juveniles feed on benthic infauna and epifauna, which are very sparse in muck habitats, and on juvenile fishes. Both taxa were present in the region for only a few months, suggesting that the seagrass-free habitats were not conducive to survival and growth, and that fish either emigrated into the IRL or were consumed by larger predatory fishes. Other members of the drum family (Atlantic croaker, silver perch and spot) were sporadic inhabitants of Turkey Creek. Comparison with the broad FIM database indicates that their abundance in the creek and the surrounding IRL is affected by varying levels of interannual variability in recruitment. Because of this larger-scale temporal and spatial variability, distinct short-term responses to dredging could not be detected. Stomach content analysis of these species indicates a strong reliance on epibenthic and infaunal prey, including a diverse array of crustaceans. If prey communities become established inside Turkey Creek after dredging, the availability of an increased prey base may result in an improved feeding environment for these fishes. This potential trophic linkage is being assessed during the current research year.

The lack of seagrass within Turkey Creek, and minimal habitat complexity of the substrate, may influence the ability of juvenile fishes to find prey and avoid predators. Working with Sea and Shorelines, LLC, we initiated transplanting experiments using *Halodule wrightii* and *Ruppia maritima* in herbivore-resistant cages to determine if seagrasses can indeed thrive within the outer Turkey Creek basin. If either of these species thrive, efforts to conduct a more intensive seagrass transplanting program may be warranted.

Determining the Effectiveness of Muck Removal on Sediment and Water Quality in the Indian River Lagoon, Florida (Subtask 4a).

Austin L. Fox, John H. Trefry, Robert P. Trocine, Stacey L. Fox, and Jessica E. Voelker
Florida Institute of Technology, Melbourne, Florida 32901
December 2017

Executive Summary

Removal of fine-grained, organic-rich sediments is an integral part of restoring the Indian River Lagoon (IRL) to a healthy ecosystem. This sediment, often referred to as IRL muck, is a concern because it can increase turbidity, consume oxygen, create an inhospitable benthic habitat and is an internal source of dissolved nitrogen (N) and phosphorus (P) that diffuse from muck into the lagoon. Dredging is an effective method for removing large reservoirs of muck with associated N and P; however, there are challenges to dredging and few data are available to quantify the efficacy of environmental dredging in the IRL.

We carried out surveys in Turkey Creek on multiple occasions during the following periods:

- Before dredging from April 2015–January 2016.
- During two separate phases of dredging.
    - Phase I. February 20, 2016–April, 22, 2016 when dredging was carried out for 24 hours/day and then stopped as planned for increased manatee activity.
    - Phase II. September 6, 2016–January 11, 2017 when dredging was carried out for 10 hours/day and alum and flocculants were added.
- After environmental dredging during May 2016–April 2017 (dates varied by area).

The goals of the study were to track changes in (1) the distribution and composition of the muck, (2) benthic fluxes of N and P from muck to the overlying water column and (3) sediment and water quality.

Our pre-dredging sediment survey (February 2015) identified little to no muck in the adjacent IRL; yet, up to 3 m of muck were found between the Florida East Coast Railroad Bridge and the mouth of Turkey Creek. We calculated the pre-dredge volume of muck in Turkey Creek at ~110,000 m^3 (140,000 yd^3) with 83,000 m^3 (~75%) in the portion of the creek selected for dredging. Our post-dredging sediment survey (March 2017) found that 52,000 m^3 of muck and a total of 160,000 m^3 (210,000 yd^3) of wet sediment were removed from the dredged area (i.e., >60% removal efficiency for muck in the dredged area). No significant differences were identified in the chemical composition of muck before versus after dredging.

Observed spikes in turbidity during dredging were driven by an algal bloom and Hurricane Matthew, not the dredging process. Dredging increased water depths and the abundance of saline water in some locations, a potential benefit to fishes, benthic fauna and seagrass. Benthic fluxes of N and P were ~50% lower at three months after dredging, which if continued would decrease annual releases of dissolved N and P from IRL muck by ~3 tons and ~1 ton, respectively (50% decrease), within the ~0.10 km^2 of Turkey Creek that were dredged. Future trends in benthic fluxes will be monitored.

Monthly water quality surveys (April 2015 to April 2017) showed that the 1- to 2-m deeper water column after dredging contained >2-fold more total dissolved oxygen. This increase in oxygen may enhance resiliency to oxygen depletion events. Before, during and after dredging,

values for dissolved ammonium and phosphate were highest in bottom water, consistent with sediments as a continuing source of these nutrients to the overlying water. Secchi depths were significantly deeper and total suspended solids (TSS) were lower after dredging, possibly aided by a prolonged drought after dredging. Overall, Secchi depths and values for TSS followed patterns for rainfall.

Dredged material was transported ~2 km north to a Dredge Material Management Area (DMMA) for settling and dewatering. Clarified water was discharged into the adjacent IRL. Residence times for water in the DMMA were about ~2.5 days during Phase I and ~6 days during Phase II, a response to the rate of filling of the holding area at different dredging rates. The overall retention efficiency for solids was >99% as ~200 tons of N and ~50 tons of P were successfully removed from Turkey Creek. Values for TSS in the outfall from the DMMA to the IRL averaged ~28 mg/L during Phase I and 12 mg/L during Phase II, with four brief episodes of higher values. Background TSS values were 10–20 mg/L in the adjacent IRL. Chemical treatments effectively reduced concentrations of dissolved phosphate from as high as 10,000 µg P/L in the incoming dredged material to <40 µg P/L in clarified water released to the lagoon during Phase II, relative to <50 µg P/L in the lagoon. Total dissolved nitrogen in water released from the DMMA to the IRL was >5 mg N/L throughout the dredging process, relative to <0.8 mg/L in the lagoon. Additional efforts are now underway to decrease concentrations of dissolved nitrogen, mostly as ammonium, during future uses of DMMAs. Nutrient concentrations were at baseline values for the IRL at ~100 m from the outfall. We estimate that ~6 tons of N (~90% dissolved) and ~0.1 ton of P (~30% dissolved) were released from the DMMA during this one-year dredging project. Although unique to this particular IRL area, freshwater discharges annually release ~80 and ~5 tons of N and P, respectively, to Turkey Creek, far more than released from the DMMA.

Inputs of Nitrogen and Phosphorus from Major Tributaries to Indian River Lagoon (Subtask 4b)

John H. Trefry, Austin L. Fox, Robert P. Trocine, Stacey L. Fox,
Jessica E. Voelker, and Katherine M. Beckett
Florida Institute of Technology, Melbourne, Florida 32901
October 2017

Executive Summary

Muck removal and control of nutrient inputs are important components of the restoration of the Indian River Lagoon (IRL). Successful management plans for controlling muck and nutrients in the IRL require continuing assessment of external and internal inputs of substances that are precursors to algal blooms and future muck deposits. Runoff from large drainage basins in the IRL provide one major pathway for external inputs. Atmospheric inputs and direct runoff from hundreds of outfalls along the lagoon also are important external sources. The main source of internal inputs is fluxes of nutrients from IRL muck. More detailed composition data for tributaries to the IRL during regular and storm flow are among the much needed baseline information.

The goal for the first year of this study was to obtain and interpret composition data for selected dissolved and particulate chemicals, including nitrogen (N) and phosphorus (P), from major tributaries to the IRL. Surveys were carried out during (1) non-storm flow from December 2015 to February 2017 (15 months) and (2) nine storm events. Our sampling locations, all of which have active U.S. Geological Survey (USGS) flow gauges, are as follows: St. Sebastian River at the South Prong (SA), St. Sebastian River system in the Fellsmere Canal (SB), Turkey Creek (TC), Crane Creek (CC) and the Eau Gallie River (EG).

Continuous profiles for salinity, temperature, dissolved oxygen and pH, along with discrete water samples, were collected at each station monthly and on multiple occasions during rain events. Water samples were analyzed for (1) total dissolved solids (TDS in mg/L), turbidity (in NTU, nephelometric turbidity units) and total suspended solids (TSS in mg/L), (2) dissolved ammonium, nitrate + nitrite, organic carbon, organic nitrogen, organic phosphorus, phosphate, total dissolved nitrogen and phosphorus, plus iron, sulfate, calcium, chloride, silica and alkalinity, and (3) particulate nitrogen, phosphorus, organic carbon, iron, aluminum and silicon.

This first year of study yielded a wealth of data plus some preliminary interpretations and conclusions, including the following:

- Mean values for total (dissolved + particulate) N and P were 890 ± 120 µg/L and 110 ± 60 µg/L, respectively, for non-storm data for all tributaries, relative to Florida water quality criteria for rivers and streams of 1540 µg total N/L and 120 µg total P/L (USEPA, 2017).

- The forms of total N (dissolved + particulate) for all monthly samples (n = 73) from all tributaries averaged 57 ± 13% dissolved organic N (DON), 19 ± 8% particulate N, 17 ± 12% nitrate + nitrite and 7 ± 4% ammonium.

- The forms of total P (dissolved + particulate) for all tributaries averaged 55 ± 17% dissolved phosphate, 36 ± 13% particulate P, and 9 ± 17 % dissolved organic P (DOP).

- Lower fractions of nitrate + nitrite and higher fractions of DON were found in less urban tributaries such as Fellsmere Canal. The opposite trends (higher nitrate + nitrite and lower DON) were found in more urban areas including Crane Creek and the Eau Gallie River.

- Concentrations of TDS inversely tracked flow with decreased values during increased (storm) flow. Values for TSS showed an opposite, more positive trend with flow. Phosphate concentrations also tended to be higher during storm flow. Concentrations of nitrate + nitrite decreased below mean, non-storm values during peak storm flow and then slowly returned to mean, non-storm values as storm flow decreased. The other forms of dissolved N showed only minor changes in concentrations relative to flow. These differences may be linked to the relative importance of baseflow (e.g., nitrate + nitrite) versus surface runoff (e.g., phosphate) as sources of the various ions to tributary waters.

- Fluxes of all ions and solids were higher during storm flow. Particulate iron (Fe) values (as a percent of the mass of TSS) decreased significantly at the beginning of a storm event, most likely due to a decrease in the relative amount of groundwater input (i.e., baseflow) of dissolved Fe; the Fe content of the particles returned to mean values as flow decreased.

- Calculated annual fluxes of total N and P for the various creeks, based simply on total flow and average concentrations were as follows:

Tributary	Total N (tons/yr)	Total P (tons/yr)
Eau Gallie River	10	1
Crane Creek	20	2
Turkey Creek	80	5
St. Sebastian B	60	3
St. Sebastian A	60	9
Total	230	20

- Estimated annual inputs of total N and P from these major tributaries are close to estimated benthic fluxes of N (280 tons) and P (45 tons) from muck sediments in the North IRL (north of Melbourne Causeway, Highway 192; excludes Banana River Lagoon).

- Recommendations for future study include (1) continued study of major tributaries, (2) sampling and analysis of minor tributaries and outfalls plus (3) continued assessment of the relative importance of baseflow versus stormwater inputs for major ions and the various chemical forms of N and P.

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

Gary Zarillo and Claudia Listopad
Florida Institute of Technology, Melbourne, Florida 32901
April 2018

Executive Summary

This project integrates water quality and hydrologic, and hydrodynamic process data into a model of the Indian River Lagoon (IRL) for long-term calibrated and validated predictions of water quality. The overall goal is to combine model simulations with measured data to assess the impact of muck dredging on local and regional water quality. Questions to be addressed include: 1) to determine 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) to determine whether improved model calibration 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, and 3) to determine if muck dredging either locally or regionally can result in a lasting improvement of IRL water quality. Question 3 will be answered more fully in year 3 of the project when all of the data collected by other members of the overall muck project team are fully represented in the model boundary conditions. The modeling platforms include the Environmental Fluid Dynamics Code (Tetra Tech, 2007) coupled hydrodynamic and water quality models (EFDC/HEM3D) and the Spatial Watershed Iterative Loading (SWIL) watershed model (Listopad, 2015). Hydrodynamic, hydrologic and atmospheric model boundary conditions are supported by the ongoing Indian River Lagoon monitoring program establish in the early 1990s by the St. Johns River Water Management District. Nutrient loadings from the Indian River Lagoon watershed sub-basins are from predictions by the SWIL model. In this report, we update model predictions from the coupled EFDC-SWIL modeling scheme into 2015 and provide further validation of water quality predictions by comparison to the SJRWMD data in the Turkey Creek area of the IRL.

Model predictions of ammonium concentrations in the water column within the Turkey Creek Basin compare well with measured data. Predicted and measured ammonium concentrations in the water column in the Turkey Creek basis compare with R-vales of between about 0.72 to 0.85 corresponding to R^2 -values of between 0,5 and 0.75, respectively. Reductions in ammonium flux of 90% and 60% were examined in model runs as two post-dredging hypothetical conditions. Reductions of 90% result in very low values of ammonium in all model layers, which divides the water column into 5-vertical segments. A hypothetical reduction in ammonium flux by 60% resulted in low concentrations on ammonium in the upper four model layers and a moderate reduction in the lowest mode layer. The 90% and 60% hypothetical cases produced detectable improvements in water quality in the IRL adjacent to the entrance of Turkey Creek. The continued validation and results of water quality modeling demonstrate that dredging of muck sediments throughout the IRL could be evaluated for local and regional water quality improvements. To date the model scenarios have shown that dredging of muck sediments is likely to locally improve water quality and will have beneficial influence on nearby IRL water quality. This finding is consistent with data collected by Trefry et al. (2016a) that indicate improvement in local water quality within the Turkey Creek basin relative to pre-dredge conditions.

Since the post-dredge period in Turkey Creek continues to be monitored in the upcoming third year of the project, further model verification and model simulations will be based on a suite of measured data collected in the post-dredging period. Based on model performance thus far we expect that model results will continue to compare well to measured data by matching trends of measured data over time and matching measured values well within an order of magnitude. Thus, application of the model can be expanded with confidence to other locations scheduled for dredging of muck deposits.

Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites (Subtask 6)

Charles R. Bostater Jr. and Tyler Rotkiske
Florida Institute of Technology, Melbourne, Florida, 32901
May 2018

Executive Summary

During this project moving fluid mud and muck samples were collected in Palm Bay and Turkey Creek from March 2015 through March 2017. Samples collected pre-dredging, during dredging and post dredging conditions are collected to help assess the environmental benefits of muck dredging. The goal was to determine if moving muck reduction occurred after dredging. If the moving fluidized mud is reduced after dredging, this is considered to be a positive benefit of the environmental dredging. Bedload fluid mud and muck sampling occurred in Turkey Creek from August through November 2016 in order to estimate the magnitude of moving fluidized mud that moved downstream within the bottom water layer. The efficacy or effects of dredging using the passive sondes indicates (1) after dredging, the average moving fluidized mud (g m^{-2} day^{-1}) decreased 55% when compared to pre-dredging conditions in the middle region of Palm Bay, (2) at the mouth of Palm Bay, pre-dredging versus post-dredging analysis suggests the maximum movement (g m^{-2} day^{-1}) of moving fluidized mud decreased by 45% after dredging and the average movement decreased by 3% after dredging, (3) the spatial variability of muck movement at stations TC1-TC6 decreased by 31% across the mouth of Palm Bay indicating fluxes across the mouth of the estuary are more uniform, (4) west of the railroad bridge in Turkey Creek, the post-dredging results indicated the maximum moving fluidized mud (g m^{-2} day^{-1}) decreased 57% compared to during dredging condition, but post-dredging mean fluid mud fluxes exceeded the pre-dredging condition. These results suggest a reduction of muck movement at the dredging site and downstream of the dredging site despite an increase in movement upstream of the project and the influence of Hurricane Matthew. The results near the bridge may have been influenced by the downstream fluid mud movement that occurred during Hurricane Matthew in the fall of 2016. Thus, there was a reduction of moving fluid mud and muck near the bottom after dredging, especially in the middle region of Palm Bay and at the mouth of Palm Bay. Extrapolation of data to the cross-sectional area at the upper Turkey Creek station suggests 55 +/- 7.7 metric tons of particulates (dry weight) moved downstream as bedload material within the lutocline from August 1 to November 12, 2016. Extrapolation to an annual basis suggests 195 +/ 28 metric tons of bedload moving fluidized mud is downstream. The calculated watershed loading rate (August-November 12, 2016) is estimated to be 7.5 +/- 1.1 kg km^{-2} inch $rain^{-1}$. Results suggest (a) a reduction of moving fluidized mud occurred due to dredging and (b) the source of this material enters Palm Bay during storm events. Comparison between data at the lutocline to the upper boundary layer water column indicated an increase from ~80 to over 500 times in Turkey creek using vertical sonde array measurements.

Wind and microclimate analysis for improved site characterization in support of environmental flow modeling (Subtask 7).

Steven M. Lazarus
Florida Institute of Technology, Melbourne, Florida 32901
November 2017

Executive Summary

The primary purpose of the study is to provide an empirical description of the IRL wind field (and its variability) for modeling purposes. Toward that end, we develop an algorithm that relates airport meteorological station data to site-specific (lagoon) wind measurements. In part, this allows airport station data to be used in the calibration and verification of the Zarillo hydrodynamic/sediment transport model in lieu of costly, site-specific wind measurements. In support of this effort, we conducted 1) a detailed wind microclimate analysis of the Palm Bay dredge site and, 2) a wind-related site characterization for three National Weather Service locations. The meteorological role as it relates to (IRL) muck intersects a broad range of environmental related issues including re-suspension, erosion, transport (i.e., advection), turbulent mixing, runoff (hydrology), algal blooms, etc.

Approximately 6 weeks of fieldwork were conducted in which the FIT wind lidar was deployed. There were extended site visits to nearby National Weather Service Automated Surface Observing System (ASOS) stations as well as a day visit to the dredge site in Palm Bay. The three ASOS site assessments/lidar visits address the QA requirements of this work (lidar wind validation) and help address ASOS siting issues – which is important given that these sites are used to develop the wind forcing. The Ft. Pierce ASOS appears to be an outlier due to blocking issues (and a lower measurement height) and thus data from this site *were not used* to generate the synthetic wind forcing. Results from the microclimate analysis indicate relatively large variability in wind speeds within Palm Bay (as much as 10 kt) – large enough to impact flow modeling.

Using a wind gust approach, an assessment of published roughness estimates at the three ASOS sites was performed. Results for both the Ft. Pierce and Vero Beach ASOS were consistent with existing reports but degraded for Melbourne. *Our analysis indicates that, for some flow directions, the published roughness estimates at the Melbourne ASOS are too low.* This underscores the problematic nature of accurately determining low end roughness values – a potential issue if one chooses to adjust (from land to water) the ASOS wind observations using this type of method.

To address the essential question of this funded work, "*What is the wind over the lagoon?*", a statistical approach is applied to model and observed winds to create a synthetic wind forcing time series along with an estimate of its variability (spread). These winds are generated by regressing observations at ASOS locations against in-situ water friendly sites, while the spread is obtained from repeated sampling of the spatial variability from 180 Weather Research and Forecast (WRF) model simulations where the wind speed and direction were systematically varied. This approach is designed to provide a water representative estimate of the wind speed as well as a measure of representativeness. The synthetic wind forcing has been applied to the FIT Coastal Modeling System to assess both the impact and sensitivity of the model, in particular the sediment loading, to uncertainty in the wind-driven circulation.

Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants (Subtask 8)

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Executive Summary

The focus of this project was to 1) implement the design and construction of a suction head for fine sediment dredging and 2) treat the dredged canal slurry mixture in a mobile treatment trailer system. The slurry treatment includes chemistry testing as outlined in the scope of work (SOW) below. The mobile solids removal/treatment system consists of a prototype suction head, a treatment trailer, and a deployment pontoon boat. Ferrate testing in the field confirmed the laboratory results, which showed that ferrate treatment was effective at removing the solids and nutrients.

The developed suction head has demonstrated that larger sediments can be precluded by implementing a variable intake area system, including a shroud. The ferrate chemistry has shown that ferrate was effective at removing nitrogen and phosphorous to levels below detection of the available instrumentation when the appropriate ferrate/ferric formulation was used. Greater than 64% reduction of ammonia and nitrite-nitrogen was achieved. In addition, greater than 95% of total suspended solids were removed and 90% of phosphorus was removed. Field testing of the coupled system confirms the feasibility of small-scale muck sump operations along canals and rivers that flow into the IRL.

A mobile system would require that sites be identified and prepared in advance, since the current pilot system still required the use of a small detention pond. That pond could be replaced by an on-site holding tank adjacent to the sump site. In addition, an autonomous scaled-up system can be developed and installed in permanent locations in canals to manage muck removal prior to entering the Lagoon. Further improvements to the system/project can be made such as optimization of a jet ring system for more efficient sediment suspension, redesign of shroud based on sediment fall velocity analyses and flow simulation analyses, testing at multiple sites, and determining remaining sediment profile of material post dredging operations.

Source to Slime Source to Slime Study in the Indian River Lagoon (Subtask 9)

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Executive Summary

This project examined groundwater nutrient concentrations in one residential community with onsite sewage treatment and disposal systems (septic tanks), one with sewer service, and one with sewer service that also received reclaimed water for irrigation. Groundwater nitrogen concentrations in the three communities were compared with those in a natural area to refine models developed to identify and allocate nutrient source contributions to the Indian River Lagoon. We were surprised to find that the three communities were equally polluting.

Research acknowledges the contribution of septic tank leachate and reclaimed water to nutrient loadings to receiving waters (Badruzzamen et. al. 2012), but there is little scientific evidence that supports the high groundwater nitrogen concentrations we found in the sewered community. This leads to a need for more research on sewered communities and ultimately presents a management challenge. To effectively address nutrient pollution in our study area, practitioners would need to address all three wastewater treatment types. Before hooking septic tanks up to sewer lines, the sewer lines must be checked for leaks to eliminate that as a possible source of contamination. Furthermore, the wastewater treatment plant that is treating the sewage must be updated to advanced treatment that will reduce the nitrogen concentrations in the irrigation water. If what we found in this pilot study is consistent throughout Brevard County, addressing just septic tank communities would do little to reduce nutrient pollution that can impact the lagoon. Repeating the study design multiple times in different areas can increase the confidence of these findings.

Wastewater contributes to nutrient pollution in receiving ground and surface waters through several different means. In this study, we focus on residential communities with varying wastewater systems including septic tanks, sewered lines. and sewered lines with reclaimed irrigation water. Septic tanks designed to treat bacteria discharge nutrient laden leachate into drainfields. If the drainfields are located too close to the water table, nutrient laden leachate reaches groundwater. Sewer lines that transfer household wastewater to the wastewater treatment plants can become compromised and leak overtime, discharging untreated sewage into groundwater. Reclaimed irrigation water used to reduce Floridian's reliance on potable water for irrigation can be rich in nutrients.

Nutrients such as nitrogen and phosphorus fuel algal blooms that can lead to toxic conditions and contribute to muck formation. During an algal bloom, dissolved nutrients are rapidly taken up and released by billions of algae cells. When the algae die, bacterial decomposition of those cells uses up the oxygen in the water column, resulting in anoxic conditions that lead to fish kills. Those billions of decomposing algae cells along with the fish and other organisms that die from anoxia, fall to the bottom and contribute to muck accumulation.

Stopping the cycle of nutrient enrichment, algal blooms, fish kills, and muck formation requires an understanding of pollutant sources and nutrient dynamics. A better understanding of sources of groundwater contamination is needed to prioritize areas for wastewater upgrades, infrastructure retrofits, and septic to sewer conversions. The goal of this pilot project was to

measure groundwater nitrogen concentrations in residential and natural areas to verify regional efforts to allocate sources of nitrogen entering the lagoon with field-collected data.

Models currently being used to estimate pollutant loads to the Indian River Lagoon may be grossly underestimating the contribution of nutrients from groundwater entering the lagoon through baseflow. A better understanding of groundwater nutrient concentrations and processes can help refine loading models and contribute to the creation of a much-needed lagoon nitrogen budget. This project installed permanent groundwater monitoring wells and collected and analyzed 92 monthly groundwater samples in accordance with rigorous data collection protocols including FDEP-SOP-001/01; FS2200 Groundwater Sampling, and EPA standard laboratory methods in a NELAP certified lab.

Study Objectives

The goal of the study was to measure groundwater nitrogen pollution in three different communities to confirm model estimates and compare differences. The following study objectives accomplished this goal.

- Conduct an extensive literature review on groundwater nutrient sources and regional studies. Identify sources of groundwater data within the IRL watershed.
- Create spatial data layers and maps of soils, groundwater, land use, and elevation data, potential sources of nutrients, and hydraulic flows to the IRL.
- Install wells to measure groundwater levels and collect samples.
- Collect 48-72 groundwater samples in sub-watershed basins of Turkey Creek.
- Analyze groundwater samples for ammonia, Total Kjeldahl Nitrogen, nitrate, $\delta^{15}N$ and $\delta^{18}O$ in nitrate, and fecal coliforms.
- Evaluate the extent that residential land uses are contributing nutrients and bacteria to groundwater.

Study Results

There is a perception that septic tank communities are contributing high concentrations of nitrogen to groundwater, because they are designed to treat bacteria and discharge nitrogen normally through the drainfield. In the case of Turkey Creek, there is no single residential community that is more polluting than another. There were interesting differences in nitrogen species among them (*Table 1*). The highest Total Nitrogen concentration (5.15 ppm) was in the septic tank community, followed by the sewered community (4.55 ppm). The highest organic nitrogen (4.35 ppm) and ammonia (2.45 ppm) concentrations were in the sewered community and the highest nitrate-nitrite concentration (2.5 ppm) was in the reuse community. The three communities had significantly higher groundwater nitrogen concentrations than the natural area, in fact an order of magnitude higher, but they were not significantly different from each other.

Based on the measured data, total nitrogen loading into the Turkey Creek is likely at least 4,623 lbs./year or 14 lbs/year of total Nitrogen per household. Furthermore, we found that nitrogen plumes extended well beyond the 20 to 60 m reported in the literature (Ming *et al*., 2017), indicating that distance from an OSTDS to the receiving waterway shouldn't be the only indicator used to predict loading potential.

Although in our study all residential communities are equally polluting, this can only be confirmed by repeating the study design multiple times in different areas. We found tremendous

variability between and within treatment types and over time that requires statistical analysis that takes this variability into account.

Table 1. Comparison of nitrogen and bacteria median concentrations across communities with septic tanks, sewer lines, and sewer lines with reuse irrigation.

Analyte	Septic	Sewer	Reuse	Natural
*NH_3 (mg/L)	1.150^{ab}	**2.450^{a}**	0.035^{bc}	0.035^{c}
*NO_X-N (mg/L)	0.025^{a}	0.036^{a}	**2.500^{b}**	0.025^{a}
*TKN (mg/L)	1.550^{a}	**4.350^{b}**	0.120^{c}	0.220^{c}
*TN (mg/L)	**5.150^{a}**	4.550^{a}	2.500^{a}	0.225^{b}
Fecal Coliform (CFUs/100mL)	1.000	1.000	1.000	1.000

*Significantly different median at p <0.001 using Kruskal-Wallis. Pairwise comparison (Mann-Whitney tests). Different letters indicate significant differences within rows at p<0.05. Highest value in bold.