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

Final Project Report Submitted to
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Final Report: EMD2 Biological Responses to Muck Dredging in the Indian River Lagoon: Seagrass Monitoring and Infaunal Surveys (Subtask 2)

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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 (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, 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 show some increase in infaunal diversity, richness, and abundances in the months following dredging, and those increases continued up through the time of this report submission (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.

Introduction

In association with Brevard County dredging in Turkey Creek's Palm Bay, we have monitored biological populations in areas that have undergone environmental dredging. IRL organic sediments are heretofore referred to as "muck" (Trefry et al., 1987), but have a different organic content than "muck" defined from other locations (e.g., Gohil et al., 2014). This monitoring has included measurements of environmental conditions, especially the sediments, and population ecology of seagrasses, drift algae, and infauna 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, both before, during, and after the dredging, allows us to evaluate the success of muck removal. 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.

Objective

- Pre-dredging assessment of seagrasses and benthic infauna near dredging sites, contrasted with away sites
- Comparisons of post-dredging conditions relative to pre-dredging baselines to evaluate dredging effects on short-term benthic biological recovery or responses

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 eutrophication. In Turkey Creek (Palm Bay), sediments in the deeper areas were muck, while sediments in the shallower waters were not purely muck, but still contained 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 potential system for testing FGORS removal effects on 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.

Approach (Including referenced methods)

The focus of biological monitoring was in the region near the mouth, but within Turkey Creek ("Palm Bay"), where environmental muck dredging occurred in 2016. In addition, biological monitoring was conducted at various sites away from the dredging for comparison with the sites adjacent to the dredge area.

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 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 every other month (study duration May 2015-May 2017). Seagrass and algal percent cover and shoot length were plotted as means ± SE. Where appropriate, statistical comparisons were made via ANOVA. The most informative data were selected as the focus of this report.

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 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 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, and % silt/clay content (dry weight). Where appropriate, statistical analyses included Analysis of Variance (ANOVA) for spatial comparisons on a given day, ANOVA for temporal comparisons for a given site, Non-Metric Multidimensional Scaling (NMDS) community analysis with posthoc Analysis of Similarity (ANOSIM), Principle Components Analysis (PCA), and regression correlation analysis comparing biological data to corresponding sediment data.

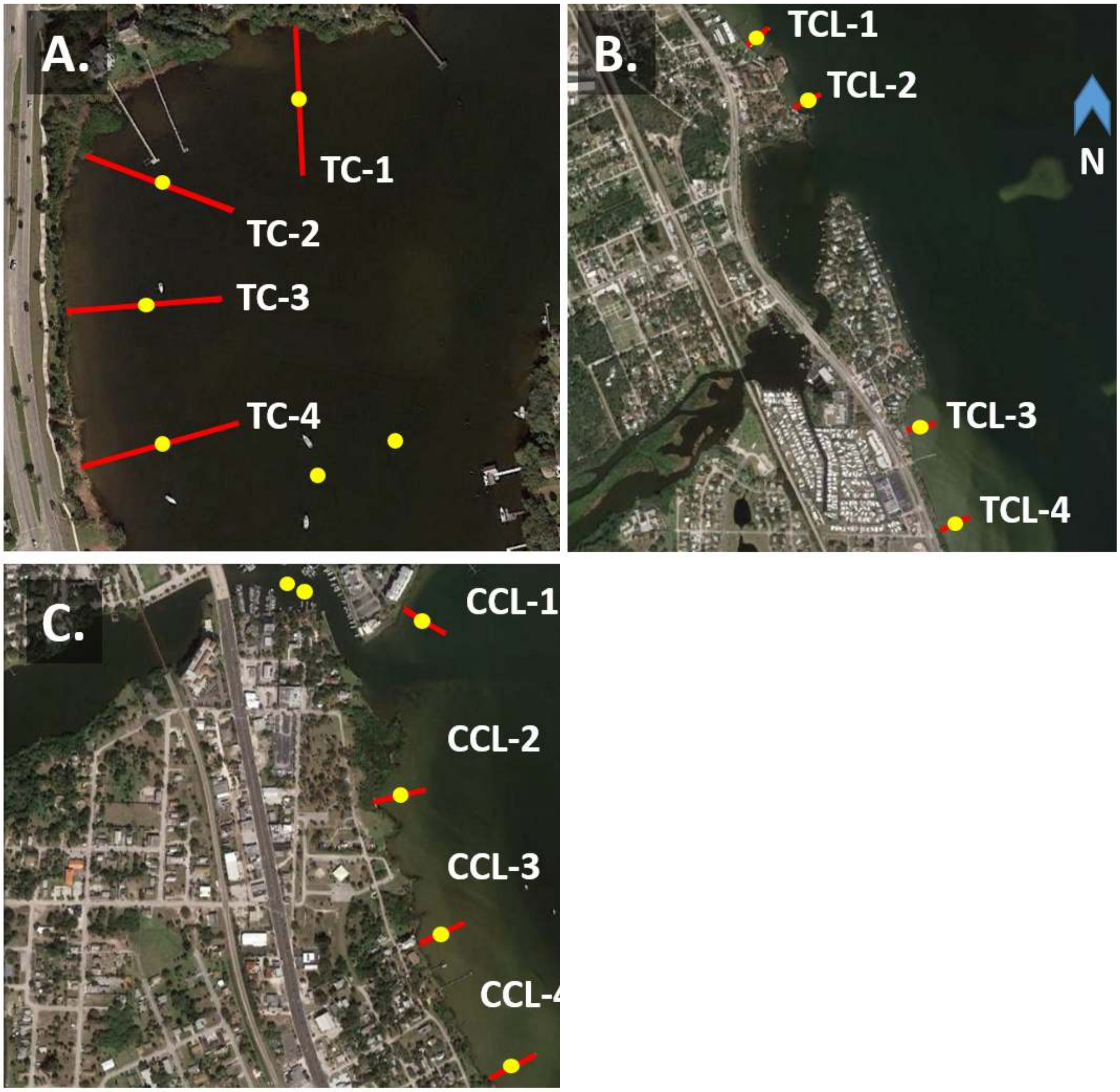

Figure 1. Primary study sites, including A. Turkey Creek ("Palm Bay") and locations of seagrass transects TC-1-TC-4. B. Comparison study site in the Indian River Lagoon near the mouth of Turkey Creek (TCL) and locations of TCL transects (TCL-1-TCL-4). C. Comparison study site in the Indian River Lagoon 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). Transect lengths (red lines) are 100 m.

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 the lead entities sampling these biological communities in Indian River Lagoon ecosystems for at least several years. 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 Xiao Ma 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. Water clarity was determined with a Secchi disk. DO sensors are calibrated by setting high and low points via forcibly saturated (100% DO) and depleted (0% DO) water.

Seagrass and drift algae surveys – The identification of seagrasses and drift algae have 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) has 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 relatively 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. 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 are 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. Water is decanted from the sediments sample in the field in a consistent manner, with minimal disturbance to the sediment, after which the sediment is placed in a Ziploc bag. The entire sediment sample is then used for water content determination and comparison. To determine the combined silt-clay content, the sample is washed through 63 micron mesh, and the dry weights determined and compared. The determination of hydrogen sulfide content is a subjective, qualitative test by which 3 personnel independently smell the sediment samples and make a sulfide score determination without knowing how others have scored the samples.

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 and stored via Google Drive.

Results and Discussion

Seagrasses and Drift Algae

Seagrasses were not abundant enough for random sampling in Turkey Creek's Palm Bay (TC, TCM). Where seagrasses occurred in the IRL (TCL, CCL), 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 had less cover in recent months of 2017 relative to the previous 6 months, but not significantly different from the same seasons a year previous based upon % cover (Figures 2 and 3) and shoot length (Figures 4 and 5). Seagrasses are less abundant in the slightly deeper water towards the end of transects (90 and 100-m markers). There was a consistent, year-round lack of occurrence of seagrasses within Turkey Creek and, therefore, Turkey Creek seagrass data are not illustrated. It should be noted, however, that struggling sparse patches of *H. wrightii* were observed in Turkey Creek during the high growth season (late spring/early summer), though not sampled via transect sampling. Canopy height, equivalent to shoot length, was extremely variable, statistically indistinguishable from zero, and no statistically significant patterns were observed. Non-significant trends apparent visually include greater abundance and height of seagrasses nearshore and in the high growth season. Seagrasses show no signal attributable to dredging. It may be that, because of the relatively slow colonization and growth of seagrasses, that possible responses to seagrasses will only be detectable over a longer period of time. We will continue monitoring seagrasses in Turkey Creek quarterly during EMD3.

Drift algae were evaluated along the same transects as those designed for seagrasses (Figures 6-8). In the Indian River Lagoon (CCL and TCL), less coverage of drift algae was measured from May-April of 2016-2017 compared to the year previous (Figures 7 and 8). More drift algae were measured within Turkey Creek (TC) relative to the years previous (Figure 6). However, because of the ephemeral and movable nature of drift algae, we cannot attribute drift algae coverage in TC to the dredging. When drift algae are abundant, they can form a shade blanket over aspirant shoots of seagrass and prevent them from thriving.

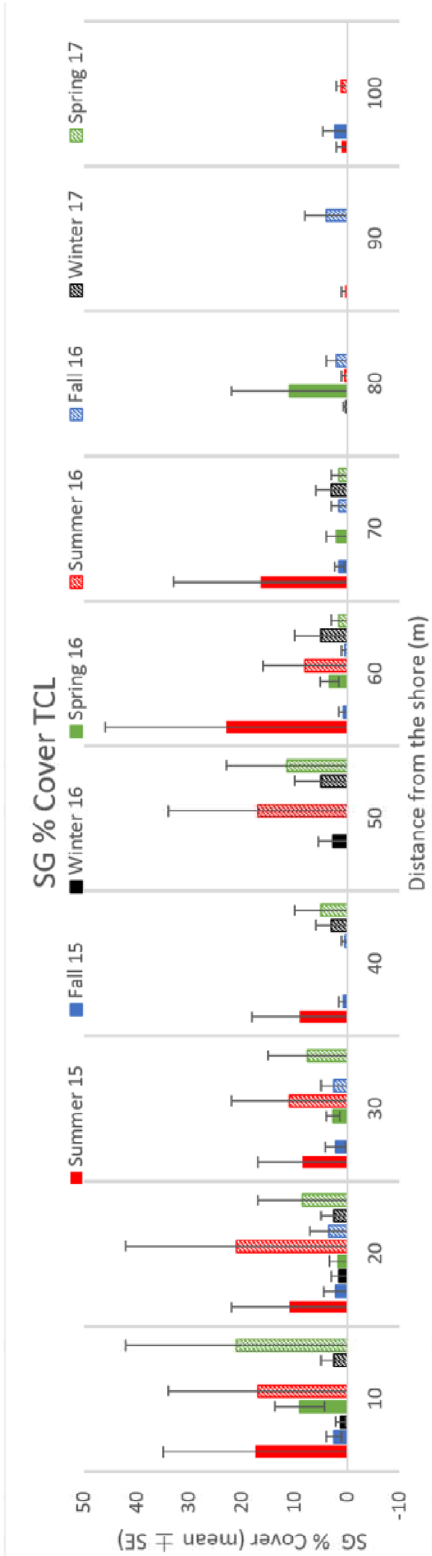

Figure 2. Seagrass mean % cover (% occurrence) in the Indian River Lagoon near Turkey Creek (TCL). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

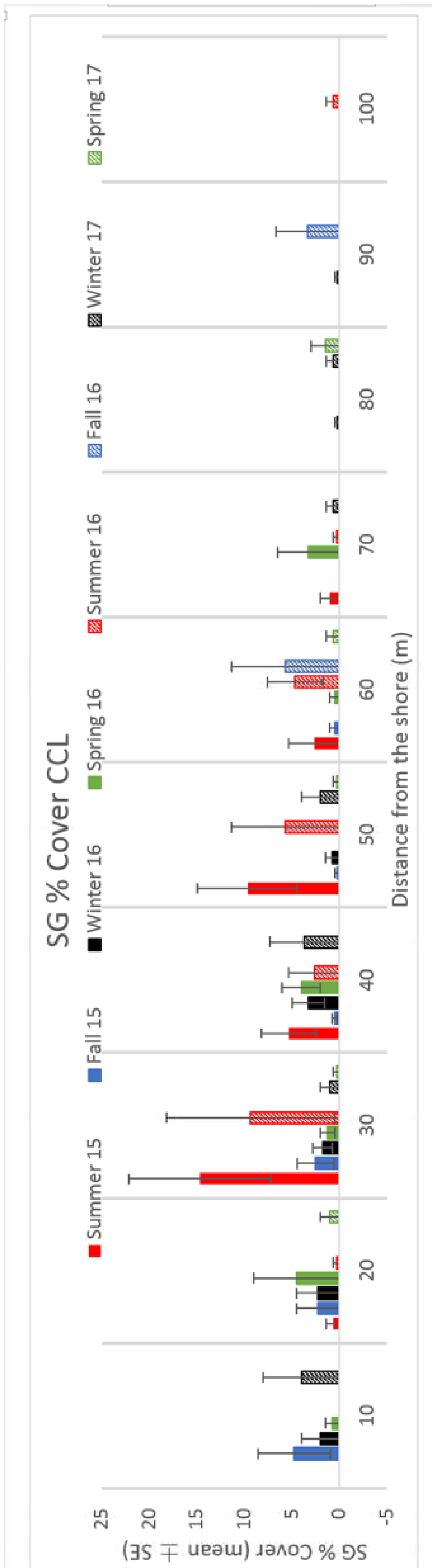

Figure 3. Seagrass mean % cover (% occurrence) in the Indian River Lagoon near Crane Creek (CCL). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

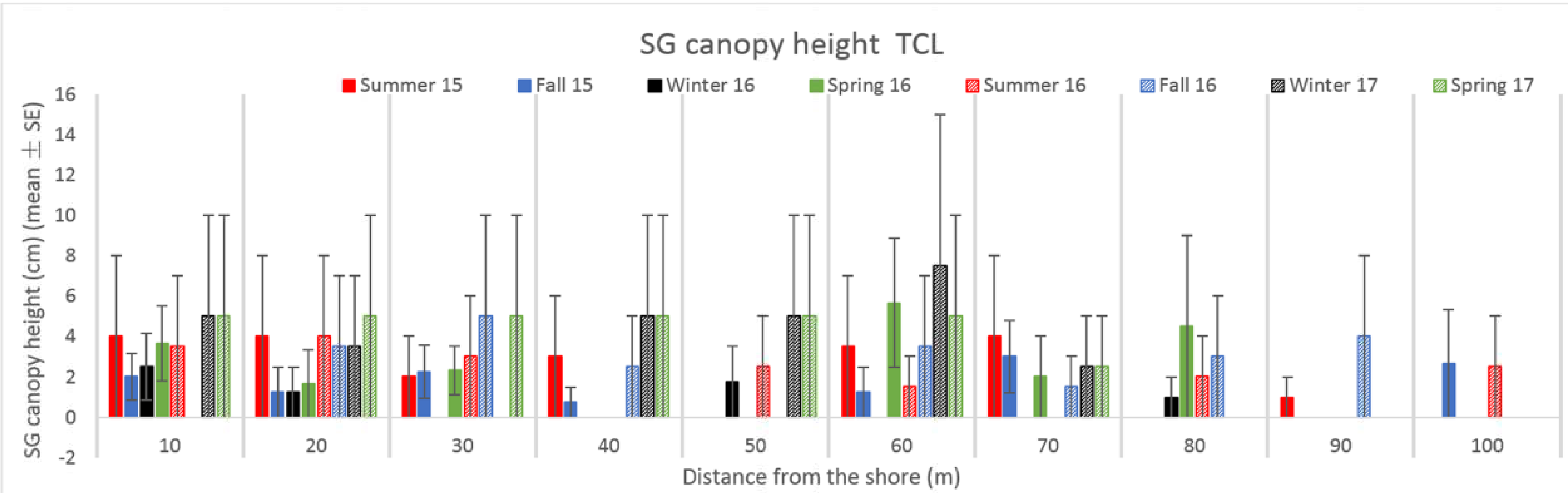

Figure 4. Seagrass mean Canopy Height in the Indian River Lagoon near Turkey Creek (TCL). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

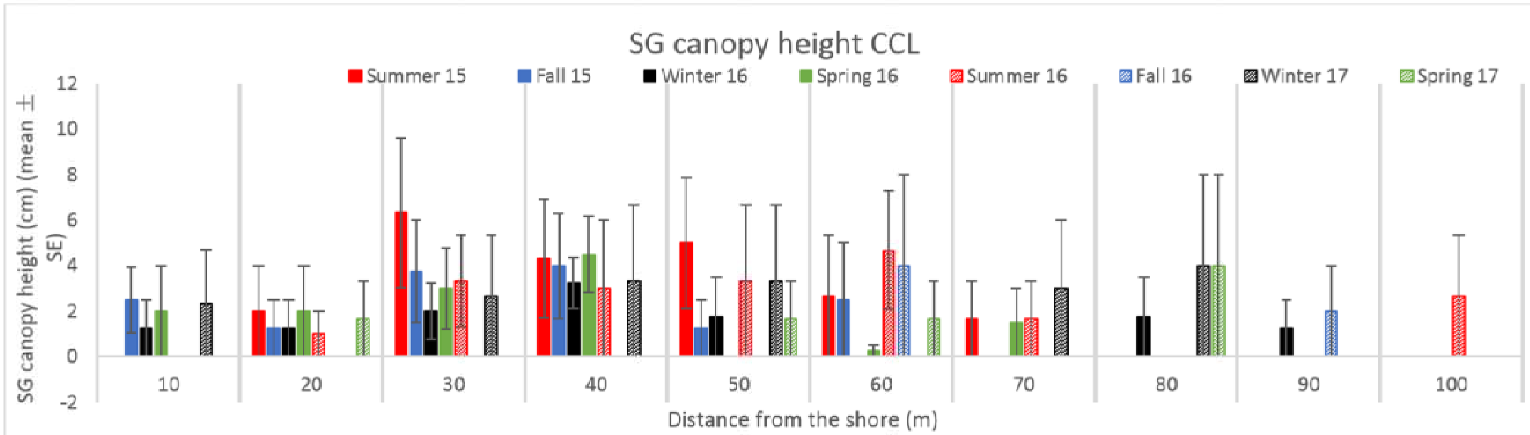

Figure 5. Seagrass mean Canopy Height in the Indian River Lagoon near Crane Creek (CCL). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

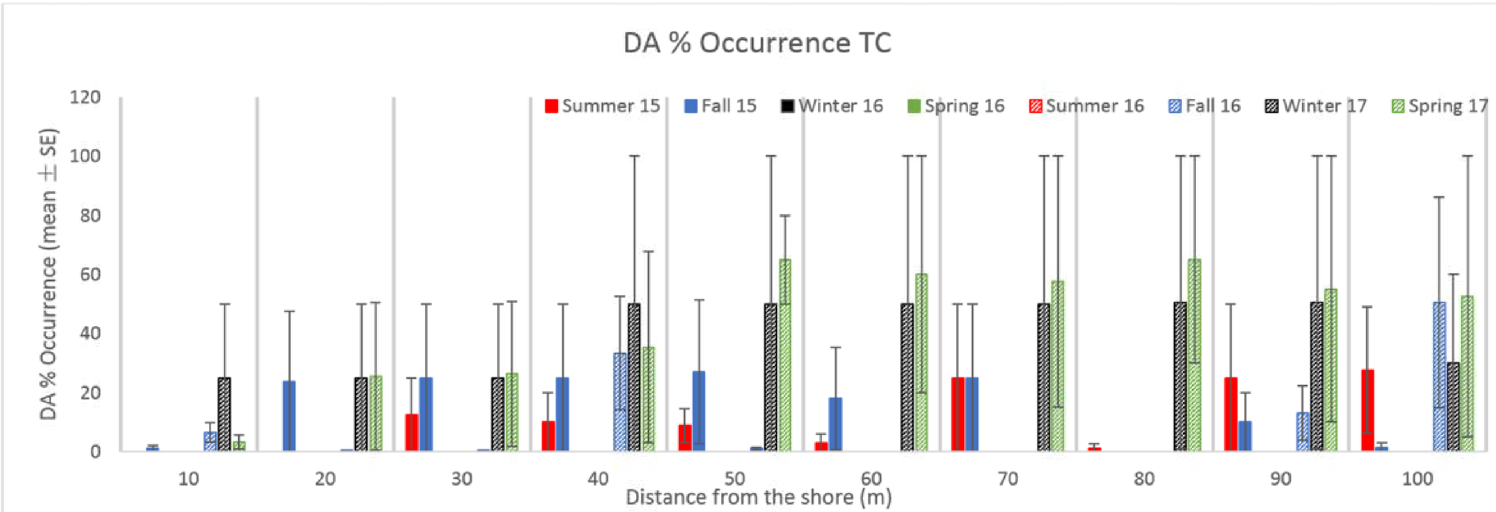

Figure 6. Drift algae (DA) % occurrence in Turkey Creek's Palm Bay (TC). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

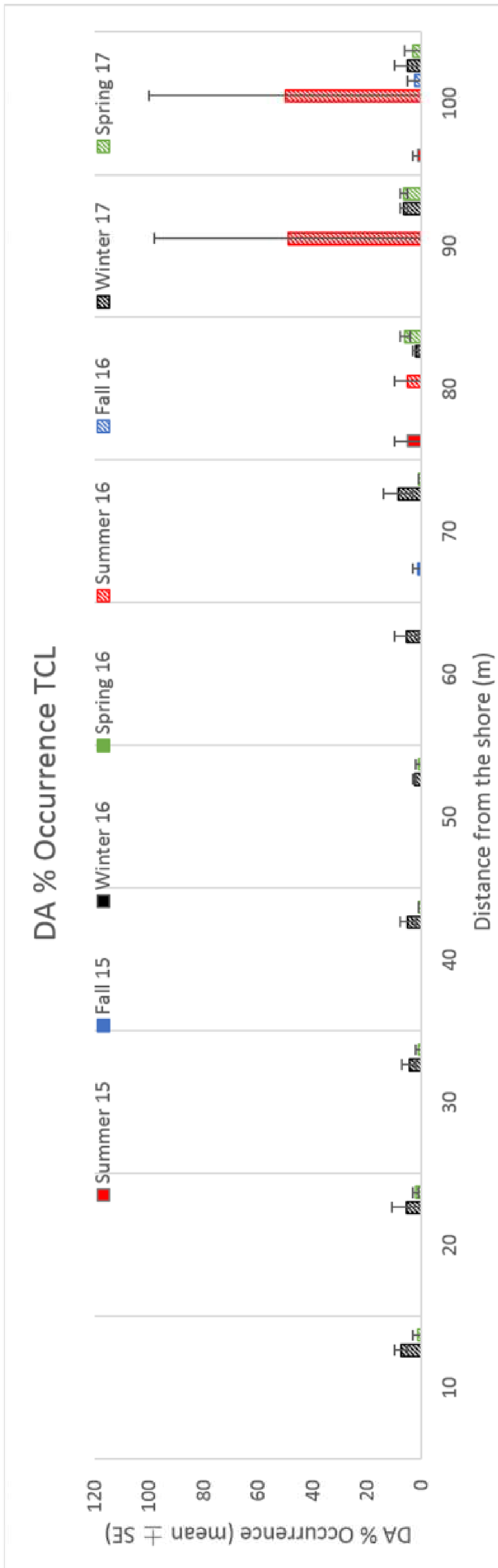

Figure 7. Drift algae (DA) % occurrence in the Indian River Lagoon near Turkey Creek (TCL). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

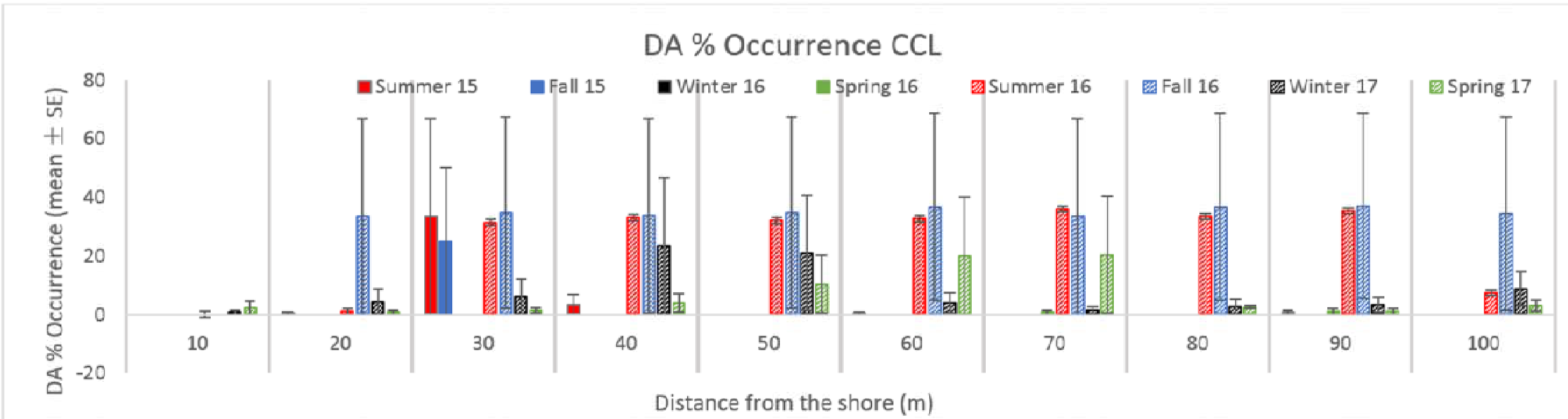

Figure 8. Drift algae (DA) % occurrence in the Indian River Lagoon near Crane Creek (CCL). Matching colors represent like seasons. Error bars = ±1SE. Dredging occurred from February 2016 to January 2017, with a hiatus from May-August 2016.

Sediments and Infauna

Prior to dredging, 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 9A), and % silt/clay content (dry weight) (Figure 9B), % organic content (dry weight) (Figure 9C). Sediments with very high FGORS components are referred to by some as "muck". In all cases, selected "muck" sites in Turkey Creek (TCM, Figure 1A) and Crane Creek (CCM) (Figure 1C), were confirmed to have very high scores in FGORS scores (Figure 9) 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 (Figure 9). 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.

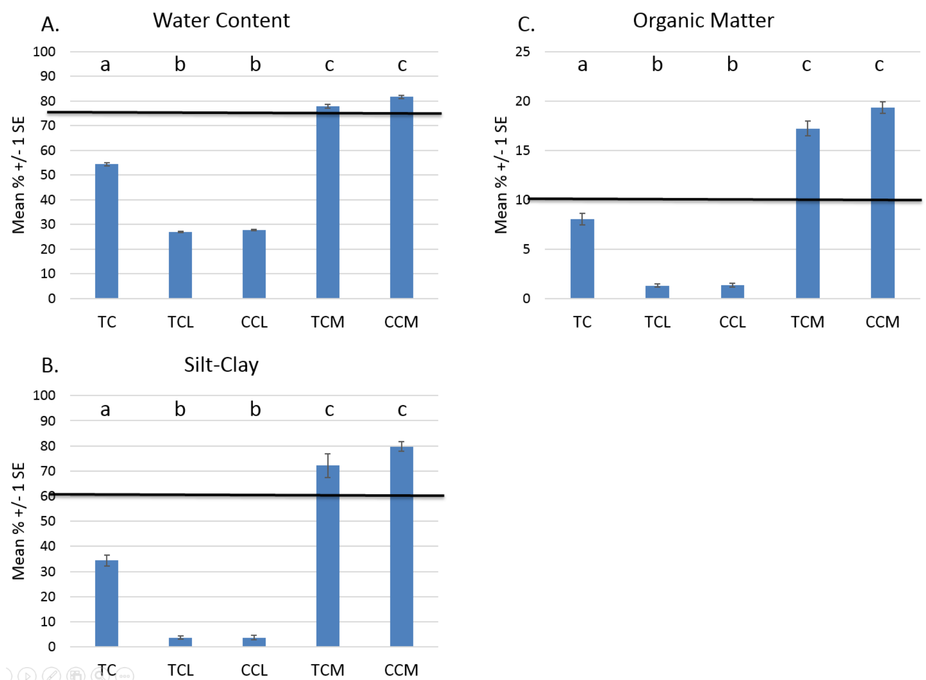

Figure 9. Mean % water content (A), silt-clay content (B), and Organic Matter (C) of sediments by weight before dredging. Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). Muck sites (TCM, CCM) have statistically higher water content relative to other stations. Turkey Creek (TC) has a statistically distinct intermediate water content relative to other stations. Error bars are ±1SE. Horizontal black lines indicate defined muck thresholds (Trefry and Trocine 2011) for each parameter. Disparate letters indicate statistically significant differences in post-hoc comparison of means following ANOVA (α=0.05).

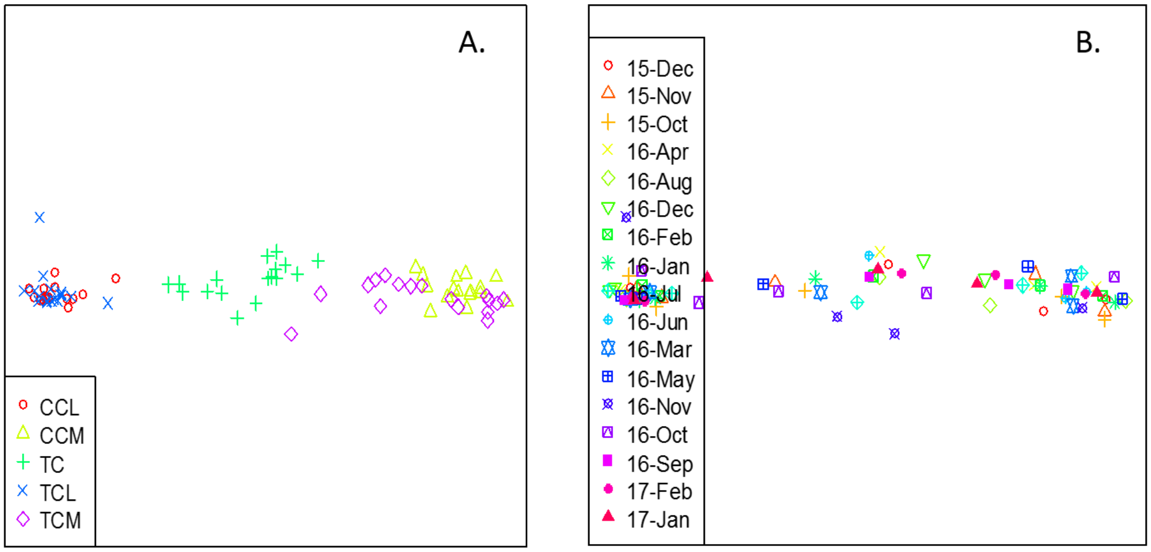

Figure 10. Non-Metric Multidimensional Scaling plots of combined sediment characteristics (% Organic Matter, % Silt-Clay Content, % Water Content) in response to location (A) and month/season (B). Sites include Turkey Creek (TC), Turkey Creek Muck (TCM), the Indian River Lagoon near Turkey Creek (TCL), Crane Creek Muck (CCM), and the Indian River Lagoon near Crane Creek (CCL). The number preceding month designation is the year data were collected. Sediment quality is heavily impacted by location (ANOSIM R = 0.78, p=0.001), but not by time (ANOSIM R = -0.16, p=1). Combined stress value is 0.0068.

Non-Metric Multidimensional Scaling (NMDS) followed by ANOSIM analyses confirms that different areas and stations have distinct sediments (Figure 10A), and these sediments retain those distinctive properties over the months, seasons, and years. Time does not appear to greatly affect sediment characteristics over the duration of this study and in the absence of human intervention (Figure 10B).

Prior to dredging, infaunal organisms from all three major phyla were less diverse in intermediate FGORS sediments and almost zero in confirmed muck sediments relative to the nearby lagoon sites (Table 1 and Figure 11). Muck sites (TCM and CCM) usually supported no species, but occasionally sampling found rare animals (Table 1). Species richness (Figure 12) 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, updated for EMD2, is given in Table 1 (n=12 grabs at each major site monthly throughout the year).

Table 1. Cumulative species list (all species observed at a site during the study period) for all sites in 2016-2017: 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. Total species observed during EMD2 was 63.

TC	TCL	CCL	CCM	TCM
sp. count = 35	*sp*. count = 50	*sp*. count = 59	*sp*. count = 7	*sp*. count = 20
**Acteocina atrata*	**Acteocina atrata*	**Acteocina atrata*	*Ammonia parkinsoniana*	*Acteocina canaliculata*
**Acteocina canaliculata*	**Acteocina canaliculata*	**Acteocina canaliculata*	*Amygdalum papyrium*	*Ammonia parkinsoniana*
**Alitta succinea*	**Alitta succinea*	**Alitta succinea*	Gammarid Amphipod D	*Amygdalum papyrium*
**Ammonia parkinsoniana*	*Ammonia parkinsoniana*	**Ammonia parkinsoniana*	*Haminoea succinea*	*Astyris lunata*
Amygdalum papyrium	**Amygdalum papyrium*	**Amygdalum papyrium*	*Japonactaeon punctostriatus*	*Capitella capitata*
*Annelid J	*Angulus versicolor*	*Angulus versicolor*	Nannastacidae A	*Cerapus* A
Astyris lunata	Annelid I	*Anomalocardia cuneimeris*	Polychaete T	*Ctenodrilus serratus*
**Capitella capitata*	*Anomalocardia cuneimeris*	*Astyris lunata*		*Eusirus cuspidatus*
**Cerapus A*	*Astyris lunata*	**Capitella capitata*		Gammarid Amphipod C
Crepidula atrasolea	**Capitella capitata*	**Cerapus A*		Gammarid Amphipod D
**Ctenodrilus serratus*	**Cerapus* A	Clam C		Gammarid Amphipod F
*Gammarid Amphipod D	Crab B	Crab B		Gammarid Amphipod G
*Gammarid Amphipod F	*Cratena pilata*	**Ctenodrilus serratus*		*Haminoea succinea*
*Gammarid Amphipod G	**Ctenodrilus serratus*	**Cyrtopleura costata*		*Hargeria rapax*
*Gammarid Amphipod I	**Cyrtopleura costata*	*Eulithidium pterocladicum*		*Japonactaeon punctostriatus*
**Glycera americana*	*Diopatra cuprea*	*Eusarsiella zostericola*		*Mulinia lateralis*
Hargeria rapax	*Eurypanopeus depressus*	*Eusirus cuspidatus*		*Odostomia laevigata*
Hypereteone heteropoda	*Eusirus cuspidatus*	feather worm / fungus		*Palaemonetes vulgaris*
Isopod B	feather worm / fungus	*Gammarid Amphipod C		*Parastarte triquetra*
Japonactaeon punctostriatus	Gammarid Amphipod C	*Gammarid Amphipod D		*Pectinaria gouldii*
Leptochelia dubia	*Gammarid Amphipod D	*Gammarid Amphipod F		
**Mulinia lateralis*	Gammarid Amphipod G	Gammarid Amphipod G		
*Nannastacidae A	*Gammarid Amphipod I	Gammarid Amphipod H		

Table 1, Continued

TC	TCL	CCL	CCM	TCM
sp. count=35	*sp*. count = 50	*sp*. count = 59	*sp*. count = 7	*sp*. count = 20
Nassarius vibex	*Glycera americana*	Gammarid Amphipod I		
**Oxyurostylis smithi*	*Haminoea succinea*	**Glycera americana*		
**Palaemonetes vulgaris*	**Hargeria rapax*	**Haminoea succinea*		
Paradiopatra hispanica	**Hypereteone heteropoda*	**Hargeria rapax*		
Parastarte triquetra	Isopod B	**Hypereteone heteropoda*		
Pectinaria gouldii	Isopod C	*Isopod A		
**Peratocytheridea setipunctata*	*Japonactaeon punctostriatus*	Isopod B		
Periglypta listeri	**Mulinia lateralis*	Isopod C		
**Phascolion cryptus*	*Nannastacidae A	**Japonactaeon punctostriatus*		
Polychaete T	*Nassarius vibex*	**Leptochelia dubia*		
Sipuncula B	*Nematode A	*Melongena Corona*		
*Sipuncula C	*Odostomia laevigata*	*Mercenaria mercenaria*		
	**Oxyurostylis smithi*	**Mulinia lateralis*		
	Palaemonetes vulgaris	*Nannastacidae A		
	**Paradiopatra hispanica*	*Nassarius vibex*		
	**Parastarte triquetra*	Nemertea A		
	**Pectinaria gouldii*	*Odostomia laevigata*		
	**Peratocytheridea setipunctata*	**Oxyurostylis smithi*		
	**Periglypta listeri*	*Palaemonetes vulgaris*		
	Phascolion cryptus	**Paradiopatra hispanica*		
	*Polychaete T	**Parastarte triquetra*		
	Polychaete Y	*Pectinaria gouldii*		
	Sipuncula B	**Peratocytheridea setipunctata*		
	Sipuncula C	*Periglypta listeri*		
	Snail P	*Phascolion cryptus*		
	Tanaid A	Pipe Fish A		
	Turbellaria A	Polychaete M		
		Polychaete S		
		Polychaete T		
		*Polychaete Y		
		Shrimp C		
		Sipuncula C		
		*Tanaid A		
		*Tanaid C		
		Turbellaria A		

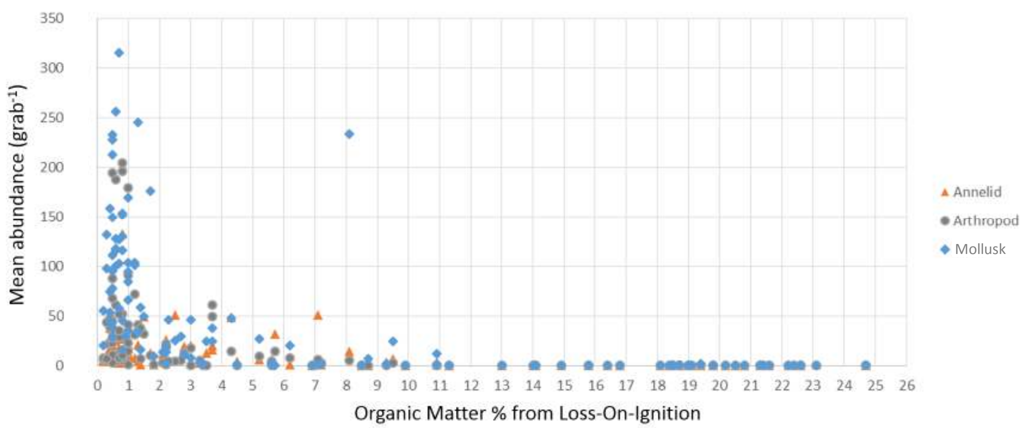

Figure 11. Mean infaunal abundances for annelids, arthropods, and mollusks as a function of sediment % Organic Matter. All phyla generally exhibit a similar inverse logarithmic correlation, with a major transition or threshold in the range of 1-3%. IRL muck as defined as having 10% Organic Matter (Trefry and Trocine 2011).

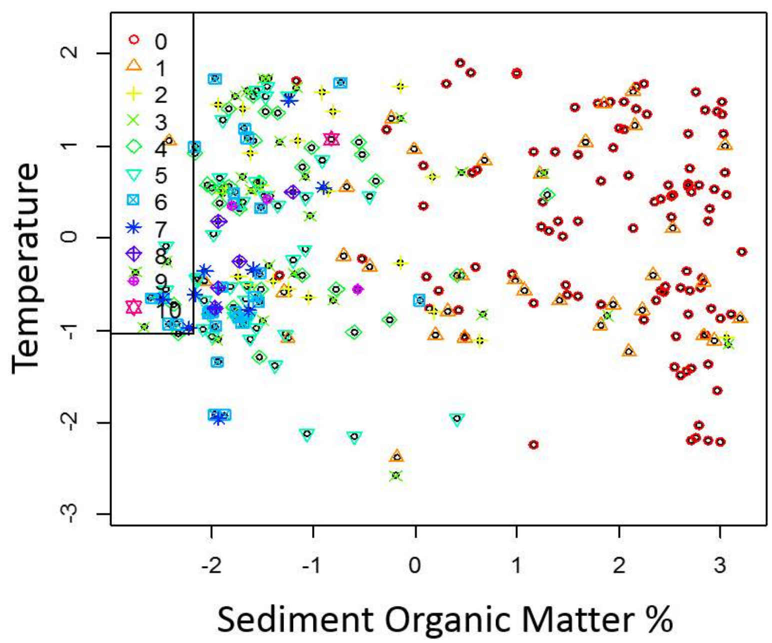

Figure 12. Principle Components Analysis for species richness (0-10, see legend) and environmental parameters. Sediment characteristics, including organic matter, and temperature were the environmental conditions with the greatest impact on species richness. Sites include Turkey Creek, Turkey Creek Muck, the Indian River Lagoon near Turkey Creek, Crane Creek Muck, and the Indian River Lagoon near Crane Creek.

Species richness and diversity showed correlations with sediment characteristics, including organic matter content (Figures 11 and 12) which shows spatial patterns very similar to sediment silt-clay and water content (Figure 9). Inverse logarithmic relationships reveal that low organic content correlates with high diversity and richness (Figure 11). In the annual report for EMD1, this relationship was robustly shown for all FGORS parameters (Figure 14, data plotted in black), which are themselves inter-correlated.

With the completion of dredging in September 2016, we are following the impacts and development of infaunal communities at sites most proximal to (TC) and within the dredging (TC and TCM). TC sites exhibited a pre-baseline community of intermediate biological indicators (species richness, biodiversity, and overall abundance). TC3 and TC4 experienced direct removal of sediments by the dredging process. In the four months of 2017 sampling, biological indicators have all decreased relative to other TC stations, suggesting that these decreases relate to the dredging rather than seasonal changes. This is likely due to the direct removal of animals living in dredged sediments. More time is needed to see if sediment quality at the TC stations experiences a long term improvement in sediment quality due to the dredging. Positive biological responses, if they occur, will also take more time to document.

In contrast, the dredged sites with the highest levels of organic sediments (TCM 1-4) had, with few exceptions, a pre-dredging baseline of no animal life. Since the completion of dredging, TCM sites are exhibiting consistent evidence of infaunal animal communities for the first time. Species richness, overall abundance, and biodiversity are continuing to increase monthly up through the time of this report (Figure 13). We have plotted the post-dredging biological data on the previously established curves to evaluate whether biological measurements are falling in ranges expected based upon the new sediment conditions (Figure 14). Species richness and diversity are on the high side of the inverse curve relationship with sediment organic content, but close to ranges consistent with other locations of like organic content (Figure 14 A and B). Post-dredging abundances are still low and consistent with other locations of like organic content.

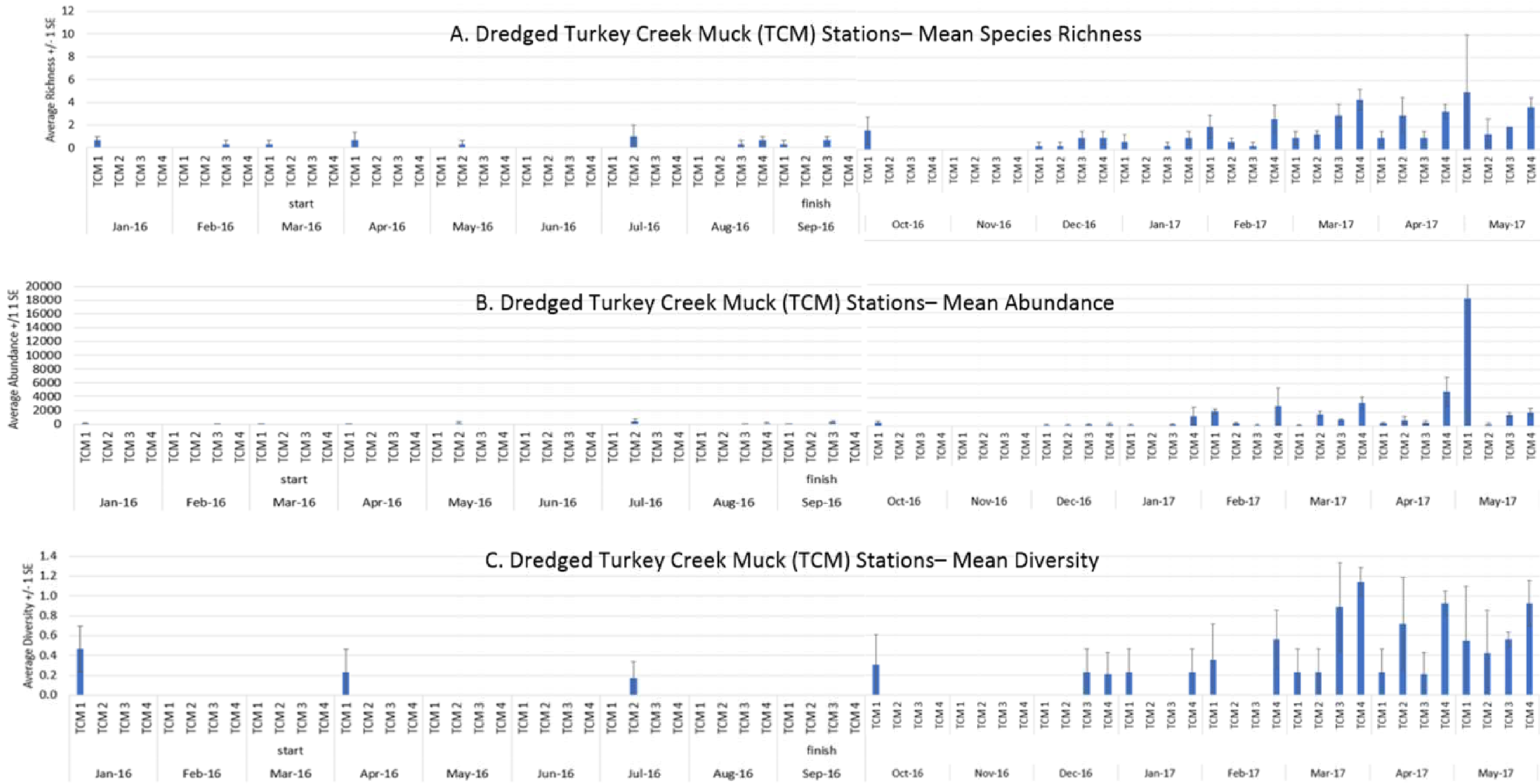

Figure 13. Mean biological responses of infaunal communities in the immediate wake of the completed dredging of muck stations in Turkey Creek's Palm Bay (TCM), largely devoid of animal life before dredging. Biological indicators include species richness (A), general animal abundances (B), and biodiversity (C). Dredging was completed towards the end of 2016 and post-dredging sampling has occurred in January-May 2017. The start (March 2016) and end (September 2016) of dredging are annotated in the figures. Error bars are ±1SE.

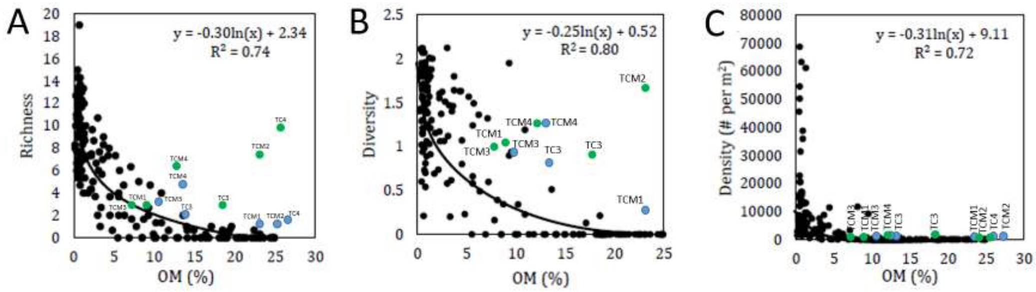

Figure 14. Species richness (A), biodiversity (B), and overall organism density (C) of infaunal communities measured at all study stations. Colored data points indicate stations in Turkey Creek's Palm Bay, either in intermediate (TC) or full muck (TCM) sediments, affected directly by dredging and sampled since dredging was completed. Dredging was completed towards the end of 2016, and these post-dredging samples were collected in March (blue) and April (green) 2017.

Conclusion

Dredging of Turkey Creek's Palm Bay was completed towards the end of 2016. The process removed sediments from stations TC3, TC4, TCM1, TCM2, TCM3, and TCM4. Seagrasses did not occur at any dredged sites prior to dredging, and this is still the case as of June 2017. Seagrass abundances at more distant sites (away from dredging) are low and extremely variable, and often statistically indistinguishable from zero. Seagrass temporal patterns are, however, reasonably consistent with expected seasonal growth and occurrence. Seagrasses colonize relatively slowly, and more time is needed to see how direct or nearby removal of muck sediments impacts seagrasses and their possible establishment in Turkey Creek. We will continue monitoring Turkey Creek and comparison site seagrasses on a quarterly basis during EMD3. Regarding infauna, biological indicators (species richness, diversity, abundance) dropped due to dredging of stations with intermediate organic sediments (TC3 and TC4), but these same indicators improved for the channel sites where sediments met the literature definition of IRL muck (TCM 1-4). As of the writing of this report, the affected dredging areas are early in their recovery period, and sediments and associated infaunal communities may still be adjusting to the dredging. We will continue monitoring Turkey Creek's infauna quarterly during EMD3.

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