Impacts of Environmental Muck Dredging 2016-2017 (Year 2 – EMD2)

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

Final Project Report to Brevard County Natural Resources Management Department

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Final Report: EMD2 Biological Responses to Muck Dredging in the Indian River Lagoon: Fish Monitoring Surveys and Seagrass Transplanting Surveys (Subtask 3)

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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.

Introduction

The accumulation of thick layers of fine grained organic rich sediments ("muck") across many habitats of the Indian River Lagoon (IRL) is considered to be a major driving factor in the declining health of the lagoon (Brevard County FL, 2017). Muck is initially derived from land runoff and nutrient input, and can directly cover many portions of the IRL. Resuspension of muck increases turbidity that blocks light needed by submerged aquatic vegetation. Decay of nutrient-rich muck feeds algae blooms, contributing to the loss of over 40,000 acres of seagrass in the IRL, reductions of water quality, and the production and deposition of additional biomass into muck sediments. Removal of this muck by dredging is considered to be a potential way to greatly reduce negative influences on the environment. Accordingly, Brevard County initiated a program to remove the muck from one lagoon region: the mouth of Turkey Creek (Brevard County FL, 2017). A comprehensive 3-year hydrological, geochemical and biological assessment of the impacts of muck removal is being performed. The results of these studies will assist in the design and operation of other muck-removal programs in the IRL.

As part of the comprehensive study, we are monitoring the populations of juvenile fishes and their feeding habits, as well as their associations with environmental conditions (including river discharge rates, temperature and salinity) within and around muck removal sites in the Indian River Lagoon. These data, collected before, during and for the first few months after the dredging occurred, will begin to help us evaluate whether muck removal has positive, negative or no effects on local fish populations. Completion of the last year of study (presently underway), and further comparison with fish populations in the broader IRL, will provide a more thorough analysis of whether and possibly how fish populations and their prey responded to removal of muck from the mouth of Turkey Creek.

Objectives – Year 2

- Assess the temporal and spatial distributions of juvenile fishes around the periphery of the dredged habitats, contrasted with sites outside Turkey Creek.
- Assess the feeding habitats of demersal juvenile fishes at the study sites for comparison with the composition of the benthic prey base before and after dredging
- Initiate a seagrass transplanting experiment to determine if seagrasses can survive in the post-dredged Turkey Creek habitat.

Fish Distributions and Feeding Habits

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

In the 1990s, the State of Florida began a very intensive survey of juvenile fishes throughout the IRL and many other estuarine habitats around Florida. The Fisheries Independent Monitoring Program (FIM) developed standardized sampling protocols that are utilized in a broad sampling program through the IRL and other targeted estuaries (FWCC 2014a). Data collected by this ongoing 25-year-long fisheries survey can be used to identify natural variations in juvenile abundance and distribution, and to assess potential anthropogenic impacts on fish populations (e.g., Tremain and Adams 1995; Paperno and Mille 2001; Paperno et al. 2006).

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

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

Approach

All fish monitoring was conducted within the mouth of Turkey Creek, east of the US 1 bridge. This region was the focus of most of the dredging activity, and provided the only areas adjacent to the dredging that could be sampled by seine net. In addition, fish monitoring was conducted in the Indian River Lagoon just north of the mouth of Turkey Creek for comparison with the sampling adjacent to the dredging activity.

Sampling Sites and Methods

Fish samples have been collected monthly from April 2015 through July 2017, with continued sampling planned through July 2018. Samples were collected from a series of 4 sites along the western shore of Turkey Creek (F-W in Figure 1), 4 sites along the north shore of Turkey Creek (F-N), and 2 sites outside the mouth of Turkey Creek (F-O). All sampling was done following standardized FIM seining protocols (FWCC 2014a). Fishes were collected with a 21.3-m long center bag seine x 1.8 m deep, and constructed of 3.2-mm knotless nylon Delta mesh. A 15.5-m rope was tied to the towing poles at each end of the seine, and 9 m-long ropes were attached to poles placed in the sediment at the beginning of each tow.

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

Figure 1. Primary fish sampling sites along the western shore of Turkey Creek (F-W; 4 monthly samples), north shore of Turkey Creek (F-N; 4 monthly samples) and outside of the mouth of Turkey Creek (F-O; 2 monthly samples).

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

Data analysis began by converting abundance data to density data (number of fish/100 m^2). Monthly mean densities were then calculated for inside Turkey Creek (generally 8 samples) and outside Turkey Creek (2 samples). Although this report focuses on data collected in 2016, some of the data from 2015 and some of the initial 2017 data are presented to help illustrate patterns or exceptions from anticipated patterns in seasonal data. Species-specific analyses examined patterns of seasonality within the region. Significant seasonal and interannual variability was observed for each of the dominant taxa of demersal juvenile fishes.

It is beyond the scope of this project to assess whether that interannual variability was due solely to responses to dredging activities that occurred during much of 2016, or due to variability in recruitment levels within the broader Indian River Lagoon. However, for an initial examination of this interannual variability, fish population data from Turkey Creek samples collected from April 2015 to December 2016 were compared to data collected from 2010 to 2016 by the FIM program in portions of the Indian River Lagoon (FWCC 2010, 2011, 2012, 2013, 2014b, 2015, 2016).

To assess the feeding habits of juvenile demersal fishes, frozen samples were thawed and stomachs were removed. Contents were rated on a 4-level scale of digestion (0 = completely unidentifiable to 3 = identifiable to species). Prey removed from each stomach were identified to the lowest feasible taxonomic level, and counted. Identifications of invertebrate taxa were conducted using the photographic atlas of benthic species collected from the Turkey Creek region that was produced by the research team studying the benthic fauna (K. Johnson, Florida Institute of Technology, pers. comm.)

Analysis of the stomach contents data were based on Frequency of Occurrence (%FO) of a prey taxon in fishes that contained at least one identifiable prey item in their stomachs. Analysis of stomach contents of larger fish often utilize %FO with proportional numbers and weights of prey in each stomach to calculate an Index of Relative Importance (IRI) for each prey taxon. Because most of these juveniles had only 1 or 2 prey items in their stomachs, and the small size of the digesting prey precluded accurate weight measurements, we used %FO, rather than IRI, to evaluate prey consumption

Quality Assurance and Quality Control

Personnel and equipment – To ensure consistency of approach, execution, and interpretation, the primary research personnel have worked on this project since its inception. Dr. Jon Shenker is the Principal Investigator, supervising all field work, data analysis, report writing and administrative duties. James King (M.S. 2015, Florida Institute of Technology) has been in charge of daily operations, including scheduling, directing all field operations, confirming identifications, supervising analysis of stomach contents, data recording and entry, and initial phases of data analyses. Graduate students Anthony Cianciotto, Jake Rennert and Molly Wightman and a team of undergraduates assisted with field sampling and stomach content analysis.

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

Fish identifications were conducted in the field by at least three trained personnel, who all had to agree with the species identification. If unanimity of identification was not achieved, representative specimens were examined in the field and the laboratory using published field guides (Lippson and

Moran 1974; Ray and Robins 1999; Hoese and Moore 2008). All data were recorded and checked in the field on waterproof data sheets.

Water quality – Salinity and temperature data were collected at the surface and near the bottom of the seine sampling sites with a YSI EcoSense EC 300A conductivity meter. The meter was calibrated with YSI conductivity standards prior to use.

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

Results and Discussion

A total of 1,959,661 fishes from 67 taxa were collected from April 2015 through May 2017 (Table 1). Fish and macroinvertebrate catch data from 2015 were presented in the Year 1 Final Report (Johnson and Shenker 2016), while 2016 and early 2017 fish data are presented in Tables 2 and 3, below. Abundance data on the macroinvertebrate taxa collected in the seine samples in 2016 and 2017 are provided in Tables 4 and 5.

Table 1. Total number of fishes captured each year by seine net at 8 stations within Turkey Creek and 2 stations in the adjacent Indian River Lagoon.

Year	Duration	Total Number of Fishes	Number of Fishes Minus Anchovies	Total Number of Taxa
2015	April – December	129,873	10,110	56
2016	January – December	1,732,958	44,916	49
2017	January – May	96,848	12,026	37
2015-2017	26 months	1,959,679	67,052	67

The adult fishes that utilize the Turkey Creek habitats are not vulnerable to capture using the FIM juvenile fish sampling techniques, and are thus not represented in our data. Interviews with anglers fishing in Turkey Creek, and our personal experiences, have identified a number of adult fishery species, including sheepshead and snook (around dock and bridge pilings), jacks and red drum (highly mobile schooling species), tarpon and (juvenile) bull sharks (generally solitary mobile predators). The mobile predators tend to follow schools of prey, including anchovies, mullet, and herrings, so their utilization of the Turkey Creek habitats can be highly variable. In the months following the completion of dredging in fall 2017, anglers were frequently seen fishing along the western edge of the Turkey Creek habitat, casting their baits or lures into the deeper water that now extends close to the shoreline. Our conversations with these anglers, to date, indicate they're catching jacks, tarpon and juvenile bull sharks from the shore.

The fishes captured in the seine net throughout the entire study period were dominated by small pelagic schooling species. Pelagic anchovies (*Anchoa* spp.) comprised 92.2 - 96.9% of each year's total seine catch, indicative of the numerical dominance of these fishes within the IRL ecosystem. On one occasion in June 2016, a massive school of anchovies spanned the entire shoreline around the near-shore site outside the mouth of Turkey Creek. The estimate of the anchovy abundance in a single seine haul made at this area was nearly 1,600,000 fish, but few were taken at any of the other stations sampled on that date. This single dense sample contained over 88% of all fishes collected during the entire 25 month survey.

The non-anchovy component of the fish catch was dominated by pelagic and demersal juvenile fishes. Pelagic herrings (Clupeidae) comprised 30% of the non-anchovy catch in 2016, while white and striped mullets (*Mugil* spp.), comprised 9.8 and 2.1% of the non-anchovy catch, respectively. The most abundant demersal juveniles were juvenile mojarras (*Eucinostomus* spp. and *Diapterus* spp.), which contributed 17.5 and 2.1% of the non-anchovy catch, and juveniles of the important fisheries family Sciaenidae (including Atlantic croaker, silver perch, red drum, spot, sea trout and kingfish), which comprised from 15.5 to 0.6% of the non-anchovy catch.

Macroinvertebrates captured in the seine net included juvenile blue crabs and Penaeid shrimp. Abundance of both of these taxa was relatively high in the spring of 2016, but much lower in fall 2016 and spring 2017 (Tables 4 and 5).

The demersal juvenile fishes were the most likely fishes that could potentially be impacted by changes to the benthic ecosystem in Turkey Creek. The two dominant mojarra taxa and five species of juvenile drums were selected for analysis. Three lines of evidence were considered for each taxon: 1) short-term temporal and spatial distribution patterns of individual species; 2) broader interannual variability in population size that influences the abundance of taxa in the study area; and 3) trophic interactions between juvenile fishes and benthic or epibenthic prey that might be affected by muck removal.

1) The first factor to consider was the relative distribution of juvenile distributions among the stations inside and outside Turkey Creek during pre-dredging (2015 and early 2016), dredging (mid-2016) and post-dredging (after September 2016) periods. Simple comparisons among sites and time periods, however, were significantly hindered by biological and environmental variability. Different fish species have different seasonal patterns of reproduction and recruitment. In addition, fish communities may respond to highly variable environmental conditions and water quality, including seasonal temperature cycles and rapid changes in salinities driven by major storm events and freshwater discharges. For example, a single major water discharge event occurred in 2015 and five larger events (including Hurricane Matthew) occurred in 2016 (Figure 2 a, b c). These elevated discharges resulted in temporary declines in salinity in the mouth of Turkey Creek to near zero for periods of time ranging from a few days to several weeks or more. The very dry late winter and spring of 2017 did not cause major changes in salinity in the study region, but a week of very strong southerly/southwesterly winds in March drove huge quantities of drift algae onto the northern portion of the bay (region F-N in Figure 1). This stranding of drift algae extended from the shoreline to 50 m into the bay, and filled the water column to a depth of a meter or more. Similar strandings were reported along the shoreline elsewhere in Brevard County, triggering numerous requests from

citizens to governmental agencies to clean up the decaying algae. We were not able to collect fish samples from areas covered with dense algal mats, but the lack of open water and the presumably low dissolved oxygen levels associated with the decaying biomass undoubtedly reduced the suitability of this region as habitat for mobile demersal juvenile fishes that month.

2) A second factor to consider in the evaluation of trends in fish abundance was interannual variability in the magnitude of fish recruitment within the Indian River Lagoon. Significant interannual variability in the success of reproduction and recruitment is characteristic of the populations of most estuarine and coastal fishes, and that variability sets the baseline upon which locally-driven changes are superimposed. Assessing interannual variation in abundance of fishes is a primary goal of the Fisheries Independent Monitoring Program (FIM). These intensive fish surveys have been conducted in many of Florida's estuaries for decades. FIM sampling within the Indian River Lagoon enabled a comparison of the Turkey Creek data to the broader fish populations within the lagoon ecosystem. Because FIM covers the entire northern Indian River Lagoon, sampling across broad sections of the ecosystem (Zones A, B, C, D, E and H in Figure 3) were used to calculate mean density data that were used as indices of fish recruitment and abundance in those sectors for each year.

FIM annual reports present the mean density data for taxa collected by seine net across all open-water habitats in the northern lagoon. Data for the two major tributaries into the lagoon (Turkey Creek and the St. Sebastian River) were summarized separately from the open-water habitats. Prior to 2013, Turkey Creek samples were separated from the Sebastian River for analysis as Zone O for Turkey Creek and Zone F for Sebastian River. Beginning in 2013, Turkey Creek samples and St. Sebastian River samples were pooled into the "river samples" category (Zone F in Figure 3). Sampling effort within these river systems covered all habitats from the mouth to the headwaters, and was thus not directly equivalent to our efforts in the dredged habitat within the mouth of Turkey Creek. The use of random stratified sampling protocols to select sampling sites across the entire lagoon hindered direct analysis of small portions of the habitat: from 1991 to 2014, only 30 seine net samples were taken inside and adjacent to the mouth of Turkey Creek (Figure 4).

For each taxon being analyzed, we present a time series of mean (+/- S.E.) annual density data for our sampling at the 8 sites within Turkey Creek and the 2 sites adjacent to the mouth of Turkey Creek for the 2015 and 2016 sampling years, and the January-May data for 2017. A longer time series (2010 to 2016) is presented for mean annual density from the FIM program for "bay" (Zones A, B, C, D, E, H) and "river" (Zone O prior to 2013, and Zone F beginning in 2013) habitats.

Table 2. Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL in 2016.

FISH														
Scientific Name	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**TOTAL**
Anchoa spp.	Anchovies	3,202	1,008	1,493	30,941	1,646	1,613,637	0	3	21,130	1,229	9,488	4,265	**1,688,042**
Clupeidae spp.	Herrings	0	247	11,266	905	108	595	114	0	183	0	0	4	**13,422**
Eucinostomus spp.	Mojarras	54	151	120	69	273	903	1,565	879	284	133	971	2,547	**7,949**
Micropogonias undulatus	Atlantic croaker	0	6,424	285	186	0	0	33	0	0	0	17	8	**6,953**
Mugil curema	White mullet	995	1,792	78	3	915	504	15	0	0	52	19	14	**4,387**
Sciaenidae spp.	Drums/croakers	0	0	2,550	487	0	0	0	0	0	23	0	0	**3,060**
Brevoortia spp.	Menhaden	15	11	1,085	1,854	0	3	4	1	1	0	0	0	**2,974**
Bairdiella chrysoura	Silver perch	5	229	302	1,001	100	0	0	0	3	1	1	0	**1,642**
Diapterus spp.	Irish pompano/mojarra	17	70	73	28	49	54	362	155	263	26	21	3	**1,121**
Mugil cephalus	Striped mullet	5	7	6	0	0	0	0	0	0	0	61	850	**929**
Menticirrhus spp.	Kingfishes	0	0	7	14	413	49	10	0	4	58	31	0	**586**
Sciaenops ocellatus	Red drum	193	1	7	17	93	0	0	0	0	1	186	36	**534**
Menidia spp.	Silversides	42	4	66	1	84	135	0	5	30	25	1	8	**401**
Cynoscion spp.	Sea trout	3	0	1	0	0	8	256	3	8	0	0	0	**279**
Gobiosoma bosc	Naked goby	1	0	6	19	0	2	1	0	0	10	29	76	**144**
Gobiosoma robustum	Code goby	0	0	0	0	0	0	0	0	4	0	75	0	**79**
Leiostomus xanthurus	Spot	0	0	0	0	68	0	0	0	0	0	0	0	**68**
Oligoplites saurus	Leatherjacket	0	0	1	5	0	12	4	3	9	21	4	0	**59**
Gobiidae spp.	Gobies	0	1	0	19	0	2	0	0	0	11	18	0	**51**
Trinectes maculatus	Hogchoker	1	0	5	19	1	11	0	0	7	0	0	5	**49**
Harengula spp.	Pilchards/sardines	22	0	0	0	0	0	0	0	0	7	1	0	**30**
Lagodon rhomboides	Pinfish	0	10	9	2	1	0	0	0	0	0	0	3	**25**
Opisthonema oglinum	Atlantic thread herring	0	0	0	0	0	0	0	23	0	0	0	0	**23**
Ariopsis felis	Hardhead catfish	2	0	4	0	1	8	0	2	5	0	0	0	**22**
Paralichthys spp.	Flounders	0	0	0	0	3	15	0	0	0	0	0	0	**18**
Micropterus salmoides	Largemouth bass	0	0	0	6	9	0	0	1	0	0	0	0	**16**
Archosargus probatocephalus	Sheepshead	2	1	2	1	2	4	1	2	0	0	0	0	**15**

Table 2 (continued). Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL in 2016

FISH														
Scientific Name	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**TOTAL**
Microgobius gulosus	Clown goby	0	0	1	0	0	0	0	0	1	1	12	0	**15**
Strongylura spp.	Needlefishes	3	0	0	0	3	5	1	0	2	1	0	0	**15**
Gerres cinereus	Yellowfin mojarra	2	0	0	0	1	0	0	5	0	0	0	0	**8**
Elops saurus	Ladyfish	0	1	1	0	0	1	0	0	0	4	0	0	**7**
Triglidae spp.	Searobins	0	5	1	1	0	0	0	0	0	0	0	0	**7**
Dasyatis sabina	Atlantic stingray	0	2	2	0	1	0	0	0	1	0	0	0	**6**
Achirus lineatus	Lined sole	0	0	0	0	0	0	0	4	0	0	0	0	**4**
Centropomus spp.	Snooks	0	0	0	0	1	1	0	0	0	1	0	0	**3**
Caranx hippos	Crevalle jack	0	0	2	0	0	0	0	0	0	0	0	0	**2**
Bagre marinus	Gafftopsail catfish	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Bathygobius spp.	Frillfiin gobies	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Carangidae spp.	Jacks	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Chaetodipterus faber	Atlantic spadefish	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Chasmodes saburrae	Florida blenny	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Citharichthys spilopterus	Bay whiff	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Fundulus spp.	Killifish	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Gobionellus oceanicus	Highfin goby	0	1	0	0	0	0	0	0	0	0	0	0	**1**
Gymnura spp.	Butterfly rays	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Hypleurochilus pseudoaequipinnis	Oyster blenny	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Lutjanus griseus	Gray snapper	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Oreochromis spp.	Blue tilapias	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Pogonias cromis	Black drum	1	0	0	0	0	0	0	0	0	0	0	0	**1**
	TOTAL	4,565	9,965	17,373	35,579	3,772	1,615,950	2,366	1,090	21,936	1,606	10,937	7,819	1,732,958
	Total minus anchovies	1,363	8,957	15,880	4,638	2,126	2,313	2,366	1,087	806	377	1,449	3,554	44,916

Table 3. Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL in January – May 2017.

FISH							
Scientific Name	Common Name	Jan	Feb	Mar	Apr	May	**TOTAL**
Anchoa spp.	Anchovies	2,091	6,579	22,501	37,125	16,527	**84,823**
Eucinostomus spp.	Mojarras	2,149	954	3,004	828	1,206	**8,141**
Diapterus spp.	Irish pompano/mojarra	1,678	27	2	0	0	**1,707**
Clupeidae spp.	Herrings	1	609	8	9	69	**696**
Bairdiella chrysoura	Silver perch	0	0	62	27	300	**389**
Mugil curema	White mullet	146	153	56	2	0	**357**
Leiostomus xanthurus	Spot	0	231	0	0	0	**231**
Gobiosoma robustum	Code goby	0	10	16	1	182	**209**
Sciaenops ocellatus	Red Drum	14	100	0	8	0	**122**
Sciaenidae spp.	Drums	5	4	0	25	0	**34**
Menidia spp.	Silversides	0	2	16	0	0	**18**
Archosargus probatocephalus	Sheepshead	0	1	4	1	9	**15**
Syngnathus scovelli	Gulf pipefish	0	0	0	0	12	**12**
Gobiosoma bosc	Naked goby	5	0	4	2	0	**11**
Ariopsis felis	Hardhead catfish	0	0	2	0	9	**11**
Paralichthys spp.	Flounders	0	0	4	5	0	**9**
Chasmodes saburrae	Florida blenny	0	3	1	0	5	**9**
Menticirrhus spp.	Kingfishes	0	0	0	0	6	**6**
Cynoscion spp.	Sea trout	0	1	3	0	1	**5**
Dasyatis sabina	Atlantic stingray	0	0	0	1	4	**5**
Centropomus spp.	Snooks	0	0	1	2	1	**4**
Sphyraena barracuda	Barracuda	0	0	0	0	4	**4**
Brevoortia spp.	Menhaden	0	3	0	0	0	**3**
Gerres cinereus	Yellowfin mojarra	0	3	0	0	0	**3**
Microgobius gulosus	Clown goby	0	1	0	2	0	**3**
Micropogonias undulatus	Atlantic croaker	0	0	3	0	0	**3**
Strongylura spp.	Needlefish	1	0	0	0	2	**3**
Hyporhamphus unifasciatus	Common halfbeak	0	0	0	0	3	**3**
Dasyatis americana	Southern stingray	0	0	0	1	1	**2**
Sphoeroides testudineus	Checkered puffer	0	0	0	0	2	**2**

Table 3 (continued). Total catch of fishes collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL in January – May 2017.

FISH Scientific Name	Common Name	Jan	Feb	Mar	Apr	May	TOTAL
Albula sp.	Bonefish	0	0	0	0	2	**2**
Trinectes maculatus	Hogchoker	0	0	0	0	2	**2**
Mugil cephalus	Striped mullet	0	0	0	1	0	**1**
Achirus lineatus	Lined sole	0	0	0	0	1	**1**
Hypleurochilus pseudoaequipinnis	Oyster blenny	0	0	0	0	1	**1**
Lutjanus griseus	Grey snapper	0	0	0	0	1	**1**
Oligoplites saurus	Leatherjacket	0	0	0	0	1	**1**
	TOTAL	**6,090**	**8,681**	**25,687**	**38,040**	**18,351**	**96,849**
	Total minus Anchovies	**3,999**	**2,102**	**3,186**	**915**	**1,824**	**12,026**

Table 4. Total catch of macroinvertebrates collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL in 2016.

INVERTEBRATES Scientific Name	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Callinectes sapidus	Blue Crab	0	4	14	13	16	12	1	4	6	0	0	2	**73**
Penaeidae spp.	Shrimp	32	35	178	11	2	9	0	0	2	4	0	0	**273**
	TOTAL	**32**	**39**	**192**	**24**	**18**	**22**	**1**	**4**	**8**	**4**	**0**	**2**	**346**

Table 5. Total catch of macroinvertebrates collected by seine net from stations inside and adjacent to the mouth of Turkey Creek, FL in January to May 2017.

INVERTEBRATES Scientific Name	Common Name	Jan	Feb	Mar	Apr	May	TOTAL
Callinectes sapidus	Blue Crab	2	0	5	2	4	**13**
Penaeidae spp.	Shrimp	0	0	4	1	2	**7**
	TOTAL	**2**	**0**	**9**	**3**	**6**	**20**

a)

b)

c)

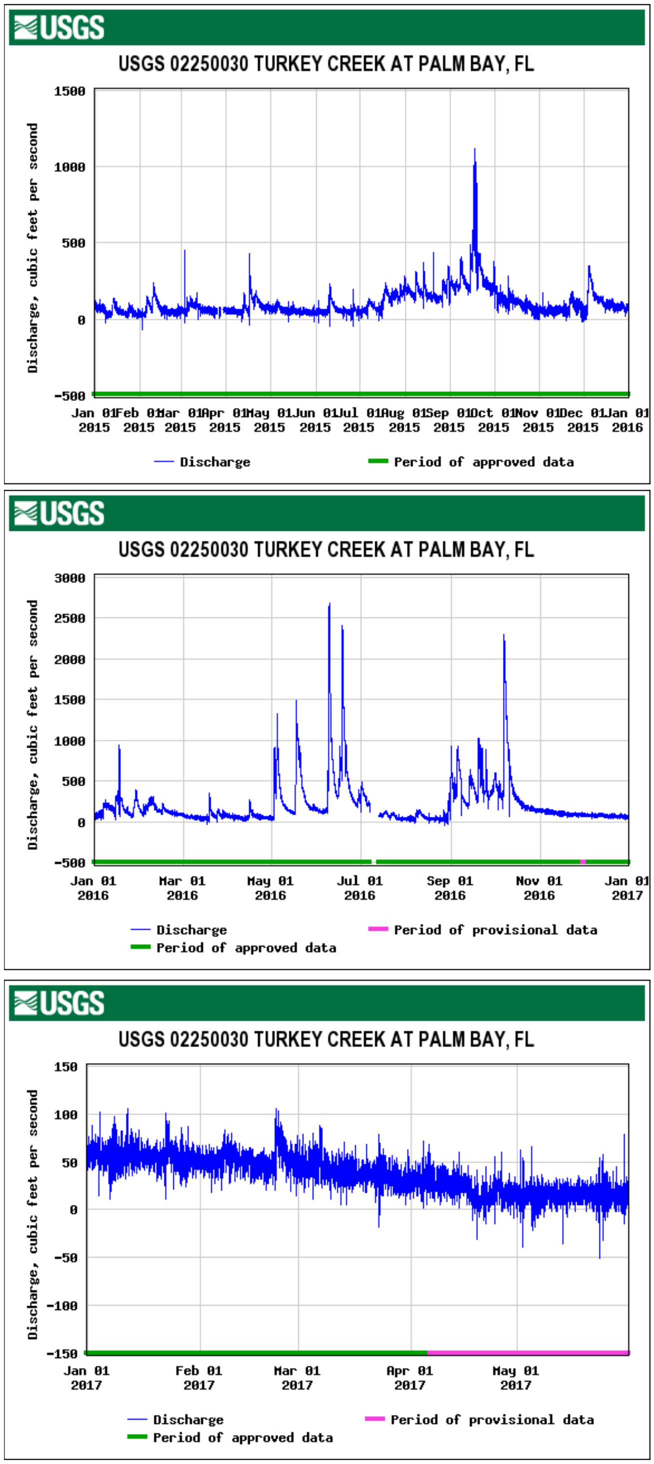

Figure 2 a, b, c. Water discharge rates into Turkey Creek, as measured by USGS Gage Station 02250030 for a) 2015; b) 2016; c) January – May 2017 (USGS 2017).

Figure 3. Sampling zones of the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program for calculation of annual density data of fishes in the northern Indian River Lagoon (FWCC 2014). Mean density data from 22 m seine net samples are calculated separately for "bay" (open lagoon) habitats in zones A, B, C, D, E and H, and for "river" habitats (Turkey Creek and St. Sebastian River) in zone F.

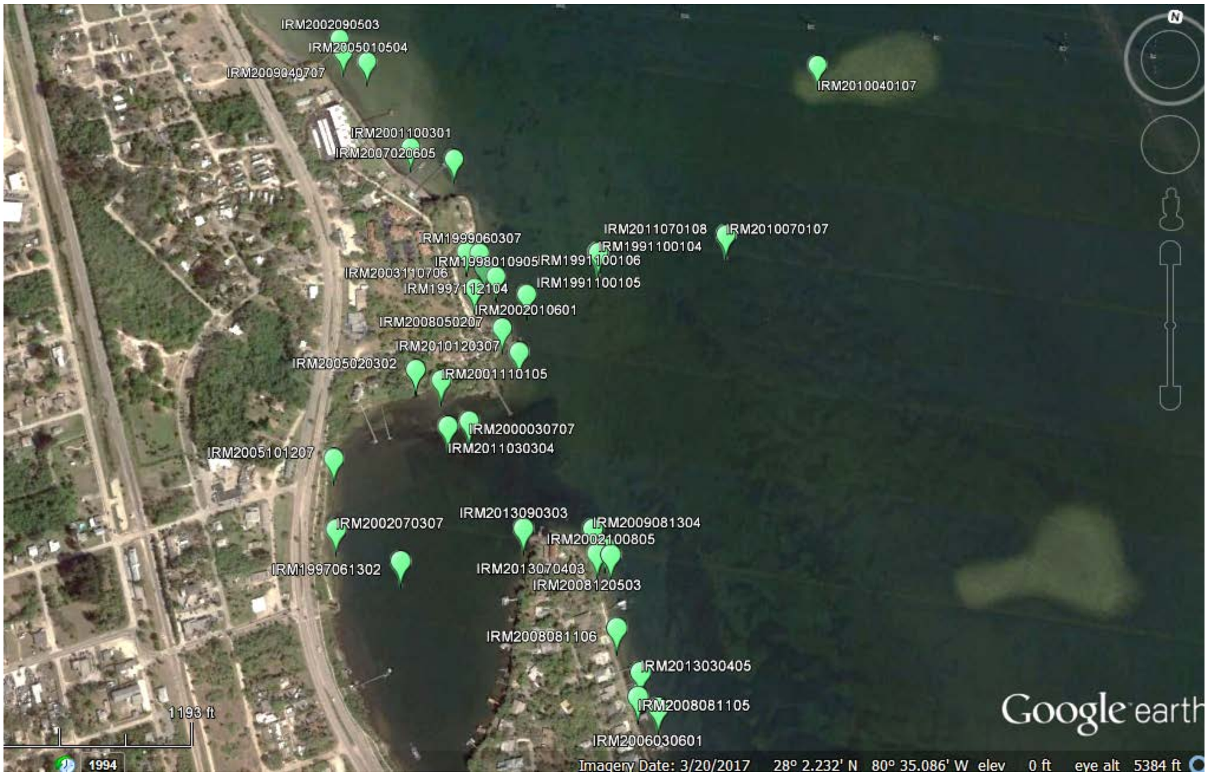

Figure 4. Location of 22 m seine net sampling sites of the Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program in and around the mouth of Turkey Creek from 1999 to 2014 (FWCC FIM data base).

During our first year of sampling (2015), prior to the commencement of dredging, we found the mojarras were seasonally abundant and generally broadly distributed within Turkey Creek and the adjacent IRL sites (Johnson and Shenker 2016). The smallest juveniles of some of the drum taxa (red drum and silver perch) were sporadically abundant inside Turkey Creek, but FIM sampling found larger juveniles in adjacent areas of the IRL. A broader community-level comparison of our data indicated that the fish fauna inside the mouth of Turkey Creek was somewhat different from that of nearshore habitats in the IRL north and south of Turkey Creek (Johnson and Shenker 2016). The data suggest that microhabitats within the IRL have may different roles in the life histories of different fish species.

For the 2018 final report on this project, we will attempt to comprehensively define the spatial distributions and ontogenetic habitat shifts of dominant fish taxa, and overall community composition of demersal fishes in these microhabitats. We will filter the FIM data set (including the 2017 data, if they are approved for release by mid-2018) to select data from geomorphologically-similar habitats around the mouth of Turkey Creek, St. Sebastian River, Crane Creek, Goat Creek and other tributaries for more detailed comparisons of habitats and assessments of interannual variability across the region. Habitats will be assessed using abiotic and biotic environmental variables such as salinity gradients and abundance of benthic substrata such as seagrass, oyster shell or other structures. A 10-year time series of FIM environmental and fish data will be utilized to evaluate inter-annual variability of selected taxa in and around the mouths of these tributaries in the northern IRL. The long-term measures of annual and seasonal distribution and abundance patterns will thus provide strong baselines for comparison to the fish populations in Turkey Creek before and after dredging.

3) The third way to assess potential impact of muck removal on fish utilization of a habitat focuses more at the mechanisms of how the fish utilize the habitat than the analysis of population sizes and distributions. Removing muck through dredging generally deepens the habitat beyond the depth where seine samples can be collected that are comparable with those collected around the periphery of the dredge site. Visual surveys in these deeper sites are also not generally feasible in the turbid waters of the Indian River Lagoon. However, analysis of feeding habits of the fishes, and the distribution of their prey, can provide important information about how the populations may be able to respond to muck removal. If the prey base expands in area and in overall abundance following environmental restoration, the habitat may be able to support larger populations of fish over larger areas of the benthic environment.

We have thus been examining the stomach contents of representative subsamples of demersal fishes collected throughout the seining program. Although analysis of these samples is not yet complete, data on the feeding habits of these taxa are presented below. The research team studying the benthic fauna is beginning an analysis of benthic infauna data collected in and around the mouth of Turkey Creek to define species-specific distribution patterns in and around the mouth of Turkey Creek before, during and after dredging (K. Johnson, Florida Institute of Technology, pers. comm.). Comparisons of fish feeding habits with benthic prey distributions will be conducted in the third year of this program. The prey data will be incorporated into the analysis of microhabitat use described above, and will further help evaluate the response of fishes to muck removal from the Turkey Creek habitat.

<u>Mojarras</u>: Two groups of juvenile mojarras were the most abundant of the demersal species found in Turkey Creek habitats, and were widely dispersed among all the sampling regions. Small juvenile *Eucinostomus* spp. and *Diapterus* spp. are difficult to identify to species, so the fishes were generally identified to the genus level. *Eucinostomus* spp. was the third most abundant taxon collected in 2016, and was the most abundant of the demersal fishes. *Diapterus* ranked ninth in abundance in 2016. Adult *Eucinostomus* and *Diapterus* species range from 150-350 mm SL, and are presumed to spawn in offshore or inlet habitats (Kerschner et al. 1985).

Eucinostomus spp.: The occurrence of juvenile *Eucinostomus* spp. throughout the study was composed of fishes ranging from 15-90 mm SL. The collection of small juveniles during most months suggests a protracted spawning season for these fishes.

Collections made in 2015 indicated a strong seasonal pattern in the abundance of these mojarras. Incorporation of the 2016 and early 2017 data into a seasonal analysis provides a more complicated pattern than seen during the first year. Pooling the monthly density data for samples collected over the first full two years of the survey enables assessment of these seasonal patterns. In Figure 5, April 2015 to March 2016 are presented as “Year 1,” and April 2016 to March 2017 are presented as “Year 2.” Year 1 can be considered as the pre-dredging period. The first 6 months of Year 2 include the months when dredge activity occurred within Turkey Creek (including a mid-summer hiatus in dredging due to manatee conservation requirements), and the last 6 months of Year 2 are the beginning of the post-dredging period.

Data in Figure 5 are presented as mean (+/- S.E.) density (number of fish/100 m^2) in each month for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

Several patterns within the monthly density data are apparent:

1) Densities of *Eucinostomus* spp. juveniles are much higher in Year 2 than in Year 1. Only one month in Year 1 (July 2015) had a mean density reaching 100 fish/100m^2, while 6 months in Year 2 had higher mean densities, with a peak of nearly 400 fish/100m^2 in February 2017.
2) Fish in Year 1 were most abundant in late spring and summer, with highest densities in the IRL stations, and very sparse during the fall and winter. In June-August of Year 2 (primarily coincident with the dredging hiatus) of Year 2, the IRL stations again held the highest densities of fish. Juveniles remained sparse through September and October.
3) A second, and denser pulse of *Eucinostomus* spp. juveniles were recorded in the Turkey Creek habitat beginning in November 2016, and remained through March 2017. This second pulse was not observed in Year 1. The March 2017 fish were concentrated in the stations along the western shore of Turkey Creek (Site F-W in Figure 1); this was the month when dense *Gracillaria* prevented sampling along the northern shore of the creek.

The interannual variability in density exhibited between the 2 years of sampling could be influenced by interannual variability in reproduction and recruitment of *Eucinostomus* spp. across the IRL. Comparison of our Turkey Creek/IRL data with the larger FIM data set illustrate the longer term temporal and spatial trends on populations of these juveniles (Figure 6). FIM data for each year from 2010 to 2016 were compiled into annual mean (+/- SE) density data for dominant taxa within the open “bay” IRL habitats and “river” habitats (FWCC 2010, 2011, 2012, 2013, 2014b, 2015, 2016).

The FIM data indicated that the mean densities of juvenile *Eucinostomus* spp. populations were far denser in the riverine tributaries (annual densities ranged between 72 - 214 fish/100m^2) than in the open habitats of the IRL (below 5 to 26 fish/100 m^2) from 2010 to 2016. Interannual variability over this 7-year period in the riverine tributaries reached 300%. Comparison of the summary 2015 and 2016 FIM data (FWCC 2015, 2016), and the data collected by this program, indicated annual mean density of juvenile *Eucinostomus* spp. in the mouth of Turkey Creek and the adjacent IRL samples were higher than the FIM "bay" densities and lower than the FIM "river" densities. It is important to remember that the FIM samples were collected across a wider range of habitats throughout Turkey Creek and the St. Sebastian River, and were not geographically restricted to the mouth of Turkey Creek, as in this study. The initial sampling performed in early 2017 indicated a large population of juveniles adjacent to the muck removal area, and it will be interesting to determine if this population persists and reflects a year with a high level of recruitment.

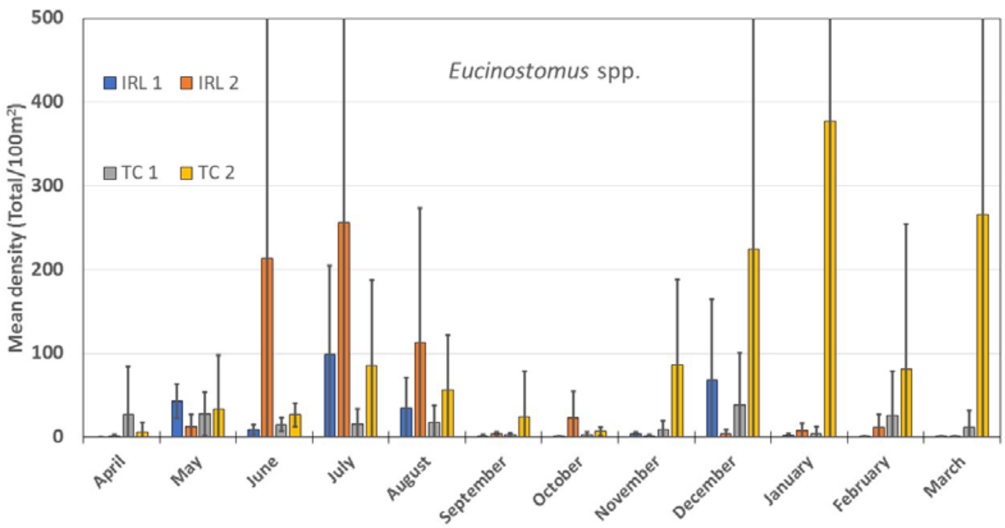

Figure 5. Mean (+/- S.E.) density of juvenile mojarra, *Eucinostomus* spp., (number of fish /100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

The abundance surveys indicate that riverine habitats support higher densities of juvenile *Eucinostomus* spp. than do open IRL habitats, and that large numbers of juveniles occurred in the sandy habitats around the perimeter of the mouth of the post-dredging Turkey Creek. The value of any of these habitats for a fish species is heavily impacted by the availability of prey for that species.

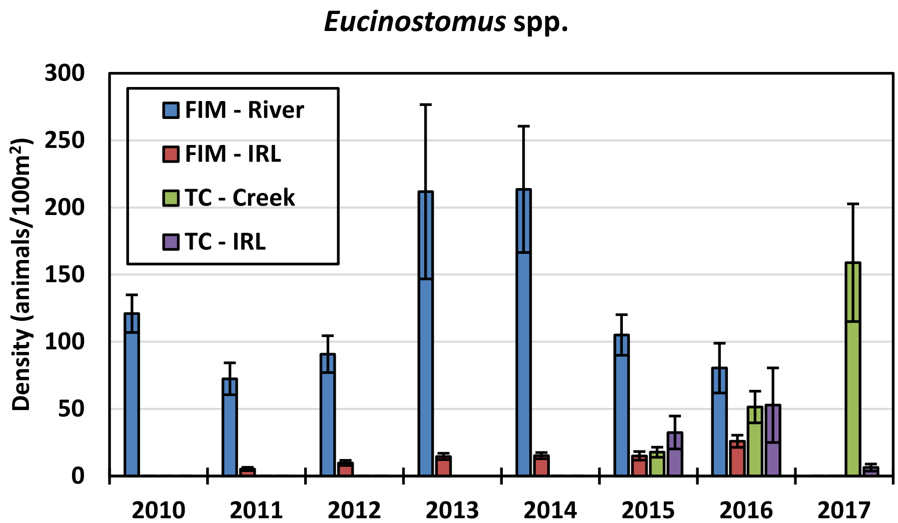

Figure 6. Annual mean (+/- S.E.) density of juvenile mojarra, *Eucinostomus* spp., (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL "bay" stations and "river stations" (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

While many specimens have yet to be examined, the data available so far indicate that these juvenile *Eucinostomus* spp. fed primarily on epibenthic and infaunal invertebrate prey (Table 6). Of the 41 juvenile *Eucinostomus* spp. examined to date, 60% contained at least one identifiable prey item in their stomachs, with a total of 11 types of prey consumed by these fishes. Of those with food in their stomachs, amphipods and mysid shrimp were dominant prey (in 27 and 24% of stomachs, respectively). Other major prey include grass shrimp, tanaids, ostracods, and gastropods. Kerschner et al (1985) and Mota et al. (1995) report that their highly protrusible mouth enables them to capture these small epibenthic and infaunal prey.

The prey consumed by juvenile *Eucinostomus* spp. were not collected in demersal habitats covered by muck (K. Johnson, Florida Institute of Technology, pers. comm.).The initial post-dredging data from Johnson (2017) show increases in infaunal and epifaunal invertebrate densities in some Turkey Creek areas that had been dredged, suggesting that development of invertebrate populations in newly-exposed habitats may increase food availability for juvenile *Eucinostomus* spp. and other fish species. We will continue to collaborate with the benthic fauna research team in 2017/2018 to more fully characterize the responses of individual invertebrate prey taxa to muck removal and the subsequent feeding biology of fishes. If the removal of muck from Turkey Creek exposes sandy substrates that can develop a community of benthic prey, it may ultimately provide resources to support a larger abundance of juvenile mojarras. This increase in mojarra population size may, in turn, enhance the prey base for the larger predatory fishes (e.g. sea trout, red drum, tarpon, and juvenile bull sharks) that utilize Turkey Creek.

Table 6. Frequency of occurrence (%) of prey taxa in stomachs of selected fish taxa. Frequency calculations are based on the numbers of stomachs containing at least one recognizable prey item.

Fish Species	Total (n)	Empty (%O)	Fish	Amphipod	Tanaids	Isopod	Copepod	Mysid Shrimp	Grass Shrimp	Penaeid Shrimp	Polychaete	Bulla occidentalis	Ostracod	Bivalve	Gastropod	Crab	Plant	Diatom	Foraminifera	Nemertean
Gerreidae - Mojarras																				
Diapterus spp.	6	50	0	33	33	0	0	0	0	0	33	0	0	0	0	0	33	0	0	0
Eucinostomus spp.	41	20	0	27	15	0	3	24	18	3	3	12	15	12	15	0	0	0	0	0
Sciaenidae - Drums																				
Bairdiella chrysoura	15	53	14	71	14	0	0	14	0	0	0	0	0	0	0	0	14	0	0	0
Cynoscion nebulosus	12	8	27	36	0	0	0	36	0	45	18	0	0	0	0	0	0	0	0	0
Micropogonias undulatus	32	63	0	50	0	0	33	0	0	0	8	0	0	0	0	0	0	8	0	0
Sciaenops ocellatus	15	0	7	40	7	27	33	0	13	40	0	0	7	0	7	0	0	0	0	0
Leiostomus xanthurus	8	0	0	0	0	0	0	38	0	0	0	0	38	0	0	0	0	0	63	13

Diapterus spp.: As seen in *Eucinostomus* spp., collections of juvenile (15-90 mm) Irish pompano, *Diapterus* spp., made in 2015 indicated that this species peaked in abundance in the region during the mid-summer (Figure 7). Overall densities were lower during the second year of sampling (Y2), until a very large catch of *Diapterus* spp. was made inside the mouth of Turkey Creek in January 2017. Densities along the western shore of the mouth of Turkey Creek reached levels 3 times higher than previously sampled throughout the study; other samples had very few fish, resulting in a very high measure of variation. An angler was collecting baitfish with a cast net on that date, and he remarked that he'd never before seen so many mojarras in the area. He noted that large schools of jacks were chasing baitfish throughout the area, and perhaps these predatory fish herded prey into a few dense schools in shallow water. The schools dispersed by the following month, and *Diapterus* spp. density dropped to near zero.

According to FIM summary data, juvenile *Diapterus* spp. were far more abundant in riverine habitats than in the open IRL from 2010 to 2016 (Figure 8). Mean densities in these riverine habitats had an interannual variation of over 200% during that time range. The mean densities from our sampling in 2015 and 2016 inside and adjacent to Turkey Creek were much lower than the FIM riverine sampling, presumably because FIM covered a much broader range of riverine habitats than our efforts. The impact of the single large pulse of juveniles captured in January 2017 is reduced because it is included with all the minimal catches made throughout the early portion of the year.

Stomachs of many juvenile *Diapterus* remain to be processed. Samples examined to date indicate that these fish also feed on epibenthic crustaceans as well as infaunal polychaetes (Table 6).

<u>Drums</u>: Seven species of juvenile drums (Sciaenidae) were collected inside and adjacent to the mouth of Turkey Creek before, during and after dredging operations. Five of those taxa have been selected for presentation here: Red drum (*Sciaenops ocellatus*); Sea trout (*Cynoscion* sp.); Atlantic croaker (*Micropogonias undulatus*); Silver perch (*Bairdiella chrysoura*); and Spot (*Leiostomus xanthurus*). The other two drum species that were collected are southern kingfish (*Menticirrhus* spp.) and black drum (*Pogonias cromis*). Juvenile kingfish were collected almost exclusively at IRL stations and rarely in any areas potentially impacted by muck removal. Only a single black drum was captured in 2016.

Sciaenops ocellatus: Red drum support one of the iconic fisheries of the Indian River Lagoon. Adults typically spawn around inlets and nearshore waters during the fall, with larvae ultimately settling into demersal estuarine habitats (Peters et al. 1987; Rooker et al. 1997). Although they may utilize a wide array of estuarine nursery habitats, Rooker et al. (1998a) determined that seagrass meadows provide better protection from predators than featureless habitats.

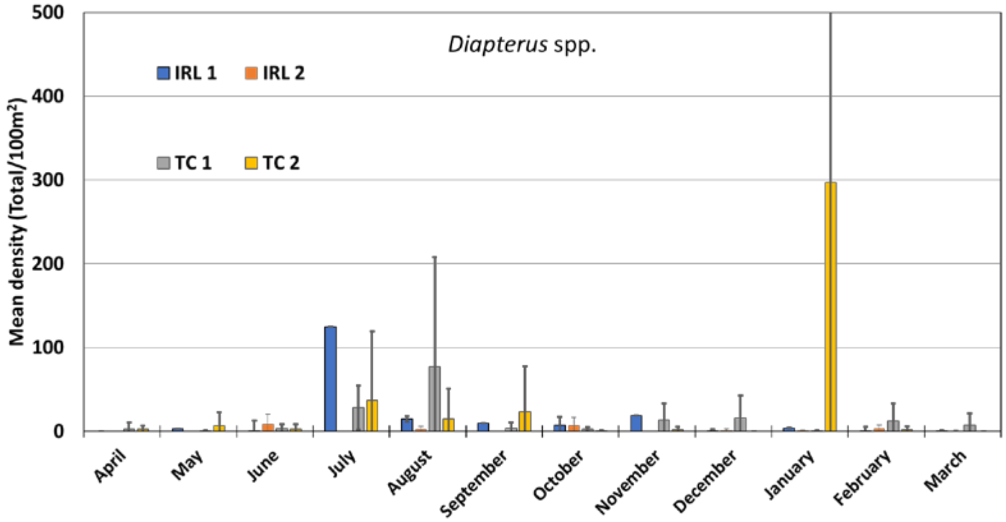

Figure 7. Mean (+/- S.E.) density of juvenile Irish pompano, *Diapterus* spp., (number of fish/100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

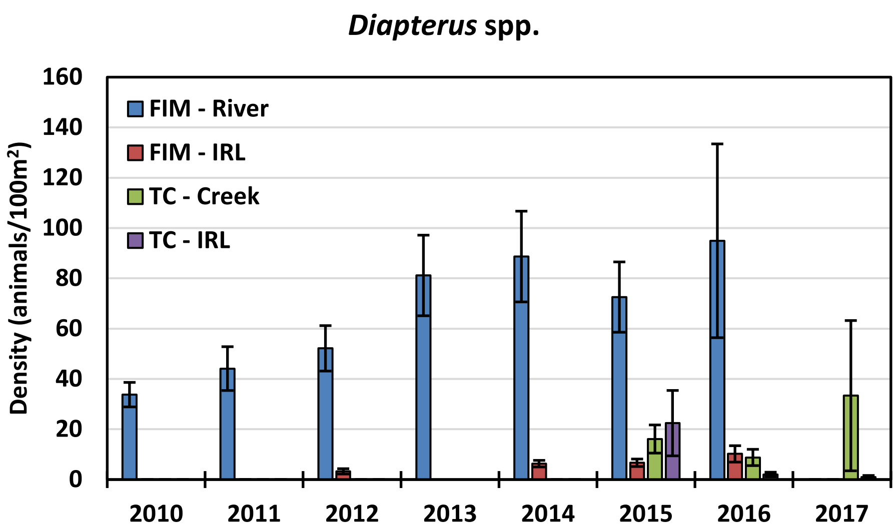

Figure 8. Annual mean (+/- S.E.) density of juvenile Irish pompano, *Diapterus* spp., (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL "bay" stations and "river stations" (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

Juvenile red drum were collected in December and January inside the mouth of Turkey Creek during the first year of sampling (Figure 9). Densities of these juveniles was very low in the fall of Year 2, after the completion of muck removal.

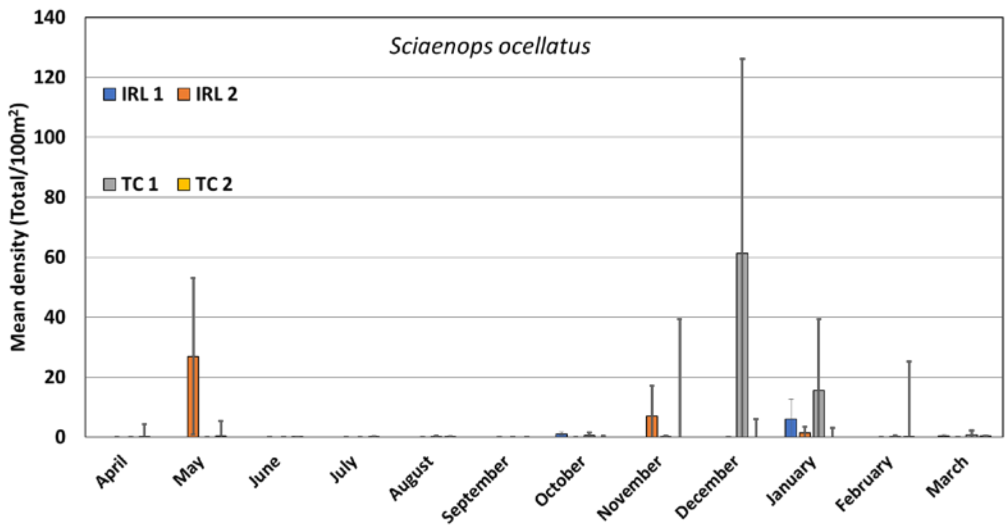

Figure 9. Mean (+/- S.E.) density of juvenile red drum, *Sciaenops ocellatus*, (number of fish/100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

Examination of temporal and spatial patterns within the broader context provided by FIM illustrate the importance of creek mouths as juvenile habitats for this species (Figure 10). FIM data collected over the open IRL, and spanning the riverine habitats, show lower densities than our sampling that focused on the mouth of Turkey Creek and the adjacent IRL, but the fish they collected in the open IRL were generally of larger size than those we found in Turkey Creek. The lack of protective seagrass or other complex structures within Turkey Creek may contribute to the dispersal of populations to the more complex habitats in the IRL. The consistent but low densities observed over 7 years by FIM suggest relatively low levels of interannual variability of recruitment. We will be focusing on the occurrence of these juveniles in upcoming fall months in the post-dredging habitats around Turkey Creek,

Juvenile red drum in Tampa Bay fed on small crustaceans such as mysids, amphipods and newly-settled shrimp (Peters and McMichael, 1987). Similar-sized juveniles in Turkey Creek fed on a broad range of epibenthic and pelagic crustaceans, dominated by amphipods, penaeid shrimp, copepods, isopods and grass shrimp (Table 6). These taxa are typically not found in muck-dominated habitats, and a potential increase in habitat available for their populations in the aftermath of muck removal may help increase the availability of prey for juvenile red drum. If habitat complexity that provides juvenile red drum with protection from predators can be achieved, and prey abundance increases, then the mouth of Turkey Creek may become a more valuable site for enhancing their population within the IRL.

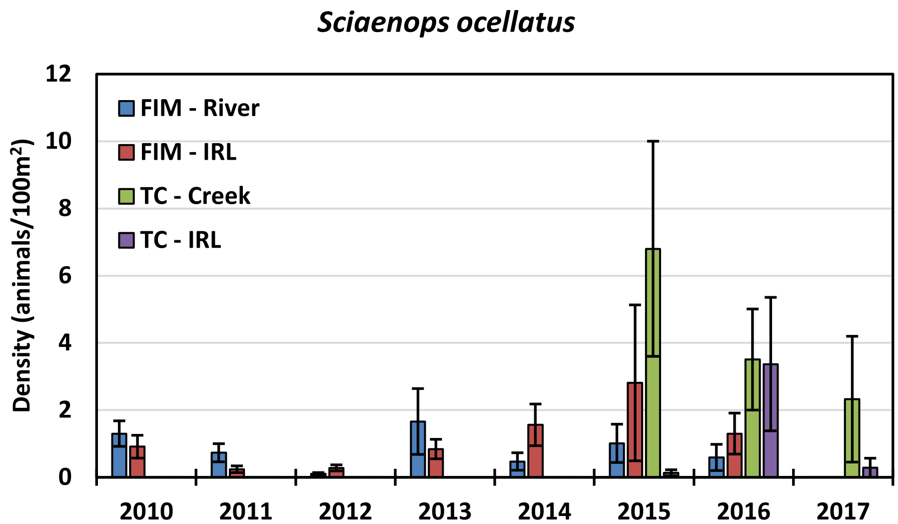

Figure 10. Annual mean (+/- S.E.) density of juvenile red drum, *Sciaenops ocellatus*, (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL “bay” stations and “river stations” (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

Cynoscion sp.: Juvenile sea trout (primarily *C. nebulosus*) support another of the most important fisheries of the Indian River Lagoon. These fishes typically spawn during the summer months within the IRL (Johnson and Seaman, 1986; McMichael and Peters, 1989).

Two monthly pulses of juvenile sea trout were observed in our sampling: November 2015 and July 2016, both in IRL habitats outside the mouth of Turkey Creek (Figure 11). Neither pulse persisted into the following month. Juvenile sea trout are generally considered to prefer living in and around seagrass beds. The seagrass provides protection from predators and ready access to the planktonic prey (copepods) of small juvenile sea trout and epibenthic crustaceans (e.g. mysids and amphipods) of larger juveniles (McMichael and Peters, 1989). Given the lack of seagrass within the mouth of Turkey Creek, their relative absence inside the creek is not surprising.

Although those 2 pulses of juvenile sea trout occurred during single months in 2015 and 2016, those relatively high densities generated mean annual densities that were dramatically larger than the mean annual densities of juveniles sampled by FIM throughout the open IRL and riverine habitats from 2010 to 2016 (Figure 12).

Juvenile sea trout fed primarily on mobile prey, including penaeid shrimp, mysids, amphipods and other fishes (Table 6). None of these prey are associated with muck habitats. However, although the removal of muck may increase the abundance of these prey, the lack of seagrass inside Turkey Creek presumably will limit the value of this habitat as a nursery for sea trout.

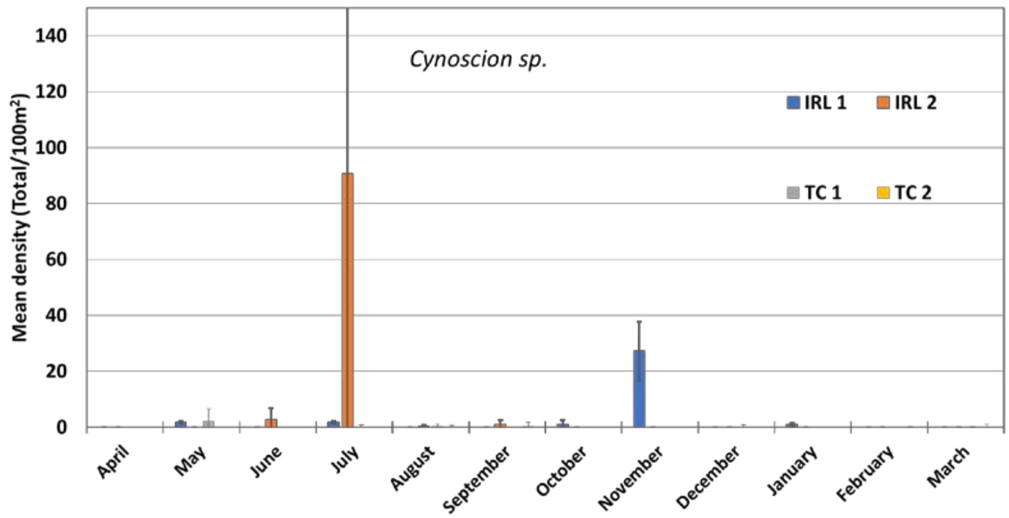

Figure 11. Mean (+/- S.E.) density of juvenile sea trout, *Cynoscion* spp., (number of fish /100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

Micropogonias undulatus: Juvenile Atlantic croaker in the IRL result from winter offshore spawning and larval ingress through Sebastian Inlet. They were very abundant only during February 2016, at both Turkey Creek and IRL sites (Figure 13). Presumably these juveniles dispersed across the region later in the spring, but densities have remained low since that initial pulse. FIM collections indicate low mean annual densities across the IRL throughout 2010 to 2016, although riverine habitats typically contained higher densities than did open water habitats in the ecosystem (Figure 14). The one set of very large catches made in our sampling in February 2016 in both the mouth of Turkey Creek and adjacent IRL resulted in a higher mean annual density for these habitats than observed by FIM, but those data are the result of a single short-lived pulse of fish inhabiting the region.

Juvenile Atlantic croaker fed primarily on mobile prey: amphipods and copepods (Table 6), which are not associated with muck habitats.

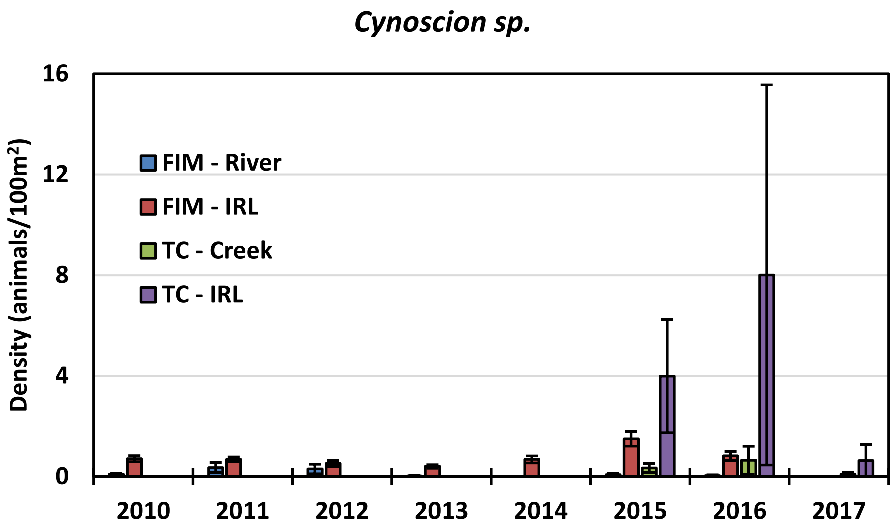

Figure 12. Annual mean (+/- S.E.) density of juvenile sea trout, *Cynoscion* spp., (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL "bay" stations and "river stations" (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

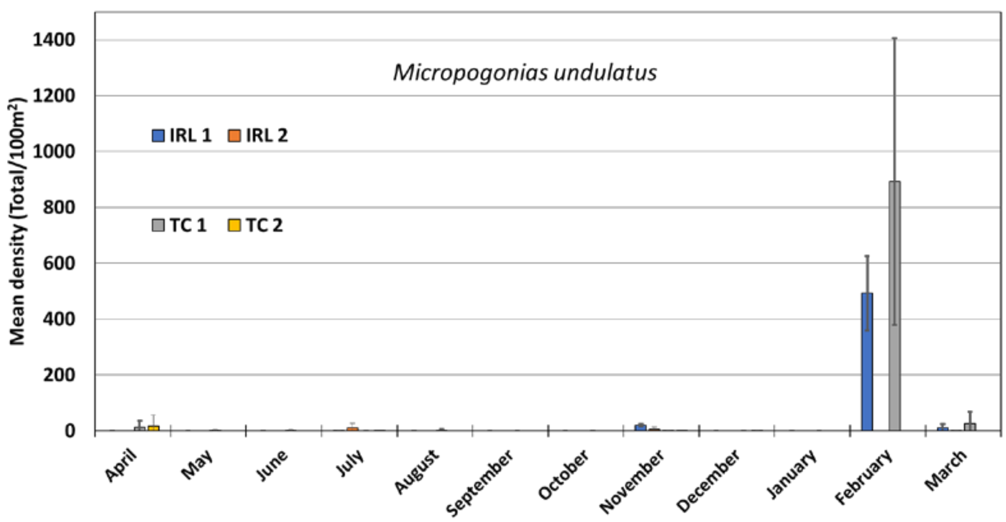

Figure 13. Mean (+/- S.E.) density of juvenile Atlantic croaker, *Micropogonias undulatus*, (number of fish /100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

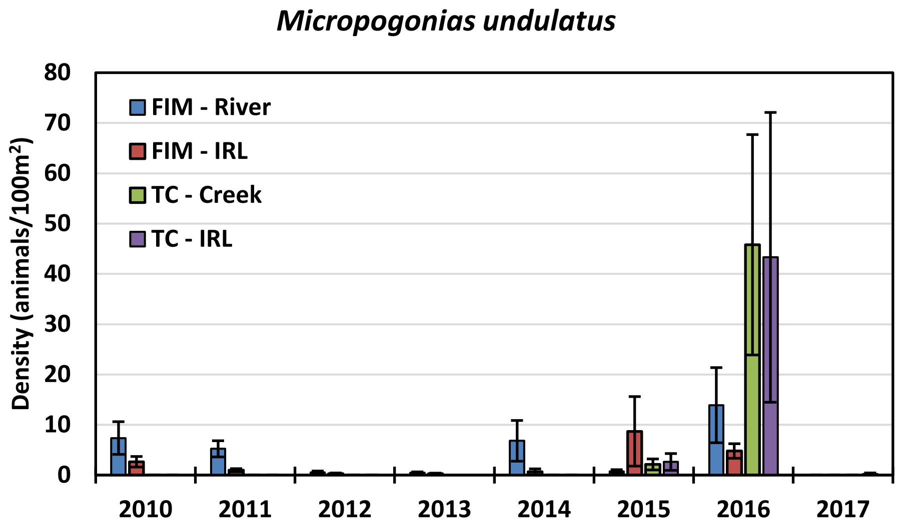

Figure 14. Annual mean (+/- S.E.) density of juvenile Atlantic croaker, *Micropogonias undulatus*, (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL "bay" stations and "river stations" (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

Bairdiella chrysoura: Silver perch spawn in early spring in estuarine channels, with larvae and early juveniles generally occurring in mesohaline seagrass, sand and oyster habitats and adults moving into higher salinity regions (Rooker et al. 1998b; Hanke et al 2013). In our study, juvenile silver perch were taken primarily during late spring through mid-summer in the mouth of Turkey Creek and the adjacent IRL (Figure 15). These fish were captured on more occasions and in higher numbers in 2015 than 2016, when fish were taken in only two sets of samples in April and May, during the early stages of dredging. These juveniles appear to have concentrated in the narrow habitat around river mouths, since they were rarely captured by the ecosystem-wide FIM sampling program (Figure 16). They fed primarily on amphipods, with tanaids, mysids and fish comprising a smaller portion of their diet (Table 6). Data from Waggy et al. (2007) indicate that the silver perch in the northern Gulf of Mexico fed primarily on a similar array of epibenthic crustaceans.

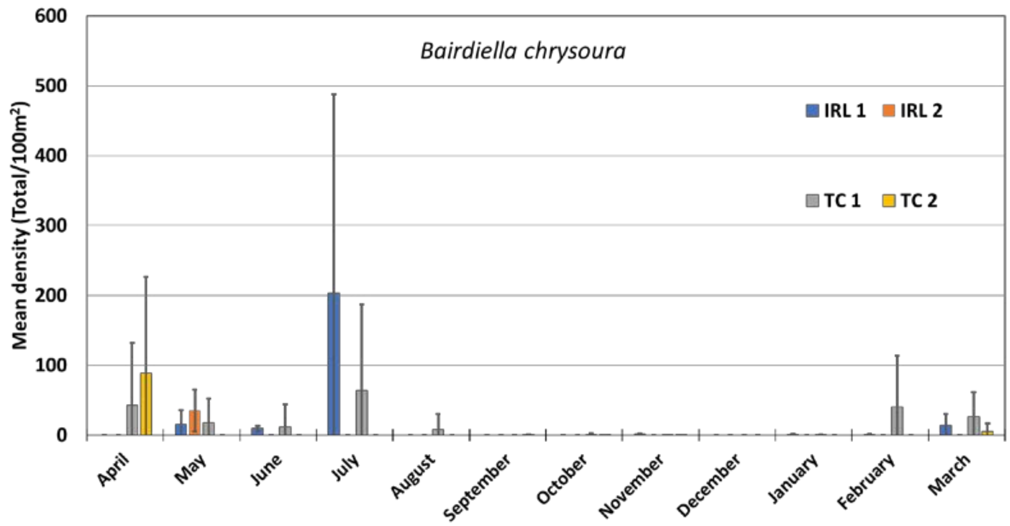

Figure 15. Mean (+/- S.E.) density of juvenile silver perch, *Bairdiella chrysoura*, (number of fish /100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

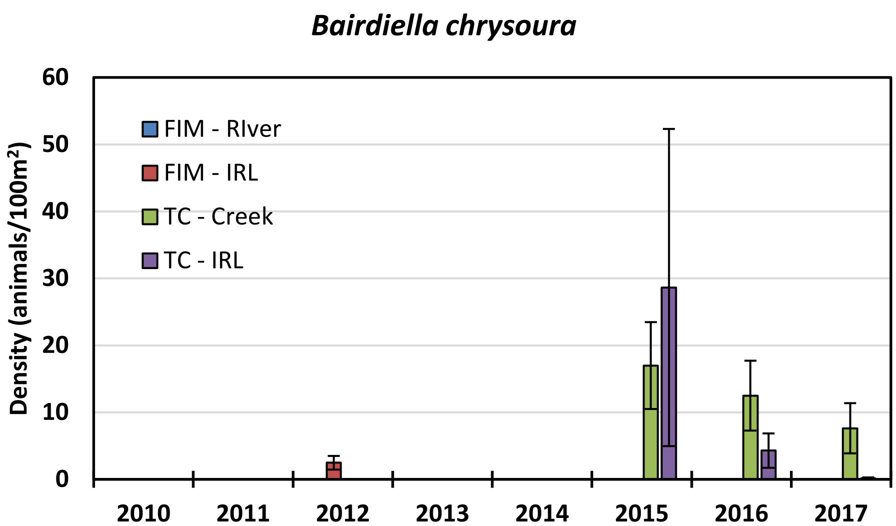

Figure 16. Mean (+/- S.E.) density of juvenile silver perch, *Bairdiella chrysoura*, (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL "bay" stations and "river stations" (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

Leiostomus xanthurus: Spot, like Atlantic croaker, spawn in offshore waters in late winter, and larvae enter the IRL through Sebastian Inlet to disperse across the estuarine ecosystem. Significant numbers of juvenile spot were captured during only 3 months in the first 24 months of the survey; May 2015 and February 2017 in the IRL outside the mouth of Turkey Creek, and May 2016 inside Turkey Creek during the early phases of dredging (Figure 17). Inter-annual variability of recruitment was more dramatic for this species than any of the other members of the Sciaenidae. FIM data from 2010 and 2011 showed high mean annual densities in riverine habitats, with much lower levels of recruitment from 2012 to 2016 (Figure 18).

The juvenile spot captured in our samples had a very different diet than exhibited by other members of the Sciaenidae family. The most commonly consumed prey taxon was the benthic foraminiferan *Ammonia parkinsonia*, followed by ostracods and mysids (Table 6). This reliance on benthic organisms suggests that spot typically winnow their prey out of the substrate rather than pick individual items at or above the sediment surface.

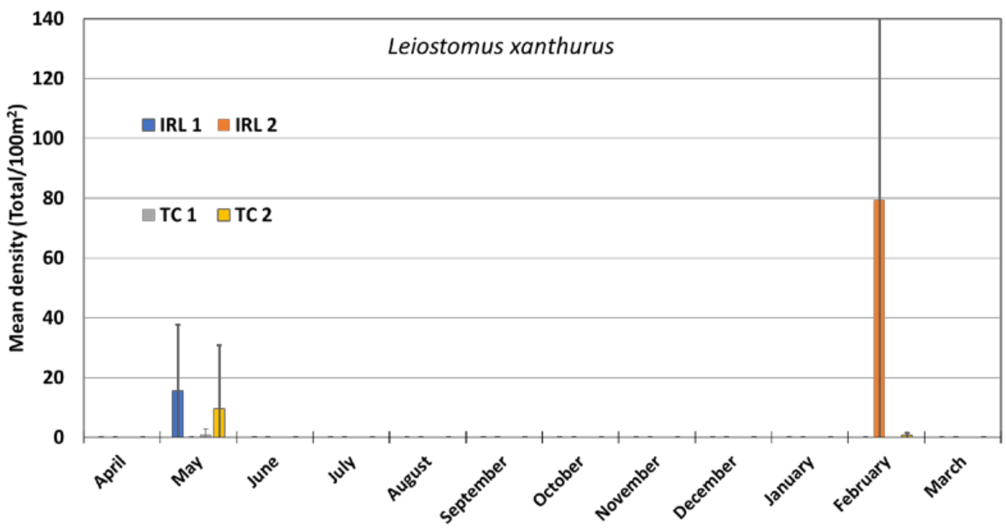

Figure 17. Mean (+/- S.E.) density of juvenile spot, *Leiostomus xanthurus,* (number of fish /100 m^2) in each month in Year 1 of sampling (April 2015 to March 2016) and Year 2 (April 2016 to March 2017) for all seine hauls collected within the mouth of Turkey Creek (TC; typically 8 samples/month), and in the adjacent Indian River Lagoon (IRL; 2 samples/month).

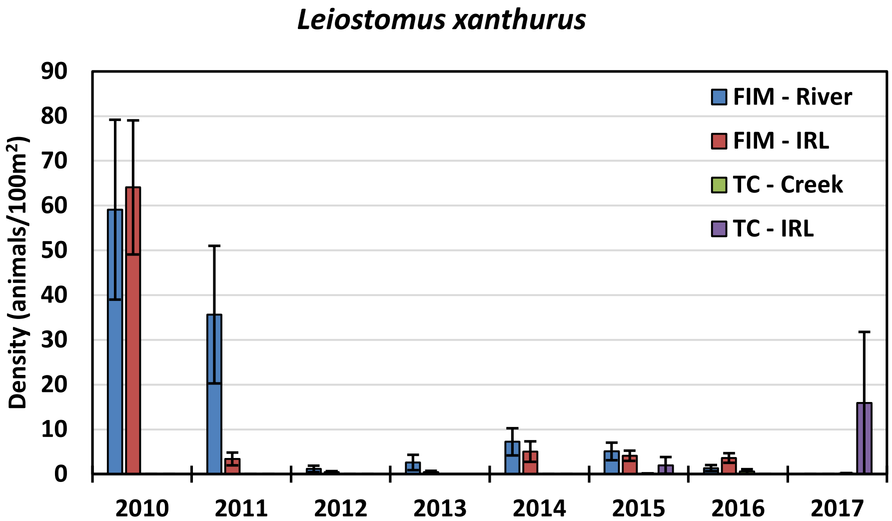

Figure 18. Mean (+/- S.E.) density of juvenile spot, *Leiostomus xanthurus*, (number of fish/100 m^3) in all samples collected by the FIM program (2010 to 2016) in IRL "bay" stations and "river stations" (Turkey Creek and St. Sebastian River), and by this program in the mouth of Turkey Creek (TC -Creek) and adjacent IRL (TC – IRL) for 2015, 2016 and January – May 2017.

Seagrass Transplanting Experiment

Seagrasses within an estuarine environment are vital habitats for many species of juvenile and adult fishes, supporting relatively dense populations of prey as well as providing physical structure that helps reduce the vulnerability of fishes to predators (Rooker et al. 1998b; Hori et al. 2009). The loss of nearly 60% of the seagrass habitats within the IRL during and after the algae "super bloom" of 2011, and subsequent alternation of minor recovery with further losses, raises concerns about potential impact of seagrass loss on fisheries recruitment, among many other ecosystem functions.

The loss of seagrass has been most severe in open areas within the IRL. However, the mouth of Turkey Creek may not have supported abundant seagrasses, at least within recent decades. The widely fluctuating salinities and high turbidity associated with freshwater discharges may impose physiological stresses that inhibit establishment or persistence of seagrass beds. The St. Johns River Water Management District has been working to re-establish much of the historical patterns of water flow along the east coast of Florida by minimizing the artificial eastward diversion of freshwater runoff into tributaries into the IRL and restoring much of the westward flow back into the St. Johns River. This reduction of freshwater flow into Turkey Creek raises the possibility that changing environmental conditions may ultimately permit the establishment of seagrasses within the mouth of Turkey Creek. We are beginning a transplanting experiment of artificially-propagated seagrass to test the hypothesis that seagrass can indeed survive within this habitat at the present time, rather than wait for slow natural recruitment to occur over many years. If transplanted seagrass does indeed survive and thrive, an expanded transplanting program in the mouth of Turkey Creek may be warranted. Given the reliance of many fishes, including juvenile sea trout and red drum, on seagrasses, such an expansion could be important for fishery species and other seagrass-associated organisms.

Approach and Methods

We are working with Sea and Shoreline, LLC (S&S) to conduct this transplanting program. Our collaboration began with their seagrass transplanting program being conducted as mitigation of the extension of the Merritt Island Airport into Sykes Creek in the northern Indian River Lagoon. Personnel from Sea and Shoreline harvested shoal grass (*Halodule wrightii*) that would have been destroyed by the runway extension. Cultivars from the recovered *H. wrightii* were established in the Sea and Shoreline FDACS Registered Aquaculture Facility in Ruskin, FL. These cultivars are available for use in our project. My students and laboratory are volunteering to help collect fisheries data for the mitigation project; in turn, S&S will provide the transplants and assist in all phases of the transplant experiments. It has taken longer than anticipated to initiate this experiment. Transplanting seagrass was scheduled for late August or early September 2017; due to very low salinity in the fall because of Hurricane Irma and periods of significant rains, the transplanting was delayed to early December 2017, when salinity rises to normal winter level. The survival and growth of the transplants will be monitored through August 2019 by the S&S personnel, and up to another 12-24 months with student volunteers from the Florida Institute of Technology.

Initial surveys of the habitat conducted by S&S personnel identified primary concerns that could affect the viability of transplanted seagrasses:

- Pulses of freshwater input released form the Melbourne Tillman Water Control District into the headwaters of Turkey Creek
- Herbivory from manatees and other large herbivores
- Wave energy
- Hard sediment composition (oyster shell and coquina rock) in some areas
- Other seasonal and short-term environmental stressors (e.g. temperature cycles, water level fluctuations, turbidity and freshwater influx, storm-driven sediment resuspension, deposition of drift algae).

The fluctuating salinities within the mouth of Turkey Creek led to the decision to use two species of seagrasses in the transplanting trials: *H. wrightii* that is found in the adjacent IRL, and widgeon grass (*Ruppia maritima*) that is physiologically tolerant of a wide range of salinities. Each of the five selected transplant sites will be planted with both *H. wrightii* and *R. maritima*, and the relative success of each species will direct future efforts.

Herbivory from manatees, sea turtles and fish is always a concern with seagrass transplanting in the IRL. Accordingly, transplanted seagrasses will be installed in 30 cm tall x 1 m diameter GrowSAV^{TM} Herbivory Exclusion Devices to protect the transplanted seagrass for at least one year (Figure 19). These stainless steel mesh cages, provided by S&S, are anchored to the substrate, and have been proven to be effective at protecting transplanted seagrasses from large herbivores. Several species of juvenile fishes (sheepshead and pinfish) have been reported to graze on transplanted seagrasses (Robert Virnstein, pers. comm.). Our two years of intensive seine sampling in the region where the transplants will be established have detected very few juvenile sheepshead and no pinfish.

If transplanted specimens grow well in a recovery area, they may begin to spread beyond the cages. Such success may warrant an expanded transplanting program to enable seagrasses to reach densities capable of withstanding herbivory from juvenile fishes and manatees.

Figure 19. Stainless steel GrowSAV™ Herbivory Exclusion Devices used by Sea and Shoreline, LLC, to protect newly-transplanted seagrasses from large herbivores.

Newly-transplanted seagrasses are vulnerable to disruption from wave energy. The transplanting area is thus located along the northern shoreline of the mouth of Turkey Creek (Figure 20). This area is relatively more protected than the western shoreline from easterly winds and the long easterly fetch that allows waves to build. As this site is located along a heavily vegetated shoreline, and more than 50 m from the public fishing pier, it should be subject to minimal direct impacts from people using the region. Although the western shoreline of the region has a better sand substrate, the western shore receives more direct wave impact and is easily accessible to shore-based anglers.

The area selected for transplanting along the northern shoreline has a mixture of sandy sediment and patches of hard oyster shell and coquina rock. For this experiment, we want to ensure that seagrasses are impacted only by water quality, and not potentially substandard sediment quality. Therefore, for the last 6-12 months, Sea and Shoreline has been growing cultivars of *H. wrightii* and *R. maritima* at their Ruskin facility in coconut-husk fiber containers filled with sediment taken from their initial habitat in Sykes Creek. These substrates will ensure that well-established plants are placed in the cages, enabling us to determine if the water quality in Turkey Creek is or is not conducive to maintenance of seagrasses.

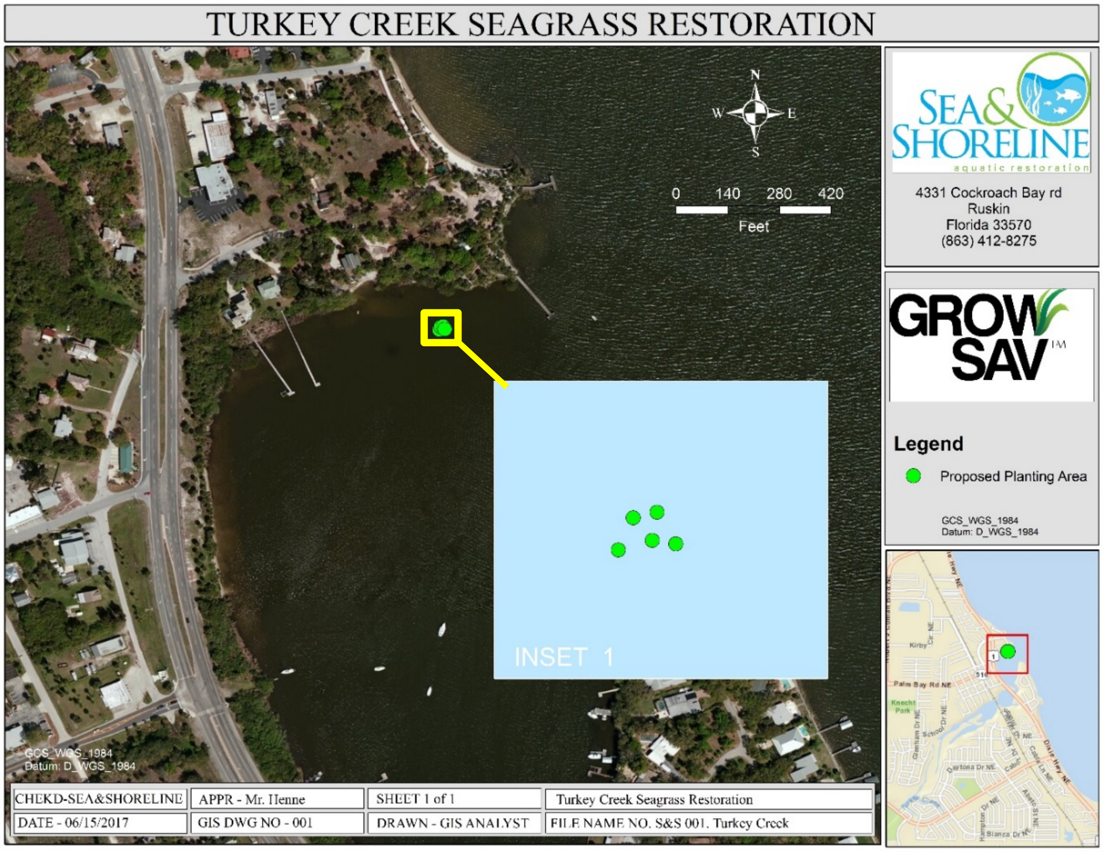

Figure 20. Projected location of five stainless steel GrowSAV™ Herbivory Exclusion Devices for seagrass transplanting experiments in Turkey Creek.

The permit to conduct the transplant experiment was been received in fall 2017. Our initial plan to deploy cages and seagrasses in mid-fall was delayed because of very low salinity levels in Turkey Creek associated with heavy rainfall earlier in the fall. In December 2017, S&S personnel deployed five exclusion cages at an approximate depth of 0.5 m, each containing 10-12 nursery-grown peat pots with well-established *H. wrightii*. *R. maritima* cultivars were added to the cages in January 2018. S&S biologists, assisted with FIT students, will conduct bimonthly maintenance events on the cages through August 2018. FIT personnel will continue the monitoring and maintenance events for an additional 12-24 months.

Maintenance events will include:

1. Visual inspection of GrowSAV™ Herbivory Exclusion Devices
2. Monitoring the shoot abundance, density and blade lengths of *H. wrightii* and *R. maritima* using visual, photographic and direct measurement techniques.
3. Scrubbing of each cage to remove bio-fouling

Data collected on survival, shoot abundance and density, blade length, and potential spread of the seagrasses beyond the planting units will be analyzed and presented in written and oral reports during the coming year.

Conclusions

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. This dredging may impact both the amount of habitat directly utilized by fishes as well as their invertebrate prey. Despite the significant environmental variability 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, move into and out of the region. Larger predatory fishes such as jacks, tarpon and red drum are assumed to track the movements of the abundant prey species. The species composition and abundance of demersal juvenile fishes changed more slowly, reflecting seasonal patterns in recruitment and growth that vary among species.

Most demersal juvenile fishes underwent seasonal patterns of abundance, but little direct evidence of a positive or negative response to muck removal was observed. The only taxon that had a distinct post-dredging increase in abundance along the shoreline inside the mouth of Turkey Creek was the dominant group of mojarras, *Eucinostomus* spp. This taxon was present in low densities in fall 2015 and much higher densities in fall 2016. If muck removal allows development of increased benthic prey communities over a wider habitat in the coming year, we may see increases around the post-dredging site of juvenile *Eucinostomus* spp. and *Diapterus* spp. These fishes recruit in spring and summer, typically live in sandy habitats, and consume those benthic prey.

The most important fishery species that utilize the demersal Turkey Creek region include juvenile red drum in fall and winter, and juvenile sea trout in summer. These juveniles fed 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 indicate that their abundance in the creek and the surrounding IRL is affected by inter-annual variability in recruitment and habitat specificity. Given their sporadic and short-lived appearances in the Turkey Creek habitat, it is difficult to determine if muck removal had any effect on their utilization of the region. As suggested above for the mojarras, if the benthic prey communities expand during the coming year, an increased availability of prey may increase the value of the mouth of Turkey Creek as a nursery for these species.

In addition to the lack of prey for juvenile fishes in the pre-dredged muck habitats, the lack of seagrass within Turkey Creek, and minimal habitat complexity of the substrate, may impact the habitat quality for juvenile red drum, sea trout and other species. Such habitat complexity directly corresponds to increasing prey abundance and the ability of juvenile fishes to avoid predators. Working with Sea and Shorelines, LLC, we have initiated transplant 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.

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