Integrated Assessment of Ecosystem Condition and Stressor Impacts in Submerged Habitats of the Guana Tolomato Matanzas (GTM) National Estuarine Research Reserve (NERR)

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1. Introduction: Background and Objectives

The Guana Tolomato Matanzas reserve is one of 28 National Estuarine Research Reserves (GTM-NERR) encompassing approximately 73,300 acres of salt marsh and mangrove tidal wetlands, oyster bars, estuarine lagoons, upland areas, and offshore ocean waters along the northeastern coast of Florida in St. Johns and Flagler Counties (Figure 1). The reserve consists of a northern and southern component separated geographically by the City of St. Augustine. The northern component includes the Tolomato and Guana River estuaries and adjacent offshore waters and the southern component contains the Matanzas River. The GTM-NERR, managed under a partnership between the National Oceanic and Atmospheric Administration (NOAA) and Florida Department of Environmental Protection (DEP), was established to promote "conservation of natural biodiversity and cultural resources through research and monitoring to guide science-based stewardship and education strategies" (www.dep.state.fl.us/coastal/sites/gtm).

A NERR System-Wide Monitoring Program (SWMP) was developed to improve fundamental understanding of the temporal and spatial dynamics of estuarine processes and to provide baseline information for evaluating change in ecosystem function in response to natural and human disturbances (NERRS 2011). Although water-quality monitoring has been a major focus of SWMP at GTM and other NERR locations, additional research efforts of various partnering institutions provide a variety of other complementary data to help address NERRS science and management needs. Accordingly, a study was initiated in summer 2014, through collaborative efforts by NOAA's National Centers for Coastal Ocean Science (NCCOS) and GTM-NERR staff, to assess the status of ecosystem condition and potential stressor impacts throughout submerged (subtidal, with the exception of intertidal oyster) habitats of the GTM reserve using multiple indicators of ecological condition. Results, reported herein, are intended to help address priority science and management research gaps identified in the GTM-NERR Site Profile and Management Plan, including characterization of submerged habitats and associated living resources, biological monitoring with measures of biodiversity and condition, and GIS-based mapping of submerged habitats to serve as baselines for future change analysis.

Specific objectives of the study are:

- To assess current status of ecosystem condition and potential stressor impacts throughout submerged habitats of the GTM-NERR, based on a field survey conducted in summer 2014 using multiple indicators of ecological condition including general habitat characteristics, stressor levels, sediment toxicity, health of resident benthic fauna, human-health risks, and aesthetics.

- To provide a quantitative baseline for detecting future change in condition in relation to natural factors (e.g., climatic) or anthropogenic impacts (e.g., pollution, habitat alteration).
- To provide GIS-based maps of habitat quality as tools for managers to use in monitoring status and trends in condition and identifying potential vulnerable areas or areas in need of management attention.
- To provide information to address priority research gaps identified in the GTM-NERR Site Profile and Management Plan as well as other evolving science and management needs.
- To generate reserve-wide measures of biological condition and sediment/water quality to complement the reserve's time-series of water-quality data from its ongoing SWMP efforts at fixed monitoring sites.

2. Methods

Sampling was conducted from July 28 – August 8, 2014 at 30 stations throughout submerged habitats of the northern and southern reserve and St. Augustine area (Fig. 1). Because of the large size of the GTM reserve (73,300 acres), the sampling design focused on subtidal portions of the main rivers and lagoons and excluded shallower inaccessible areas and deeper ocean waters. Specific station locations were selected using a Generalized Random-Tessellation Stratified (GRTS) design. This is a probabilistic sampling framework from which resulting data can be used to make unbiased statistical estimates (with confidence intervals) of the spatial extent and magnitude of condition relative to various measured indicators and corresponding management thresholds. This method has been used widely in EPA's EMAP and National Coastal Assessment programs and is very good for achieving both a random and spatially balanced coverage (Stevens & Olsen 2004). The sampling design and other methods described below are also consistent with those used in similar placed-based assessments

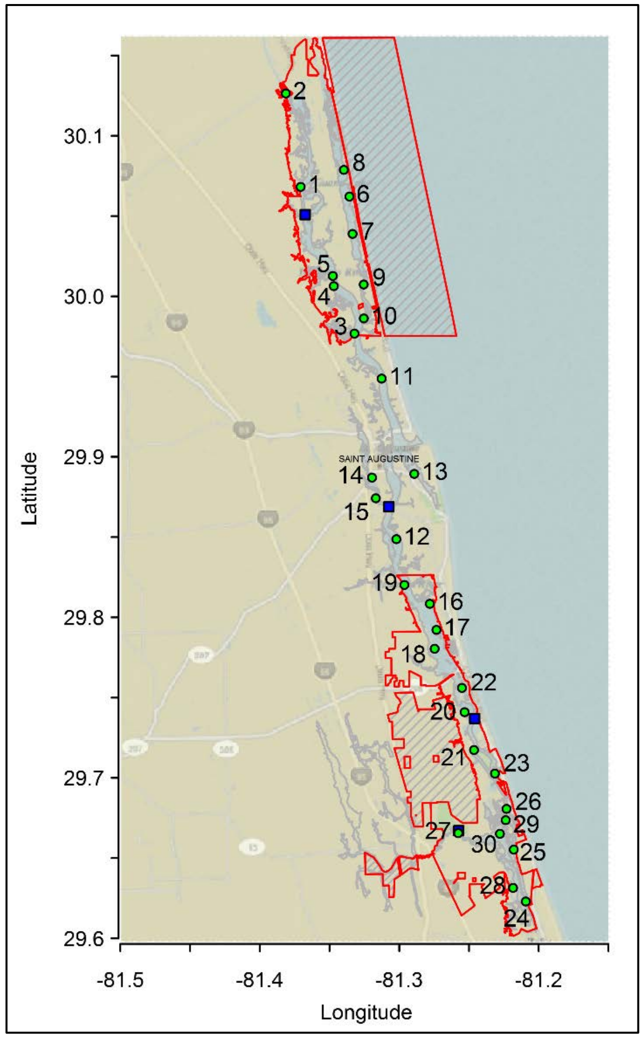

Figure 1. Locations of sampling sites in the GTM NERR-North, GTM NERR-South, and St. Augustine areas. GTM NERR boundaries are outlined in red, with portions excluded from the study area indicated by gray hatching. Blue squares indicate SWMP fixed monitoring sites.

of ecological condition conducted by NCCOS at other southeastern NERRS locations (Cooksey et al. 2008; Balthis et al. 2012, 2015).

Multiple ecological indicators were sampled synoptically at each station, including:

- General habitat characteristics: Water-column depth, temperature, salinity, dissolved oxygen (DO), pH, turbidity, total suspended solids (TSS), nutrients (ammonium, nitrate/nitrite, total nitrogen, orthophosphate, total phosphorus), phaeophytin, and chlorophyll *a*; sediment grain-size (% silt+clay) and total organic carbon (TOC).
- Stressor levels: Chemical contaminants in sediments (metals, pesticides, PCBs, PAHs), hypoxia/anoxia, organic over-enrichment (elevated TOC).
- Sediment toxicity: Microtox solid-phase assay, Microtox organic extract assay, and reporter gene assay.
- Health of resident benthic infaunal communities (animals sampled with 0.04-m^2 grab, sieved on 0.5-mm screen, and identified to species where possible).
- Human-health risks: Water-column fecal coliforms; chemical contaminants in oysters and finfish (spotted seatrout, mangrove snapper, striped mullet, summer flounder, red drum).
- Aesthetics: Water clarity, incidence of noxious sediment odor, oily sediment, marine debris.

Field Sampling

Field work was conducted using two small (< 25 ft) trailerable boats, one provided by the NCCOS/CCEHBR lab in Charleston and one provided by the GTM-NERR. The NCCOS boat, equipped with a davit and winch, was used for bottom grab sampling and water-column measurements. The GTM-NERR boat was used to collect biota for contaminant body-burden analysis. All work was staged out of St Augustine, FL from the GTM-NERRS facilities. Station coordinates are provided in Appendix A. Stations were sampled during daylight hours and scheduled so that tidal conditions would allow boat access to shallow sites.

In-situ point measurements of temperature, salinity, dissolved oxygen, pH, and depth were acquired using a YSI 6-series multi-parameter sonde. For station depths > 1 m, separate readings were taken for surface and bottom water. Discrete samples (1 L) of near-surface water (~ 0.5 m below surface) were also collected at each station for the analysis of nutrients, TSS, turbidity, chlorophyll a, and fecal-coliform bacteria.

Sediment samples were collected at each station for analysis of chemical contaminants, total organic carbon (TOC), grain-size, toxicity bioassays, and benthic community characteristics using a 0.04-m^2 Young grab sampler. Grabs were collected to a maximum depth of 10 cm and rejected if < 5 cm or if there was other evidence of sample disturbance. Two discrete grab samples for the analysis of benthic macroinfauna were collected at each station and processed as individual replicates. The contents of each grab were sieved in the field with a 0.5-mm mesh screen. Material remaining on the screen was fixed in 10% buffered formalin with rose Bengal and transferred to the laboratory for further processing.

Surficial sediments (upper 2 – 3 cm) were collected and composited from additional multiple grabs to provide a quantity sufficient for the TOC, grain size, sediment bioassays, and contaminant analyses. Subsamples of the composited sediment were removed and placed into appropriate sample containers. Sediments collected for contaminant analyses were maintained on ice throughout sampling and shipment and stored frozen (at -40 °C) once transferred to the laboratory. Sediments collected for toxicity testing were maintained on ice throughout sampling and shipment, kept under refrigeration (~ 4 °C) in the laboratory, and analyzed within 30 days of receipt. Fishing was attempted at each station, either by hook and line or cast net, to obtain samples of finfish for tissue-contaminant analysis. Oysters, *Crassostrea virginica*, were also collected by hand at selected stations for contaminant analysis.

Nutrient, Chlorophyll, Phaeophytin, TSS, and Turbidity Analysis

Initial sample preparations were performed by the field crew within a day of collection. Approximately 0.5 L of water from each station was vacuum-filtered using Filterware microfiltration glassware and a Whatman GF/F 47-mm filter. The filtered water sample was then transferred to a 120-mL polypropylene bottle, frozen (< -20°C), and analyzed within 30 days for dissolved nutrients including ammonium (NH_4^+), nitrate/nitrite ($NO_{2/3}$), and orthophosphate (PO_4^{3-}). Each filter was folded and wrapped in a foil pouch, frozen, and analyzed for chlorophyll *a* (CHL*a*) and phaeophytin (PHAEO). Whole (unfiltered) water samples were also obtained from each station, portions of which were placed in 60-mL polypropylene bottles and kept frozen until later analyzed for total nitrogen (TN) and total phosphorus (TP). A 25 mL aliquot of the unfiltered water was also removed and measured on site for turbidity using a Hach 2100P turbidity meter;

resulting measurements were expressed in standard Nephelometric Turbidity Units (NTU). The remaining unfiltered water from each station was used to measure TSS.

Subsequent instrumental analyses were performed using established analytical methods. Dissolved nutrients were measured as follows: NH_4^+ (Method 804-86T, Technicon 1986a), $NO_{2/3}$ (Method 158-71, Technicon 1977), and PO_4^{3-} (Method 155-71W, Technicon 1973). Concentrations of TN and TP were determined by a persulfate digestion method (Valderrama 1981). The Welschmeyer method (Welschmeyer 1994) was used to determine both CHL*a* and PHAEO. Concentrations of TSS were measured on a HACH DR/2500 TSS analyzer using a photometric method (Method 8006, Hach 2003).

Fecal-Coliform Analysis

Fecal coliform densities were determined using the membrane-filter technique (APHA 1998). Briefly, surface-water samples were filtered through a 0.45-µm nitrocellulose filter within 24 hours of collection, using sterile filter funnels on a vacuum manifold, and placed onto mFC Agar plates (60 x 12 mm). The plates were placed in Whirlpack bags, sealed, and incubated in a circulating waterbath for 24 hours ± 2 hours at 44.5 °C ± 0.5 °C. Typical fecal-coliform colonies were counted and bacterial numbers calculated as CFU/100 mL water.

Chemical Contaminant Analysis

Sediment samples were kept frozen at approximately - 40 ºC until analyzed. To thaw, samples were left in closed containers in a 4 ºC cooler for approximately 24 hours. Samples were thoroughly homogenized by hand prior to any sample extraction. Fish and oyster tissue samples were frozen upon receipt in the laboratory and stored at - 40 ºC. Prior to analysis, samples were removed from the freezer and stored overnight at 4 ºC to partially thaw. Tissue samples (fish fillets: skin on, oysters: whole body) were homogenized using a ProScientific homogenizer in 500 mL Teflon containers. The homogenized tissue sample was split into organic and inorganic subsamples, placed in pre-cleaned glass and polypropylene containers, respectively, and stored at - 40 ºC until extraction or digestion. A percent dry-weight determination was made gravimetrically on an aliquot of the wet sediment and tissues.

Inorganic Sample Preparation and Analysis

Dried sediment was ground with a mortar and pestle and transferred to a 20-mL plastic screw-top container. A 0.25-g subsample of the ground material was transferred to a Teflon-lined digestion vessel and digested in 5 mL of concentrated nitric acid using microwave digestion. The sample was brought to a fixed volume of 50 mL in a volumetric flask with deionized water and stored in a 50-mL polypropylene centrifuge tube for subsequent analysis of Li, Be, Al, Fe, Mg, Ni, Cu, Zn, Cd, and Ag. A second 0.25-g subsample of dried sediment was transferred to a Teflon-lined vessel and digested with 5 mL of concentrated nitric acid and 1 mL of concentrated hydrofluoric acid in a microwave digestion unit. The sample was then evaporated on a hotplate at 225 °C to near dryness and 1 mL of nitric acid was added. The sample was brought to a fixed volume of 50 mL in a volumetric flask with deionized water and stored in a 50-mL polypropylene centrifuge tube for subsequent analysis of V, Cr, Co, As, Sn, Sb, Ba, Tl, Pb, and U. Samples for selenium analysis were prepared by hotplate digestion using a 0.25-g subsample of dried sediment and 5 mL of concentrated nitric acid. Each sample was brought to a fixed volume of 50 mL in a volumetric flask with deionized water and stored in a 50-mL polypropylene centrifuge tube for subsequent analysis.

For tissue analyses, 2 – 3 grams of wet tissue were microwave-digested in Teflon-lined digestion vessels using 10 mL of concentrated nitric acid along with 2 mL of hydrogen peroxide. Digested samples were brought to a fixed volume with deionized water in graduated polypropylene centrifuge tubes and stored until analysis.

The analysis of mercury, for both sediments and tissue samples, was performed on separate aliquots of wet sediment or tissue material using a Milestone DMA-80 Direct Mercury Analyzer. All remaining elemental analyses were performed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Data-quality procedures included the use of blanks, spiked solutions, and standard reference materials (NRC MESS-3: marine sediments and NIST 1566b: freeze-dried mussel tissue).

Organic Sample Preparation and Analysis

An aliquot (10 g sediment or 5 g tissue wet weight) was extracted with anhydrous sodium sulfate using accelerated solvent extraction in either a 1:1 mixture of methylene chloride and acetone (for sediments) or 100% dichlormethane (for tissues) (Schantz 1997). Following extraction, samples were dried and cleaned using gel-permeation chromatography and solid-phase extraction to remove lipids and then solvent-exchanged into hexane for analysis. Samples were analyzed for PAHs, PBDEs, PCBs (individual congeners), and a suite of chlorinated pesticides using GC/MS technology. Data-quality procedures included the use of spiked blanks, reagent blanks, and appropriate standard reference materials (NIST 1944: sediments and NIST 1947: fish-muscle tissue).

Sediment Toxicity Testing

Microtox Solid-Phase Assay

This Microtox assay was conducted using the standard solid-phase test protocol and a Microtox Model 500 analyzer (Modern Water, Inc., New Castle, DE manual). For each sample, the sediment was homogenized and a 7.0 – 7.1-g subsample was used to make a series of sediment dilutions with 3.5 % NaCl diluent, which were incubated for 10 minutes at 15 ºC. Luminescent bacteria (*Vibrio fischeri*) were then added to the test concentrations. The liquid phase was filtered from the sediment phase and bacterial post-exposure light output was measured using Microtox Omni Software. An EC50 value (the sediment concentration that reduced light output by 50 % relative to controls) was calculated for each sample. Triplicate samples were analyzed simultaneously. Sediment samples were classified as either toxic or nontoxic using criteria provided in Ringwood et al. (1997).

Microtox Solvent-Extract Assay

This Microtox assay measures light output in bioluminescent bacteria exposed to solvent (methylene chloride) extracts of sediment. Assays were conducted using standard solvent-phase procedures for the Microtox Model 500 analyzer (Modern Water, Inc., New Castle, DE manual). Briefly, solvent-extract samples were used to make a series of dilutions with 1% DMSO saline (2%NaCl) diluent. Cuvettes containing 1% DMSO diluent were placed in the analyzer for a 5-minute incubation at a constant temperature of 15°C. Freeze-dried luminescent bacteria, *Vibrio fischeri*, were reconstituted then added to the test cuvettes for a 15-minute incubation. At the end of incubation, bacterial luminescence was measured prior to sample addition (0 minute reading), then 5 and 15 minutes after sample addition, using the Microtox Omni Software. An EC50 value (the sample concentration that reduces light output by 50% relative to controls) was calculated for each sample at each time point. Triplicate samples were analyzed simultaneously. Sediments were considered toxic when EC50s were significantly ($p < 0.05$) lower than published EC_{50}s for reference-site sediments (from Long et al. 1998).

Reporter-Gene Assay

This assay utilizes a reporter gene system (RGS) based on cytochrome P450 to screen samples for a range of organic compounds (Denison et al. 2004, Baston et al. 2010, Brennan et al. 2015). The reporter-gene system utilizes a human cell line (101L) into which a plasmid containing a human CYP1A1 promoter and 5'-flanking sequences fused to a reporter gene, firefly luciferase, has been integrated. In the presence of CYP1A1-inducing compounds, the enzyme luciferase is produced, and its reaction with luciferin can be detected by measuring relative light units (RLUs) in a luminometer. To quantify the inducing compounds in the sample, the mean response, in RLUs, of the three sample replicates is divided by the mean response of three replicates of a solvent blank, yielding a "fold induction," which is a measure of the increase of the sample response over the background response. Fold-induction values are converted to benzo[a]pyrene equivalents (B[a]PEq) for PAHs based on the fold-induction responses to standards containing benzo[a]pyrene.

Benthic Community Analysis

Benthic samples were transferred from formalin to 70 % ethanol in the laboratory. Macroinfaunal invertebrates (sampled with 0.04 m^2 grab, sieved on 0.5 mm screen) were sorted from the sample debris under a dissecting microscope and identified to the lowest practical taxon (usually to species). Data-quality steps included: (1) tests of ongoing sorting proficiency on 10 % of samples by independent sorters to assure that > 95 % of animals in each sample were removed by the original sorter, (2) use of skilled taxonomists with updated standard taxonomic keys and reference collections to perform species identifications, (3) checks for potential misidentifications on a minimum of 10 % of samples by independent qualified taxonomists, and (4) appropriate corrective actions to resolve any potential sorting or species identification errors. Resulting data were used to calculate # taxa, density (m^{-2}), diversity (Shannon H′, calculated with base-2 logarithms), and benthic condition based on the benthic index of biotic integrity for southeastern estuaries (B-IBI, Van Dolah et al. 1999).

Data Analysis

Individual contaminant concentrations in a sample were compared to corresponding Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines (SQGs, Long et al. 1995) as a means of evaluating their potential risks to benthic fauna. Mean ERM Quotients (mERM-Q, Long et al. 1998, Hyland et al. 1999) were also calculated to provide a single measure of the mixture of multiple contaminants present in a sample; values were compared to corresponding benthic-risk thresholds provided in Hyland et al. (1999).

The synoptic measurement of sediment contaminants, sediment toxicity, and condition of ambient benthic fauna supports a weight-of-evidence, Sediment Quality Triad (SQT), approach to assessing any signs of pollution-induced degradation of the benthos at sampling sites (Chapman 1990). The three components of the SQT were combined graphically and displayed on maps herein to illustrate the spatial distribution of benthic condition throughout the study area.

Additionally, individual measures of water quality (DO, salinity-corrected pH, fecal coliform bacteria, total nitrogen, total phosphorus, chlorophyll *a*), sediment quality (TOC, toxicity, chemical contaminants), and condition of benthic fauna (B-IBI) were combined using scoring criteria shown in Fig. 2 (modified from Balthis et al. 2015, Van Dolah et al. 2013) to derive corresponding indices of water quality, sediment quality, and benthic condition. Briefly, the individual measures were classified into categories of “poor” (= 0), “fair” (= 3), and “good” (= 5). Scores for each index were obtained by averaging the component scores, then reclassifying the resulting mean score as “poor” (< 3), “fair” (≥ 3 and <4), or “good” (≥ 4). These three indices were then averaged to derive an overall score and reclassified as above to obtain a single index of overall habitat quality (HQI) for each station. The values of these indices were then interpolated spatially to produce maps of habitat quality throughout the study region. Results reflect conditions at the time of sampling in summer (July-August) 2014.

Additional data on human-health risks from measures of chemical contaminants in targeted fish and shellfish are also reported here and compared to corresponding management thresholds.

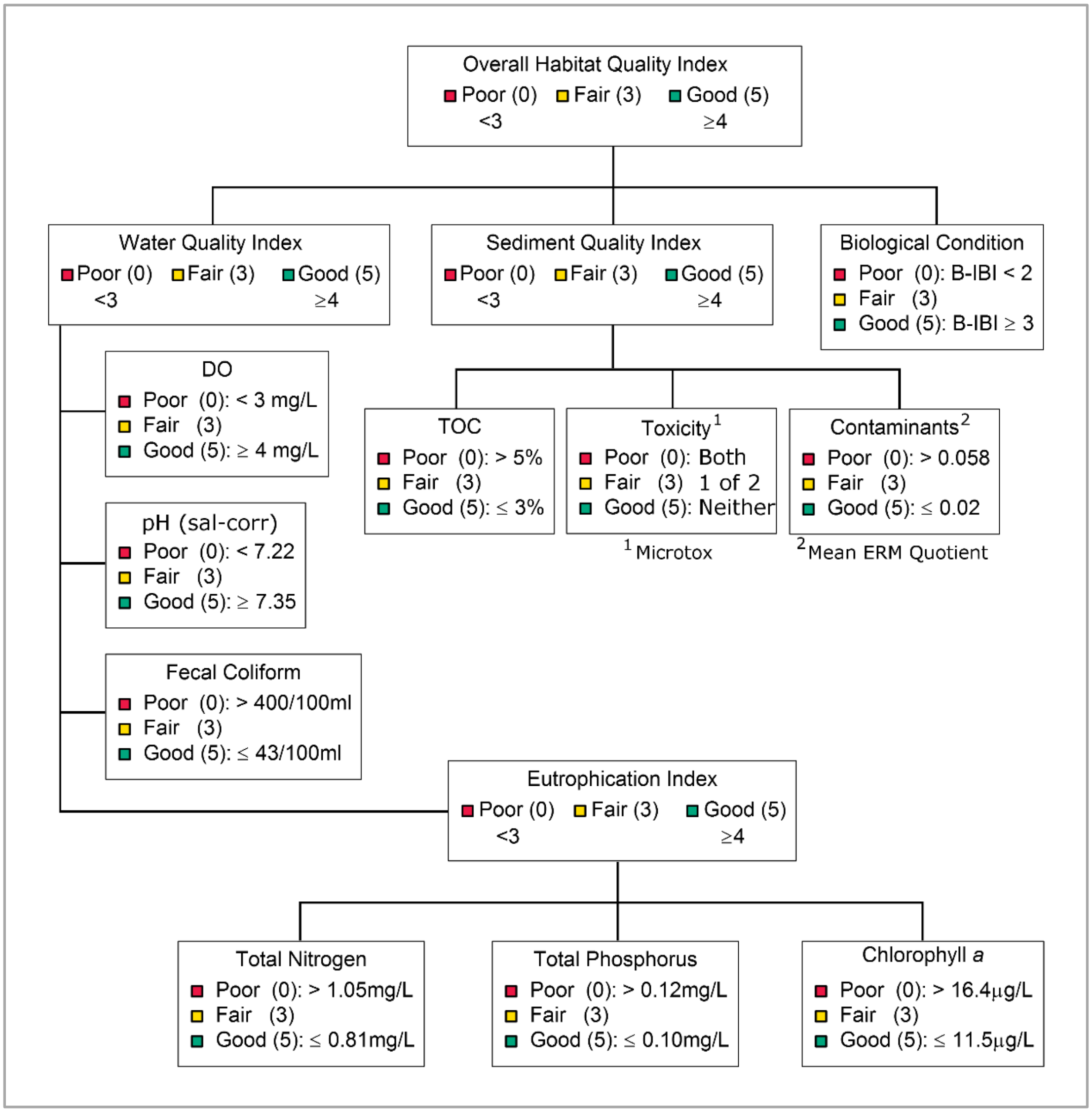

Figure 2. Sampling indicators and scoring criteria used to derive indices of water quality, sediment quality, biological (benthic) condition, and overall habitat quality (modified from Balthis et al. 2015, Van Dolah et al. 2013).

3. Summary of Findings

Results of the various analyses are summarized below, with a focus on measures of overall habitat quality and its components. Further details for these and other key sampling variables are provided by station in the appendices. The data resulting from this study can also be accessed online at https://products.coastalscience.noaa.gov/rea/ and https://nbi.noaa.gov/.

Water Quality and Nutrients

Plots of selected water quality and nutrient parameters are presented in Figure 3. These plots illustrate the distributions of monthly mean measurements from the four SWMP monitoring stations (shown as blue boxes in Fig. 1) over the period roughly between 2002-2015 (some measurements may include 2001 and/or 2016). The red box-and-whisker between July and August represents the observations resulting from the present study, conducted between July 28 and August 8, 2014. Hence these plots provide an illustration of temporal variation in monthly mean values across years as well as the change in the distribution of values by month, including spatial variation among the four SWMP stations, in relation to the spatial variation among the 30 stations sampled in summer 2014. Values for these parameters measured during the 2014 study all fell within the SWMP daily ranges recorded in July and August (2002-2015).

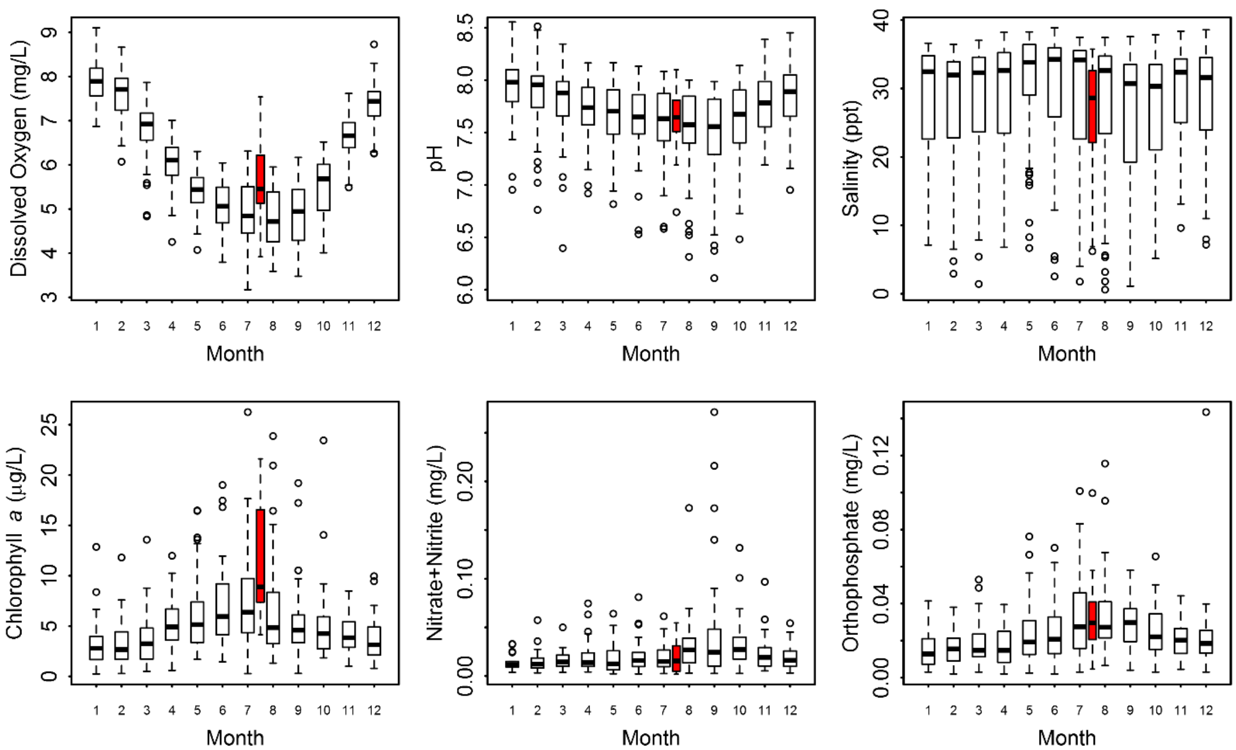

Figure 3. Plots of selected water quality and nutrient parameters from SWMP monitoring stations (2002 – 2015). Red box-and-whisker symbols between July and August represent observations resulting from the present study (July 28 – August 8, 2014).

Benthic Communities

- A total of 6,181 individual benthic specimens were collected from the 30 sampling sites (60, 0.04-m^2 grab samples). These fauna represented at least 188 taxa, 143 of which were identified to species level. The five most abundant taxa (all samples combined) were the amphipods *Cerapus benthophilus* and *Apocorophium lacustre* and the polychaetes *Streblospio benedicti*, *Mediomastus* sp., *Scoletoma tenuis,* and *Aphelochaeta* sp.

- Mean # taxa/grab, mean H′/grab, and density (# individuals/m^2) averaged 15, 2.72, and 2,579 respectively and ranged from 3 to 32, 0.88 to 4.14, and 125 to 32,688 respectively throughout the reserve overall (Table 1, Appendix E).
- There was a trend of increasing biodiversity and density from north to south within the sampling area. The lowest measures of diversity and density occurred within the North GTM stratum while the highest occurred within the South GTM stratum (Table 1).
- The B-IBI can range from 1 to 5: values ≤ 1.5 are indicative of a highly-degraded benthos, values ≥ 3 are indicative of a healthy benthos, and transitional values between 1.5 and 3 reflect partial symptoms of stress or data uncertainty (Van Dolah et al. 1999).
- B-IBI scores for the 30 sites ranged from 1.5 to 5.0 and averaged 2.7 overall (Table 1, Appendix F). The healthiest assemblages (scores ≥ 3) were observed at six of the ten sites sampled in the North GTM stratum and at seven of the 15 sites sampled in the South GTM stratum. Degraded benthic condition (score ≤ 1.5) was observed at only one site in the North GTM stratum (Station 01, Tolomato River/ICW just north of Pine Island near Spanish Landing). Despite its low B-IBI score, this was a sandy site with a relatively low level of TOC (6.2 mg/g, Appendix A) and no evidence of unusually high sediment contamination (e.g., low mERM-Q of 0.007 and no ERL or ERM exceedances, Appendix C) or toxicity (Appendix D).
- Degraded benthic condition (score ≤ 1.5) was also accompanied by low values of infaunal density, # of taxa, and diversity (Fig. 4). For example, Station 1 with a low B-IBI score of 1.5 also had a relatively low density (125/m^2), # of taxa (mean of 3.5/grab and total of 6/station), and H′ diversity (1.6) (Appendix E). Similarly, the highest B-IBI values (scores ≥ 4) co-occurred with high values of benthic abundance, richness, and diversity. For intermediate B-IBI scores, however, benthic measures were highly variable (Fig. 4).

Table 1. Summary of results for key biological, sediment-quality and water-quality measures by stratum.

Measure	GTM-North (n=10) Mean [min – max]	GTM-South (n=15) Mean [min – max]	St. Augustine (n=5) Mean [min – max]	Overall (n=30) Mean [min – max]
Biological Condition				
# taxa	10 [3 – 26]	17 [7 – 32]	13 [3 – 24]	14 [3 – 32]
H´ (log_2)	2.3 [0.9 – 3.8]	3.0 [1.8 – 4.1]	2.4 [0.9 – 3.2]	2.7 [0.9 – 4.1]
Density (#/m^2)	949 [125 – 2262]	3910 [413 – 32,590]	1825 [738 – 4475]	2575 [125 – 32,590]
B-IBI	2.8 [1.5 – 4.5]	2.8 [2.0 – 5.0]	2.1 [2.0 – 2.5]	2.7 [1.5 – 5.0]
Sediment Quality				
Mean ERM-Q	0.013 [0.007 – 0.025]	0.009 [0.005 – 0.016]	0.036 [0.005 – 0.128]	0.015 [0.005 – 0.128]
# ERLs exceeded	0 [0 – 0]	0 [0 – 0]	1.6 [0 – 8]	0.3 [0 – 8]
# ERMs exceeded	0 [0 – 0]	0 [0 – 0]	0 [0 – 0]	0 [0 – 0]
TOC (mg/g)	19.7 [1.8 – 60.9]	5.4 [0 – 15.3]	9.1 [0 – 26.0]	10.8 [0 – 60.9]
Silt+Clay (%)	39.2 [4.6 – 95.0]	13.5 [1.1 – 42.0]	27.9 [1.8 – 94.4]	24.5 [1.1 – 95.0]
Microtox solid-phase assay:				
mean corr. EC_{50} (%) *	2.91 [0.58 – 16.03]	6.40 [0.34 – 16.37]	4.69 [0.69 – 15.35]	4.95 [0.34 – 16.37]
Microtox solvent-extract assay:				
mean EC_{50} (mg/mL) $^+$	1.69 [0.26 – 10.47]	7.35 [0.93 – 76.56]	5.05 [0.66 – 18.98]	5.08 [0.26 – 76.56]
Reporter-gene assay:				
mean B[a]PEq (µg/g)	26.80 [2.95 – 61.49]	12.91 [1.19 – 43.80]	22.94 [4.84 – 47.86]	19.21 [1.19 – 61.49]
Water Quality				
Fecal Coliforms (CFU/100ml)	44.3 [3.7 – 294]	37.6 [0 – 334]	7.6 [0.3 – 21.0]	34.8 [0 – 334]
Total N (mg/L)	0.91 [0.59 – 1.56]	0.59 [0.24 – 1.11]	0.49 [0.38 – 0.56]	0.68 [0.24 – 1.56]
Total P (mg/L)	0.10 [0.08 – 0.17]	0.09 [0.04 – 0.17]	0.08 [0.06 – 0.09]	0.09 [0.04 – 0.17]
Chl *a* (µg/L)	18.0 [5.61 – 46.71]	14.7 [4.13 – 46.43]	9.2 [7.6 – 10.7]	14.9 [4.13 – 46.71]
TSS (mg/L)	53.6 [24 – 79]	66.9 [43 – 102]	76.6 [70 – 85]	64.1 [24 – 102]
Turbidity (NTU)	16.1 [11.1 – 32.7]	14.3 [5.8 – 36.6]	13.2 [9.1 – 16.6]	14.7 [5.8 – 36.6]
DO (mg/L)	5.3 [3.9 – 7.5]	5.9 [5.0 – 7.1]	5.4 [4.9 – 5.73]	5.6 [3.9 – 7.5]
Salinity (ppt)	20.9 [6.9 – 28.6]	27.5 [6.2 – 35.8]	33.0 [32.0 – 35.2]	26.2 [6.2 – 35.8]
pH	7.6 [7.2 – 8.1]	7.7 [6.7 – 7.9]	7.6 [7.2 – 7.8]	7.6 [6.7 – 8.1]
Temperature (°C)	30.6 [29.7 – 31.1]	30.0 [28.3 – 32.0]	30.6 [30.2 – 30.8]	30.3 [28.3 – 32.0]
Overall Habitat Quality				
HQI score	4.1 [2.0 – 5.0]	4.5 [3.7 – 5.0]	4.1 [3.0 – 4.3]	4.3 [2.0 – 5.0]

* Microtox solid-phase assay toxic if % EC50 < 0.5 and % Silt+Clay <20 or % EC50 < 0.2 and % Silt+Clay >20.

$^+$ Microtox solvent-extract assay toxic if EC50 significantly < Control ($p < 0.05$).

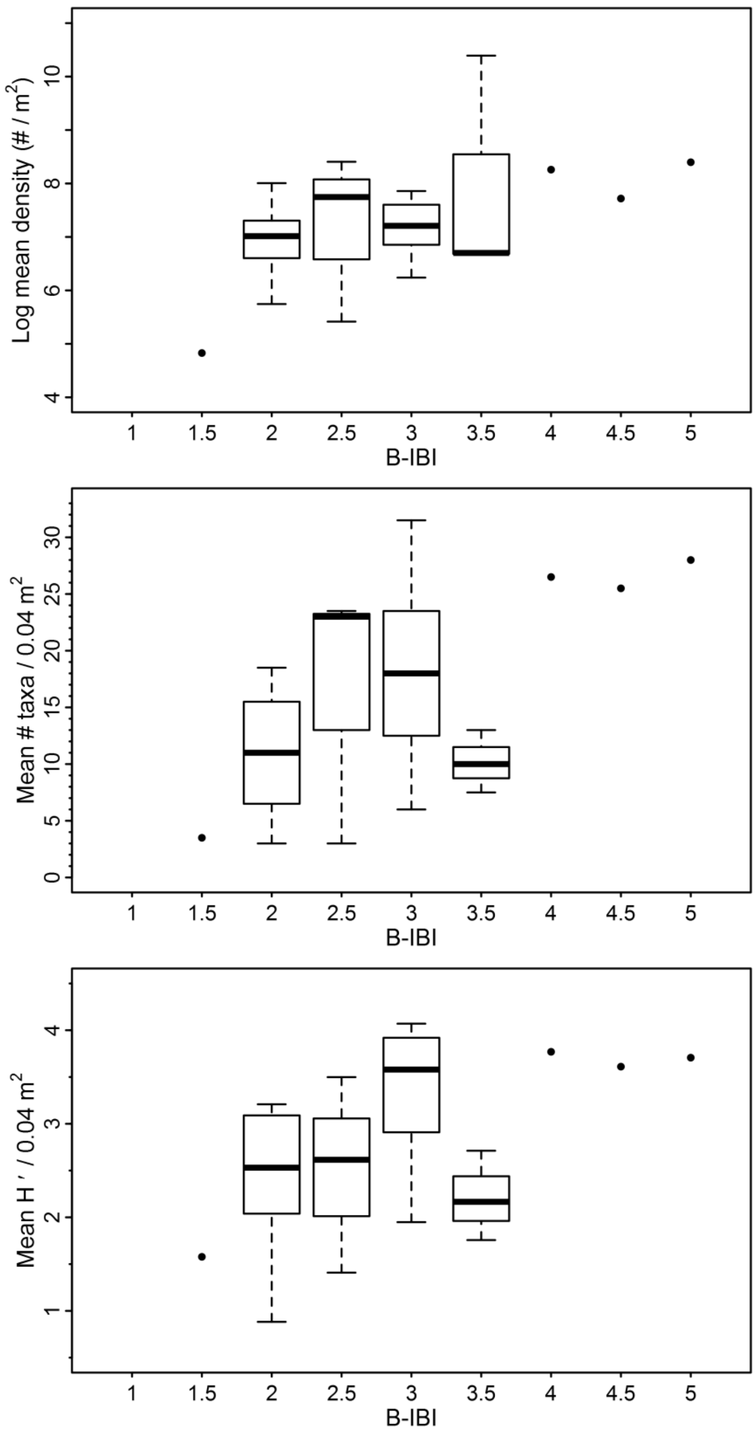

Figure 4. Measures of mean infaunal density, number of taxa, and Shannon H' in relation to the B-IBI.

Sediment Contaminants

- The number of contaminants that exceeded their corresponding ERL values at an individual station ranged from 0 to 8 throughout the reserve overall. All ERL exceedances occurred at a single station (14) located in the St. Augustine stratum in an urbanized area of the San Sebastian River (Table 1, Appendix C).
- There were no ERM exceedances at any of the 30 sites (Table 1, Appendix C).
- All eight ERL exceedances were due to PAHs: Acenaphthylene, Benzo[a]anthracene, Benzo[a]pyrene, Chrysene (+Triphenylene), Dibenz[a,h]anthracene, Pyrene, total High Molecular Weight PAHs, and Total PAHs.
- mERM-Qs ranged from 0.005 to 0.128 and averaged 0.015 throughout the reserve overall (Table 1, Appendix C). High values in the range likely to have adverse effects on the benthos (> 0.058, Hyland et al. 1999) occurred at one of the 30 sites (Station 14) located within the St. Augustine sampling area. This site had a relatively low B-IBI value of 2.0, in the intermediate range indicative of partial signs of benthic stress or data uncertainty. Moderate mERM-Q values (> 0.020 – 0.058, Hyland et al. 1999) occurred at four stations, including one in the St. Augustine area (Station 13, Salt Run) and three in the northern reserve (stations 6 and 8 in Guana Lake; station 9 in the Guana River).

Sediment Toxicity

- Microtox Solid-Phase Assays: No significant sediment toxicity based on this assay was observed at any of the 30 sites (Table 1, Appendix D).
- Microtox Solvent-Extract Assays: No significant sediment toxicity based on this assay was observed at any of the 30 sites (Table 1, Appendix D).
- Reporter-Gene Assays:
  - In the absence of reference data for this assay or other objective criteria for deciding whether or not a sample is toxic, reporter-gene assay results were not used to rate the level of toxicity at present sampling sites. However, resulting data are presented here and assessed for their level of agreement with the two Microtox tests (Table 1, Appendix D).
  - Results of the reporter-gene assay correlated significantly ($p < 0.05$) with both the solid-phase (Fig. 5A) and solvent-extract (Fig. 5B) Microtox results. Therefore, present conclusions about the incidence of toxicity at individual sampling sites would not likely change if reporter-gene assay results were included.

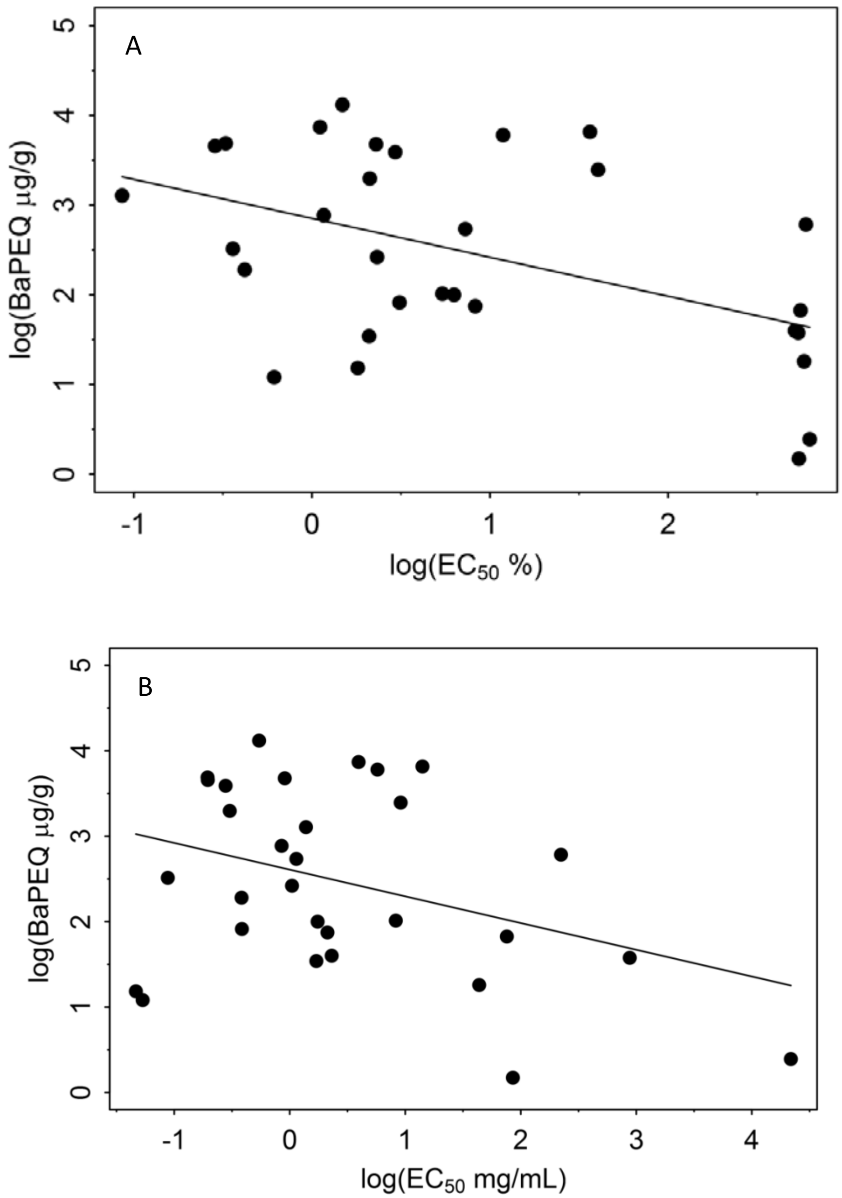

Figure 5. Reporter gene assay results in relation to (A) Microtox solid-phase tests (R^2 = 0.22, p = 0.008) and (B) Microtox solvent-extract tests (R^2 = 0.13, p = 0.046).

Sediment Quality Triad

- Combined results of the sediment quality triad (SQT) showed evidence of a healthy benthos and good sediment quality (low levels of sediment contamination and toxicity) at 11 of the 30 sites (Fig. 6). Co-occurrences of a degraded benthos, high concentrations of chemical contaminants, and significant sediment toxicity – hits in all 3 components of the SQT – was not observed at any of the 30 sampling sites, although poor condition in at least one of the three SQT components occurred at one site in the Tolomato River (benthos) and one site in the St. Augustine area (chemical contamination).

Human-Health Risks

- Surface water quality standards for Class II Waters (Shellfish Propagation or Harvesting) in the state of Florida specify that "…fecal coliform bacteria shall not exceed a median value of 14, nor exceed 43 in 10% of the samples, nor exceed 800 on any one day" (Florida Administrative Code). Water-column levels of fecal-coliform bacteria varied widely across the sampling area, ranging from 0 – 334 CFU/100ml and averaging 34.8 CFU/100ml (Table 1, Fig. 7, Appendix B), with a median of 7.4 CFU/100ml. The criterion of 43 CFU/100ml was exceeded at five of the 30 sampling sites: Station 04 in the Tolomato River (49 CFU/100ml), Station 08 in Guana Lake (294 CFU/100ml), Station 24 in the Matanzas River (334 CFU/100ml), Station 25 in the Matanzas River (49.5 CFU/100ml), and Station 27 in Pellicer Creek and Flats (114 CFU/100ml). No samples exceeded the instantaneous fecal coliform criterion of 800 CFU/100ml. Stations with high fecal coliform levels are consistent with locations having historically high concentrations of fecal coliforms (from 1978 – 2015), based on data extracted from the Florida STORET system (http://www.dep.state.fl.us/water/storet/). A follow-up study is being planned in order to identify and distinguish among sources of fecal coliform contamination.
- Concentrations of chemical contaminants in tissues of oysters (Appendix I-1) and finfish (Appendices I-2 – I-6) were typically below the range of concentrations (listed in Appendix H) for which EPA recommends limiting fish consumption to four meals per month. Levels of mercury in one specimen of spotted seatrout (Station 18 in the Matanzas River) fell within the range of concentrations for methylmercury for which the EPA recommends limiting consumption to three meals per month (under the conservative assumption that all mercury was present as methylmercury).

Overall Habitat Quality

- Overall Habitat Quality Index (HQI) scores, based on combined measures of water quality, sediment quality, and condition of benthic infauna, ranged from 2 to 5 and averaged 4.3 across the 30 sites (Table 1, Appendix F). As noted above, HQI scores can range from 0 to 5 and are rated either as "poor" (< 3), "fair" (≥ 3 and < 4), or "good" (≥ 4) (Balthis et al. 2015, Van Dolah et al. 2013). Based on this scoring system, 23 of the 30 sampling sites, representing 77% of the total sampling area, were rated as good (Fig. 8). Only one site (Station 08 in Guana Lake), representing 3% of the sampling area, was rated as poor.

- Habitat conditions, limited to 25 sites within GTM-NERR boundaries, are illustrated in Fig. 9 in relation to other southeastern NERRs in NC, SC, and GA. Overall habitat quality (HQI) was rated as “good” at 24 of the 25 GTM-NERR sites (73% area). As noted above, only one site (Station 08 in Guana Lake) was rated as “poor” for overall HQI, which resulted from high TOC (> 5 %) and elevated mean ERM-Q (0.02 – 0.058).

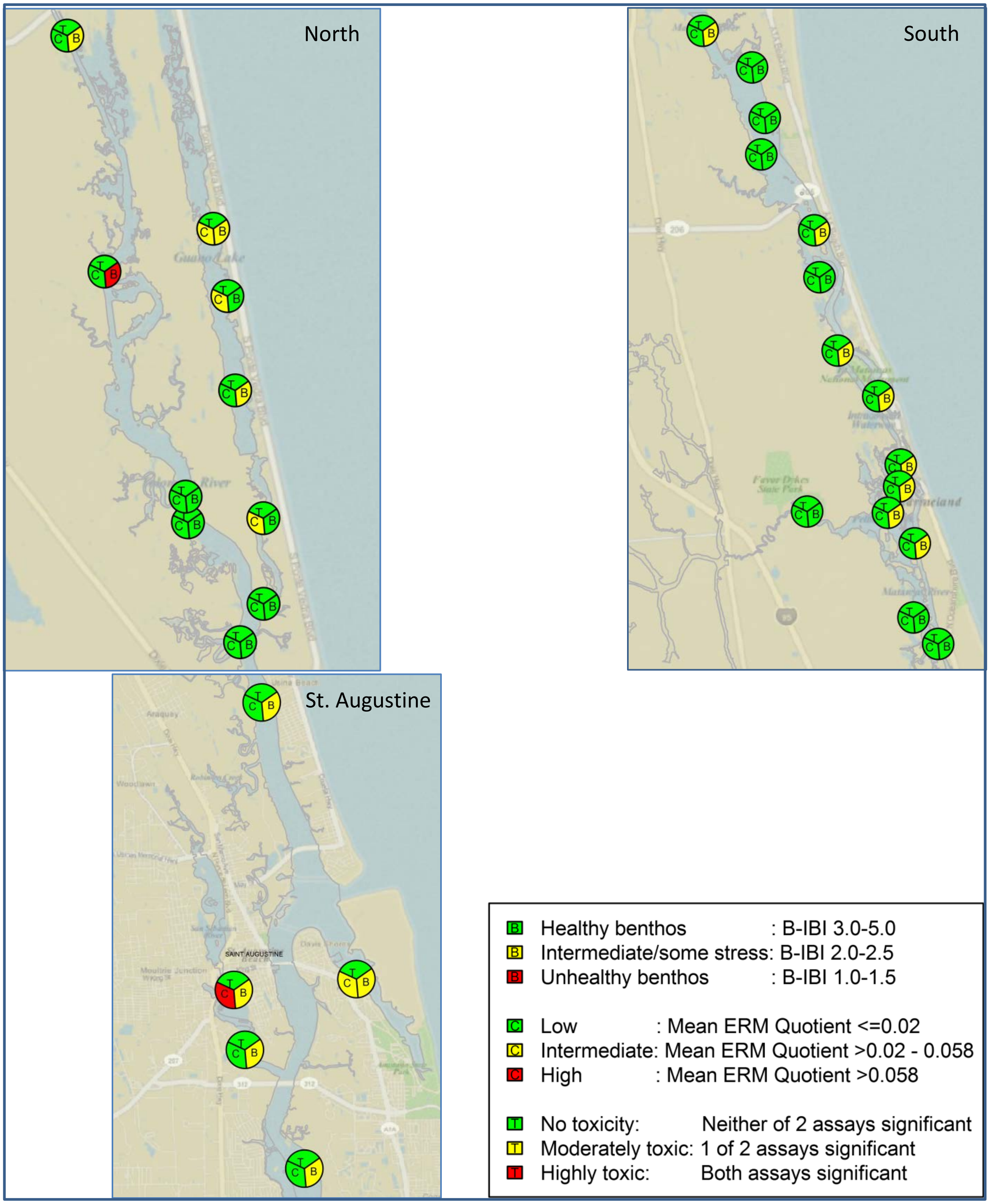

Figure 6. Sediment quality triad results for GTM-NERR-North, GTM-NERR-South, and the St. Augustine area. In the key, B = benthic condition based on southeastern estuarine B-IBI; C = contaminant concentrations in sediments; and T = toxicity based on Microtox solid-phase and organic solvent-extract assays.

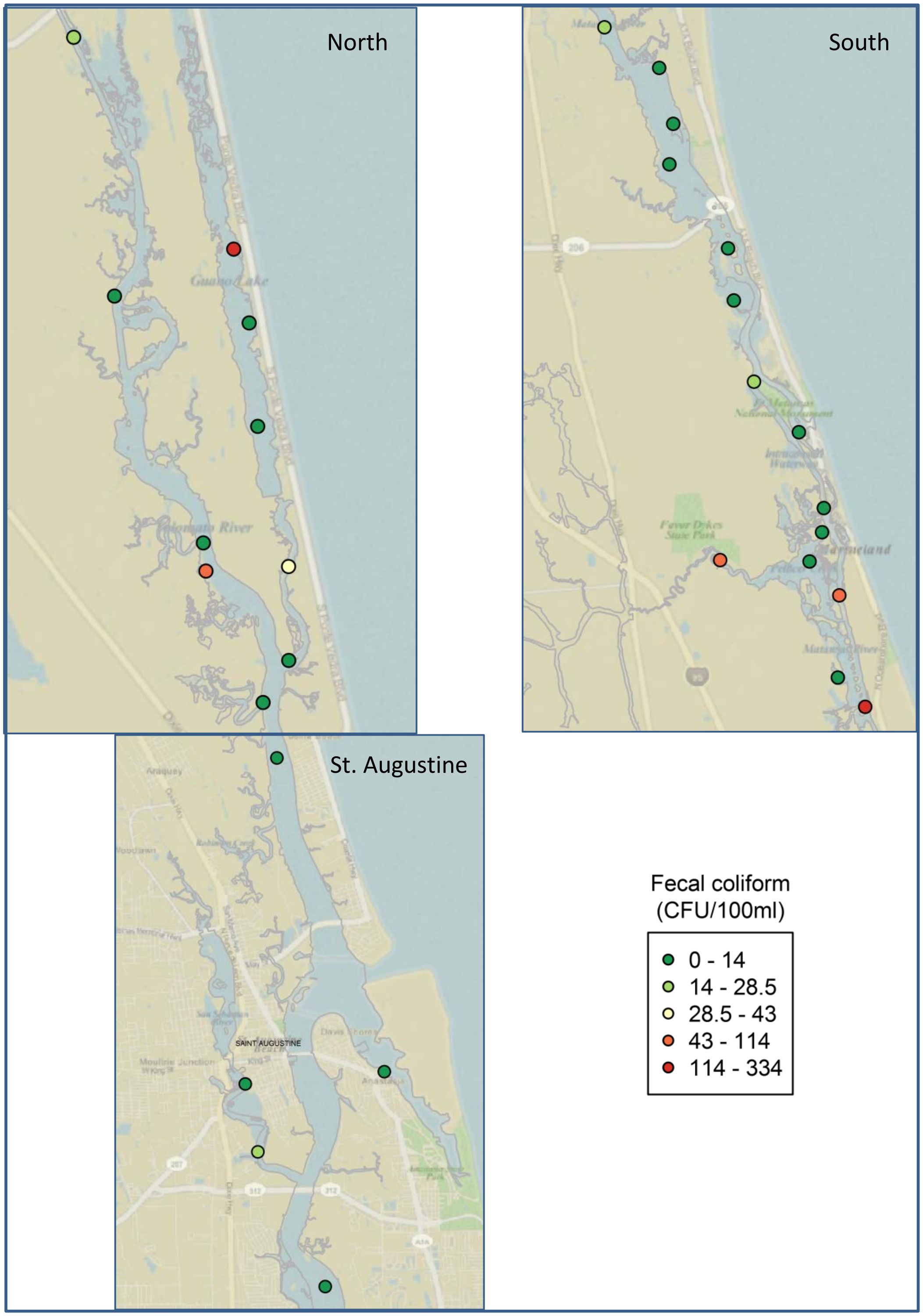

Figure 7. Water column fecal coliform bacteria results for GTM-NERR-North, GTM-NERR-South, and the St. Augustine area. Ranges in fecal coliform levels shown in the legend are based on Jenks natural breaks, but modified to incorporate Florida Surface Water Quality Standards criteria: "fecal coliform bacteria shall not exceed a median value of 14, nor exceed 43 in 10 percent of the samples, nor exceed 800 on any one day" (Florida Administrative Code).

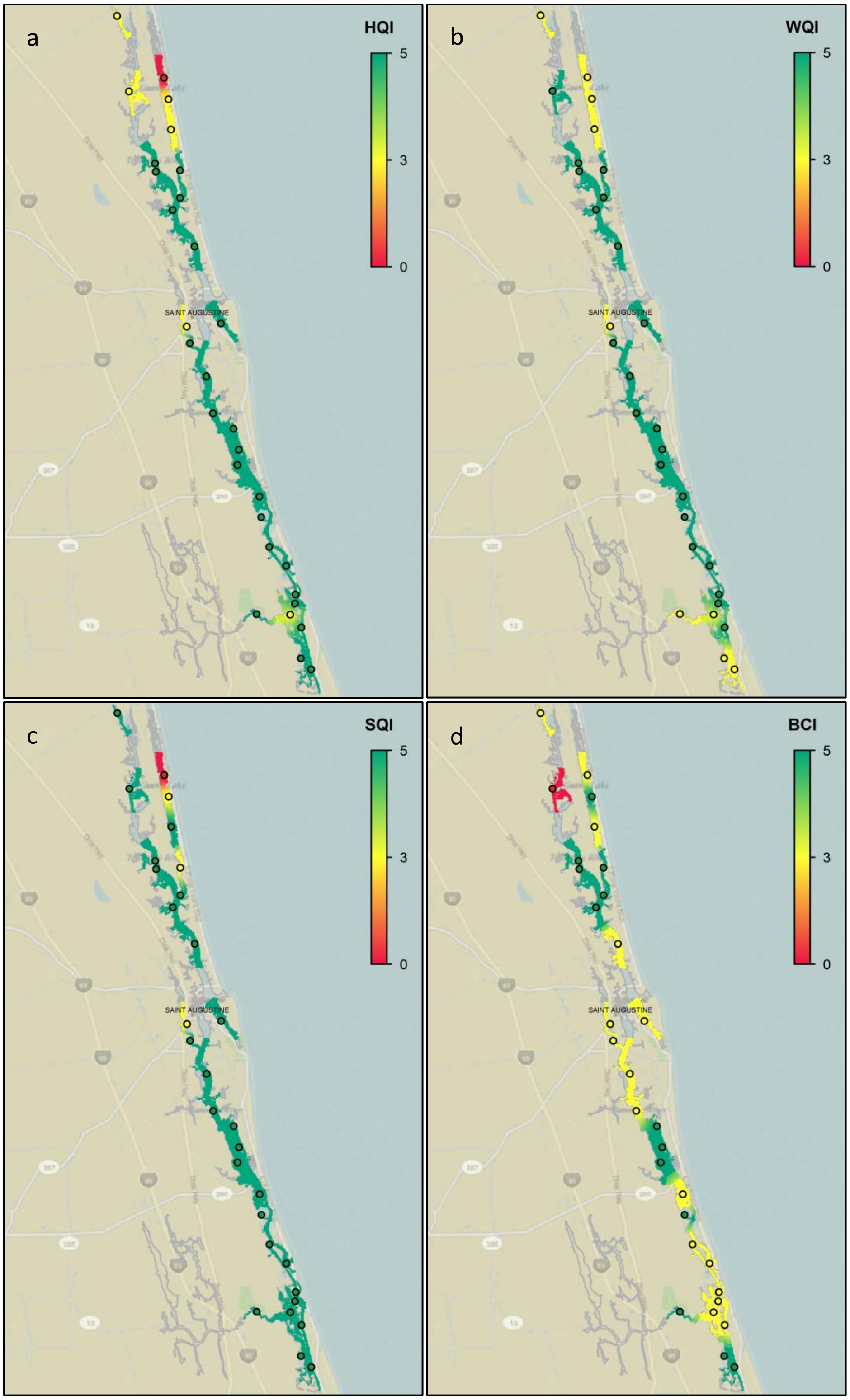

Figure 8. Graphical representation of spatially-interpolated values calculated for (a) overall habitat quality index (HQI) derived from component scores calculated for (b) water quality index (WQI), (c) sediment quality index (SQI), and (d) benthic condition index (BCI).

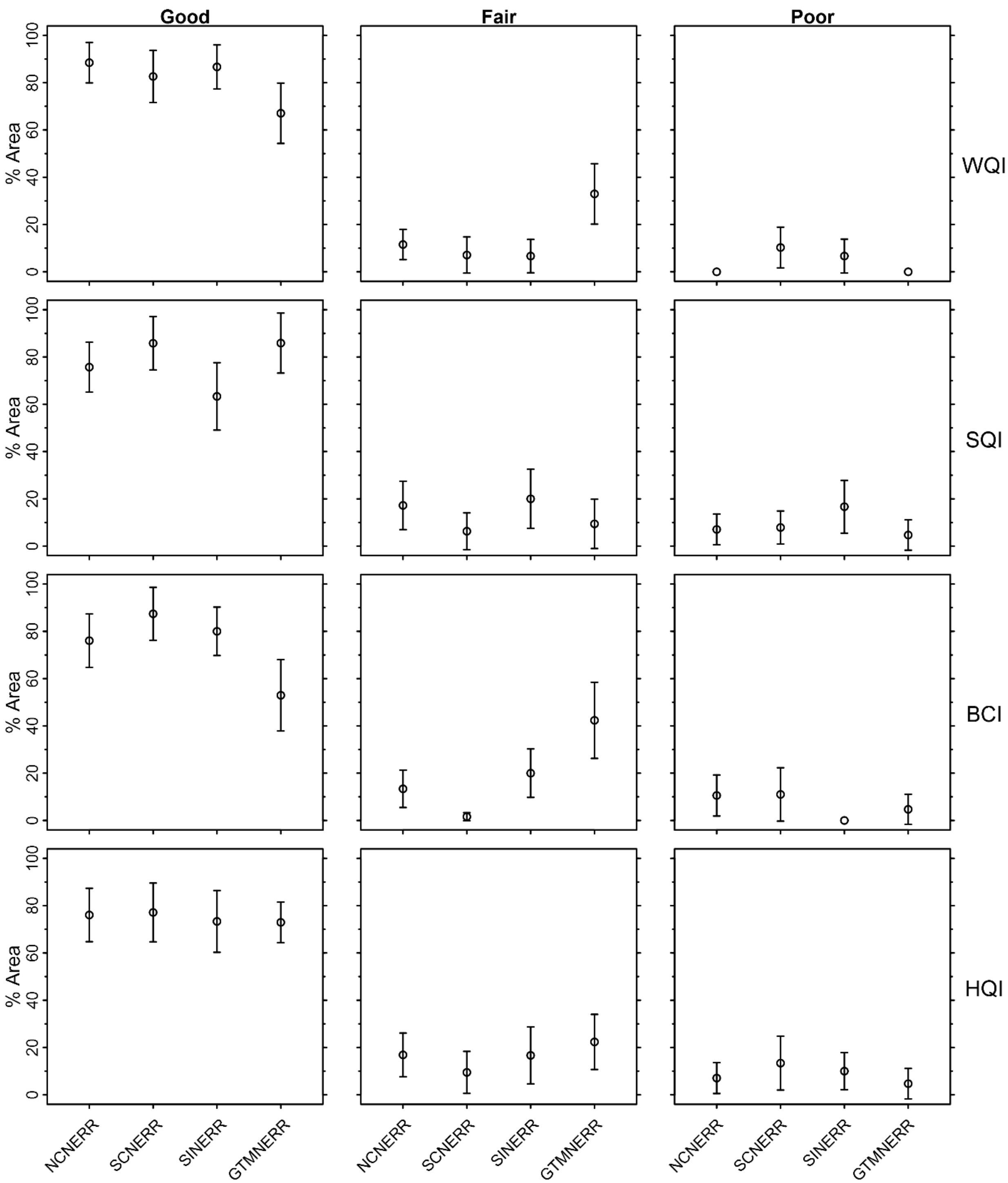

Figure 9. Percent area rated as "Good," "Fair," or "Poor," with respect to water quality (WQI), sediment quality (SQI), benthic condition (BCI), and overall habitat quality (HQI) for 25 stations in GTM-NERR shown in relation to NERRs in NC, SC, and GA.

4. Conclusions

High HQI values at most sites, together with the generally low levels of chemical contaminants in oysters and finfish, and of fecal-coliform bacteria in the water column, suggest that the majority of the GTM-NERR is in good ecological condition and that poor environmental quality is limited to relatively small portions of the reserve. This is consistent with results reported for other southeastern NERRS locations based on similar methods (Balthis et al. 2015). However, indications of environmental stress at some sites – e.g., poor sediment quality in at least one of the three SQT components at two sites and elevated levels of fecal-coliform bacteria at five sites – suggest that the reserve may not be free from pressures that originate from within or outside its boundaries and that long-term monitoring is warranted in order to track potential changes in the future. This study establishes an important baseline of ecological condition within the GTM reserve that can be used to evaluate any such future changes and to trigger appropriate management actions.

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6. References:

American Public Health Association (APHA). 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition. American Public Health Association, Washington, DC.

Balthis, W. L., C. Cooksey, M.F. Fulton, J.L. Hyland, G.H.M. Riekerk, R.F. Van Dolah, and E.F. Wirth. 2015. An integrated assessment of habitat quality of national estuarine research reserves in the southeastern United States. *Integr. Environ. Assess. Manag.* 11: 266–275. doi: 10.1002/ieam.1601

Balthis, W. L., J. Hyland, C. Cooksey, E. Wirth, M. Fulton, J. Moore, and D. Hurley. 2012. Support for Integrated Ecosystem Assessments of NOAA's National Estuarine Research Reserve System (NERRS): Assessment of Ecological Condition and Stressor Impacts in Subtidal Waters of the Sapelo Island National Estuarine Research Reserve. NOAA Tech. Memo. NOS NCCOS 150, 79 pp.

Baston, D.S. and M.S. Denison. 2010. Considerations for potency equivalent calculations in the Ah receptor-based CALUX bioassay: Normalization of superinduction results for improved sample potency estimation. *Talanta* 83:1415-1421.

Brennan, J.C., G. He, T. Tsutsumi, J. Zhao, E. Wirth, M. H. Fulton, and M.S. Denison. 2015. Development of species-specific Ah receptor-responsive third generation CALUX cell lines with increased sensitivity and responsiveness. *Environ Sci Tech* 49(19):11903-11912.

Chapman, P.M., 1990. The sediment quality triad approach to determining pollution-induced degradation. *Sci. Total Environ*. 97(98):815-825.

Cooksey, C., J. Hyland, E. Wirth, W.L. Balthis, M. Fulton, D.Whitall and S. White. 2008. Support for Integrated Ecosystem Assessments of NOAA's National Estuarine Research Reserves System (NERRS), Volume II: Assessment of Ecological Condition and Stressor Impacts in Subtidal Waters of the North Carolina NERRS. NOAA Technical Memorandum NOS NCCOS 83. NOAA Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC. 64 pp.

Denison, M.S., B. Zhao, D.S. Baston, G.C. Clark, H. Murata, and D.H. Han. 2004. Recombinant cell bioassay systems for the detection and relative quantitation of halogenated dioxins and related chemicals *Talanta* 63:1123-1133.

Florida Administrative Code. Chapter 62-302, Surface Water Quality Standards.

Hach. 2003. DR/2500 Spectrophotometer Procedures Manual. Method 8006 Hach Chemical Company, Loveland, CO.

Hyland, J.L., R. Van Dolah, and T. Snoots. 1999. Predicting stress in benthic communities of southeastern U.S. estuaries in relation to chemical contamination of sediments. *Environ. Toxicol. Chem*. 18:2557-2564.

Long, E.R., J. Field, D. MacDonald. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. *Environ. Toxicol. Chem.* 17:714-727.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder, 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environ. Manage*. 19:81–97.

Long E.R., G.I. Scott, J. Kucklick, M. Fulton, B. Thompson, R.S. Carr, J. Biedenbach, K.J. Scott, G.B. Thursby, G.T. Chandler, J.W. Anderson, G.M. Sloane. 1998. Magnitude and extent of sediment toxicity in selected estuaries of South Carolina and Georgia. NOAA Technical Memorandum NOS ORCA 128, Silver Spring, MD. 289 pp.

National Estuarine Research Reserve System (NERRS). 2011. National Estuarine Research Reserve System—System-wide monitoring program plan. Silver Spring (MD): NOAA Estuarine Reserves Pivision. [accessed 2017 March 24]. Available from: https://coast.noaa.gov/data/docs/nerrs/Research_2011SWMPPlan.pdf

Ringwood, A., DeLorenzo, M., Ross, P., Holland, A. 1997. Interpretation of Microtox® solid-phase toxicity tests: the effects of sediment composition. *Environ. Toxicol. Chem.* 16(6):1135-1140.

Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *J. Am. Stat. Ass.* 99(465):262-278.

Technicon, 1973. Technicon Industrial Method No. 155-71W/Tentative. Technicon Industrial Systems. Tarrytown, New York, 10591.

Technicon. 1977. Technicon Industrial Method No. 158-71 W/A Tentative. Technicon Industrial Systems. Tarrytown, New York, 10591.

Technicon. 1986a. Technicon Industrial Method No. 804-86T, August 1986. Technicon Industrial Systems. Tarrytown, New York, 10591.

Technicon. 1986b. Technicon Industrial Method No. 811-86T, November 1986. Technicon Industrial Systems. Tarrytown, New York, 10591.

USEPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2: Risk Assessment and Fish Consumption Limits. EPA-823-B-00-008. U.S. Environmental Protection Agency, Office of Water, Washington, DC. 383 pp.

Valderrama, J. C. 1981. The simultaneous analysis of total nitrogen and total phosphorus in natural waters. *Mar. Chem.* 10: 109-122.

Van Dolah, R. F., J. L. Hyland, A. F. Holland, J. S. Rosen, and T. R. Snoots. 1999. A benthic index of biological integrity for assessing habitat quality in estuaries of the southeastern USA. *Mar. Environ. Res.* 48:269-283.

Van Dolah R.F., D.M. Sanger, G.H.M. Riekerk, S.E. Crowe, M.V. Levisen, D.C. Bergquist, D.E. Chestnut, W. McDermott, M.H. Fulton, and E. Wirth . 2013. The condition of South Carolina's estuarine and coastal habitats during 2009–2010: Technical Report. Charleston (SC): South Carolina Marine Resources Division. Technical Report No. 107.

Welschmeyer, N.A. 1994. Fluorometric analysis of chlorophyll a in the presence of chlorophyll b and phaeopigments. *Limnol. and Oceanogr.* 39: 1985-1992.

Appendix A. Station coordinates and selected water-column and sediment parameters.

				Water Column				Bottom Sediments		
Station	Latitude (DD)	Longitude (DD)	Depth (m)	Temp. (°C)	Salinity (ppt)	DO (mg/L)	pH	TOC (mg/g)	Sand (%)	Silt+Clay (%)
1	30.06816	-81.37072	3.0	31.1	23.8	4.3	7.2	6.2	86.8	13.2
2	30.12635	-81.38132	1.0	31.0	16.8	4.7	7.3	11.0	78.9	21.1
3	29.97677	-81.33210	0.5	31.1	28.6	5.5	7.6	4.0	91.1	8.9
4	30.00633	-81.34695	1.2	29.7	26.0	5.2	7.5	4.7	92.1	7.9
5	30.01266	-81.34763	5.2	29.9	24.9	4.1	7.4	1.8	95.4	4.6
6	30.06212	-81.33572	0.8	30.8	10.3	7.5	8.1	32.4	21.9	78.1
7	30.03886	-81.33350	0.8	30.6	15.1	6.2	8.1	29.1	40.1	59.9
8	30.07872	-81.33974	1.0	31.0	6.9	6.1	7.7	60.9	6.5	93.5
9	30.00735	-81.32548	2.5	30.3	28.4	3.9	7.3	41.0	5.0	95.0
10	29.98623	-81.32543	1.0	31.0	28.4	5.2	7.5	6.3	90.0	10.0
11	29.94874	-81.31264	2.0	30.7	32.0	4.9	7.8	0.0	98.2	1.8
12	29.84869	-81.30209	2.0	30.7	32.6	5.5	7.8	4.3	92.2	7.8
13	29.88936	-81.28921	2.0	30.2	35.2	5.6	7.6	26.0	5.6	94.4
14	29.88704	-81.31953	5.5	30.8	32.9	5.2	7.2	10.0	78.0	22.0
15	29.87419	-81.31679	4.5	30.6	32.3	5.7	7.7	5.4	86.5	13.6
16	29.80842	-81.27804	1.0	30.3	31.9	5.0	7.8	6.8	86.0	14.0
17	29.79218	-81.27335	1.0	30.3	32.0	5.3	7.7	7.0	82.6	17.4
18	29.78043	-81.27463	3.0	30.2	32.3	5.1	7.6	8.1	81.2	18.8
19	29.82020	-81.29631	3.5	30.6	32.4	5.3	7.8	5.4	85.1	14.9
20	29.74093	-81.25311	3.1	30.3	34.6	6.1	7.7	3.3	87.7	12.3
21	29.71735	-81.24638	2.6	28.3	35.8	6.4	7.9	0.0	98.3	1.7
22	29.75605	-81.25504	1.2	30.3	33.5	6.0	7.7	4.0	91.5	8.5
23	29.70270	-81.23139	1.0	28.6	35.5	6.7	7.9	0.0	97.9	2.1
24	29.62299	-81.20924	0.5	29.6	14.0	5.5	7.6	2.8	95.5	4.5
25	29.65534	-81.21789	3.1	29.3	22.9	5.2	7.9	2.3	97.4	2.6
26	29.68068	-81.22307	2.7	29.0	28.6	5.1	7.9	0.0	98.9	1.1
27	29.66557	-81.25768	1.0	32.0	6.2	6.3	6.7	15.3	76.2	23.8
28	29.63149	-81.21838	0.5	30.6	17.8	7.1	7.6	11.5	58.0	42.0
29	29.67366	-81.22366	0.7	29.4	33.6	6.9	7.6	1.4	96.9	3.1
30	29.66518	-81.22782	3.1	31.3	22.1	6.7	7.6	12.9	64.6	35.4

Appendix B. Water-column nutrients, chlorophyll, turbidity, total suspended solids, and fecal coliform results, by station.

Station	Ammonium (µg/L)	Nitrate (µg/L)	Nitrite (µg/L)	Orthophosphate (µg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll a (µg/L)	Phaeophytin (µg/L)	Turbidity (NTU)	TSS (mg/L)	Fecal Coliform (CFU/100ml)
1	23	6.7	20.9	57.9	0.73	0.106	7.4	2.9	11.9	64	8.3
2	22	0.8	53.8	99.7	0.86	0.168	21.6	5.6	13.0	37	24.3
3	6	3.4	1.1	36.7	0.61	0.081	8.9	3.0	11.3	79	6.3
4	52	8.7	10.5	49.0	0.64	0.091	6.1	3.1	16.0	68	49.0
5	26	11.8	19.9	50.2	0.69	0.102	5.6	3.6	16.8	53	13.7
6	15	1.3	2.7	14.6	1.38	0.094	46.7	5.5	13.7	24	9.7
7	8	4.9	0.0	4.6	1.26	0.078	16.6	2.9	12.2	41	4.3
8	14	1.9	0.0	5.4	1.56	0.094	44.1	7.6	32.7	40	294.0
9	5	4.9	0.0	23.9	0.73	0.093	15.4	4.2	11.1	69	29.3
10	9	5.5	1.5	30.0	0.59	0.075	8.1	2.9	21.9	61	3.7
11	7	12.7	0.0	22.8	0.54	0.087	7.7	3.6	9.2	83	4.0
12	31	29.6	6.4	29.7	0.56	0.091	8.0	3.8	15.3	85	11.3
13	21	2.8	0.0	23.7	0.38	0.073	9.9	2.2	9.1	70	1.3
14	28	28.4	6.2	29.5	0.55	0.083	9.7	2.5	16.6	73	0.3
15	18	28.0	4.9	25.0	0.41	0.062	10.7	4.6	15.7	72	21.0
16	51	27.0	7.9	36.1	0.54	0.088	7.7	2.9	12.9	76	2.0
17	47	24.4	6.7	33.0	0.54	0.080	6.6	3.0	9.4	60	0.0
18	31	23.7	6.3	31.7	0.49	0.078	7.3	2.5	9.1	64	0.0
19	30	23.7	6.3	29.0	0.53	0.077	8.0	2.9	12.2	68	19.0
20	15	6.0	1.7	19.9	0.38	0.061	4.1	1.6	11.3	67	0.0
21	6	3.5	0.9	13.6	0.27	0.050	8.1	2.3	11.4	102	19.5
22	16	11.7	3.3	20.6	0.43	0.065	6.5	1.9	6.2	69	0.0
23	16	4.9	2.4	11.4	0.24	0.044	6.5	1.9	5.8	84	3.0
24	40	13.6	3.6	57.8	1.04	0.168	32.6	11.1	36.6	54	334.0
25	10	20.3	0.0	40.9	0.69	0.110	13.3	4.9	11.3	60	49.5
26	3	8.8	0.0	26.1	0.54	0.081	11.1	3.4	8.2	48	3.0
27	32	45.1	0.0	54.0	1.11	0.136	46.4	4.9	17.2	54	114.0
28	8	6.0	0.0	51.6	0.88	0.148	33.5	8.3	24.8	43	4.0
29	4	4.9	0.0	15.2	0.37	0.066	8.9	2.7	11.9	88	9.0
30	15	13.9	2.0	38.3	0.78	0.122	19.9	5.8	25.6	67	6.5

Appendix C. Mean ERM quotient, number of ERLs exceeded, and number of ERMs exceeded, by station.

Station	Mean ERM Quotient	# of ERLs Exceeded	# of ERMs Exceeded
1	0.007	0	0
2	0.012	0	0
3	0.008	0	0
4	0.007	0	0
5	0.007	0	0
6	0.021	0	0
7	0.016	0	0
8	0.021	0	0
9	0.025	0	0
10	0.010	0	0
11	0.005	0	0
12	0.011	0	0
13	0.024	0	0
14	0.128	8	0
15	0.012	0	0
16	0.010	0	0
17	0.011	0	0
18	0.012	0	0
19	0.010	0	0
20	0.010	0	0
21	0.005	0	0
22	0.007	0	0
23	0.005	0	0
24	0.008	0	0
25	0.005	0	0
26	0.005	0	0
27	0.012	0	0
28	0.015	0	0
29	0.006	0	0
30	0.016	0	0

Appendix D. Percent silt+clay and results of three toxicity assays, by station.

Station	Silt+Clay (%)	Microtox Solid-Phase Mean EC50 (%)	Microtox Solvent Extract Mean EC50 (mg/mL)	Reporter Gene Assay B[a]PEQ (µg/g)	Significant Toxicity
1	13.2	1.60	0.57	36.25	No
2	21.1	0.58	0.49	38.78	No
3	8.9	1.38	0.60	27.01	No
4	7.9	4.99	2.61	29.76	No
5	4.6	16.03	10.47	16.18	No
6	78.1	0.62	0.49	39.96	No
7	59.9	0.81	0.28	2.95	No
8	93.5	1.29	0.26	3.27	No
9	95.0	0.64	0.35	12.34	No
10	10.0	1.19	0.77	61.49	No
11	1.8	15.35	18.98	4.84	No
12	7.8	4.77	3.15	45.42	No
13	94.4	0.69	0.66	9.78	No
14	22.0	1.64	0.66	6.78	No
15	13.6	1.05	1.81	47.86	No
16	14.0	1.38	1.26	4.66	No
17	17.4	2.37	1.06	15.40	No
18	18.8	2.22	1.27	7.39	No
19	14.9	2.93	2.14	43.80	No
20	12.3	1.44	1.02	11.25	No
21	1.7	15.55	6.55	6.21	No
22	8.5	2.08	2.51	7.48	No
23	2.1	15.41	6.90	1.19	No
24	4.5	2.50	1.39	6.51	No
25	2.6	15.86	5.16	3.52	No
26	1.1	16.37	76.56	1.48	No
27	23.8	0.34	1.15	22.34	No
28	42.0	1.43	0.96	39.57	No
29	3.1	15.07	1.44	4.96	No
30	35.4	1.07	0.93	17.94	No

Appendix E. Measures of benthic abundance (density), richness (# of taxa), and diversity (Shannon H′), by station.

Station	Mean Density (# of ind./m^2)	Total # of Taxa	Mean # of Taxa Per Grab	Mean H′ Per Grab
1	125	6	3.5	1.6
2	313	5	3.0	0.9
3	1775	24	18.0	3.6
4	2250	40	25.5	3.6
5	813	11	7.5	2.2
6	513	9	6.0	1.9
7	225	5	3.0	1.4
8	488	3	3.0	1.2
9	725	15	10.0	2.8
10	2263	34	23.5	3.8
11	738	6	3.0	0.9
12	1175	19	15.5	3.2
13	1488	17	9.5	2.0
14	1250	25	15.5	3.2
15	4475	41	23.5	2.6
16	1238	24	15.0	3.0
17	2588	41	31.5	4.0
18	1350	35	23.5	4.1
19	1788	28	18.5	3.2
20	3863	34	26.5	3.8
21	1588	23	16.0	3.1
22	2313	33	23.0	3.5
23	825	9	6.5	2.3
24	4438	40	28.0	3.7
25	763	17	11.0	2.7
26	1113	18	12.5	2.5
27	32588	15	13.0	1.8
28	788	15	10.0	2.7
29	413	11	6.5	2.3
30	3000	24	17.0	2.9

Appendix F. Integrated scores and indices for water quality, sediment quality, benthic condition, and overall habitat quality, by station.

Station	WQI Score	WQI	SQI Score	SQI	B-IBI	BCI	HQI Score	HQI
1	4.5	5	5.0	5	1.5	0	3.3	3
2	3.8	3	5.0	5	2.0	3	3.7	3
3	5.0	5	5.0	5	3.0	5	5.0	5
4	4.5	5	5.0	5	4.5	5	5.0	5
5	5.0	5	5.0	5	3.5	5	5.0	5
6	3.8	3	3.7	3	3.0	5	3.7	3
7	3.8	3	5.0	5	2.5	3	3.7	3
8	3.3	3	2.7	0	2.0	3	2.0	0
9	4.0	5	3.7	3	3.0	5	4.3	5
10	5.0	5	5.0	5	3.0	5	5.0	5
11	5.0	5	5.0	5	2.0	3	4.3	5
12	5.0	5	5.0	5	2.0	3	4.3	5
13	5.0	5	4.3	5	2.0	3	4.3	5
14	3.8	3	3.3	3	2.0	3	3.0	3
15	5.0	5	5.0	5	2.5	3	4.3	5
16	5.0	5	5.0	5	3.0	5	5.0	5
17	5.0	5	5.0	5	3.0	5	5.0	5
18	5.0	5	5.0	5	3.0	5	5.0	5
19	5.0	5	5.0	5	2.0	3	4.3	5
20	5.0	5	5.0	5	4.0	5	5.0	5
21	5.0	5	5.0	5	2.0	3	4.3	5
22	5.0	5	5.0	5	2.5	3	4.3	5
23	5.0	5	5.0	5	2.0	3	4.3	5
24	3.3	3	5.0	5	5.0	5	4.3	5
25	4.0	5	5.0	5	2.0	3	4.3	5
26	5.0	5	5.0	5	2.0	3	4.3	5
27	3.3	3	5.0	5	3.5	5	4.3	5
28	3.8	3	5.0	5	3.5	5	4.3	5
29	5.0	5	5.0	5	2.0	3	4.3	5
30	3.8	3	5.0	5	2.0	3	3.7	3

Appendix G. Summary of sediment contaminant levels (*mean [min – max]*) by sampling region (GTM-North, GTM-South, St. Augustine area) and overall study area.

Analyte	GTM-North (10 stations)	GTM-South (15 stations)	St. Augustine area (5 stations)	Overall (30 stations)
Metals (µg/g dry wt.)				
Silver	< MDL	< MDL	< MDL	< MDL
Aluminum	1.715 [0.284 - 3.915]	0.598 [0.031 - 1.453]	0.964 [0.088 - 2.615]	1.031 [0.031 - 3.915]
Arsenic	3.44 [0.971 - 6.941]	1.912 [0.59 - 4.104]	2.69 [0.831 - 5.634]	2.551 [0.59 - 6.941]
Barium	153.602 [48.331 - 286.653]	144.34 [27.951 - 263.074]	138.705 [91.515 - 221.863]	146.488 [27.951 - 286.653]
Beryllium	0.196 [0.076 - 0.318]	0.107 [0 - 0.192]	0.151 [0.074 - 0.276]	0.144 [0 - 0.318]
Cadmium	0.02 [0 - 0.204]	< MDL	< MDL	0.007 [0 - 0.204]
Cobalt	1.06 [0.416 - 1.603]	0.796 [0 - 1.357]	1.055 [0.398 - 1.527]	0.927 [0 - 1.603]
Chromium	8.252 [3.517 - 11.736]	5.613 [1.089 - 9.08]	6.585 [3.987 - 10.096]	6.655 [1.089 - 11.736]
Copper	2.734 [0 - 7.404]	1.437 [0 - 5.073]	5.282 [0 - 11.507]	2.51 [0 - 11.507]
Iron	1.116 [0.171 - 2.662]	0.446 [0.07 - 1.121]	0.654 [0.087 - 1.736]	0.704 [0.07 - 2.662]
Mercury	0.027 [0.003 - 0.074]	0.01 [0.001 - 0.027]	0.017 [0 - 0.037]	0.017 [0 - 0.074]
Lithium	10.903 [2.26 - 20.452]	5.09 [0.496 - 12.307]	7.675 [0.966 - 20.19]	7.458 [0.496 - 20.452]
Manganese	70.012 [34.864 - 170.252]	36.263 [6.042 - 73.315]	70.087 [15.863 - 151.117]	53.15 [6.042 - 170.252]
Nickel	5.194 [0.877 - 11.776]	2.199 [0.387 - 4.657]	3.534 [0.409 - 9.207]	3.42 [0.387 - 11.776]
Lead	14.212 [3.996 - 27.257]	7.52 [1.571 - 13.903]	10.032 [4.444 - 17.529]	10.17 [1.571 - 27.257]
Antimony	< MDL	< MDL	< MDL	< MDL
Selenium	0.352 [0 - 0.892]	0.06 [0 - 0.314]	0.16 [0 - 0.517]	0.174 [0 - 0.892]
Tin	1.069 [0.328 - 2.027]	1.382 [0.225 - 11.641]	0.854 [0.334 - 1.466]	1.19 [0.225 - 11.641]
Thallium	0.229 [0 - 0.482]	0.13 [0 - 0.28]	0.177 [0.1 - 0.356]	0.171 [0 - 0.482]
Uranium	2.568 [0.728 - 4.34]	1.238 [0.299 - 2.05]	1.522 [1.045 - 2.709]	1.729 [0.299 - 4.34]
Vanadium	9.968 [4.375 - 14.422]	6.887 [1.703 - 11.063]	8.014 [4.284 - 12.231]	8.102 [1.703 - 14.422]
Zinc	49.752 [24.85 - 73.336]	45.478 [30.436 - 59.043]	60.835 [34.475 - 91.27]	49.462 [24.85 - 91.27]

Appendix G (continued).

Analyte	GTM-North (10 stations)	GTM-South (15 stations)	St. Augustine area (5 stations)	Overall (30 stations)
PAHs (ng/g dry wt.)				
1-Methylnaphthalene	< MDL	0.073 [0 - 1.101]	3.133 [0 - 15.664]	0.559 [0 - 15.664]
1-Methylphenanthrene	1.33 [0 - 5.932]	0.31 [0 - 1.008]	9.415 [0 - 43.34]	2.168 [0 - 43.34]
1,6,7-Trimethylnaphthalene	< MDL	< MDL	< MDL	< MDL
2-Methylnaphthalene	< MDL	< MDL	5.242 [0 - 26.212]	0.874 [0 - 26.212]
2,6+2,7-Dimethylnaphthalene	0.066 [0 - 0.663]	< MDL	3.098 [0 - 15.488]	0.538 [0 - 15.488]
Acenaphthene	0.167 [0 - 1.028]	< MDL	2.263 [0 - 11.315]	0.433 [0 - 11.315]
Acenaphthylene	0.057 [0 - 0.292]	0.173 [0 - 1.448]	31.854 [0 - 154.257]	5.415 [0 - 154.257]
Anthracene	1.14 [0.214 - 2.58]	0.555 [0 - 1.723]	10.767 [0 - 47.289]	2.452 [0 - 47.289]
Benz [a]anthracene	1.743 [0 - 6.192]	1.369 [0 - 4.68]	82.77 [0 - 386.061]	15.06 [0 - 386.061]
Benzo [a]pyrene	2.328 [0 - 10.59]	2.656 [0 - 8.474]	226.606 [0 - 1088.481]	39.872 [0 - 1088.481]
Benzo [b]fluoranthene	4.028 [1.854 - 12.168]	3.045 [0 - 9.055]	129.372 [0 - 606.113]	24.427 [0 - 606.113]
Benzo [e]pyrene	2.451 [0 - 9.5]	1.946 [0 - 6.571]	136.975 [0 - 646.681]	24.619 [0 - 646.681]
Benzo [g,h,i]perylene	2.419 [0 - 7.573]	1.875 [0 - 5.359]	109.866 [0 - 518.36]	20.055 [0 - 518.36]
Benzo [j]fluoranthene	1.462 [0 - 5.786]	1.265 [0 - 4.245]	90.582 [0 - 431.061]	16.217 [0 - 431.061]
Benzo [k]fluoranthene	1.27 [0 - 6.149]	1.216 [0 - 3.858]	81.599 [0 - 386.461]	14.631 [0 - 386.461]
Biphenyl	< MDL	< MDL	1.268 [0 - 6.34]	0.211 [0 - 6.34]
Chrysene+Triphenylene	3.085 [1.382 - 9.346]	2.531 [0 - 6.984]	113.572 [0 - 529.21]	21.222 [0 - 529.21]
Dibenz [a,h]anthracene	< MDL	< MDL	29.752 [0 - 145.741]	4.959 [0 - 145.741]
Dibenzothiophene	< MDL	< MDL	< MDL	< MDL
Fluoranthene	5.949 [2.39 - 13.535]	4.074 [0 - 8.89]	86.036 [0 - 374.028]	18.359 [0 - 374.028]
Fluorene	0.812 [0 - 2.309]	0.203 [0 - 1.243]	0.683 [0 - 2.062]	0.486 [0 - 2.309]
Indeno [1,2,3-c,d]pyrene	2.519 [0 - 7.976]	1.984 [0 - 5.041]	113.905 [0 - 539.677]	20.816 [0 - 539.677]
Naphthalene	< MDL	< MDL	8.272 [0 - 41.361]	1.379 [0 - 41.361]
Perylene	4.681 [0 - 13.521]	4.501 [0 - 16.394]	43.756 [0 - 189.776]	11.104 [0 - 189.776]
Phenanthrene	1.742 [0 - 5.041]	1.269 [0 - 3.168]	13.514 [0 - 54.362]	3.468 [0 - 54.362]
Pyrene	4.723 [1.776 - 10.435]	3.746 [0 - 8.489]	273.511 [0 - 1304.849]	49.032 [0 - 1304.849]
Low Molecular Weight PAHs	5.249 [0.804 - 15.708]	2.584 [0 - 7.359]	86.411 [0 - 400.141]	17.444 [0 - 400.141]
High Molecular Weight PAHs	29.527 [10.788 - 89.75]	23.76 [0 - 62.521]	1337.57 [0 - 6310.043]	244.651 [0 - 6310.043]
Total PAHs	37.227 [16.938 - 110.57]	28.29 [0 - 72.419]	1560.957 [0 - 7356.865]	286.713 [0 - 7356.865]

Appendix G (continued).

Analyte	GTM-North (10 stations)	GTM-South (15 stations)	St. Augustine area (5 stations)	Overall (30 stations)
PBDEs (ng/g dry wt.)				
Total PBDEs	0.087 [0 - 0.307]	< MDL	0.075 [0 - 0.373]	0.041 [0 - 0.373]
PCBs (ng/g dry wt.)				
Total PCBs	0.137 [0 - 0.521]	1.013 [0 - 7.998]	3.274 [0 - 13.348]	1.098 [0 - 13.348]
Pesticides (ng/g dry wt.)				
2,4'-DDD (o,p'-DDD)	< MDL	< MDL	< MDL	< MDL
4,4'-DDD (p,p'-DDD)	0.043 [0 - 0.258]	0.004 [0 - 0.043]	< MDL	0.016 [0 - 0.258]
2,4'-DDE (o,p'-DDE)	< MDL	< MDL	< MDL	< MDL
4,4'-DDE (p,p'-DDE)	0.034 [0 - 0.148]	0.019 [0 - 0.118]	0.021 [0 - 0.107]	0.024 [0 - 0.148]
2,4'-DDT (o,p'-DDT)	< MDL	< MDL	< MDL	< MDL
4,4'-DDT (p,p'-DDT)	< MDL	< MDL	< MDL	< MDL
Aldrin	< MDL	< MDL	< MDL	< MDL
alpha-Chlordane	0.006 [0 - 0.029]	< MDL	0.17 [0 - 0.828]	0.03 [0 - 0.828]
alpha-Hexachlorocyclohexane (alpha-BHC)	< MDL	< MDL	< MDL	< MDL
beta-Hexachlorocyclohexane (beta-BHC)	< MDL	< MDL	< MDL	< MDL
Chlorpyrifos	0 [0 - 0.003]	< MDL	0.003 [0 - 0.017]	0.001 [0 - 0.017]
cis-Nonachlor	0.006 [0 - 0.019]	0.002 [0 - 0.009]	0.058 [0 - 0.27]	0.012 [0 - 0.27]
Dieldrin	< MDL	< MDL	< MDL	< MDL
Endosulfan I	< MDL	< MDL	< MDL	< MDL
Endosulfan II (Beta-Endosulfan)	< MDL	< MDL	< MDL	< MDL
Endosulfan sulfate	0.001 [0 - 0.004]	0.002 [0 - 0.023]	< MDL	0.001 [0 - 0.023]
Endrin	< MDL	< MDL	< MDL	< MDL
gamma-Chlordane	0.006 [0 - 0.038]	< MDL	0.219 [0 - 1.008]	0.039 [0 - 1.008]
gamma-Hexachlorocyclohexane (gamma-BHC = Lindane)	< MDL	< MDL	< MDL	< MDL
Heptachlor	< MDL	< MDL	0.012 [0 - 0.061]	0.002 [0 - 0.061]
Heptachlor epoxide	< MDL	< MDL	< MDL	< MDL
Hexachlorobenzene (HCB)	0.001 [0 - 0.01]	< MDL	0.056 [0 - 0.282]	0.01 [0 - 0.282]
Mirex	< MDL	< MDL	0.011 [0 - 0.057]	0.002 [0 - 0.057]
Oxychlordane	< MDL	< MDL	< MDL	< MDL
trans-Nonachlor	0.004 [0 - 0.023]	< MDL	0.114 [0 - 0.527]	0.02 [0 - 0.527]
Total DDTs	0.076 [0 - 0.407]	0.023 [0 - 0.118]	0.021 [0 - 0.107]	0.04 [0 - 0.407]

Appendix H. Risk-based EPA advisory guidelines for recreational fishers corresponding to four fish meals per month (USEPA 2000).

	EPA Advisory Guidelines Concentration Range		
Metals (µg/g wet wt.)			
Arsenic (inorganic)[c]	>0.35	–	0.70[a]
Cadmium	>0.35	–	0.70[a]
Mercury (methylmercury)[d]	>0.12	–	0.23[a]
Selenium	>5.90	–	12.00[a]
Organics (ng/g wet wt.)			
Chlordane	>590	–	1,200[a]
Chlorpyrifos	>350	–	700[a]
DDT (total)	>59	–	120[a]
Dieldrin	>59	–	120[a]
Endosulfan	>7,000	–	14,000[a]
Heptachlor epoxide	>15	–	31[a]
Hexachlorobenzene	>940	–	1,900[a]
Lindane	>350	–	700[a]
Mirex	>230	–	470[a]
Toxaphene	>290	–	590[a]
PAHs (benzo[a]pyrene)	>1.6	–	3.2[b]
PCB (total)	>23	–	47[a]

[a] Range of concentrations for non-cancer health endpoints; based on the assumption that consumption over a lifetime of four 8-oz meals per month would not generate a chronic, systemic health risk.

[b] Range of concentrations for cancer health endpoints; based on the assumption that consumption over a lifetime of four 8-oz meals per month would yield a lifetime cancer risk no greater than an acceptable risk of 1 in 100,000.

[c] Inorganic arsenic, the form considered toxic, estimated as 2% of total arsenic.

[d] Because most mercury in fish and shellfish tissue is present primarily as methylmercury and because of the relatively high cost of analyzing for methylmercury, the conservative assumption was made that all mercury is present as methylmercury (U.S. EPA, 2000).

Appendix I-1. Summary of contaminant concentrations (wet weight, *mean [min - max]*) observed in edible tissues of oysters (*Crassostrea virginica*). Concentrations below method detection limits are reported as < MDL; in these cases, a value of zero was used for data computations (e.g., averaging across all stations). Tissue concentrations are compared to risk-based U.S. EPA guidance ranges (wet weights) for recreational fishers where available (Appendix H herein; USEPA 2000). Concentrations relative to guideline ranges for corresponding chemicals are flagged as follows: * concentration falls within the range of values for which EPA recommends limiting fish consumption to four meals per month; ** concentration exceeds the upper limit of EPA guidance range (limit consumption to fewer than four meals per month).

Analyte	GTM-North (2 of 10 stations)	GTM-South (1 of 15 stations)	St. Augustine area (2 of 5 stations)	Overall (5 of 30 stations)
Metals (µg/g wet wt.)				
Aluminum	23.598 [23.577 - 23.62]	47.644	59.372 [26.211 - 92.533]	42.717 [23.577 - 92.533]
Arsenic	1.425 [1.085 - 1.766]	0.981	1.501 [1.217 - 1.785]	1.367 [0.981 - 1.785]
Arsenic (inorganic)	0.029 [0.022 - 0.035]	0.020	0.03 [0.024 - 0.036]	0.027 [0.02 - 0.036]
Barium	0.133 [0.067 - 0.2]	0.1	0.216 [0.134 - 0.298]	0.16 [0.067 - 0.298]
Beryllium	< MDL	< MDL	< MDL	< MDL
Cadmium	0.065 [0.046 - 0.084]	0.058	0.057 [0.055 - 0.06]	0.061 [0.046 - 0.084]
Cobalt	0.055 [0.049 - 0.06]	0.041	0.036 [0.031 - 0.042]	0.044 [0.031 - 0.06]
Chromium	0.207 [0.145 - 0.268]	0.265	0.128 [0.106 - 0.149]	0.187 [0.106 - 0.268]
Copper	2.281 [1.399 - 3.162]	7.355	15.179 [7.533 - 22.825]	8.455 [1.399 - 22.825]
Iron	25.726 [22.756 - 28.696]	43.370	29.167 [20.834 - 37.499]	30.631 [20.834 - 43.37]
Mercury	0.005 [0.005 - 0.006]	0.008	0.027 [0.003 - 0.052]	0.015 [0.003 - 0.052]
Lithium	0.101 [0.063 - 0.139]	0.078	0.158 [0.155 - 0.162]	0.12 [0.063 - 0.162]
Manganese	1.687 [1.446 - 1.929]	3.732	1.657 [1.546 - 1.767]	2.084 [1.446 - 3.732]
Nickel	0.129 [0.12 - 0.138]	0.097	0.108 [0.079 - 0.137]	0.114 [0.079 - 0.138]
Lead	0.034 [0.033 - 0.036]	0.056	0.048 [0.029 - 0.067]	0.044 [0.029 - 0.067]
Antimony	< MDL	< MDL	< MDL	< MDL
Selenium	0.786 [0.613 - 0.959]	0.548	0.586 [0.457 - 0.715]	0.658 [0.457 - 0.959]
Silver	0.058 [0.025 - 0.091]	0.075	0.132 [0.067 - 0.196]	0.091 [0.025 - 0.196]
Tin	0.024 [0.02 - 0.029]	0.020	0.025 [0.02 - 0.029]	0.024 [0.02 - 0.029]
Thallium	< MDL	< MDL	< MDL	< MDL
Uranium	0.016 [0 - 0.032]	< MDL	0.016 [0 - 0.032]	0.013 [0 - 0.032]
Vanadium	0.733 [0.69 - 0.776]	0.428	0.523 [0.402 - 0.643]	0.588 [0.402 - 0.776]
Zinc	101.3 [81.998 - 120.602]	220.153	187.223 [175.943 - 198.503]	159.44 [81.998 - 220.153]

Appendix I-1 (continued).

Analyte	GTM-North (2 of 10 stations)	GTM-South (1 of 15 stations)	St. Augustine area (2 of 5 stations)	Overall (5 of 30 stations)
PAHs (ng/g wet wt.)				
Acenaphthene	< MDL	< MDL	0.759 [0 - 1.518]	0.304 [0 - 1.518]
Acenaphthylene	< MDL	< MDL	< MDL	< MDL
Anthracene	< MDL	< MDL	0.17 [0 - 0.339]	0.068 [0 - 0.339]
Benz[a]anthracene	0.103 [0 - 0.206]	0.248	0.984 [0.222 - 1.745]	0.484 [0 - 1.745]
Benzo[a]pyrene	< MDL	< MDL	0.256 [0 - 0.512]	0.102 [0 - 0.512]
Benzo[e]pyrene	< MDL	< MDL	0.623 [0.248 - 0.998]	0.249 [0 - 0.998]
Benzo[a]fluoranthene	< MDL	< MDL	0.104 [0 - 0.208]	0.042 [0 - 0.208]
Benzo[b]fluoranthene	0.076 [0 - 0.152]	0.192	0.897 [0.298 - 1.496]	0.428 [0 - 1.496]
Benzo[j]fluoranthene	< MDL	< MDL	0.404 [0.113 - 0.694]	0.161 [0 - 0.694]
Benzo[k]fluoranthene	0.037 [0 - 0.073]	0.085	0.403 [0.125 - 0.68]	0.193 [0 - 0.68]
Benzo[g,h,i]perylene	< MDL	< MDL	0.151 [0 - 0.302]	0.06 [0 - 0.302]
Biphenyl	< MDL	< MDL	< MDL	< MDL
Chrysene+Triphenylene	0.259 [0.193 - 0.326]	0.202	1.263 [0.232 - 2.294]	0.649 [0.193 - 2.294]
Dibenz[a,h]anthracene	< MDL	< MDL	< MDL	< MDL
Dibenzothiophene	< MDL	< MDL	< MDL	< MDL
Fluoranthene	0.868 [0.635 - 1.101]	1.117	3.884 [1.371 - 6.396]	2.124 [0.635 - 6.396]
Fluorene	< MDL	< MDL	< MDL	< MDL
Indeno[1,2,3-c,d]pyrene	< MDL	< MDL	0.12 [0 - 0.239]	0.048 [0 - 0.239]
1-Methylnaphthalene	< MDL	< MDL	< MDL	< MDL
2-Methylnaphthalene	< MDL	< MDL	< MDL	< MDL
1-Methylphenanthrene	0.185 [0.185 - 0.186]	< MDL	0.433 [0.383 - 0.482]	0.247 [0 - 0.482]
Naphthalene	< MDL	< MDL	< MDL	< MDL
Perylene	0.17 [0.148 - 0.193]	< MDL	0.326 [0.23 - 0.422]	0.199 [0 - 0.422]
Phenanthrene	< MDL	< MDL	1.281 [0.726 - 1.835]	0.512 [0 - 1.835]
Pyrene	0.267 [0 - 0.534]	1.117	3.456 [0.94 - 5.971]	1.712 [0 - 5.971]
1,6,7-Trimethylnaphthalene	< MDL	< MDL	< MDL	< MDL
Total PAH	2.643 [1.383 - 3.903]	4.972	25.431 [10.567 - 40.294]	12.224 [1.383 - 40.294]
PBDEs (ng/g wet wt.)				
Total PBDE	< MDL	< MDL	< MDL	< MDL
PCBs (ng/g wet wt.)				
Total PCB	0.706 [0.507 - 0.905]	1.64	2.529 [1.786 - 3.273]	1.622 [0.507 - 3.273]

Appendix I-1 (continued).

Analyte	GTM-North (2 of 10 stations)	GTM-South (1 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
Pesticides (ng/g wet wt.)				
Aldrin	< MDL	< MDL	< MDL	< MDL
alpha-Hexachlorocyclohexane (alpha-BHC)	< MDL	< MDL	< MDL	< MDL
alpha-Chlordane	< MDL	0.038	0.015 [0 - 0.03]	0.014 [0 - 0.038]
beta-Hexachlorocyclohexane (beta-BHC)	< MDL	< MDL	< MDL	< MDL
Chlorpyrifos	< MDL	< MDL	< MDL	< MDL
cis-Nonachlor	< MDL	0.028	< MDL	0.006 [0 - 0.028]
2,4'-DDD (o,p'-DDD)	< MDL	< MDL	< MDL	< MDL
4,4'-DDD (p,p'-DDD)	< MDL	< MDL	< MDL	< MDL
2,4'-DDE (o,p'-DDE)	0.036 [0 - 0.071]	< MDL	0.028 [0 - 0.056]	0.025 [0 - 0.071]
4,4'-DDE (p,p'-DDE)	0.075 [0.075 - 0.075]	0.152	0.167 [0.129 - 0.204]	0.127 [0.075 - 0.204]
2,4'-DDT (o,p'-DDT)	< MDL	< MDL	< MDL	< MDL
4,4'-DDT (p,p'-DDT)	< MDL	< MDL	< MDL	< MDL
Dieldrin	< MDL	0.067	0.006 [0 - 0.012]	0.016 [0 - 0.067]
Endosulfan I	< MDL	< MDL	< MDL	< MDL
Endosulfan II (Beta-Endosulfan)	< MDL	< MDL	< MDL	< MDL
Endrin	< MDL	< MDL	< MDL	< MDL
Endosulfan sulfate	0.016 [0.016 - 0.016]	0.016	< MDL	0.01 [0 - 0.016]
gamma-Chlordane	< MDL	0.032	0.03 [0.029 - 0.03]	0.018 [0 - 0.032]
Hexachlorobenzene (HCB)	< MDL	< MDL	< MDL	< MDL
Heptachlor	< MDL	< MDL	0.017 [0 - 0.034]	0.007 [0 - 0.034]
Heptachlor epoxide	< MDL	< MDL	< MDL	< MDL
gamma-Hexachlorocyclohexane (Lindane)	< MDL	< MDL	< MDL	< MDL
Mirex	< MDL	< MDL	< MDL	< MDL
Oxychlordane	< MDL	< MDL	< MDL	< MDL
trans-Nonachlor	< MDL	0.061	0.034 [0.031 - 0.036]	0.026 [0 - 0.061]
Total Chlordane	< MDL	0.160	0.078 [0.061 - 0.095]	0.063 [0 - 0.16]
Total DDT	0.111 [0.075 - 0.146]	0.152	0.195 [0.129 - 0.26]	0.152 [0.075 - 0.26]

Appendix I-2. Summary of contaminant concentrations (wet weight, *mean [min - max]*) observed in edible tissues of spotted seatrout (*Cynoscion nebulosus*). Concentrations below method detection limits are reported as < MDL; in these cases, a value of zero was used for data computations (e.g., averaging across all stations). Tissue concentrations are compared to risk-based U.S. EPA guidance ranges (wet weights) for recreational fishers where available (Appendix H herein; USEPA 2000). Concentrations relative to guideline ranges for corresponding chemicals are flagged as follows: * concentration falls within the range of values for which EPA recommends limiting fish consumption to four meals per month; ** concentration exceeds the upper limit of EPA guidance range (limit consumption to fewer than four meals per month).

Analyte	GTM-North (2 of 10 stations)	GTM-South (1 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
Metals (µg/g wet wt.)				
Aluminum	7.079 [2.578 - 11.58]	22.206		12.121 [2.578 - 22.206]
Arsenic	0.41 [0.199 - 0.621]	0.316		0.378 [0.199 - 0.621]
Arsenic (inorganic)	0.008 [0.004 - 0.012]	0.006		0.008 [0.004 - 0.012]
Barium	0.066 [0.056 - 0.075]	0.106		0.079 [0.056 - 0.106]
Beryllium	< MDL	< MDL		< MDL
Cadmium	< MDL	< MDL		< MDL
Cobalt	< MDL	< MDL		< MDL
Chromium	0.326 [0.308 - 0.344]	0.145		0.266 [0.145 - 0.344]
Copper	0.254 [0.143 - 0.366]	0.161		0.223 [0.143 - 0.366]
Iron	6.64 [6.109 - 7.171]	6.08		6.453 [6.08 - 7.171]
Mercury	0.059 [0.052 - 0.066]	**0.284****		0.134 [0.052 - 0.284]
Lithium	< MDL	0.057		0.019 [0 - 0.057]
Manganese	0.082 [0.058 - 0.106]	0.135		0.099 [0.058 - 0.135]
Nickel	< MDL	< MDL		< MDL
Lead	0.011 [0 - 0.021]	0.166		0.063 [0 - 0.166]
Antimony	< MDL	< MDL		< MDL
Selenium	0.52 [0.455 - 0.586]	0.468		0.503 [0.455 - 0.586]
Silver	< MDL	< MDL		< MDL
Tin	0.012 [0 - 0.023]	0.019		0.014 [0 - 0.023]
Thallium	< MDL	< MDL		< MDL
Uranium	< MDL	< MDL		< MDL
Vanadium	0.201 [0.174 - 0.227]	0.126		0.176 [0.126 - 0.227]
Zinc	4.163 [3.883 - 4.444]	4.903		4.41 [3.883 - 4.903]

Appendix I-2. (Continued).

Analyte	GTM-North (2 of 10 stations)	GTM-South (1 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
PAHs (ng/g wet wt.)				
Acenaphthene	< MDL	< MDL		< MDL
Acenaphthylene	< MDL	< MDL		< MDL
Anthracene	< MDL	< MDL		< MDL
Benz[a]anthracene	< MDL	< MDL		< MDL
Benzo[a]pyrene	< MDL	< MDL		< MDL
Benzo[e]pyrene	< MDL	< MDL		< MDL
Benzo[a]fluoranthene	< MDL	< MDL		< MDL
Benzo[b]fluoranthene	< MDL	< MDL		< MDL
Benzo[j]fluoranthene	< MDL	< MDL		< MDL
Benzo[k]fluoranthene	< MDL	0.058		0.019 [0 - 0.058]
Benzo[g,h,i]perylene	< MDL	< MDL		< MDL
Biphenyl	< MDL	< MDL		< MDL
Chrysene+Triphenylene	< MDL	< MDL		< MDL
Dibenz[a,h]anthracene	< MDL	0.109		0.036 [0 - 0.109]
Dibenzothiophene	< MDL	< MDL		< MDL
Fluoranthene	0.161 [0 - 0.323]	< MDL		0.108 [0 - 0.323]
Fluorene	< MDL	< MDL		< MDL
Indeno[1,2,3-c,d]pyrene	< MDL	< MDL		< MDL
1-Methylnaphthalene	< MDL	< MDL		< MDL
2-Methylnaphthalene	< MDL	< MDL		< MDL
1-Methylphenanthrene	0.13 [0 - 0.261]	< MDL		0.087 [0 - 0.261]
Naphthalene	< MDL	< MDL		< MDL
Perylene	< MDL	< MDL		< MDL
Phenanthrene	0.456 [0 - 0.912]	< MDL		0.304 [0 - 0.912]
Pyrene	< MDL	< MDL		< MDL
1,6,7-Trimethylnaphthalene	< MDL	< MDL		< MDL
Total PAH	0.748 [0 - 1.496]	0.167		0.554 [0 - 1.496]
PBDEs (ng/g wet wt.)				
Total PBDE	< MDL	< MDL		< MDL
PCBs (ng/g wet wt.)				
Total PCB	1.488 [0.163 - 2.812]	3.137		2.038 [0.163 - 3.137]

Appendix I-2. (Continued).

Analyte	GTM-North (2 of 10 stations)	GTM-South (1 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
Pesticides (ng/g wet wt.)				
Aldrin	< MDL	< MDL		< MDL
alpha-Hexachlorocyclohexane (alpha-BHC)	< MDL	< MDL		< MDL
alpha-Chlordane	< MDL	< MDL		< MDL
beta-Hexachlorocyclohexane (beta-BHC)	< MDL	< MDL		< MDL
Chlorpyrifos	< MDL	< MDL		< MDL
cis-Nonachlor	< MDL	< MDL		< MDL
DDD	< MDL	< MDL		< MDL
2,4'-DDD (o,p'-DDD)	< MDL	< MDL		< MDL
4,4'-DDD (p,p'-DDD)	< MDL	< MDL		< MDL
DDE	0.161 [0.097 - 0.224]	0.119		0.147 [0.097 - 0.224]
2,4'-DDE (o,p'-DDE)	< MDL	< MDL		< MDL
4,4'-DDE (p,p'-DDE)	0.161 [0.097 - 0.224]	0.119		0.147 [0.097 - 0.224]
DDT	< MDL	< MDL		< MDL
2,4'-DDT (o,p'-DDT)	< MDL	< MDL		< MDL
4,4'-DDT (p,p'-DDT)	< MDL	< MDL		< MDL
Dieldrin	< MDL	< MDL		< MDL
Endosulfan I	< MDL	< MDL		< MDL
Endosulfan II (Beta-Endosulfan)	< MDL	< MDL		< MDL
Endrin	< MDL	< MDL		< MDL
Endosulfan sulfate	0.008 [0 - 0.016]	0.012		0.009 [0 - 0.016]
gamma-Chlordane	< MDL	< MDL		< MDL
Hexachlorobenzene (HCB)	< MDL	< MDL		< MDL
Heptachlor	< MDL	< MDL		< MDL
Heptachlor epoxide	< MDL	< MDL		< MDL
gamma-Hexachlorocyclohexane (Lindane)	< MDL	< MDL		< MDL
Mirex	< MDL	< MDL		< MDL
Oxychlordane	< MDL	< MDL		< MDL
trans-Nonachlor	0.021 [0 - 0.042]	0.016		0.019 [0 - 0.042]
Total Chlordane	0.021 [0 - 0.042]	0.016		0.019 [0 - 0.042]
Total DDT	0.161 [0.097 - 0.224]	0.119		0.147 [0.097 - 0.224]

Appendix I-3. Summary of contaminant concentrations (wet weight, *mean [min - max]*) observed in edible tissues of mangrove snapper (*Lutjanus griseus*). Concentrations below method detection limits are reported as < MDL; in these cases, a value of zero was used for data computations (e.g., averaging across all stations). Tissue concentrations are compared to risk-based U.S. EPA guidance ranges (wet weights) for recreational fishers where available (Appendix H herein; USEPA 2000). Concentrations relative to guideline ranges for corresponding chemicals are flagged as follows: * concentration falls within the range of values for which EPA recommends limiting fish consumption to four meals per month; ** concentration exceeds the upper limit of EPA guidance range (limit consumption to fewer than four meals per month).

Analyte	GTM-North (0 of 10 stations)	GTM-South (2 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (3 of 30 stations)
Metals (µg/g wet wt.)				
Aluminum		7.122 [6.886 - 7.358]	10.763	8.335 [6.886 - 10.763]
Arsenic		2.451 [1.531 - 3.37]	3.2	2.7 [1.531 - 3.37]
Arsenic (inorganic)		0.049 [0.031 - 0.067]	0.064	0.054 [0.031 - 0.067]
Barium		0.021 [0.019 - 0.023]	0.044	0.029 [0.019 - 0.044]
Beryllium		< MDL	< MDL	< MDL
Cadmium		< MDL	< MDL	< MDL
Cobalt		< MDL	< MDL	< MDL
Chromium		0.31 [0.248 - 0.371]	0.153	0.257 [0.153 - 0.371]
Copper		0.284 [0.281 - 0.288]	0.223	0.264 [0.223 - 0.288]
Iron		4.47 [4.07 - 4.869]	4.969	4.636 [4.07 - 4.969]
Mercury		0.052 [0.026 - 0.079]	0.053	0.053 [0.026 - 0.079]
Lithium		< MDL	< MDL	< MDL
Manganese		0.11 [0.097 - 0.122]	0.162	0.127 [0.097 - 0.162]
Nickel		< MDL	< MDL	< MDL
Lead		0.003 [0 - 0.006]	0.007	0.004 [0 - 0.007]
Antimony		< MDL	< MDL	< MDL
Selenium		0.523 [0.5 - 0.545]	0.511	0.519 [0.5 - 0.545]
Silver		< MDL	< MDL	< MDL
Tin		0.022 [0.021 - 0.022]	0.024	0.023 [0.021 - 0.024]
Thallium		< MDL	< MDL	< MDL
Uranium		< MDL	< MDL	< MDL
Vanadium		0.152 [0.142 - 0.162]	0.166	0.157 [0.142 - 0.166]
Zinc		5.164 [4.18 - 6.147]	4.564	4.964 [4.18 - 6.147]

Appendix I-3. (Continued).

Analyte	GTM-North (0 of 10 stations)	GTM-South (2 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (3 of 30 stations)
PAHs (ng/g wet wt.)				
Acenaphthene		< MDL	1.92	0.64 [0 - 1.92]
Acenaphthylene		< MDL	< MDL	< MDL
Anthracene		< MDL	0.525	0.175 [0 - 0.525]
Benz[a]anthracene		< MDL	< MDL	< MDL
Benzo[a]pyrene		< MDL	< MDL	< MDL
Benzo[e]pyrene		< MDL	< MDL	< MDL
Benzo[a]fluoranthene		< MDL	< MDL	< MDL
Benzo[b]fluoranthene		< MDL	< MDL	< MDL
Benzo[j]fluoranthene		< MDL	< MDL	< MDL
Benzo[k]fluoranthene		< MDL	0.099	0.033 [0 - 0.099]
Benzo[g,h,i]perylene		< MDL	< MDL	< MDL
Biphenyl		< MDL	< MDL	< MDL
Chrysene+Triphenylene		< MDL	< MDL	< MDL
Dibenz[a,h]anthracene		< MDL	0.131	0.044 [0 - 0.131]
Dibenzothiophene		< MDL	< MDL	< MDL
Fluoranthene		< MDL	1.052	0.351 [0 - 1.052]
Fluorene		< MDL	0.976	0.325 [0 - 0.976]
Indeno[1,2,3-c,d]pyrene		< MDL	< MDL	< MDL
1-Methylnaphthalene		< MDL	< MDL	< MDL
2-Methylnaphthalene		< MDL	< MDL	< MDL
1-Methylphenanthrene		< MDL	< MDL	< MDL
Naphthalene		< MDL	< MDL	< MDL
Perylene		< MDL	< MDL	< MDL
Phenanthrene		< MDL	1.787	0.596 [0 - 1.787]
Pyrene		< MDL	0.356	0.119 [0 - 0.356]
1,6,7-Trimethylnaphthalene		< MDL	< MDL	< MDL
Total PAH		< MDL	6.956	2.319 [0 - 6.956]
PBDEs (ng/g wet wt.)				
Total PBDE		< MDL	0.231	0.077 [0 - 0.231]
PCBs (ng/g wet wt.)				
Total PCB		7.486 [2.224 - 12.749]	11.111	8.695 [2.224 - 12.749]

Appendix I-3. (Continued).

Analyte	GTM-North (0 of 10 stations)	GTM-South (2 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (3 of 30 stations)
Pesticides (ng/g wet wt.)				
Aldrin		< MDL	< MDL	< MDL
alpha-Hexachlorocyclohexane (alpha-BHC)		< MDL	< MDL	< MDL
alpha-Chlordane		0.035 [0 - 0.071]	0.05	0.04 [0 - 0.071]
beta-Hexachlorocyclohexane (beta-BHC)		< MDL	< MDL	< MDL
Chlorpyrifos		< MDL	< MDL	< MDL
cis-Nonachlor		0.183 [0.054 - 0.312]	0.093	0.153 [0.054 - 0.312]
2,4'-DDD (o,p'-DDD)		< MDL	< MDL	< MDL
4,4'-DDD (p,p'-DDD)		< MDL	0.175	0.058 [0 - 0.175]
2,4'-DDE (o,p'-DDE)		< MDL	< MDL	< MDL
4,4'-DDE (p,p'-DDE)		0.445 [0.405 - 0.486]	0.535	0.475 [0.405 - 0.535]
2,4'-DDT (o,p'-DDT)		< MDL	< MDL	< MDL
4,4'-DDT (p,p'-DDT)		< MDL	< MDL	< MDL
Dieldrin		0.089 [0.068 - 0.11]	0.153	0.11 [0.068 - 0.153]
Endosulfan I		< MDL	< MDL	< MDL
Endosulfan II (Beta-Endosulfan)		< MDL	< MDL	< MDL
Endrin		< MDL	< MDL	< MDL
Endosulfan sulfate		0.022 [0.02 - 0.024]	0.014	0.019 [0.014 - 0.024]
gamma-Chlordane		0.015 [0 - 0.029]	0.026	0.019 [0 - 0.029]
Hexachlorobenzene (HCB)		< MDL	< MDL	< MDL
Heptachlor		< MDL	< MDL	< MDL
Heptachlor epoxide		0.016 [0 - 0.031]	< MDL	0.01 [0 - 0.031]
gamma-Hexachlorocyclohexane (Lindane)		< MDL	< MDL	< MDL
Mirex		< MDL	< MDL	< MDL
Oxychlordane		0.058 [0 - 0.116]	0.066	0.061 [0 - 0.116]
trans-Nonachlor		0.423 [0.098 - 0.749]	0.183	0.343 [0.098 - 0.749]
Total Chlordane		0.715 [0.153 - 1.277]	0.418	0.616 [0.153 - 1.277]
Total DDT		0.445 [0.405 - 0.486]	0.710	0.534 [0.405 - 0.71]

Appendix I-4. Summary of contaminant concentrations (wet weight, *mean [min - max]*) observed in edible tissues of striped mullet (*Mugil cephalus*). Concentrations below method detection limits are reported as < MDL; in these cases, a value of zero was used for data computations (e.g., averaging across all stations). Tissue concentrations are compared to risk-based U.S. EPA guidance ranges (wet weights) for recreational fishers where available (Appendix H herein; USEPA 2000). Concentrations relative to guideline ranges for corresponding chemicals are flagged as follows: * concentration falls within the range of values for which EPA recommends limiting fish consumption to four meals per month; ** concentration exceeds the upper limit of EPA guidance range (limit consumption to fewer than four meals per month).

Analyte	GTM-North (0 of 10 stations)	GTM-South (3 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (4 of 30 stations)
Metals (µg/g wet wt.)				
Aluminum		9.995 [8.096 - 12.084]	11.381	10.342 [8.096 - 12.084]
Arsenic		1.031 [0.449 - 1.516]	1.732	1.206 [0.449 - 1.732]
Arsenic (inorganic)		0.021 [0.009 - 0.03]	0.035	0.024 [0.009 - 0.035]
Barium		0.546 [0.07 - 1.306]	0.098	0.434 [0.07 - 1.306]
Beryllium		< MDL	< MDL	< MDL
Cadmium		< MDL	< MDL	< MDL
Cobalt		< MDL	< MDL	< MDL
Chromium		0.307 [0.245 - 0.384]	0.148	0.268 [0.148 - 0.384]
Copper		0.272 [0.215 - 0.31]	0.264	0.27 [0.215 - 0.31]
Iron		13.056 [10.539 - 14.704]	10.253	12.356 [10.253 - 14.704]
Mercury		0.002 [0.001 - 0.003]	0.007	0.003 [0.001 - 0.007]
Lithium		< MDL	< MDL	< MDL
Manganese		0.41 [0.112 - 0.713]	0.239	0.367 [0.112 - 0.713]
Nickel		0.037 [0.029 - 0.052]	0.020	0.033 [0.02 - 0.052]
Lead		0.356 [0.007 - 0.676]	0.135	0.3 [0.007 - 0.676]
Antimony		< MDL	< MDL	< MDL
Selenium		0.434 [0.352 - 0.515]	0.420	0.431 [0.352 - 0.515]
Silver		< MDL	< MDL	< MDL
Tin		0.021 [0.021 - 0.022]	0.020	0.021 [0.02 - 0.022]
Thallium		< MDL	< MDL	< MDL
Uranium		< MDL	< MDL	< MDL
Vanadium		0.222 [0.164 - 0.273]	0.274	0.235 [0.164 - 0.274]
Zinc		12.706 [9.423 - 18.688]	10.708	12.206 [9.423 - 18.688]

Appendix I-4. (Continued).

Analyte	GTM-North (0 of 10 stations)	GTM-South (3 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (4 of 30 stations)
PAHs (ng/g wet wt.)				
Acenaphthene		< MDL	< MDL	< MDL
Acenaphthylene		< MDL	< MDL	< MDL
Anthracene		0.059 [0 - 0.176]	< MDL	0.044 [0 - 0.176]
Benz[a]anthracene		< MDL	< MDL	< MDL
Benzo[a]pyrene		< MDL	< MDL	< MDL
Benzo[e]pyrene		< MDL	< MDL	< MDL
Benzo[a]fluoranthene		< MDL	< MDL	< MDL
Benzo[b]fluoranthene		< MDL	< MDL	< MDL
Benzo[j]fluoranthene		< MDL	< MDL	< MDL
Benzo[k]fluoranthene		< MDL	< MDL	< MDL
Benzo[g,h,i]perylene		< MDL	< MDL	< MDL
Biphenyl		< MDL	< MDL	< MDL
Chrysene+Triphenylene		< MDL	< MDL	< MDL
Dibenz[a,h]anthracene		< MDL	< MDL	< MDL
Dibenzothiophene		< MDL	< MDL	< MDL
Fluoranthene		0.136 [0 - 0.408]	< MDL	0.102 [0 - 0.408]
Fluorene		< MDL	< MDL	< MDL
Indeno[1,2,3-c,d]pyrene		< MDL	< MDL	< MDL
1-Methylnaphthalene		< MDL	< MDL	< MDL
2-Methylnaphthalene		< MDL	< MDL	< MDL
1-Methylphenanthrene		< MDL	< MDL	< MDL
Naphthalene		< MDL	< MDL	< MDL
Perylene		< MDL	< MDL	< MDL
Phenanthrene		< MDL	< MDL	< MDL
Pyrene		0.102 [0 - 0.307]	< MDL	0.077 [0 - 0.307]
1,6,7-Trimethylnaphthalene		< MDL	< MDL	< MDL
Total PAH		0.441 [0 - 1.323]	0.391	0.429 [0 - 1.323]
PBDEs (ng/g wet wt.)				
Total PBDE		< MDL	0.159	0.04 [0 - 0.159]
PCBs (ng/g wet wt.)				
Total PCB		8.238 [0.429 - 14.083]	4.5	7.303 [0.429 - 14.083]

Appendix I-4. (Continued).

Analyte	GTM-North (0 of 10 stations)	GTM-South (3 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (4 of 30 stations)
Pesticides (ng/g wet wt.)				
Aldrin		< MDL	< MDL	< MDL
alpha-Hexachlorocyclohexane (alpha-BHC)		< MDL	< MDL	< MDL
alpha-Chlordane		0.042 [0 - 0.063]	0.1	0.056 [0 - 0.1]
beta-Hexachlorocyclohexane (beta-BHC)		< MDL	< MDL	< MDL
Chlorpyrifos		< MDL	< MDL	< MDL
cis-Nonachlor		0.043 [0 - 0.067]	0.036	0.042 [0 - 0.067]
2,4'-DDD (o,p'-DDD)		< MDL	< MDL	< MDL
4,4'-DDD (p,p'-DDD)		0.096 [0 - 0.162]	< MDL	0.072 [0 - 0.162]
2,4'-DDE (o,p'-DDE)		< MDL	< MDL	< MDL
4,4'-DDE (p,p'-DDE)		0.454 [0.111 - 0.77]	0.421	0.446 [0.111 - 0.77]
2,4'-DDT (o,p'-DDT)		< MDL	< MDL	< MDL
4,4'-DDT (p,p'-DDT)		< MDL	< MDL	< MDL
Dieldrin		0.057 [0 - 0.087]	0.065	0.059 [0 - 0.087]
Endosulfan I		< MDL	< MDL	< MDL
Endosulfan II (Beta-Endosulfan)		< MDL	< MDL	< MDL
Endrin		< MDL	< MDL	< MDL
Endosulfan sulfate		0.023 [0.02 - 0.026]	0.015	0.021 [0.015 - 0.026]
gamma-Chlordane		0.021 [0 - 0.034]	0.048	0.027 [0 - 0.048]
Hexachlorobenzene (HCB)		0.002 [0 - 0.006]	0.073	0.02 [0 - 0.073]
Heptachlor		< MDL	< MDL	< MDL
Heptachlor epoxide		< MDL	0.019	0.005 [0 - 0.019]
gamma-Hexachlorocyclohexane (Lindane)		< MDL	< MDL	< MDL
Mirex		< MDL	< MDL	< MDL
Oxychlordane		< MDL	< MDL	< MDL
trans-Nonachlor		0.079 [0 - 0.123]	0.096	0.083 [0 - 0.123]
Total Chlordane		0.185 [0 - 0.288]	0.280	0.209 [0 - 0.288]
Total DDT		0.55 [0.111 - 0.931]	0.421	0.518 [0.111 - 0.931]

Appendix I-5. Summary of contaminant concentrations (wet weight, *mean [min - max]*) observed in edible tissues of summer flounder (*Paralichthys dentatus*). Concentrations below method detection limits are reported as < MDL; in these cases, a value of zero was used for data computations (e.g., averaging across all stations). Tissue concentrations are compared to risk-based U.S. EPA guidance ranges (wet weights) for recreational fishers where available (Appendix H herein; USEPA 2000). Concentrations relative to guideline ranges for corresponding chemicals are flagged as follows: * concentration falls within the range of values for which EPA recommends limiting fish consumption to four meals per month; ** concentration exceeds the upper limit of EPA guidance range (limit consumption to fewer than four meals per month).

Analyte	GTM-North (1 of 10 stations)	GTM-South (0 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (2 of 30 stations)
Metals (µg/g wet wt.)				
Aluminum	12.589		13.512	13.05 [12.589 - 13.512]
Arsenic	0.978		2.456	1.717 [0.978 - 2.456]
Arsenic (inorganic)	0.020		0.049	0.034 [0.02 - 0.049]
Barium	0.075		0.078	0.076 [0.075 - 0.078]
Beryllium	< MDL		< MDL	< MDL
Cadmium	< MDL		< MDL	< MDL
Cobalt	< MDL		< MDL	< MDL
Chromium	0.392		0.122	0.257 [0.122 - 0.392]
Copper	0.177		0.181	0.179 [0.177 - 0.181]
Iron	8.751		5.327	7.039 [5.327 - 8.751]
Mercury	0.021		0.006	0.014 [0.006 - 0.021]
Lithium	< MDL		0.054	0.027 [0 - 0.054]
Manganese	0.130		0.168	0.149 [0.13 - 0.168]
Nickel	< MDL		< MDL	< MDL
Lead	0.005		0.013	0.009 [0.005 - 0.013]
Antimony	< MDL		< MDL	< MDL
Selenium	0.576		0.585	0.581 [0.576 - 0.585]
Silver	< MDL		< MDL	< MDL
Tin	0.023		0.024	0.023 [0.023 - 0.024]
Thallium	< MDL		< MDL	< MDL
Uranium	< MDL		< MDL	< MDL
Vanadium	0.255		0.184	0.22 [0.184 - 0.255]
Zinc	5.454		5.656	5.555 [5.454 - 5.656]

Appendix I-5. (Continued).

Analyte	GTM-North (1 of 10 stations)	GTM-South (0 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (2 of 30 stations)
PAHs (ng/g wet wt.)				
Acenaphthene	< MDL		< MDL	< MDL
Acenaphthylene	< MDL		< MDL	< MDL
Anthracene	< MDL		< MDL	< MDL
Benz[a]anthracene	< MDL		< MDL	< MDL
Benzo[a]pyrene	< MDL		< MDL	< MDL
Benzo[e]pyrene	< MDL		< MDL	< MDL
Benzo[a]fluoranthene	< MDL		< MDL	< MDL
Benzo[b]fluoranthene	< MDL		< MDL	< MDL
Benzo[j]fluoranthene	< MDL		< MDL	< MDL
Benzo[k]fluoranthene	< MDL		< MDL	< MDL
Benzo[g,h,i]perylene	< MDL		< MDL	< MDL
Biphenyl	< MDL		< MDL	< MDL
Chrysene+Triphenylene	< MDL		< MDL	< MDL
Dibenz[a,h]anthracene	< MDL		< MDL	< MDL
Dibenzothiophene	< MDL		< MDL	< MDL
Fluoranthene	< MDL		< MDL	< MDL
Fluorene	< MDL		< MDL	< MDL
Indeno[1,2,3-c,d]pyrene	< MDL		< MDL	< MDL
1-Methylnaphthalene	< MDL		< MDL	< MDL
2-Methylnaphthalene	< MDL		< MDL	< MDL
1-Methylphenanthrene	0.386		< MDL	0.193 [0 - 0.386]
Naphthalene	< MDL		< MDL	< MDL
Perylene	< MDL		< MDL	< MDL
Phenanthrene	< MDL		< MDL	< MDL
Pyrene	< MDL		< MDL	< MDL
1,6,7-Trimethylnaphthalene	< MDL		< MDL	< MDL
Total PAH	0.386		< MDL	0.193 [0 - 0.386]
PBDEs (ng/g wet wt.)				
Total PBDE	< MDL		< MDL	< MDL
PCBs (ng/g wet wt.)				
Total PCB	0.344		2.386	1.365 [0.344 - 2.386]

Appendix I-5. (Continued).

Analyte	GTM-North (1 of 10 stations)	GTM-South (0 of 15 stations)	St. Augustine area (1 of 5 stations)	Overall (2 of 30 stations)
Pesticides (ng/g wet wt.)				
Aldrin	< MDL		< MDL	< MDL
alpha-Hexachlorocyclohexane (alpha-BHC)	< MDL		< MDL	< MDL
alpha-Chlordane	0.046		< MDL	0.023 [0 - 0.046]
beta-Hexachlorocyclohexane (beta-BHC)	< MDL		< MDL	< MDL
Chlorpyrifos	< MDL		< MDL	< MDL
cis-Nonachlor	0.078		< MDL	0.039 [0 - 0.078]
2,4'-DDD (o,p'-DDD)	< MDL		< MDL	< MDL
4,4'-DDD (p,p'-DDD)	< MDL		< MDL	< MDL
2,4'-DDE (o,p'-DDE)	< MDL		< MDL	< MDL
4,4'-DDE (p,p'-DDE)	0.184		0.088	0.136 [0.088 - 0.184]
2,4'-DDT (o,p'-DDT)	< MDL		< MDL	< MDL
4,4'-DDT (p,p'-DDT)	< MDL		< MDL	< MDL
Dieldrin	0.004		< MDL	0.002 [0 - 0.004]
Endosulfan I	< MDL		< MDL	< MDL
Endosulfan II (Beta-Endosulfan)	< MDL		< MDL	< MDL
Endrin	< MDL		< MDL	< MDL
Endosulfan sulfate	< MDL		< MDL	< MDL
gamma-Chlordane	< MDL		< MDL	< MDL
Hexachlorobenzene (HCB)	< MDL		< MDL	< MDL
Heptachlor	< MDL		< MDL	< MDL
Heptachlor epoxide	< MDL		< MDL	< MDL
gamma-Hexachlorocyclohexane (Lindane)	< MDL		< MDL	< MDL
Mirex	< MDL		0.070	0.035 [0 - 0.07]
Oxychlordane	< MDL		< MDL	< MDL
trans-Nonachlor	0.166		< MDL	0.083 [0 - 0.166]
Total Chlordane	0.290		< MDL	0.145 [0 - 0.29]
Total DDT	0.184		0.088	0.136 [0.088 - 0.184]

Appendix I-6. Summary of contaminant concentrations (wet weight, *mean [min - max]*) observed in edible tissues of red drum (*Sciaenops ocellatus*). Concentrations below method detection limits are reported as < MDL; in these cases, a value of zero was used for data computations (e.g., averaging across all stations). Tissue concentrations are compared to risk-based U.S. EPA guidance ranges (wet weights) for recreational fishers where available (Appendix H herein; USEPA 2000). Concentrations relative to guideline ranges for corresponding chemicals are flagged as follows: * concentration falls within the range of values for which EPA recommends limiting fish consumption to four meals per month; ** concentration exceeds the upper limit of EPA guidance range (limit consumption to fewer than four meals per month).

Analyte	GTM-North (3 of 10 stations)	GTM-South (0 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
Metals (µg/g wet wt.)				
Aluminum	8.061 [2.642 - 12.071]			8.061 [2.642 - 12.071]
Arsenic	0.693 [0.36 - 1.055]			0.693 [0.36 - 1.055]
Arsenic (inorganic)	0.014 [0.007 - 0.021]			0.014 [0.007 - 0.021]
Barium	0.041 [0.013 - 0.094]			0.041 [0.013 - 0.094]
Beryllium	< MDL			< MDL
Cadmium	< MDL			< MDL
Cobalt	0.01 [0 - 0.031]			0.01 [0 - 0.031]
Chromium	0.349 [0.07 - 0.538]			0.349 [0.07 - 0.538]
Copper	0.187 [0.057 - 0.256]			0.187 [0.057 - 0.256]
Iron	6.046 [1.643 - 10.419]			6.046 [1.643 - 10.419]
Mercury	0.026 [0.012 - 0.05]			0.026 [0.012 - 0.05]
Lithium	< MDL			< MDL
Manganese	0.16 [0.029 - 0.37]			0.16 [0.029 - 0.37]
Nickel	0.08 [0.006 - 0.213]			0.08 [0.006 - 0.213]
Lead	0.025 [0 - 0.07]			0.025 [0 - 0.07]
Antimony	< MDL			< MDL
Selenium	0.409 [0.101 - 0.623]			0.409 [0.101 - 0.623]
Silver	< MDL			< MDL
Tin	0.016 [0.005 - 0.023]			0.016 [0.005 - 0.023]
Thallium	< MDL			< MDL
Uranium	< MDL			< MDL
Vanadium	0.134 [0.039 - 0.189]			0.134 [0.039 - 0.189]
Zinc	3.156 [0.986 - 4.249]			3.156 [0.986 - 4.249]

Appendix I-6. (Continued).

Analyte	GTM-North (3 of 10 stations)	GTM-South (0 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
PAHs (ng/g wet wt.)				
Acenaphthene	< MDL			< MDL
Acenaphthylene	< MDL			< MDL
Anthracene	< MDL			< MDL
Benz[a]anthracene	< MDL			< MDL
Benzo[a]pyrene	< MDL			< MDL
Benzo[e]pyrene	< MDL			< MDL
Benzo[a]fluoranthene	< MDL			< MDL
Benzo[b]fluoranthene	< MDL			< MDL
Benzo[j]fluoranthene	< MDL			< MDL
Benzo[k]fluoranthene	< MDL			< MDL
Benzo[g,h,i]perylene	< MDL			< MDL
Biphenyl	< MDL			< MDL
Chrysene+Triphenylene	< MDL			< MDL
Dibenz[a,h]anthracene	< MDL			< MDL
Dibenzothiophene	< MDL			< MDL
Fluoranthene	< MDL			< MDL
Fluorene	< MDL			< MDL
Indeno[1,2,3-c,d]pyrene	< MDL			< MDL
1-Methylnaphthalene	< MDL			< MDL
2-Methylnaphthalene	< MDL			< MDL
1-Methylphenanthrene	0.096 [0 - 0.288]			0.096 [0 - 0.288]
Naphthalene	< MDL			< MDL
Perylene	< MDL			< MDL
Phenanthrene	< MDL			< MDL
Pyrene	< MDL			< MDL
1,6,7-Trimethylnaphthalene	< MDL			< MDL
Total PAH	0.575 [0 - 1.438]			0.575 [0 - 1.438]
PBDEs (ng/g wet wt.)				
Total PBDE	< MDL			< MDL
PCBs (ng/g wet wt.)				
Total PCB	0.688 [0.325 - 1.112]			0.688 [0.325 - 1.112]

Appendix I-6. (Continued).

Analyte	GTM-North (3 of 10 stations)	GTM-South (0 of 15 stations)	St. Augustine area (0 of 5 stations)	Overall (3 of 30 stations)
Pesticides (ng/g wet wt.)				
Aldrin	< MDL			< MDL
alpha-Hexachlorocyclohexane (alpha-BHC)	< MDL			< MDL
alpha-Chlordane	0.017 [0 - 0.05]			0.017 [0 - 0.05]
beta-Hexachlorocyclohexane (beta-BHC)	< MDL			< MDL
Chlorpyrifos	< MDL			< MDL
cis-Nonachlor	0.017 [0 - 0.05]			0.017 [0 - 0.05]
DDD	0.097 [0 - 0.291]			0.097 [0 - 0.291]
2,4'-DDD (o,p'-DDD)	0.097 [0 - 0.291]			0.097 [0 - 0.291]
4,4'-DDD (p,p'-DDD)	< MDL			< MDL
DDE	0.168 [0.033 - 0.363]			0.168 [0.033 - 0.363]
2,4'-DDE (o,p'-DDE)	< MDL			< MDL
4,4'-DDE (p,p'-DDE)	0.168 [0.033 - 0.363]			0.168 [0.033 - 0.363]
DDT	< MDL			< MDL
2,4'-DDT (o,p'-DDT)	< MDL			< MDL
4,4'-DDT (p,p'-DDT)	< MDL			< MDL
Dieldrin	0.001 [0 - 0.004]			0.001 [0 - 0.004]
Endosulfan I	< MDL			< MDL
Endosulfan II (Beta-Endosulfan)	0.004 [0 - 0.012]			0.004 [0 - 0.012]
Endrin	< MDL			< MDL
Endosulfan sulfate	0.007 [0 - 0.02]			0.007 [0 - 0.02]
gamma-Chlordane	< MDL			< MDL
Hexachlorobenzene (HCB)	< MDL			< MDL
Heptachlor	< MDL			< MDL
Heptachlor epoxide	< MDL			< MDL
gamma-Hexachlorocyclohexane (Lindane)	< MDL			< MDL
Mirex	< MDL			< MDL
Oxychlordane	< MDL			< MDL
trans-Nonachlor	0.017 [0 - 0.052]			0.017 [0 - 0.052]
Total Chlordane	0.05 [0 - 0.151]			0.05 [0 - 0.151]
Total DDT	0.265 [0.033 - 0.653]			0.265 [0.033 - 0.653]

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