COASTAL BEND BAYS & ESTUARIES PROGRAM

REGIONAL COASTAL ASSESSMENT PROGRAM (RCAP)

RCAP 2004

ANNUAL REPORT

Prepared for:

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EXECUTIVE SUMMARY

The Coastal Bend Bays & Estuaries Program, Inc. (CBBEP) initiated the Regional Coastal Assessment Program (RCAP) in 2000 to meet the stated goals of the *Implementation Strategy for the Coastal Bend Bays Plan*. The *Bays Plan* called for a program in which comprehensive water and sediment quality monitoring and assessment is a stated primary goal necessary for understanding local estuarine conditions and providing the tools required for protecting, preserving, and enhancing the unique estuarine and marine resources of the Texas Coastal Bend.

Nicolau and Nuñez documented initial program development, described past RCAP sampling events, and the cooperative partnerships formed between the Center for Coastal Studies (CCS), the Texas Parks & Wildlife Department (TPWD), and the United States Environmental Protection Agency (EPA) Office of Research and Development, Environmental Monitoring and Assessment Program (EMAP) - National Coastal Assessment (NCA). Starting in the summer of 2002, CCS researchers began conducting one major sampling event during the summer index period (mid July through mid September) for RCAP 2002 that coincided with, and complemented, the EMAP-NCA effort. Sampling within the summer index period represented a "worse case scenario", in which water quality conditions might be stressful and thereby limiting to biota.

As a multi-year effort, led by National Health and Environmental Effects Research Laboratory's Gulf Ecology Division in Gulf Breeze, FL, NCA evaluates assessment methods developed to advance the science of ecosystem condition monitoring by creating an integrated, comprehensive coastal monitoring program among states. Integrated sampling programs yield data collected by the same quality assured methods that are directly comparable, easily transferable, and significantly more detailed in scope than individual monitoring programs. Using a probabilistic design and a common set of survey indicators, each state conducts the survey and assesses the condition of their coastal resources independently; aggregation of this data can then assess conditions at the State, EPA Regional, biogeographical, and National levels. Designed to provide scientifically sound water and sediment quality data, EMAP NCA provides essential spatial and temporal components for monitoring coastal waters; helping to determine resource conditions, providing information to aid in evaluation of environmental policies, and helping to identify emerging environmental problems before they become widespread.

The initial attempt at providing data for comparisons on a local, regional, and national level began with the RCAP 2002 assessment. Unfortunately, a problem in making a standardized assessment exists within Texas because of the different ways that Texas Commission on Environmental Quality (TCEQ) and EPA evaluate water and sediment quality within the CBBEP region. As an evolving process, the collection and assimilation of additional RCAP data is aiding in developing indicators that will give us a better picture as to what may represent healthy or degraded conditions or habitat within the CBBEP region.

This technical report is the fourth in a series planned to support the continuing goal of the CBBEP in providing information to protect, preserve, and enhance the natural resources of our coastal environment by providing descriptive and quantitative data and developing diagnostic procedures to characterize the physical, chemical, and biological dynamics of the CBBEP coastal environment. A comprehensive RCAP addressing these goals and objectives has the unique ability to interact with many of the other Action Plans as described in the *Bays Plan* in an overall adaptive management structure.

WATER MONITORING

Field Data

Field data collected continues to be representative of the CBBEP region, with values recorded during RCAP 2004 typical for the summer index period. In contrast to RCAP 2002, salinity concentrations recorded in RCAP 2003 showed increases within most coastal Segments as major inflow events ceased towards the end of 2002; but declined in RCAP 2004 as inflows to the system once again increased. Freshwater inflows remain as one of the most critical factors for sustaining long-term estuarine health within the CBBEP region and it is important to document these dramatic short-term shifts in salinity and to continue assessing the conditions created in the region.

Dissolved oxygen continues to represent one of the most essential water quality parameters utilized by both TCEQ and EPA in assessments of aquatic life use and the health of a water body. While a few near-surface dissolved oxygen concentrations fell in the "biologically stressful" range of >2.0 mg/L but <5.0 mg/L, based on one-time grab sampling, overall near-surface dissolved oxygen quality for the CBBEP region can be considered very good. However, analysis of RCAP 2004 near-bottom DO data revealed a different picture with six sites having low near-bottom DO concentrations, of which two were hypoxic.

Routine Conventional Water Chemistry

The continued lack of nutrient criteria, and conflicting methodologies utilized by TCEQ and EPA for assessing coastal waters, continues to produce different water quality assessments for the region. According to TCEQ screening levels, some nutrient values exceeded screening levels in RCAP 2004. While the one exceedance for ammonia in the Baffin Bay Complex (Segment 2492) warrants little concern, there was a clustering of ammonia exceedances in Baffin Bay during RCAP 2003, and one exceedance in RCAP 2002. Concerning total phosphorus concentrations, the elevated levels recorded in Nueces Bay (Segment 2482) during RCAP 2000 and RCAP 2002, were again elevated in RCAP 2004. The Copano Bay Complex (Segment 2472) is on the 305(b) list for *Secondary Concerns* regarding total phosphorus, and while a few levels were elevated in RCAP 2000, elevated levels did not occur again until RCAP 2004. However, the increasing trend seen in orthophosphate concentrations (overall mean site concentrations; 0.031 mg/L for RCAP 2002, versus 0.054 mg/L in RCAP 2003, and 0.087 mg/L in RCAP 2004) may warrant some concern, as there were 4 exceedances and 11 elevated concentrations occurring in four of the eight segments sampled for RCAP 2004. Presently the 2002 305(b) list does not list orthophosphate for *Secondary Concerns* in any of these segments sampled for RCAP 2004.

As stated in past RCAP reports, based on TCEQ screening levels, *Secondary Concerns* may exist for excessive algal growth, or chlorophyll *a* concentrations, within those segments listed on the 2002 305(b) list. The authors still feel the TCEQ screening level (>11.50 µg/L) for this region may not be warranted and that elevated concentrations may relate to natural phytoplankton responses to increased nutrients into the receiving waters from inflow events prior to sampling. This fact coupled with the optimal conditions of high temperatures and increased light levels that occur during the south Texas summer are conditions that often produce high chlorophyll *a* concentrations.

Continued use of EPA National Coastal Condition Report (NCCR) II guidance, which looks at near-surface Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorus (DIP) concentrations, typically yields a more unfavorable assessment of the region than evaluation using TCEQ Screening Levels. In the case of DIN, the region rated better in RCAP 2004; with 31 sites (96.9%) rated as good and one site (3.1%) rated as fair. This is in contrast to RCAP 2003 when sampling produced 27 sites (84.4%) rated as good, 2 sites (6.2%) rated as fair, and 3 sites (9.4%) rated as poor. Data for RCAP 2004 was similar to data collected in RCAP 2002 when DIN concentrations were primarily <0.10 mg/L.

EPA NCCR II guidance concerning DIP concentrations is more restrictive than TCEQ methodologies used to establish criteria ranges. While the point may be debatable, as to which concentration range to use, EPA is attempting to use a range for all Gulf Coast states so that conditions are comparable throughout the region. Comparing RCAP 2002 DIP concentrations with concentrations from RCAP 2003 revealed that approximately the same percentage (26.5% versus 25.0%) of sites exceeded EPA NCCR II guidelines for DIP and rated as poor. This is in sharp contrast to RCAP 2004 when 23 (71.9%) of the sites sampled rated as poor and 9 (28.1%) of the sites rated as fair. The increases in the number of sites with elevated DIP, or orthophosphate, concentrations may signify a trend, which requires continued monitoring.

Based on EPA NCCR II guidance, chlorophyll *a* concentrations for RCAP 2004 looked similar to past RCAP events with 8 sites (25.0%) listed as good, 22 sites (68.8%) listed as fair, and 2 sites (6.2%) listed as poor. In RCAP 2003 10 sites (31.3%) ranked as good, 21 sites (65.6%) received a fair ranking, and one site (3.1%) ranked as poor. RCAP 2002 showed 16 sites (32.7%) ranking as good, 30 sites (61.2%) received a fair rating, and 2 sites (6.1%) ranked as poor. While the upper end of the EPA range is higher than the TCEQ screening levels (>20.00 µg/L versus 11.50 µg/L) we still consider the lower end of the fair category (5.00 µg/L to 20.00) as to low based on the historical concentrations observed for this region. Comparatively, of 30 sites receiving a fair ranking in RCAP 2002, 17 sites had chlorophyll *a* concentrations ranging between 5.00 µg/L and 9.00 µg/L, with five of those sites having concentrations between 5.00 µg/L and 6.00 µg/L. The same picture was evident in RCAP 2003; 21 sites received a fair rating, with 10 of those sites having chlorophyll *a* concentrations between 5.00 µg/L and 9.00 µg/L and five of those sites having concentrations between 5.00 µg/L and 6.00 µg/L. For RCAP 2004 there were 22 sites receiving a fair ranking. Of those, 12 sites had chlorophyll *a* concentrations between 5.00 µg/L and 9.00 µg/L with two of those sites having concentrations between 5.00 µg/L and 6.00 µg/L.

The authors feel that EPA should also use a modified scale for this region of Texas based on the extreme climate conditions (air temperatures routinely above 35.0 °C during the summer), and intense light levels. Based on analysis of all chlorophyll *a* data collected for RCAP, approximately 79.1% of all concentrations are <11.50 µg/L. The authors feel that perhaps the new scale should be <11.50 µg/L would be considered as good, 11.50 µg/L to 20.00 µg/L would be rated as fair, and >20.00 µg/L would be considered as poor.

Overall, the combined EPA Water Quality Index for RCAP 2004 ranked 2 (6.2%) sites as good, 28 (87.5%) sites as fair, and 2 (6.2%) sites as poor, with primarily a combination of DIP and chlorophyll *a* concentrations the justification for a fair ranking. EPA guidelines for NCCR II developed criteria for DIP and DIN as possible estimators of eutrophication. However, the authors question the utility of DIN as an estimator of possible eutrophication within the CBBEP region for all RCAP events. In RCAP 2002, all DIN concentrations were <0.10 mg/L and did not correspond with high chlorophyll *a* concentrations. For RCAP 2003 high levels of DIN did correspond with high levels of chlorophyll *a* in one site Hynes Bay (Site 295) and relatively moderate levels at two sites (Sites 318 and 322) in the Baffin Bay Complex. In RCAP 2004, only one site (Site 329) in the Baffin Bay Complex had a moderate DIN concentration that corresponded with a low to moderate chlorophyll *a* concentration (8.75 µg/L). All other DIN concentrations were <0.10 mg/L during RCAP 2004.

Regarding DIP comparisons, no clear association with high levels of chlorophyll *a* existed for RCAP 2002. Of the 13 sites rated as having poor DIP concentrations (>0.05 mg/L), five had low (good or <5.00 µg/L) concentrations of chlorophyll *a*, seven had moderate (fair or >5.00 µg/L and <20.00 µg/L) concentrations, of which 4 were <9.00 µg/L, and only one had high (poor or >20.00 µg/L) chlorophyll *a* concentrations. For RCAP 2003, of the eight sites having poor DIP concentrations one had low (good) concentrations of chlorophyll *a*, six had moderate (fair) concentrations and only one had high (poor) chlorophyll *a* concentrations. Of six sites listed as fair, only one site would have exceeded the TCEQ screening level of 11.50 µg/L, with three sites having chlorophyll *a* concentrations <9.00 µg/L, two sites <10.00 µg/L, and one site was 12.80 µg/L. In RCAP 2004 there were 23 sites rated as being poor regarding DIP concentrations; 6 sites had low (good) concentrations of chlorophyll *a*, 16 had moderate (fair) concentrations, and one site had high (poor) concentrations of chlorophyll *a*. Of the 16 sites listed as fair, only two sites would have exceeded the TCEQ standard of 11.50 µg/L, with 9 sites having chlorophyll *a* concentrations <9.00 µg/L, and five sites having concentrations less than the TCEQ screening level of 11.50 µg/L. Additional data assessment of CBBEP and Texas coastal waters is still necessary with the hope that additional data may provide concentration ranges more applicable within our estuaries.

Microbiological Indicators

Many water body segments in Texas are still undergoing assessment by TCEQ for bacteria impairments related to the Oyster Water Use (Fecal Coliform criteria). The continuation of bacteria sampling in RCAP 2004 provided data using the new criterion, enterococci, in the assessment of the Contact Recreation Use (CRU) for water within the CBBEP region. Analysis of RCAP 2004 data continues to indicate that for the areas and sites sampled, based on the current CRU single sample criteria of 104 CFU/100ml, water quality regarding enterococci concentrations continues to be very good throughout the CBBEP region for the third straight year.

SEDIMENT MONITORING

Sediment Characteristics and Inorganic/Organic Contaminants

As seen in RCAP 2002 and RCAP 2003, sediment contamination was low for RCAP 2004 and the region rates as good according to TCEQ protocols. However, as was the case in previous RCAP sampling events, different methodologies used by TCEQ and EPA produced different assessments.

In contrast to RCAP 2002 sampling results, data analysis produced similar results to RCAP 2003 with no cases of high (poor) Total Organic Carbon (TOC) levels existing at sites sampled for RCAP 2004. Concerning sediment metal and organic contaminants, according to TCEQ screening levels, no *Secondary Concerns* exists. Unlike RCAP 2002, when one site exhibited elevated concentrations of PCBs and Total DDT, no sites had concentrations above respective PEL values in RCAP 2004. However, some concerns may exist as various sites throughout the region continually have concentrations above the TCEQ 85th percentile screening levels for arsenic, cadmium, chromium, lead, and zinc. These metals also had concentrations above the 85th percentiles during the RCAP 2002 and RCAP 2003 studies.

Following NCCR II assessment guidelines for RCAP 2004 produced no sites with poor sediment quality due to sediment contaminants based on ERL and ERM exceedances and for the first time no sites had poor sediment quality due to the expression of toxic effects. As a fundamental part of the EPA Sediment Quality Index (TOC, Sediment Toxicity, and Sediment Contaminants) used in the EPA NCCR II report, the expression of toxic effects in sediment ranked eight of the 32 RCAP 2003 sites and 18 of the 50 RCAP 2002 sites as having poor sediment quality. In both RCAP 2002 and RCAP 2003, the amphipod toxicity test continued to produce conflicting results, with no straightforward cause-effect relationship appearing to exist, as none of the sites sampled had co-occurring toxicity and elevated sediment contaminants. While unmeasured chemicals or other confounding factors such as elevated ammonia concentrations during the testing process, and/or habitat preference of the test organism may have influenced sediment toxicity results, the lack of co-occurring sediment contamination and toxicity raised questions that for RCAP 2004 are not an issue.

Use of the Sediment Quality Guideline Quotient (SQGQ) in RCAP 2004 continued to provide an alternate method of investigating potential contaminant impacts that address cumulative effects of multiple contaminants, as opposed to a single sediment screening level assessment. This process produced 14 sites with “Moderate” contaminant levels relative to the other RCAP 2004 sites sampled. These “moderately” contaminated sites occurred in five of the eight TCEQ segments sampled during RCAP 2004. Similar contaminants had increased concentrations in the same segments during RCAP 2002 and RCAP 2003. As observed during RCAP 2002 and RCAP 2003, increased contaminant deposition occurred in Copano Bay (Segment 2472) Aransas Bay (Segment 2471), Corpus Christi Bay (Segment 2481), Nueces Bay (Segment 2482), and Baffin Bay (Segment 2492). Typically, the contaminants contributing the most to elevated concentrations are metals. Overall, PCBs, DDT, Total Chlorinated Pesticides, and PAHs are of little concern as the majority of the concentrations at most sites are at or near minimum detection limits.

Benthic Community

Benthic community characterization for RCAP 2004 resulted in the delineation of six assemblages, with many benthic assemblages sharing similar characteristics as those in RCAP 2003 and RCAP 2002, respectively. Typically, sites within the assemblages are located in often naturally stressed areas and consist of organisms characterized as pollution-tolerant or pollution-sensitive species, which are indicative of environmental stress and possible organic enrichment. Since these assemblages are located in dynamic portions of the estuaries, other unmeasured factors ought to be considered as negatively affecting the benthic community. However, as stated in previous reports, co-occurring moderate Sediment Contaminant Distribution (SCD) rankings and/or past expressions of sediment toxicity at sites exhibiting the greatest evidence of benthic stress and attaining poor EPA-Benthic Condition Index scores should not be ignored.

The one constant assemblage over the years is primarily located in Corpus Christi Bay (Segment 2481) and tends to differ from year to year depending on salinity. The DPMS assemblage of RCAP 2004 shared the same benthic characteristics and SCD rankings as the respective assemblages of the previous RCAP sampling events. Characteristically more stable and exhibiting little environmental variability, this system tends to produce complex benthic communities. Similar SQGQ values associated with SCD rankings occurred in other assemblages in each of the respective sampling years but the impact to the benthic community in this assemblage has been minimal. This may suggest that similar contaminant loadings in a dynamic system may have a greater impact on a benthic community than that of a stable system. The complex process of understanding sediment interactions within the CBBEP region continues to evolve, and we expect that additional data collection and refinement of the methods will lead to improved indices.

TISSUE MONITORING

The approach EPA NCA uses in the collection of data for the NCCR II report continues to make RCAP tissue contaminant data difficult to assess in Texas, as existing standards and methods are not comparable (e.g. whole-body versus edible tissue). Analysis of edible tissue (filets) took place at five sites in RCAP 2004 but data results were not noticeably different from those of whole-body samples.

Although not applicable, the results of whole-body tissue analysis were compared to screening levels normally used for edible tissue as a basis for determining extent of possible contamination and bioaccumulation in tissue. Based on the joint TCEQ and Texas Department of State Health Services screening levels the region ranks as good, since most contaminants were non-detectable or well below any applicable screening level. When evaluating the CBBEP region according to EPA guidelines the CBBEP region also rated as good as only one site exceeded the maximum concentration range value (>0.23 ppm) for mercury. While the presence of mercury in edible fish tissue can be a major concern for public health, overall RCAP data does not suggest that mercury in estuarine fish tissue represents an increasing trend within the area. As seen in past RCAP sampling events, most sites had very low concentrations of aluminum, chromium, mercury, and iron. A limited amount of nickel, lead and selenium followed by zinc and copper occurred at some locations, with many sites having metals concentration values that were non-detectable.

Detectable PCB concentrations occurred in whole-body tissue at only one site (Baffin Bay Complex-Segment 2492) during RCAP 2004 sampling, as opposed to one site in RCAP 2003 (Copano Bay Complex-Segment 2472) and eight sites throughout the region during RCAP 2002. All concentrations were well below screening levels. Detectable concentrations of DDT occurred at three sites; with one site located in the Copano Bay Complex and two sites in the Baffin Bay Complex. As seen with PCB the highest values were below screening levels. Total Chlorinated Pesticides, other than DDT, registered in whole-body tissue samples at one site in the Baffin Bay Complex, and consisted of small detectable amounts of Lindane. No detectable concentrations of PAHs occurred in any of the 31 sites sampled.

As seen in RCAP 2002 and 2003 no specimens collected in RCAP 2004 showed evidence of lesions or tumors during the external gross pathology examination performed on-board TPWD vessels during sampling. Future events and reevaluation of sampling and analysis protocols may produce results that are comparable to existing state guidelines and /or federal guidelines.

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ACKNOWLEDGEMENTS

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Numerous individuals over the years provided assistance during the course of the RCAP project. Without their dedication and strong work ethic, this project would not have been possible. We greatly appreciated their enthusiasm and energy in assisting with all aspects of the RCAP project. For RCAP 2004 we graciously appreciate the help of Ms. Holly Bellringer for her assistance in the field and working up the benthic samples in the laboratory, Mr. Al Oswalt and Mr. Casey Krause for their assistance with field sampling, and Dr. Marion Nipper, Dr. R. Scott Carr, and Mr. James Biedenbach for the sediment toxicity testing and data analysis. In addition, we also thank the entire staff at the Center for Coastal Studies for administrative support, encouragement, and patience.

1.0 INTRODUCTION

1.1 RCAP Background and Objectives

The Coastal Bend Bays & Estuaries Program, Inc. (CBBEP) initiated the Regional Coastal Assessment Program (RCAP) in 2000 to meet the stated goals of the *Implementation Strategy for the Coastal Bend Bays Plan* (CBBEP 1998). The *Bays Plan* called for a program in which comprehensive water and sediment quality monitoring and assessment is a stated primary goal necessary for understanding local estuarine conditions and providing the tools required for protecting, preserving, and enhancing the unique estuarine and marine resources of the Texas Coastal Bend.

Essential for collection, analysis, and dissemination of the highest quality data to both the public and coastal managers, RCAP allows CBBEP and the communities within the program area, to interact with local, state, and federal entities in the larger goal of protecting and preserving the entire Gulf Coast environment. Established and built first at the local level, these interactions develop highly effective communication lines that provide for data collection, analysis, and improved information transfer that ultimately foster partnerships specifically designed to provide the means for effective coastal monitoring.

Nicolau and Nuñez (2004; 2005a; 2005b) described the RCAP in past reports and documented program development, which began in 2000 with an intensive quarterly baseline-monitoring effort to address the numerous historical concerns of the bay system's water quality parameters and metals concentrations that appeared in CBBEP study reports (Ward and Armstrong 1997 CCBNEP-13; Ward and Armstrong 1997 CCBNEP-23). Significantly expanding on historical monitoring efforts the RCAP yielded accurate and reliable data for initial characterization and assessment of water and sediment quality conditions within the region.

In addition, RCAP development produced cooperative partnerships between the Center for Coastal Studies (CCS), the Texas Parks & Wildlife Department (TPWD), and the United States Environmental Protection Agency (EPA) Office of Research and Development, Environmental Monitoring and Assessment Program (EMAP) - National Coastal Assessment (NCA), for RCAP 2002. With baseline monitoring concluded, CCS researchers began conducting one major sampling event during the summer index period (mid July through mid September) for RCAP 2002 that coincided with, and complemented, the EMAP NCA effort. Sampling within the summer index period represented a "worse case scenario", in which water quality conditions might be stressful and thereby limiting to biota.

As a multi-year effort, led by National Health and Environmental Effects Research Laboratory's Gulf Ecology Division in Gulf Breeze, FL, NCA evaluates assessment methods developed to advance the science of ecosystem condition monitoring by creating an integrated, comprehensive coastal monitoring program among states (USEPA 2001). Integrated sampling programs yield data collected by the same quality assured methods that are directly comparable, easily transferable, and significantly more detailed in scope than individual monitoring programs. Using a probabilistic design and a common set of survey indicators, each state conducts the survey at a minimum of 50 sites, and assesses the condition of their coastal resources independently; these estimates can then be aggregated to assess conditions at the State, EPA Regional, biogeographical, and National levels. Designed to provide scientifically sound water and sediment quality data, EMAP NCA provides essential spatial and temporal components for monitoring coastal waters; helping to determine resource conditions, providing information to aid in evaluation of environmental policies, and helping to identify emerging environmental problems before they become widespread.

Through the dedication and foresight of the CBBEP, RCAP sampling for 2002, 2003, and 2004 occurred at multiple sites within the CBBEP region, at the same time, and for the same parameters (plus additional parameters of local concern) as the EMAP NCA. This cooperative effort allowed TPWD (EPA-EMAP NCA lead agency in Texas) and EPA significantly increase the sampling coverage for the remaining waters of the state, thereby yielding a stronger dataset for assessing coastal conditions on a local and regional level.

This technical report is the fourth in a series planned to support the continuing goal of the CBBEP in providing information to protect, preserve, and enhance the natural resources of our coastal environment by providing descriptive and quantitative data and developing diagnostic procedures to characterize the physical, chemical, and biological dynamics of the CBBEP coastal environment. A comprehensive RCAP addressing these goals and objectives has the unique ability to interact with many of the other Action Plans as described in the *Bays Plan* in an overall adaptive management structure. Therefore, the continued objectives of this project are to build upon the current RCAP while interfacing with the broader NCA that assesses all coastal waters of the United States.

1.2 Regional Coastal Assessment Program Participants and Contractors

RCAP 2004 involved partnership efforts of the federal, state, local agencies, and stakeholder groups listed in Table 1.1. These groups were instrumental in providing funding, in-kind services, and/or expertise. CBBEP and CCS are grateful for their continued support. Table 1.2 lists participating RCAP 2004 contractors and primary personnel.

Table 1.1. Regional Coastal Assessment Program 2004 participants.

Institution
• **Coastal Bend Bays & Estuaries Program**
• **Texas Commission on Environmental Quality (TCEQ)**
• **Texas Parks and Wildlife Department**
• Coastal Ecology
• Coastal Fisheries
• **U.S. Environmental Protection Agency (USEPA)**
• Region 6 – Dallas, Texas
• National Health and Environmental Effects Research Laboratory - Gulf Ecology Division

Table 1.2. Regional Coastal Assessment Program 2004 contractors.

	Contractor/Institution	Primary Personnel
Principal Contractor	Center for Coastal Studies (CCS)	Mr. Brien A. Nicolau Mr. Alex X. Nuñez
Water Chemistry Nutrients	Texas A&M University Department of Oceanography	Mr. Christopher Schmidt
Chlorophyll *a*	University of Texas Marine Science Institute (UTMSI)	Dr. Tracy Villareal
Sediment/Tissue Trace Element Chemistry Organic Chemistry	Texas Parks and Wildlife Department Environmental Contaminants Laboratory (TPWD – ECL)	Dr. David Klein Mr. Gary Steinmetz Ms. Pamela Hamlett
Sediment/Water Chemistry Grain Size Total Organic Carbon Total Suspended Solids	FUGRO South, Inc (FSI)	Mr. Steve DeGregorio
Sediment Toxicity Testing	Center for Coastal Studies (CCS)	Dr. Marion Nipper
Microbiological	Texas A&M University-Corpus Christi (TAMUCC)	Dr. Joanna Mott

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2.0 METHODS

2.1 Sampling Process Design

RCAP development originally consisted of a three-phase process based on providing data that would characterize water and sediment quality conditions in the CBBEP region (Fig 2.1) and begin to identify significant long-term trends. In addition, RCAP would provide support for the TCEQ Surface Water Quality Monitoring Program (SWQM) and Total Maximum Daily Load (TMDL) process. Input from local, state, and federal representatives, facilitated stakeholder workgroup consensus regarding appropriate and effective sampling and analytical protocols for monitoring the region. As part of the initial process, coordination with TCEQ ensured a comprehensive monitoring strategy that determined effective methods of identifying water and sediment quality concerns for the CBBEP area. This included the Upper Laguna Madre and Baffin Bay; an area determined to be deficient in recent data collection. With attaining achievable water and sediment quality objectives as the goal, development of the work plan attempted to balance objectives with available resources.

Baseline quarterly monitoring for RCAP 2000 consisted of 120 (30 per quarter) randomly selected sites sampled in the northern and central portions of the CBBEP area. In addition, sampling occurred at 10 targeted fixed TCEQ sites each quarter, and 8 fixed sites in Oso Creek and Oso Bay for two quarters; bringing the total number of sites sampled to 176 for RCAP 2000. During RCAP 2001, sampling took place in the Upper Laguna Madre and Baffin Bay complex at 31 randomly selected sites per quarter for a total number of 124 sites sampled (Nicolau and Nuñez 2004). For RCAP 2002, sampling occurred once during the summer index period and consisted of 50 randomly selected sites located within 11 of the 13 TCEQ defined Segments in the CBBEP region (Nicolau and Nuñez 2005a). During RCAP 2003, sampling occurred once during the summer index period and consisted of 32 randomly selected sites located within 10 of the 13 TCEQ defined coastal Segments in the CBBEP region (Nicolau and Nuñez 2005b).

RCAP 2004 sampling consisted of 32 randomly selected sites (Fig. 2.2), located within 8 of 13 possible TCEQ defined coastal Segments in the CBBEP region. Site selection continued to utilize the EPA-EMAP sampling design in which each sampling site becomes a statistically valid probability-based sample (Stevens 1997; Stevens and Olsen 1999). Selection of sites by the EPA-NCA team involved placement of multiple hexagonal grids, of predetermined size, over the study areas with sites then selected by a systematic random approach. The uniform spatial coverage provided by a grid ensured sampling of parameters was proportional to geographical location.

The following 8 Segments contained the 32 sites selected for sampling: Aransas Bay (Segment 2471), Copano Bay/Mission Bay/Port Bay (Segment 2472), Corpus Christi Bay (Segment 2481), Nueces Bay (Segment 2482), Redfish Bay (Segment 2483), Oso Bay (Segment 2485), Laguna Madre (Segment 2491), and Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada (Segment 2492) (Fig. 2.1). The random sampling design did not generate any sites to be sampled in the remaining five Segments: San Antonio Bay/Hynes Bay/Guadalupe Bay (Segment 2462), Mesquite Bay/Carlos Bay/Ayers Bay (Segment 2463), St. Charles Bay (Segment 2473), Corpus Christi Inner Harbor (Segment 2484), or Oso Creek (Segment 2485A-TCEQ unclassified Tidal Stream segment).

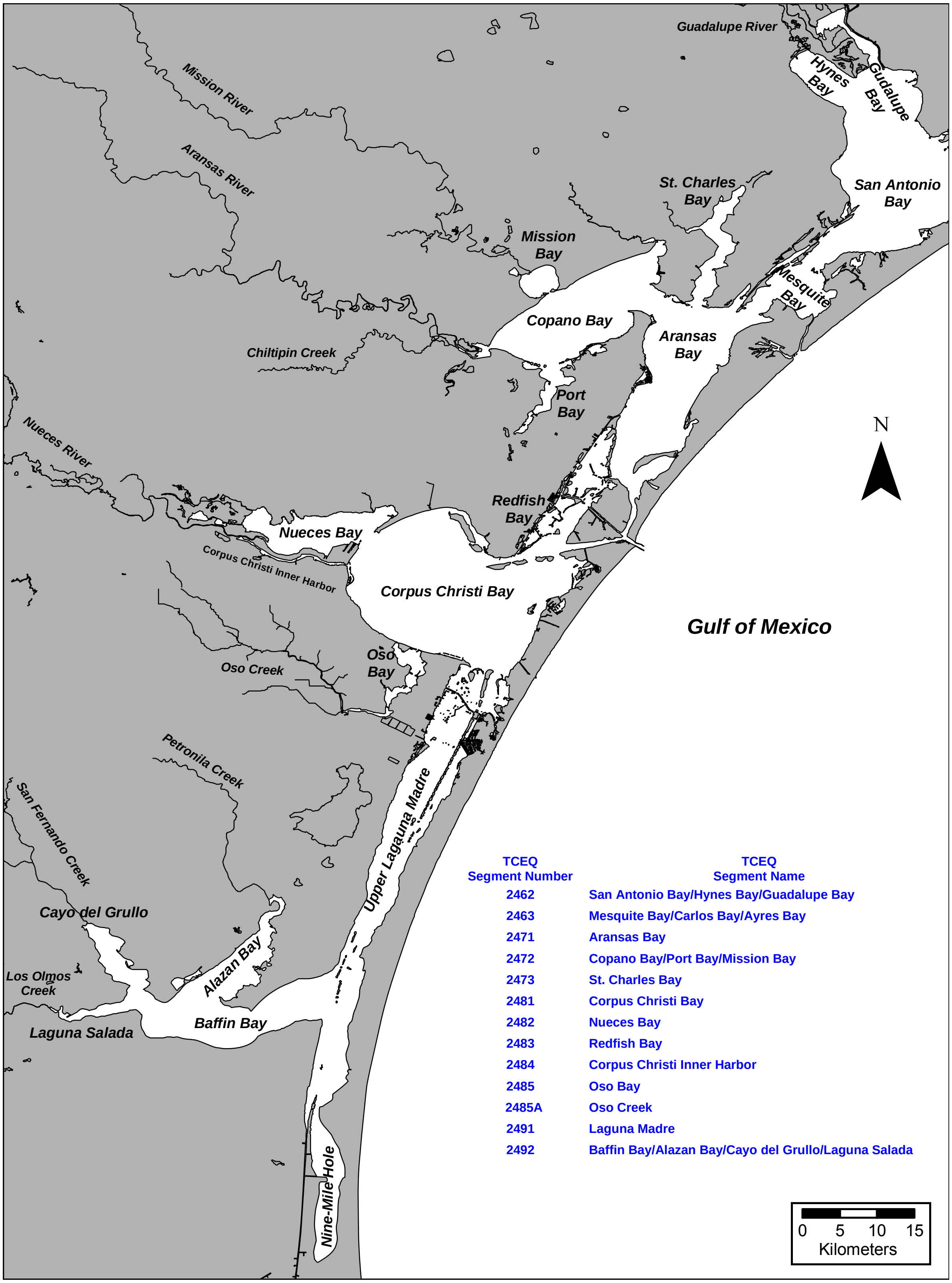

Fig. 2.1. Map depicting CBBEP RCAP sampling area with listing of TCEQ Segment Numbers and Segment Names.

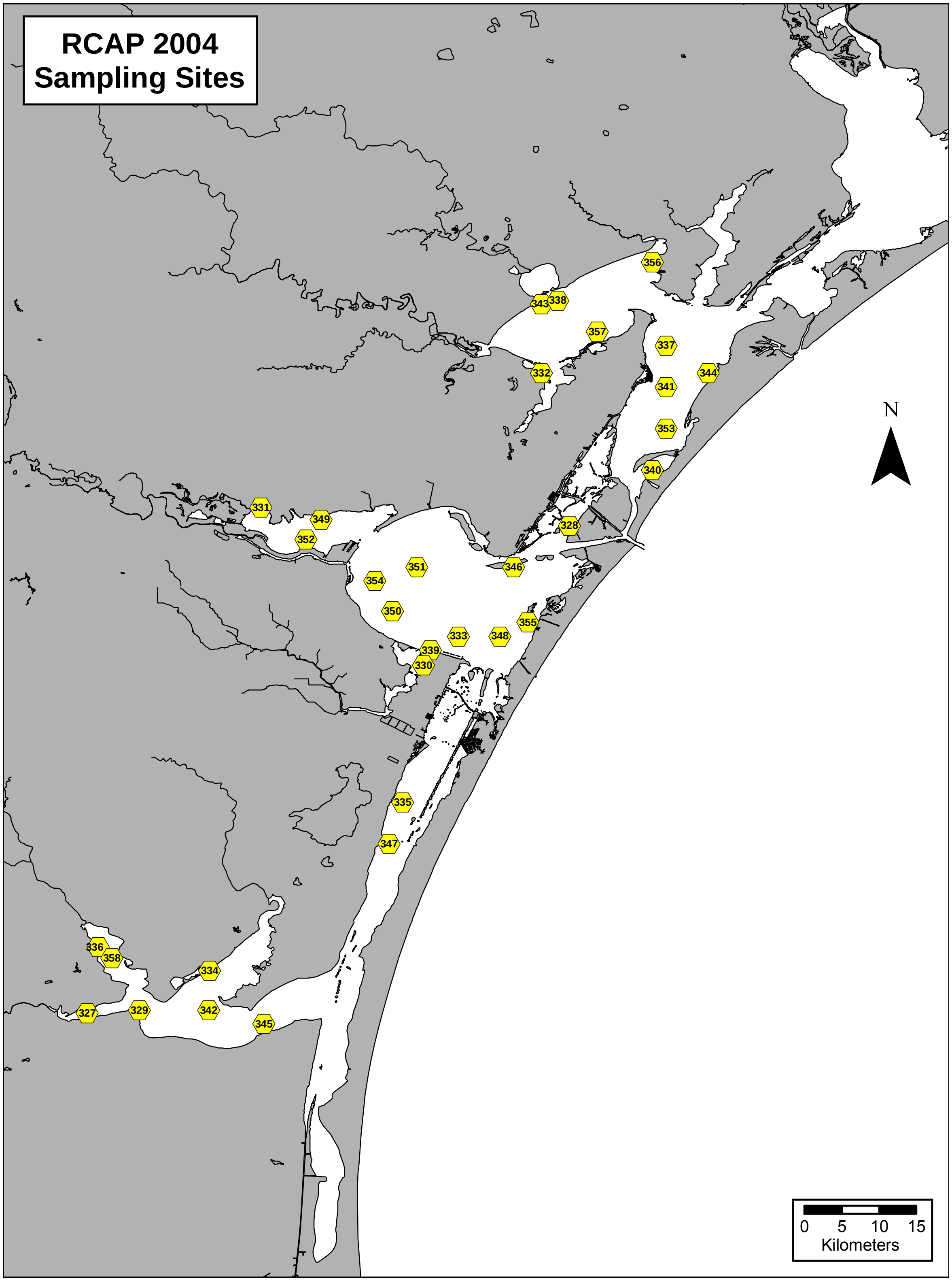

Fig. 2.2. Distribution of RCAP 2004 sampling sites (32) with corresponding CCS Site ID number. See Table 6.1.1 for corresponding TCEQ Station ID numbers and other pertinent information.

2.2 Parameters Sampled

Table 2.1 lists all parameters measured for RCAP 2004. Parameters measured but not presented within the scope of this report are available upon request to the CBBEP and CCS Project Managers.

Table 2.1. Parameters collected and analyzed for RCAP 2004.

FIELD PARAMETERS (Water)	Units	Lab
Conductivity	µS/cm	CCS
Depth Sample Collected	Meters	CCS
Dissolved Oxygen	mg/L	CCS
Dissolved Oxygen	% Saturation	CCS
Habitat Type	Description	CCS
Marine Debris	Description	CCS
PAR – Terrestrial	µmol s^{-1} m^{-2}	CCS
PAR – Flat Cosine	µmol s^{-1} m^{-2}	CCS
PAR –- Spherical	µmol s^{-1} m^{-2}	CCS
pH	su	CCS
Salinity	PSU	CCS
Seagrass Type (Species)	Scientific name	CCS
Seagrass Percent Cover	%	CCS
Secchi Depth	Meters	CCS
Tide Stage	DNR Tide Gauge	CCS
Total Depth	Meters	CCS
Turbidity	Visual assessment	CCS
Turbidity	NTU	CCS
Water Color	Visual assessment	CCS
Water Odor	Olfactory assessment	CCS
Water Surface	Visual assessment	CCS
Water Temperature	°C	CCS
FIELD PARAMETERS (Weather)	**Units**	**Lab**
Air Temperature	°C	CCS
Barometric Pressure	mm/Hg	CCS
Cloud Cover	%	CCS
Dew Point	°C	CCS
Heat Index	°C	CCS
Present Weather	Visual assessment	CCS
Rainfall (Days since last)	Days	CCS
Rainfall (Inches past 1 day)	Inches	CCS
Rainfall (Inches past 7 days)	Inches	CCS
Relative Humidity	%	CCS
Wind Chill	°C	CCS
Wind Direction	Compass Direction	CCS
Wind Speed	MPH	CCS

Table 2.1. (continued).

ROUTINE CONVENTIONAL CHEMISTRY (Water)	Units	Lab
Ammonia	mg/L	TAMU
Nitrate	mg/L	TAMU
Nitrite	mg/L	TAMU
Nitrate/Nitrite	mg/L	TAMU
Orthophosphate	mg/L	TAMU
Total Phosphorus	mg/L	TAMU
Total Suspended Solids (TSS)	mg/L	FSI
Chlorophyll *a*	µg/L	UTMSI
MICROBIOLOGICAL (Water)	**Units**	**Lab**
Enterococci (IDEXX 97 Method)	CFU/100ml	TAMUCC
SEDIMENT QUALITY PARAMETERS	**Units**	**Lab**
SGS Clay (<0.0039 mm)	% dry wt.	FSI
SGS Silt (0.0039 to 0.0625 mm)	% dry wt.	FSI
SGS Sand (0.0625 to 2.0 mm)	% dry wt.	FSI
SGS Gravel + shell hash (>2.0 mm)	% dry wt.	FSI
Total Organic Carbon (TOC)	mg/kg (% dry wt)	FSI
INORGANICS – SEDIMENT and TISSUE TRACE METALS	**Units**	**Lab**
Aluminum (Al)	mg/kg (dry and wet wt.)	TPWD ECL
Antimony (Sb) (Sediment only)	mg/kg (dry wt.)	TPWD ECL
Arsenic (As)	mg/kg (dry and wet wt.)	TPWD ECL
Cadmium (Cd)	mg/kg (dry and wet wt.)	TPWD ECL
Chromium (Cr)	mg/kg (dry and wet wt.)	TPWD ECL
Copper (Cu)	mg/kg (dry and wet wt.)	TPWD ECL
Iron (Fe)	mg/kg (dry and wet wt.)	TPWD ECL
Lead (Pb)	mg/kg (dry and wet wt.)	TPWD ECL
Manganese (Mn) (Sediment only)	mg/kg (dry wt.)	TPWD ECL
Mercury (Hg)	mg/kg (dry and wet wt.)	TPWD ECL
Nickel (Ni)	mg/kg (dry and wet wt.)	TPWD ECL
Selenium (Se)	mg/kg (dry and wet wt.)	TPWD ECL
Silver (Ag)	mg/kg (dry and wet wt.)	TPWD ECL
Tin (Sn)	mg/kg (dry and wet wt.)	TPWD ECL
Zinc (Zn)	mg/kg (dry and wet wt.)	TPWD ECL

Table 2.1. (continued).

ORGANICS – SEDIMENT AND TISSUE PAHs	Units	Lab
1-Methylnaphthalene	ng/g (dry and wet wt.)	TPWD ECL
1-Methylphenanthrene	ng/g (dry and wet wt.)	TPWD ECL
2,3,5-Trimethylnaphthalene	ng/g (dry and wet wt.)	TPWD ECL
2,6-Dimethylnaphthalene	ng/g (dry and wet wt.)	TPWD ECL
2-Methylnaphthalene	ng/g (dry and wet wt.)	TPWD ECL
Acenaphthene	ng/g (dry and wet wt.)	TPWD ECL
Acenaphthylene	ng/g (dry and wet wt.)	TPWD ECL
Anthracene	ng/g (dry and wet wt.)	TPWD ECL
Benzo(a)anthracene	ng/g (dry and wet wt.)	TPWD ECL
Benzo(a)pyrene	ng/g (dry and wet wt.)	TPWD ECL
Benzo(b)fluoranthene	ng/g (dry and wet wt.)	TPWD ECL
Benzo(g,h,i)perylene	ng/g (dry and wet wt.)	TPWD ECL
Benzo(k)fluoranthene	ng/g (dry and wet wt.)	TPWD ECL
Biphenyl	ng/g (dry and wet wt.)	TPWD ECL
Chrysene	ng/g (dry and wet wt.)	TPWD ECL
Dibenz(a,h)anthracene	ng/g (dry and wet wt.)	TPWD ECL
Dibenzothiophene	ng/g (dry and wet wt.)	TPWD ECL
Fluoranthene	ng/g (dry and wet wt.)	TPWD ECL
Fluorene	ng/g (dry and wet wt.)	TPWD ECL
Indeno(1,2,3-cd)pyrene	ng/g (dry and wet wt.)	TPWD ECL
Naphthalene	ng/g (dry and wet wt.)	TPWD ECL
Phenanthrene	ng/g (dry and wet wt.)	TPWD ECL
Pyrene	ng/g (dry and wet wt.)	TPWD ECL
ORGANICS – SEDIMENT AND TISSUE PCB CONGENERS		
PCB Nos. 8, 18, 28, 44, 52, 66, 77, 101,105, 118, 126, 128, 138, 153, 170, 180, 187, 195, 206, 209	ng/g (dry and wet wt.)	TPWD ECL
ORGANICS – SEDIMENT AND TISSUE DDTs		
2,4'-DDD	ng/g (dry and wet wt.)	TPWD ECL
4,4'-DDD	ng/g (dry and wet wt.)	TPWD ECL
2,4'-DDE	ng/g (dry and wet wt.)	TPWD ECL
4,4'-DDE	ng/g (dry and wet wt.)	TPWD ECL
2,4'-DDT	ng/g (dry and wet wt.)	TPWD ECL
4,4'-DDT	ng/g (dry and wet wt.)	TPWD ECL

Table 2.1. (continued).

ORGANICS – SEDIMENT AND TISSUE CHLORINATED PESTICIDES		
Aldrin	ng/g (dry and wet wt.)	TPWD ECL
Alpha-Chlordane	ng/g (dry and wet wt.)	TPWD ECL
Dieldrin	ng/g (dry and wet wt.)	TPWD ECL
Endosulfan I	ng/g (dry and wet wt.)	TPWD ECL
Endosulfan sulfate	ng/g (dry and wet wt.)	TPWD ECL
Endrin	ng/g (dry and wet wt.)	TPWD ECL
Heptachlor	ng/g (dry and wet wt.)	TPWD ECL
Heptachlor epoxide	ng/g (dry and wet wt.)	TPWD ECL
Hexachlorobenzene	ng/g (dry and wet wt.)	TPWD ECL
Lindane (gamma-BHC)	ng/g (dry and wet wt.)	TPWD ECL
Mirex	ng/g (dry and wet wt.)	TPWD ECL
Toxaphene	ng/g (dry and wet wt.)	TPWD ECL
Trans-Nonachlor	ng/g (dry and wet wt.)	TPWD ECL
SEDIMENT TOXICITY		
Sediment Toxicity Amphipods; *Ampelisca abdita*, *Leptocheirus plumulosus*	% Survival	CCS
BENTHIC SPECIES COMPOSITION		
Sorting	Number of vials	CCS
Counting	Integer	CCS
Biomass	mg (dry wt.)	CCS
Taxonomy	Classification	CCS
FISH COMMUNITY COMPOSITION *		
Counting	Integer	TPWD CF
Taxonomy	Classification	TPWD CF
Gross Pathology	Various	TPWD CF

* RCAP is providing additional funding for the tissue analysis and will eventually receive the community data from this sampling activity; however, the CCS RCAP Field Team did not conduct the actual trawl sampling. This is an integral aspect of the NCA and the TPWD-Coastal Fisheries branch has conducted the sampling in Texas since August 2000. The information provided is for documentation purposes only since the CBBEP receives the data collected.

2.3 Sampling Methods

Past RCAP annual reports previously described sampling methods employed by CCS personnel during monitoring. These methods, along with any changes and/or additions, appear again in this annual report to document modifications associated with any revisions to the RCAP monitoring design. In general, RCAP follows methods consistent with the *USEPA National Coastal Assessment–Coastal 2001-2004 Quality Assurance Project Plan* and the *TCEQ Surface Water Quality Monitoring Procedures Manual (1999).*

Unique conditions differentiate EMAP Provinces or geographic regions (e.g., climate, depth, bottom type, tidal influence, biota, etc.), therefore, on occasions; it is necessary to modify standard EMAP field procedures to meet the needs particular to a region or sub region. Such modifications generally gain approval as long as the altered procedures meet the general guidelines of established protocol and adhere to the spirit of the Quality Assurance/Quality Control (QA/QC) established for EMAP so that the resultant data remain comparable to that collected by standard procedures.

During RCAP 2004, a 3 to 4-person CCS field crew conducted sampling from a shallow draft bay skiff. Utilizing this craft facilitated sampling in areas often encountered on a daily basis in which water depth typically averaged <1 meter, a common occurrence throughout the Coastal Bend. Field activities performed at each site required approximately 1 to 2 hours per site; therefore, a team sampled 4 to 6 sites in a normal day. Of course, this was subject to factors such as weather, seas, travel distance, and holding times for microbiological samples; with some microbiological samples actually passed to waiting shore personnel for direct transport to the lab, so that the field crews could continue sampling.

At each sampling site, CCS field crews uniformly collected a core set of data and samples according to defined methods and protocols. Core field data and samples included those specifically detailed in applicable QAPPs and listed previously in Table 2.1. CCS field crews had the option of gathering additional environmental information for other researchers or agencies, as long as those activities did not take precedence over core activities. Samples collected from the field arrived back at the CCS facilities the afternoon of sampling to be properly stored, or immediately shipped, to the appropriate laboratories for analysis. Applicable QAPPs list sample handling and storage guidelines.

Additional aspects outlined in the following sections reflect specific requirements for RCAP sampling parameters and/or provide additional clarification. Field crews adhered to these methods as closely as possible during the course of this program.

2.3.1. Field Sampling Procedures

RCAP procedures for field collection of environmental samples and data follow methods developed by the TCEQ SWQM program and EMAP-Estuaries over long-term experience with large-scale, regional monitoring projects (e.g., EPA National Coastal Assessment, EMAP-E Province Monitoring, the Mid-Atlantic Integrated Assessment, and the Western Pilot Coastal Monitoring).

Full documentation of procedures utilized for all RCAP sampling events exists in the following approved QAPPs, state, and federal documents:

1. *Quality Assurance Project Plan for the Coastal Bend Bays Project – Surface Water Quality Monitoring and Assessment, 2000.*
2. *Quality Assurance Project Plan for the Coastal Bend Bays Project – Surface Water Quality Monitoring and Assessment, Amendment 2 – Sediment Collection, 2000.*

3. *Quality Assurance Project Plan for the Coastal Bend Bays Project – Phase III, Surface Water and Sediment Quality Monitoring and Assessment, Upper Laguna Madre and Baffin Bay, 2001.*
4. *Quality Assurance Project Plan for the Coastal Bend Bays & Estuaries Program, Regional Coastal Assessment Program (RCAP), 2002.*
5. *Quality Assurance Project Plan for the Coastal Bend Bays & Estuaries Program, Regional Coastal Assessment Program (RCAP), 2003.*
6. *Quality Assurance Project Plan for the Coastal Bend Bays & Estuaries Program, Regional Coastal Assessment Program (RCAP), 2004.*
7. *TCEQ Surface Water Quality Monitoring Procedures Manual. 2003.*
8. *USEPA National Coastal Assessment-Coastal 2001-2004 Quality Assurance Project Plan – 2001.*

2.3.2. Site Location

EPA provided CCS field crews with randomly selected RCAP sampling locations as coordinates of latitude/longitude in degrees-minutes, expressed to the nearest 0.01 minute (i.e., 00° 00.00'). CCS crews used GPS to locate the site. The acceptable tolerance goal was that the sampling site be within 0.02 nautical miles (nm), or ±120-ft, of the given coordinates. This reflects the accuracy expected from a properly functioning GPS unit of the caliber used for the study. Verification of GPS's performance occurred on a daily basis.

CCS field crews strictly adhered to site positioning guidelines, unless substantiated reasons prevented sampling within that defined area. Because EMAPs probabilistic sampling design is unbiased, potentially, some of the generated sites fell in locations not always conducive to sampling (e.g., shallow conditions, inaccessible due to oyster reefs, shallow conditions over protected seagrass beds, etc.). Prior planning by CCS personnel helped resolve potential problems before the actual sampling day, with substitute sites selected from a list of alternative randomly generated sampling sites.

To ascertain spatial distribution of sites required plotting coordinates of random locations on NOAA nautical charts, or other acceptable charts, to reconnoiter on paper obvious problem situations (e.g., water depth, hazards to navigation, etc.). If suspect sites appeared in this exercise, CCS field crews conducted a field reconnaissance to determine actual site conditions. If an intended site location presented an obvious problem, then depending on the situation, the CCS Project Manager, in consultation with the EPA, elected to relocate the site within an acceptable range of the original location. The CCS Project Manager and EPA made decisions on this level (i.e., significant changes to the sampling design), not the CCS field crews.

Field teams, however, had a limited degree of onsite flexibility to relocate sampling sites when confronted with unexpected obstacles or impediments associated with locating within the ±0.02 nm guideline (e.g., shallow conditions, danger, or risk, to crew from ship traffic, man-made obstructions, etc.). CCS field crews then moved the site to the nearest location from the intended site amenable to conduct sampling; making every effort to relocate to an area that appeared similar in character to that of the intended site.

When necessary to relocate the site >0.02 nm the reason for the shift became part of the documented field record. Document records for any site relocation, >0.05 nm (300 ft), required review before data collected from the site would be acceptable for inclusion in the study database. At times, crews might have trouble in obtaining a "good grab" when collecting sediment due to the nature of the bottom at the established site. In these situations, even after collecting the water quality samples and data, it was permissible to move around within a 120-ft radius to locate more favorable sediment conditions without having to resample the water quality indicators.

2.3.3. Water Column Measurements

The first activities conducted upon arriving onsite involved water sampling and water column measurements; as these data and samples strictly required collection before disturbing bottom sediments. If upon arrival at the site, CCS field crews ascertained that sediments had been disturbed (e.g. shallow depth or other disturbance creating turbid conditions) then field crews allowed adequate time so that the disturbance dissipated before sample collection began.

Instantaneous water column profiles and visual assessments performed at each site by CCS field crews measured basic water quality parameters (Table 2.1) and ambient conditions utilizing hand-held multiparameter water quality probes (e.g., YSI Sondes). Water column profiling followed EPA protocols. Instantaneous near-surface measurements occurred 0.5 m below the surface (near-surface) and bottom condition measurements took place at 0.5 m off the bottom (near-bottom). To obtain undisturbed near-bottom readings required ascertaining bottom depth, pulling up the probe approximately 0.5 m, and then allowing 2-3 minutes for disturbed conditions to settle before taking the near-bottom measurements.

At least one measurement of light attenuation (Photosynthetically Active Radiation or PAR) occurred, with secchi depth also measured at each site. Measurements of light penetration, taken by hand-held light meters, occurred at discrete depth intervals in a manner similar to that for profiling water quality parameters. The underwater sensors are hand lowered slowly with the deck reading and underwater readings recorded at each discrete interval. If light measurements become negative before reaching bottom, the measurement terminates at that depth. Secchi depth determination used a standard 20-cm diameter black and white secchi disc lowered to the depth at which it no longer discernable; and then slowly retrieved until it just reappears; depth is marked and recorded as secchi depth (rounded to nearest 0.1 m).

2.3.4. Routine Conventional Water Chemistry

Due to different methods used by EPA (samples field filtered from 3 depths) and TCEQ (typically one whole water unfiltered sample collected at near-surface but for RCAP 2004 water collection occurred at the same depths as EPA samples) in the NCA and SWQM programs, respectively, required CCS field crews to collect two individual sets of samples where methods differed. This ensured that data collected would be comparable to historical TCEQ near-surface data used in the assessment of Texas coastal waters and to data from TPWD/EPA-NCA Texas sites and other states.

CCS field crews collected water samples for the determination of dissolved and total nutrients (see Table 2.1), chlorophyll *a*, and total suspended solids by using a Van Doren sampler. Depending on depth at the sampling site, water sample collection followed EPA-NCA protocols as follows:

> Shallow sites (<2 m) - sample at 0.5 m (near-surface) and 0.5 m off-bottom,[1]
>
> Standard site (>2 m) - sample at 0.5 m (near-surface), mid-depth, and 0.5 m off-bottom,
>
> [1]Unless the depth is so shallow that near-surface and near-bottom overlap; then sample mid-depth, only.

For EPA-NCA samples, an approximate 3 L sub-sample was drawn into a clean, wide-mouth Nalgene container from each applicable water depth at the site. This provided enough water for the remainder of the sample processing which essentially was filtration; with the filtrate becoming the dissolved nutrient sample and the filters retained for chlorophyll *a* analysis. Total Suspended Solids (TSS) and total nutrient samples required unfiltered water collection. TCEQ sample collection took place in the same manner except that nutrient samples (except orthophosphate) were not field filtered.

2.3.4.1. Chlorophyll *a*

At each site, a new sampling pack consisting of a disposable, graduated 60 ml polypropylene syringe, fitted with a polypropylene filtering assembly, filtered the site water from applicable water depths, through a 25 mm GF/F filter. If conditions allowed (low suspended solids load) then field crews filtered 100 ml of site water for each chlorophyll sample. If another filter was required then field crews carefully detached the filter assembly, replaced the filter, and continued with the filtration until the desired volume was processed. Field crews used tweezers to carefully remove the filter from its holder and fold once upon the pigment side, and then placed it onto a pre-labeled aluminum sheet, wrapped and folded the sheet, and then placed the contents into a pre-labeled, disposable whirl-pak bag. CCS field crews recorded the volume of water filtered on all sample containers, and the field form, and then placed the whirl-pak bag into a small instant-freeze chamber (small ice chest with several pounds of dry ice). Samples remained frozen until time of analysis.

2.3.4.2. Dissolved and Total Nutrients

For dissolved nutrients, CCS field crews collected approximately 30 ml of filtrate from the above chlorophyll filtration into a pre-labeled, clean 30 ml Nalgene screw-capped bottle, which was also stored in the dry ice freezing chamber. Before placing sample in the freezer, they recorded the approximate salinity (±2 ppt) on the container, a convenience for the analyst who performs the nutrient analysis. Depending on the analytical instrumentation used, matrix matching of solutions (e.g., standards or wash solutions) was necessary for certain analytes. The nutrient samples remained frozen until time of analysis. For TCEQ total nutrient samples, crews collected 30 ml of unfiltered seawater from each applicable depth. The samples were held on wet ice in the field and stored at 4ºC to await laboratory determinations.

2.3.4.3. Total Suspended Solids (TSS)

After chlorophyll and nutrient sample collection, CCS field crews vigorously shook the remaining water in one 3 L sub-sample to re-suspend the particles and collected 1 L into a pre-labeled Nalgene container. The samples were held on wet ice in the field and stored at 4ºC to await laboratory determinations.

2.3.5. Composited Surficial Sediment

At each site, CCS field crews utilized a modified 0.04 m^2 Van Veen sampler to obtain multiple grabs; collecting the surficial sediment layer (top 2-3 cm) by spatula or scoop. The sample was then composited to provide sediment for the analyses of trace metal and organic contaminants, total organic carbon (TOC), and sediment grain size. The number of grabs required to yield an adequate volume of composited sediment depended on the surface area obtained by the particular grab; however, surficial sediment from a minimum of eight grabs usually yielded enough quality material for the final sample. Sediment sampling followed established TCEQ and EPA protocols (TCEQ 2003; EPA 2001). CCS field crews combined the surficial sediment from the individual grabs in a clean, high-grade stainless steel or Teflon vessel. To protect the sample from contamination between grabs, CCS field crews covered the sample bucket with a lid and placed the sample on ice. Stirring action blended in each addition of sediment to the composite, with the final mixture stirred consistently to ensure a homogenous sample before taking required sub-samples.

2.3.5.1. Organic chemical contaminants

The collection of composited sediment for organic contaminants analysis required placing approximately 500 cc into a clean, pre-labeled, glass wide-mouth, I-Chem jar with jars filled to approximately 75% of capacity to allow for expansion during freezing. The sample was held on wet ice aboard and upon transfer to shore storage was frozen, unless it was scheduled for extraction within 7 days; in that case, the sample was held at 4ºC to await processing.

2.3.5.2. Inorganic chemical contaminants

The collection of composited sediment for inorganic contaminants analysis required placing approximately 125 cc into a clean, pre-labeled, wide-mouth Nalgene bottle with bottles filled to approximately 75% of capacity to allow for expansion during freezing. The sample was held on wet ice while aboard and upon transfer to shore storage was frozen, unless it was scheduled for digestion within 7 days; in that case, the sample was held at 4ºC to await processing.

2.3.5.3. Total Organic Carbon (TOC)

The collection of composited sediment for TOC analysis required placing approximately 250 cc of composited sediment into a small, clean, pre-labeled amber glass jar with jars filled to approximately 75% of capacity to allow for expansion during freezing. The sample was held on wet ice aboard and upon transfer to shore storage was frozen, unless it was scheduled for extraction within 7 days; in that case, the sample was held at 4ºC to await processing.

2.3.5.4. Sediment Grain Size

The collection of composited sediment for Sediment Grain Size analysis required placing approximately 500 cc of composited sediment into a clean, pre-labeled, wide-mouth polypropylene jar. The sample was held on wet ice aboard and upon transfer to shore storage, the sample was held at 4ºC to await laboratory processing.

2.3.5.5. Toxicity testing

The collection of composited sediment for toxicity analysis required placing approximately 4000 cc into a clean, pre-labeled, wide- mouth Nalgene jar. The sample was held on wet ice aboard and upon transfer to shore storage was held at 4ºC to await further processing and initiation of testing within 30 days of collection.

2.3.6. Benthic Infaunal Community

Biological sampling procedures and methods had prior approval by TCEQ and EPA. CCS field crews sampling benthic biota in this region have historically utilized these methods to provide characterizations and quantify benthic habitat. Sampling protocols and CCS benthic laboratory Quality Assurance/Quality Control procedures are adapted from the Environmental Monitoring and Assessment Program (EMAP): Laboratory Methods Manual-Estuaries, Volume 1: Biological and Physical Analyses (1995) and are maintained and available upon request from the CCS Project Manager.

The method employed by CCS field crews for benthic macroinvertebrate infauna sampling involved using a PVC cylindrical (10.16 cm diameter) push corer to sample benthic infauna to a depth of 10 cm in the sediment. Multiple extensions extended the corer to reach bottom sediments in deeper waters. A minimum of five (5) replicate samples (81.1 cm^2) taken at each site yielded a total area of 405.4 cm^2. Each sample was then placed in a 0.5 mm mesh biobag and field washed by gently homogenizing the sample by hand. Following this procedure, sediment sample storage on ice occurred to preserve samples for transport to CCS facilities before sample placement in a 10% formalin and seawater mixture. All benthic samples required a minimum of one (1) week for fixation. Sample transfer to 45% isopropyl alcohol took place approximately seven days later. Laboratory analysis consisted of washing samples through nested sieves (minimum mesh size = 0.5 mm), with organisms sorted, counted, and identified to the lowest possible taxon. Biomass determination required drying all specimens, for a minimum of two days, at 90°C in a standard drying oven before weighing to the nearest 0.0001 g. All macrobenthic abundance data were transformed to number of individuals per meter square ($n\ m^{-2}$) and biomass data was transformed to grams per meter square ($g\ m^{-2}$).

2.3.7. Habitat Evaluation

Several observations took place in the field to document certain attributes or conditions of the site to help characterize overall ecological site health. Observations made by CCS field crews included the occurrence of submerged aquatic vegetation (SAV), the occurrence of macro algae beds/mats, the presence of marine debris (litter), and if there was obvious evidence of disruptive anthropogenic activities (e.g., dredging or prop scouring or scarring), these observations, and a brief description, became part of the permanent field record.

2.3.8. Fish Trawls

Fish trawls are an integral aspect of EMAP-NCA and TPWD-Coastal Fisheries (TPWD-CF) branch has conducted the sampling in Texas since August 2000. While CCS will not be doing this sampling, the data will eventually become a part of the RCAP data record. The information provided below is for documentation purposes.

Using standard agency protocols, TPWD-Coastal Fisheries conducts fish trawls, where possible, at each site to collect fish and shellfish for community structure and abundance estimates; target species for contaminant analyses, and specimens for histopathological examination. Additional trawls supplemented the sample, if needed, to obtain enough target species for contaminant analyses. Trawling should be the last field activity that the crew performs while onsite because of their disturbance to conditions at the site.

2.3.8.1. Community Structure

TPWD-CF personnel sorted and identified to the lowest taxonomic level possible all fish and invertebrates from a successful trawl (fulltime on bottom with no hangs or other interruptions). The first nineteen individuals per species required measuring to the nearest centimeter (fork length when tail forked, otherwise overall length - snout to tip of caudal). TPWD-CF personnel recorded lengths on a field form, made a total count for each species, and returned fish to the estuary if not retained for histopathology or chemistry.

2.3.8.2. Gross Pathology

All fish were field screened for external gross pathologies while being measured and counted for the community structure evaluation. A brief examination of each fish documented any obvious external conditions such as lesions, lumps, tumors, and fin erosion. In addition, an examination of the gills took place for discoloration or erosion. Any fish exhibiting a pathological condition required saving for further laboratory histopathological evaluation. Field personnel on the Fish Data form recorded a generic description of the observed condition, and then tagged the specimen before immediately preserving in Dietrich's solution to await shipment to the laboratory.

Each fish preserved had its body cavity opened to expose internal tissues to the fixative. Stainless steel surgical scissors were used to open the body starting at the anal pore and cutting anteriorly through the body wall, taking care not to cause undue damage to the internal organs; the cut continued through the thoracic region and over to the gill slits. The body cavity was then be spread apart (popped open) by hand to further ensure the fixative flooded the internal organs. An appropriate container (e.g., a 1-2 gallon plastic bucket), with enough Dietrich's solution to completely cover the specimen, served as storage for each tagged fish, with multiple samples held in a common container provided fish were appropriately tagged.

2.3.8.3. Tissue Contaminant Analyses

Several species designated as target samples for analyses of chemical contaminants in whole-body tissue were: Spot (*Leiostomus xanthurus*), Atlantic Croaker (*Micropogonias undulatus*), Catfish (*Arius felis*, *Bagre marinus*, *Ictalurus punctatus*, *Ictalurus furcatus*), Brown Shrimp (*Farfantepenaeus aztecus*), White Shrimp (*Litopenaeus setiferus*), and Pink Shrimp

(*Farfantepenaeus duorarum*). In the Laguna Madre, the following species were acceptable surrogates: Pinfish (*Lagodon rhomboides*), Pigfish (*Orthopristis chrysoptera*), and Toadfish (*Opsanus beta*). Five to ten individuals (minimum total wet weight of 300 g) of a species comprised a composited sample at sites where target species collection was sufficient. After measurement and recording on the sampling form as chemistry fish, TPWD-CF personnel rinsed the fish with site water and individually wrapped the fish with heavy-duty aluminum foil before placing samples together in a plastic, Ziploc bag, labeled with Site ID and a Species ID Code (e.g., the first four letters of both the genus and species). Sample placement on wet ice in the field maintained samples until the samples were transferred to shore and frozen to await laboratory analysis.

2.3.9. Microbiological

To collect additional tidal water data for evaluation of the IDEXX (chromogenic substrate, or enzyme specific) method used by TCEQ for microbiological analysis required collection of two near-surface water samples from each site. Collection involved directly immersing the inverted polypropylene screw cap, 125 ml sterile plastic bottles beneath the water surface to the appropriate depth, quickly turning the bottle upright, and filling the container at that depth. The samples were held on wet ice in the field at 4ºC. Depending on holding times (six hours), sample delivery involved passing the samples to waiting shore personnel for direct transport to the lab, or involved delivery by the field crews within the appropriate holding times for applicable analysis.

2.4 Analytical Laboratories and Methods

Analytical procedures for RCAP ranged from straightforward determinations such as percent gravel/silt/sand/clay to comprehensive analyses of trace metal and organic contaminants in complex environmental matrices. Laboratory Directors/Scientists/Managers were responsible for overseeing laboratory sample analyses, and data processing duties related to the parameters as defined in, and according to guidelines included in, the QAPPs.

Analyses were in accordance with the most recently published edition of *Standard Methods for the Examination of Water and Wastewater*, the TCEQ *Surface Water Quality Monitoring Procedures Manual 2003*, alternate TCEQ approved methods, or EPA approved methods. Many procedures for various analyses derive from those developed for the EMAP-Estuaries Program, which documents specific analytical processes details (USEPA 1995). Additional information is contained in Section B4 of the National Coastal Assessment Program QAPP (USEPA 2001).

The Laboratory Director/Manager/Scientist of all contract laboratories and the CCS Project Manager retain copies of all documentation, raw data, and calibration data that are applicable. The CCS Project Manager retains custody of all project records for perpetuity except laboratory calibration and equipment maintenance records, which will remain with the laboratories. Copies of laboratory SOPs are available for review by CBBEP, TCEQ, and EPA. All laboratory SOPs were consistent with EPA requirements as specified in the method.

2.5 Quality Assurance

RCAP monitoring took place under an approved Quality Assurance Project Plan (QAPP). The purpose of the QAPP, which includes sample sites and a sampling plan, is to provide a clear delineation of the CCS Quality Assurance (QA) policy, management structure, and policies used to implement the extensive QA requirements necessary to document reliability, quality, precision, accuracy, completeness, and validity of the data. All participants used Standard Operating Procedures and maintained QA records. QA documentation accompanied all data report submissions. The Laboratory Manager of all contract laboratories and the CCS Project Manager retain copies of all documentation, raw data, and calibration data that is applicable.

QAPP review by the CBBEP, TCEQ, and EPA ensured that data generated for the purposes described above are scientifically valid and legally defensible. A process insured that data collected, analyzed, and submitted to the statewide database guaranteed reliability and therefore use of the data in possible TMDL development, permit decisions, water quality assessments, and other programs deemed appropriate. The individual QAPPs for the all RCAP events are available from CCS upon request.

2.6 Data Analyses

Data analysis utilized various standard parametric and non-parametric tests dependent on meeting test assumptions of the particular analysis required. Additional data evaluation utilized in this report derives from comparisons or evaluations to applicable TCEQ water and sediment quality criteria obtained the Texas Surface Water Quality Standards (TSWQS) adopted by the TCEQ on July 26, 2000. The TSWQS provide a quantitative basis for evaluating use support by identifing *Primary Concerns*, or if no criteria exist, then to TCEQ SWQM based screening levels that identify *Secondary Concerns* (e.g. Tidal Water Chronic criteria for Toxic Substance in Water vs. Nutrients and Chlorophyll *a* Screening Levels). Further comparison and evaluation of RCAP 2004 data used EPA National Coastal Condition Report II (NCCR II) guidelines (USEPA 2004). Use of this evaluation technique was to provide continuity between locally collected data and the ongoing NCA program for assessing coastal waters and to see if the broad based EPA regional approach is applicable in all estuarine systems. More details concerning these approaches, and the particular methods utilized, are available within the individual chapters of this document.

2.7 References

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3.0 WATER MONITORING

3.1 Introduction

As stated in previous RCAP reports by Nicolau and Nuñez (2004; 2005a; 2005b), estuaries are vital natural and economic resources representing a significant coastal watershed component. Within the Coastal Bend region, our local bays and estuaries either directly, or indirectly, relate in some way to almost 70% of the economy, and coastal communities such as ours depend on having healthy estuarine conditions (CBBEP 2005). As extremely productive systems, estuaries are highly vulnerable to human impacts (Mann 2000). With more than 50% of the nation's population residing along coastal margins, population increases place demands on our natural resources; often producing deleterious effects on an estuary that directly affect the livelihood of people living and working in coastal areas (USEPA 2004).

While many factors, such as reduced freshwater inflow, habitat modification/destruction, and climate change, can affect estuarine system health, the fundamental health of an estuarine system depends on the type and quantity of pollutants, such as heavy metals, excessive nutrients, and disease causing microorganisms, or pathogens, (viruses, bacteria, and parasites) that may enter the water column. The process of eutrophication, caused by the addition of excessive nutrients into an estuarine system, may result in accelerated production of organic matter and produce undesirable effects (Rabalais 1992; Bricker et al. 1999; CENR 2003). Elevated concentrations of priority pollutants in the water column, sediments, and tissues of aquatic animals may affect diverse groups of species, either through direct exposure or indirectly through the food chain, and eventually may be harmful to humans.

The ability to predict definitive water quality trends for all estuaries remains hampered by scarce trend data and large gaps in data and information (Bricker et al. 1999). However, local programs (RCAP), state programs (TCEQ-SWQM), and national programs (EMAP-NCA), are attempting to address the national goal of improving and protecting water quality through comprehensive monitoring, interpretation, modeling, and research. The mission of protecting coastal regions is too daunting a task for one entity alone. Only through cooperative partnerships will we achieve maximum effectiveness in creating an adaptive management framework that aids in protecting our watershed and estuarine systems (Bricker et al. 1999; CENR 2003). Therefore, sampling and analysis of water quality parameters remains a primary focus of the RCAP program in assessing status and trends within the CBBEP area.

3.2 Sampling Design and Data Evaluation

Water quality sampling for RCAP 2004 took place on various days from July 20th through August 11th 2004 at 32 randomly selected sites throughout the CBBEP region as described in Chapter 2.0. Table 6.1.1 in the *Data Tables* chapter and Fig. 2.2 provide site information and location. Table 2.1 provides a complete list of parameters measured during RCAP 2004 sampling.

The *Data Tables* in Chapter 6.0 provide individual concentration values for near-surface and near-bottom Field Parameters measured (Table 6.2.1 and 6.2.2), with summary statistics by TCEQ segments (Table 6.3.1 through 6.3.8). In the case of near-bottom measurements the total number of sites with data collected was 25, as water depth at 7 of the sites was too shallow (e.g. near-surface and near-bottom depths are equal) to obtain multiple measurements.

For Routine Conventional Water Chemistry, the *Data Tables* in Chapter 6.0 present individual parameter concentrations (Tables 6.4.1 through 6.4.7) according to each sampling method, with summary statistics by TCEQ segments (Table 6.5.1 through 6.5.12). Individual microbiological concentrations are in Table 6.6.1. While information exists for multiple parameters at additional depths, presently TCEQ and EPA only use near-surface data for assessment. Additional data provided in the *Data Tables* serves only as a reference.

If a criterion, screening level, or concentration range existed, then data evaluation followed two different approaches; 1) the TCEQ regulatory approach and 2) according to guidelines utilized in the EPA NCCR II (USEPA 2004). Where no criteria or screening level exists, data presentation considers how the parameter compares between segments or applies to water quality within the CBBEP region in general.

3.2.1. TCEQ Criteria and Screening Levels

TCEQ uses many physical, chemical, and biological characteristics in assessing support of designated uses and criteria of a water body, or Segment. Primarily, comparison of individual parameter values to either numerical criteria or screening levels determines the number of values exceeded. Based on number of exceedances, the assessment classifies a segment as either being in full support, partial support, or not supportive of the official designated use. Similar exceedances of numerical screening levels identify segments with no concerns or concerns for impairment. As defined in the *Texas Surface Water Quality Standards* (TSWQS) the identification of *Primary Concerns*" relates directly to criteria adopted in the TSWQS that protect the designated use of a water body. *Secondary Concerns* are parameters for which there are no existing standards adopted but that have elevated concentrations exceeding screening levels.

Results of the assessment appear in the *Texas Water Quality Inventory and 303(d) List*, as required by Sections 305(*b*) and 303(*d*) of the federal Clean Water Act on a periodic basis. Section 305(*b*) requires states to report the extent to which water bodies attain designated water quality standards while Section 303(*d*) of the act requires states to identify water bodies for which constituent loadings are not stringent enough to attain water quality standards. Therefore, the 303(*d*) list contains Segments with *Primary Concerns* and while water bodies with *Secondary Concerns* appear on the 305(*b*) report, they are not included on the 303(*d*) list. Typically, areas exhibiting *Secondary Concerns* will receive more frequent and possible additional parameter monitoring (TCEQ 2003).

To establish whether *Primary Concerns* exist, and if a segment supports the Aquatic Life Use, TCEQ assesses dissolved oxygen (DO) and toxic substances in water criteria, among others. Contact Recreation Use assessment utilizes the Enterococci criterion as an indicator of concern and support for bacterial pathogens in Tidal Waters. TCEQ uses methodologies for assessing *Secondary Concerns* for nutrients and chlorophyll *a* in water, as no water quality criteria exists on a national or state level. However, EPA, state regulatory agencies, and a multitude of researchers are working to address this situation to better protect and restore the waters of the country. Individual criteria and screening levels for the various parameters sampled for RCAP 2004 appear in the following applicable sections.

At the time of RCAP 2004 sampling, the following segments within the CBBEP area appeared on the 2002 303(d) list for *Primary Concerns*:

Bacteria in Oyster Waters
Segment 2462 – San Antonio Bay/Hynes Bay/Guadalupe Bay
Segment 2472 – Copano Bay/Port Bay/Mission Bay

Bacteria (Contact Recreation)
Segment 2485A – Oso Creek (unclassified water body)

Depressed Dissolved Oxygen Levels
Segment 2483A – Conn Brown Harbor (unclassified water body)
Segment 2485 – Oso Bay
Segment 2491 – Laguna Madre

Zinc in Oyster Tissue
Segment 2482 – Nueces Bay

At the time of RCAP 2004 sampling, the following segments within the CBBEP area appeared on the 2002 305(b) list for S*econdary Concerns*:

Ammonia
Segment 2484 – Corpus Christi Inner Harbor

Nitrate + Nitrite Nitrogen
Segment 2462 – San Antonio Bay/Hynes Bay/Guadalupe Bay
Segment 2484 – Corpus Christi Inner Harbor
Segment 2485A – Oso Creek (unclassified water body)

Orthophosphorus
Segment 2462 – San Antonio Bay/Hynes Bay/Guadalupe Bay
Segment 2485A – Oso Creek (unclassified water body)

Total Phosphorus
Segment 2462 – San Antonio Bay/Hynes Bay/Guadalupe Bay
Segment 2472 – Copano Bay/Port Bay/Mission Bay
Segment 2485A – Oso Creek (unclassified water body)

Excessive Algal Growth (Chlorophyll *a*)
Segment 2485 – Oso Bay
Segment 2491 – Laguna Madre (near mouth of Baffin Bay)
Segment 2492 – Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada (Upper Baffin)

3.2.2. EPA NCCR II Guidelines

RCAP 2004 data evaluation continued to use a subset of the EPA NCCR II guidelines for assessing water quality at individual sites (Table 3.1). Use of this evaluation approach continues to provide continuity between locally collected data and the ongoing NCA program for assessing coastal waters and to see if the broad based EPA regional approach is applicable in all estuarine systems. As in previous RCAP sampling events, evaluation of RCAP 2004 sites utilized four of the five parameters comprising the overall EPA Water Quality Index (DO, DIN, DIP, Chlorophyll *a*), as questions of applicability of the fifth parameter, the Water Clarity criteria, still exist for this region.

Table 3.1. EPA NCA guidelines for assessing Dissolved Oxygen, Dissolved Inorganic Nitrogen, Dissolved Inorganic Phosphorus, Chlorophyll *a*, and the modified Water Quality Index by site (USEPA 2004).

Rating		Dissolved Oxygen (DO)
Good		DO concentration >5.0 mg/L.
Fair		DO concentration between 2.0 mg/L and 5.0 mg/L.
Poor		DO concentration <2.0 mg/L.
Rating		**Dissolved Inorganic Nitrogen (DIN)**
Good		DIN concentration <0.1 mg/L.
Fair		DIN concentration between 0.1 mg/L and 0.5 mg/L.
Poor		DIN concentration >0.5 mg/L.
Rating		**Dissolved Inorganic Phosphorus (DIP)**
Good		DIP concentration <0.01 mg/L.
Fair		DIP concentration between 0.01 mg/L and 0.05 mg/L.
Poor		DIP concentration >0.05 mg/L.
Rating		**Chlorophyll *a***
Good		Chlorophyll *a* concentration <5.0 µg/L.
Fair		Chlorophyll *a* concentration between 5.0 µg/L and 20 µg/L.
Poor		Chlorophyll *a* concentration >20.0 µg/L.
Rating		**Water Quality Index (WQI)**
Good		A maximum of one indicator is rated fair, and no indicators are poor.
Fair		One of the indicators is rated poor, or two or more indicators are rated fair.
Poor		Two or more of the four indicators are rated poor.

3.3 Results and Discussion

3.3.1. Field Data

A complete list of instantaneous core field parameters, along with summary statistics, appears in Chapter 6-*Data Tables* 6.2.1 and 6.2.2 and 6.3.1 through 6.3.8, respectively. For many parameters no established state or federal criteria exists. However, data collected serves as initial descriptors of a water body, or segment, and aid as indicators when making determinations of whether unusual or stressful conditions exist. As standard protocol in most monitoring programs, collection of multi-year datasets may allow for future status and trends analysis and be useful in ascertaining changing conditions within the CBBEP region.

3.3.1.1. Precipitation and Gauged Inflows

Precipitation recorded at Corpus Christi International Airport (CRP) totaled 60.15 cm from January 1st through August 31st 2004; representing an increase of 27.23 cm for the same period preceding RCAP 2003 sampling (NOAA 2002, 2003, 2004). Cyclical patterns of precipitation and inflow for this region are evident when one looks at the historical data for each RCAP event. Regarding inflow, for RCAP 2002, a slow moving tropical wave produced enough rainfall in the upper Nueces River watershed to spill approximately 1,000,000 ac-ft of water from Lake Corpus Christi to the Nueces River in July 2002 (Fig. 3.1). However, substantial declines in Nueces River inflows preceded RCAP 2003 sampling, with only 80,000 ac-ft of recorded pass-throughs recorded at the Calallen USGS Gauge No. 08211500 in July 2003. While still a considered a substantial amount of inflow for this region, it did not have the same effect of dramatically lowering salinity concentrations as seen in RCAP 2002. For RCAP 2004, inflows increased to approximately 220,000 ac-ft for July 2004 and declines in salinity within each Segment were at, or nearing, RCAP 2002 levels.

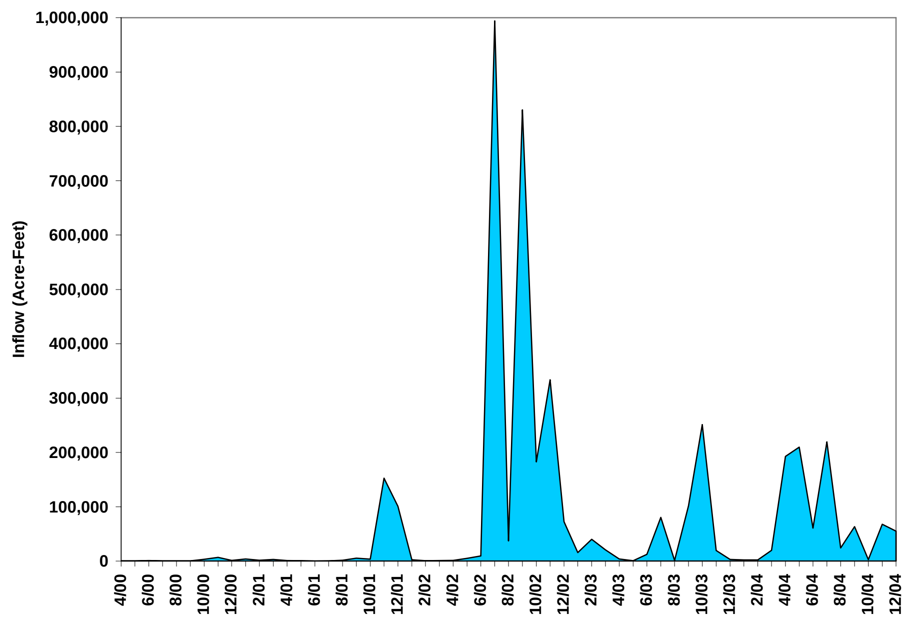

Fig. 3.1. Total monthly inflow (acre-feet) on the Nueces River recorded at the Saltwater Diversion Dam in Calallen, Texas from April 2000 through December 2004 (USGS Gauge No. 08211500).

3.3.1.2. Total Depth

For all 32 RCAP 2004 sampling sites Total Depth ranged from 0.70 m in Oso Bay (Segment 2485) to 4.50 m in Corpus Christi Bay (Segment 2481) (Table 6.2.1). Mean Total Depth was greatest in Corpus Christi Bay at 3.71 m and shallowest in Oso Bay (Segment 2485) at 0.70 m (Table 6.3.8). Mean Total Depth in all other Segments ranged from 1.50 m to 3.05 m. Water depths were typically representative of all water bodies sampled, except perhaps the Upper Laguna Madre (Segment 2491). Typically, water depth for many parts of the Upper Laguna Madre are <1.0 m but for the second straight year random sampling points fell in waters that were approximately 1.5 m deep.

3.3.1.3. Water Temperature

Water temperature ranged from 29.32°C to 32.31°C (Tables 6.2.1 and 6.2.2) at sites sampled during the summer index period with water temperatures being slightly (<1.0°C) higher than in RCAP 2003. Within Segments, mean near-surface water temperature ranged from 30.25°C in the Baffin Bay Complex (Segment 2492) to 31.60°C in Corpus Christi Bay (Segment 2481), respectively (Table 6.3.7). At sites where multiple depth sampling occurred (n = 25) mean near-bottom water temperature ranged from 30.38°C in the Baffin Bay Complex to 31.31°C in the Corpus Christi Bay (Segment 2481) (Table 6.3.7). Mean difference between near-surface and near-bottom measurements was <0.30°C during RCAP 2004. Comparison of all sites where multiple-depth sampling occurred showed no statistically significant differences (p = 0.95) between near-surface and near-bottom water temperatures. Recorded temperatures were typical of summer months in this area and were below the established TCEQ standard of 35.0°C and consistent with temperatures recorded in past RCAP events.

3.3.1.4. pH

pH values for RCAP 2004 fell within range of the established TCEQ standard (6.5 - 9.5); ranging from 7.92 at Site 333 in Corpus Christi Bay (Segment 2481) to a high of 9.00 at Site 331 located in Nueces Bay (Segment 2482) (Tables 6.2.1 and 6.2.2), Mean near-surface pH concentrations ranged from 8.19 in Oso Bay (segment 2485) to 8.73 in Nueces Bay (Table 6.3.5). Mean near-surface pH values tended to be slightly higher than values recorded for RCAP 2003 sites with all but five sites having values in the range (7.5 to 8.5) typical of estuarine waters. At sites where multiple depth sampling occurred (n = 25) mean near-bottom pH ranged from 8.06 in Aransas Bay (Segment 2471) to 8.68 in Nueces Bay (Segment 2482) (Table 6.3.5). The mean difference between near-surface and near-bottom pH was <0.24, with some segments exhibiting practically no mean difference between depths. No significant statistical differences (p = 0.12) existed between near-surface and near-bottom pH.

3.3.1.5. Secchi Depth

Secchi depth data, while highly subjective, provides a visual method to ascertain some relative measure of water clarity. Bay systems, or water body segments, within the CBBEP region are typically turbid and Secchi Depth measurements for RCAP 2004 tended to validate readings recorded from earlier RCAP sampling events. Secchi Depth ranged from 0.20 m in the Copano/Port/Mission Bay complex (Segment 2472) to 1.0 m in Corpus Christi Bay (Segment 2481) and the Upper Laguna Madre (Segment 2491) (Table 6.2.1). Mean Secchi Depth for all segments averaged <1.00 m (Table 6.3.8) with Oso Bay (Segment 2485), the

Copano/Port/Mission Bay complex, Nueces Bay (Segment 2482), and the Baffin Bay Complex being the most turbid with Secchi Depth readings of <0.39 m.

3.3.1.6. Turbidity

Turbidity also serves as a measurement of water clarity by measuring the amount of suspended particles resulting from such sources as natural erosion, organic decay, and algae in the water. No criteria or screening level exists in Texas for turbidity, but the addition of reliable instrument data that removes the visual subjectivity of the person recording Secchi Depth may aid TCEQ in the establishment of applicable screening levels for the naturally turbid bay systems of Texas.

Turbidity values during RCAP 2004 ranged from 3.21 NTU in Corpus Christi Bay (Segment 2481) to 56.78 NTU in Oso Bay (Segment 2485) (Table 6.2.1 and 6.22). Mean near-surface turbidity ranged from 4.16 NTU in the Upper Laguna Madre (Segment 2491) to 56.78 NTU in Oso Bay while at sites where multiple depth sampling occurred (n = 25) mean near-bottom turbidity ranged from 5.59 in the Upper Laguna Madre to 52.31 NTU in the Copano/Port/Mission Bay complex (Segment 2472) (Table 6.3.6). The mean difference between near-surface and near-bottom turbidity was greatest in Aransas Bay (Segment 2471) at 23.20 NTU while all other stations the difference was <4.55 NTU (Tables 6.2.1 and 6.2.2 and 6.3.6).). Comparison of all sites where multiple-depth sampling occurred showed statistically significant differences ($p = <0.01$) did exist between near-surface and near-bottom turbidities.

3.3.1.7. Salinity

Various aspects of the CBBEP regional salinity regime stated by Nicolau and Nuñez (2004; 2005a; 2005b) in earlier RCAP reports summarize how salinity concentrations typically are quite high due to natural conditions, reduced freshwater inflows, and the hypersaline Upper Laguna Madre. However, many species in the region are adapted to stressful conditions of hypersaline waters and are also able to adjust to wide salinity fluctuations that often occur when significant amounts of freshwater flows into the system.

The impact of significant amounts of freshwater inflow became evident during RCAP 2002 sampling (see Section 3.3.1.1). As previously stated, dramatic changes in salinity regimes occurred throughout most of the region in July 2002 due to the approximately 1,000,000 ac-ft of water which flowed from Lake Corpus Christi to the Nueces River and downstream to Nueces Bay. The greatest reduction observed in mean salinity concentrations occurred in Nueces Bay (Segment 2482) but inflows into the Mission/Aransas estuary also lowered salinities in the Copano/Port/Mission Bay complex (Segment 2472) and St. Charles Bay (Segment 2473) (Table 3.2). Mean concentrations actually increased in the Upper Laguna Madre, once again demonstrating the variability in regional freshwater inflows, with location being as important as volume.

However, despite approximately 80,000 ac-ft of freshwater entering Nueces Bay in July 2003 and the approximate 16,000 ac-ft of recorded inflows to the Mission-Aransas estuary from the Aransas and Mission Rivers, overall declines in inflows allowed salinities to increase throughout most of the region for RCAP 2003 (Fig. 3.1; Table 3.2). The greatest increases in PSU occurred in Aransas Bay (Segment 2471), Redfish Bay (Segment 2483), and Nueces Bay

(Segment 2482). In contrast, both the Upper Laguna Madre (Segment 2491) and the Baffin Bay Complex (Segment 2492) actually showed declines in salinities; reinforcing the highly variable nature of the CBBEP region. Most segments still recorded salinity values in RCAP 2003 lower then first RCAP events (2000/2001) used in this comparison.

As previously stated, for RCAP 2004, inflows to Nueces Bay increased to approximately 220,000 ac-ft for July 2004 and declines in salinity within each Segment were at, or nearing, RCAP 2002 levels due to increased inflows during the months prior to sampling within the watersheds influencing these Segments. For RCAP 2004, salinity values ranged from 1.81 PSU at Site 343 in the Copano Bay/Port Bay/Mission Bay complex (Segment 2472) to 35.17 PSU at Site 340 located in Aransas Bay (Segment 2471) (Fig. 2.2; Figs. 3.2 and 3.3; Tables 6.2.1 and 6.2.2). Mean near-surface salinity within Segments ranged from 2.83 PSU in Copano Bay/Mission Bay/Port Bay to 33.33 PSU in the Upper Laguna Madre (Table 6.3.2). At sites where multiple depth sampling occurred (n = 25) mean near-bottom salinity ranged from 2.84 PSU in Copano Bay/Mission Bay/Port Bay area to 33.53 PSU in the Upper Laguna Madre (Table 6.3.2). The mean difference between near-surface and near-bottom salinity was <1.79 PSU for most Segments, except Aransas Bay (Segment 2472) where the mean difference was 7.47 PSU (Tables 6.2.1; 6.2.2; 6.3.2). Comparison of all sites (n = 25) where multiple-depth sampling occurred showed no statistically significant differences (p = 0.35) between near-surface and near-bottom salinities.

Table 3.2. Mean near-surface salinity concentrations recorded for the same Segments during RCAP 2000 and RCAP 2001 summer sampling events, RCAP 2002, RCAP 2003, and RCAP 2004.

Segment	2000/2001* Mean PSU	2002 Mean PSU	2003 Mean PSU	2004 Mean PSU
2471	37.40	18.82	32.51	16.27
2472	29.30	10.83	10.00	2.83
2481	39.51	21.15	32.49	26.93
2482	37.96	5.76	17.84	5.84
2483	37.43	24.57	37.60	30.99
2485	37.67	30.60	36.02	31.91
2491	42.30	46.78	37.71	33.33
2492	53.61	48.67	36.75	16.31

2471 - Aransas Bay
2472 - Copano Bay/Port Bay/Mission Bay
2481 - Corpus Christi Bay
2482 - Nueces Bay
2483 - Redfish Bay
2485 - Oso Bay
2491 - Laguna Madre (Upper)
2492 - Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada

*Segments 2471 through 2485 sampled Summer 2000 and Segments 2491 and 2492 sampled summer 2001

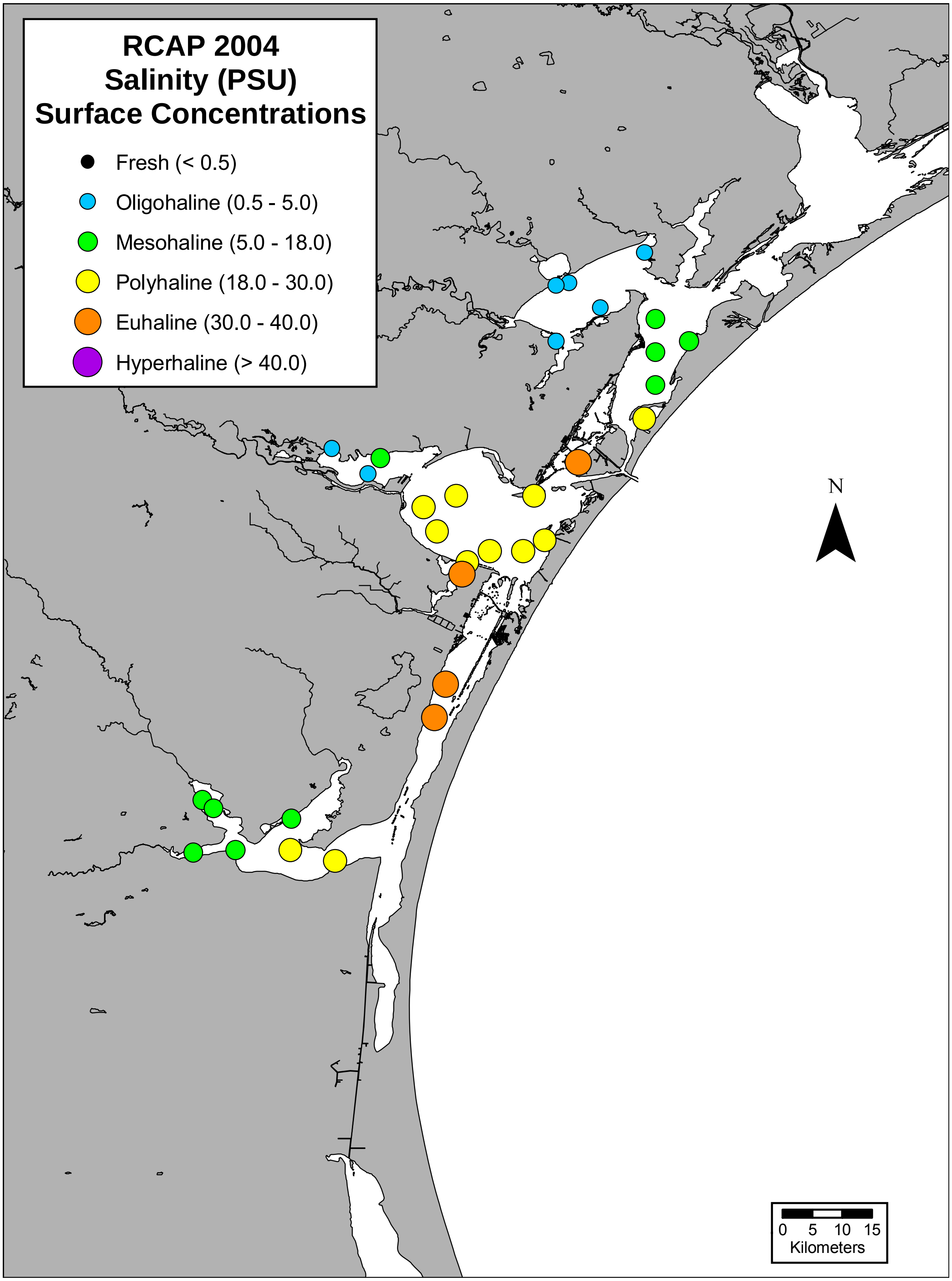

Fig. 3.2. Surface salinity concentrations (PSU) at RCAP 2004 sampling sites.

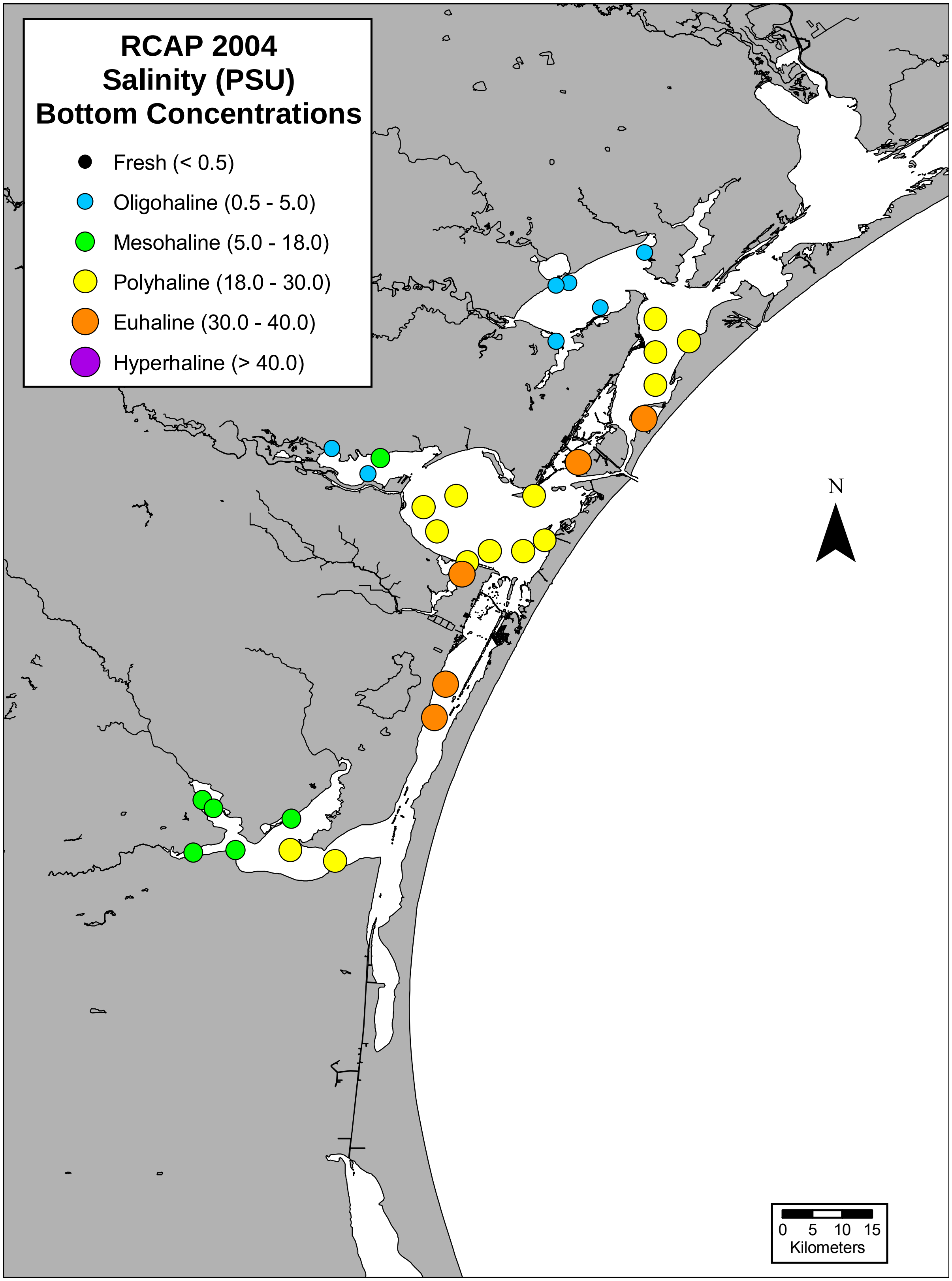

Fig. 3.3. Bottom salinity concentrations (PSU) at RCAP 2004 sampling sites.

3.3.1.8. Dissolved Oxygen

As the primary water quality parameter TCEQ utilizes in assessing Aquatic Life Use (ALU) and water body health, the near-surface Dissolved Oxygen (DO) criterion is important. Water body segments in Texas classify as *exceptional, high,* or *intermediate,* with criteria based on meeting 24-hour near-surface (0.30 m below) average concentrations of 5.0, 4.0, and 3.0 mg/L, respectively. In addition, absolute minimum criteria to protect the range of ALUs in tidal waters are 1.0 mg/L less for all categories (TCEQ 2003). All segments monitored for RCAP 2004 carry a 24-hour surface DO criterion of 5.0 mg/L for *exceptional* habitat, except the Baffin Bay complex; classified as *high* habitat with a 4.0 mg/L criterion.

Based on sites sampled for RCAP 2004, near-surface DO quality continues to be good throughout the CBBEP region. However, it is important to note that while many monitoring programs, Texas included, routinely measures DO (grab sample) throughout the water column on a quarterly basis, assessments are made only on 24-hour near-surface DO measurements, which in many cases may incorrectly interpret actual DO conditions and resultant aquatic health. Discounting the effect of low DO concentrations over the bottom sediments can affect numerous estuarine aquatic species and have varying detrimental effects (USEPA 2001).

RCAP 2004 instantaneous grab sampling (entire water column) took place during the most critical part of the summer index period when expected DO levels are routinely low. Specifically chosen because warmer water temperatures hold less DO than colder waters, the summer index period provides periods in which water quality conditions might be stressful and thereby limiting to biota. The combined effect of warmer waters and higher salinities can further depress DO concentrations as high salinity waters also hold less DO. While instantaneous grab sampling within a Segment does not warrant using the 24-hour criterion to evaluate DO conditions, RCAP DO data serves as a valuable tool to assess if conditions perhaps warrant further monitoring due to depressed DO concentrations at near-surface and near-bottom depths.

During RCAP 2004, no recorded instances of near-surface hypoxia (<2.0 mg/L) occurred at any site sampled (Fig. 3.4; Tables 6.2.1 and 6.3.3). While three sites recorded near-surface DO concentrations in the "biologically stressful" range (>2.0 mg/L but <5.0 mg/L), all were sites sampled in the early morning and one was in shallow water (0.70 m). Regarding segment criterion, this represents one site (Site 330 in Oso Bay), or 3.2% of the sites sampled, that failed to meet the respective criteria, as Sites 327 and 329 in the Baffin Bay Complex did meet the 4.0 mg/L TCEQ criterion established for Segment 2492. However, analysis of RCAP 2004 near-bottom DO data revealed a different picture. As opposed to RCAP 2003, when evaluation of near-bottom DO concentrations recorded only one additional site in Corpus Christi Bay (Segment 2481) which fell below the 5.0 mg/L criterion, in RCAP 2004 six sites had low near-bottom DO concentrations. Three sites in Aransas Bay (Segment 2471) were <3.0 mg/L, one site in Redfish Bay (Segment 2483) was <4.0 mg/L, and two sites in Corpus Christi Bay (Segment 2481) were considered hypoxic, with DO concentrations of <2.0 mg/L (Fig. 3.5; Tables 6.2.2 and 6.3.3). In addition, the two sites in Corpus Christi Bay are within a region of the bay in which historical low DO concentrations routinely occur (Ritter and Montagna 1999; Morehead and Montagna 2004).

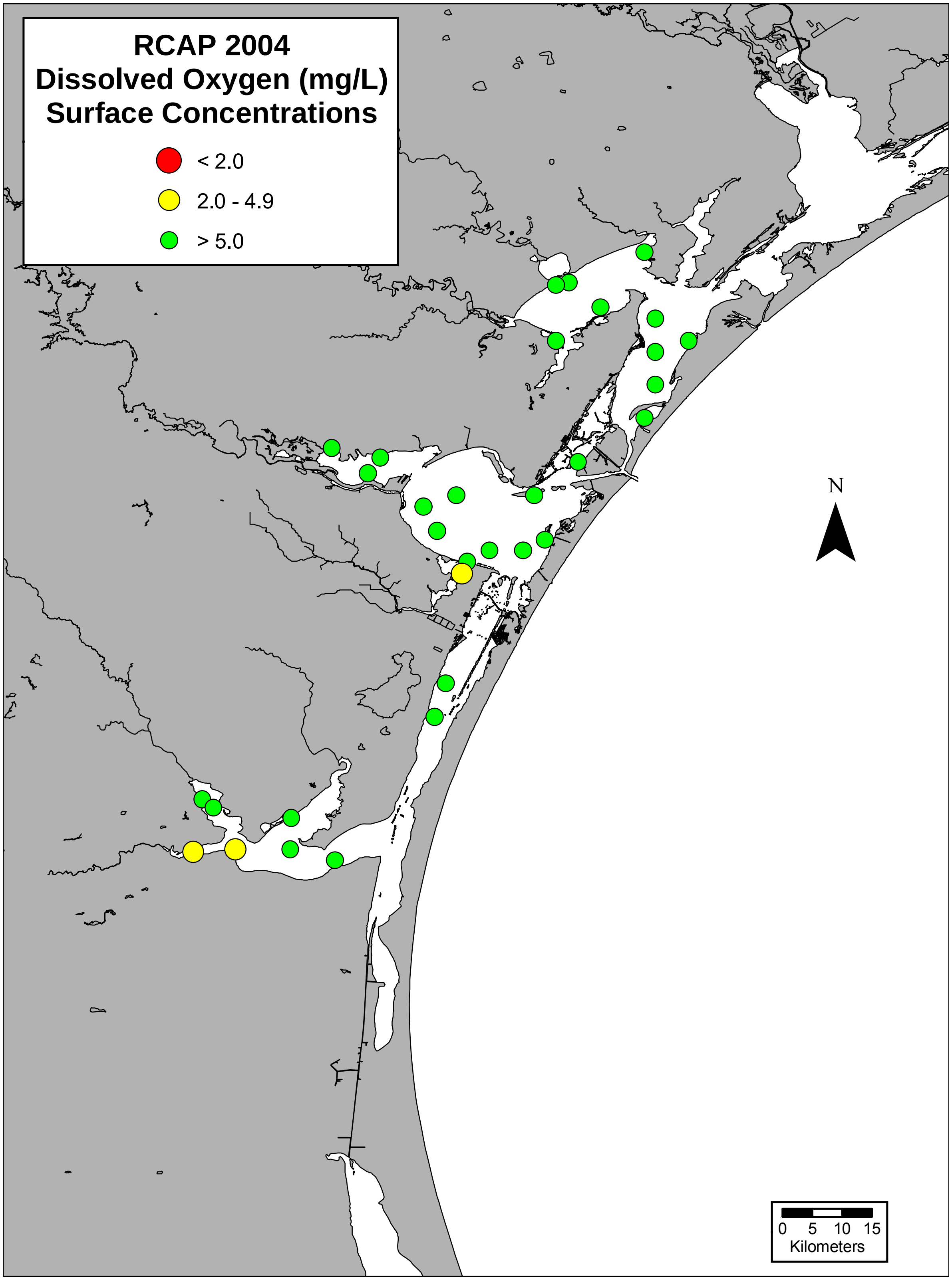

Fig. 3.4. Surface dissolved oxygen concentrations (mg/L) at RCAP 2004 sampling sites (sites in Baffin Bay coded as yellow while <5.0 mg/L did meet the TCEQ established criterion of 4.0 mg/L for this Segment).

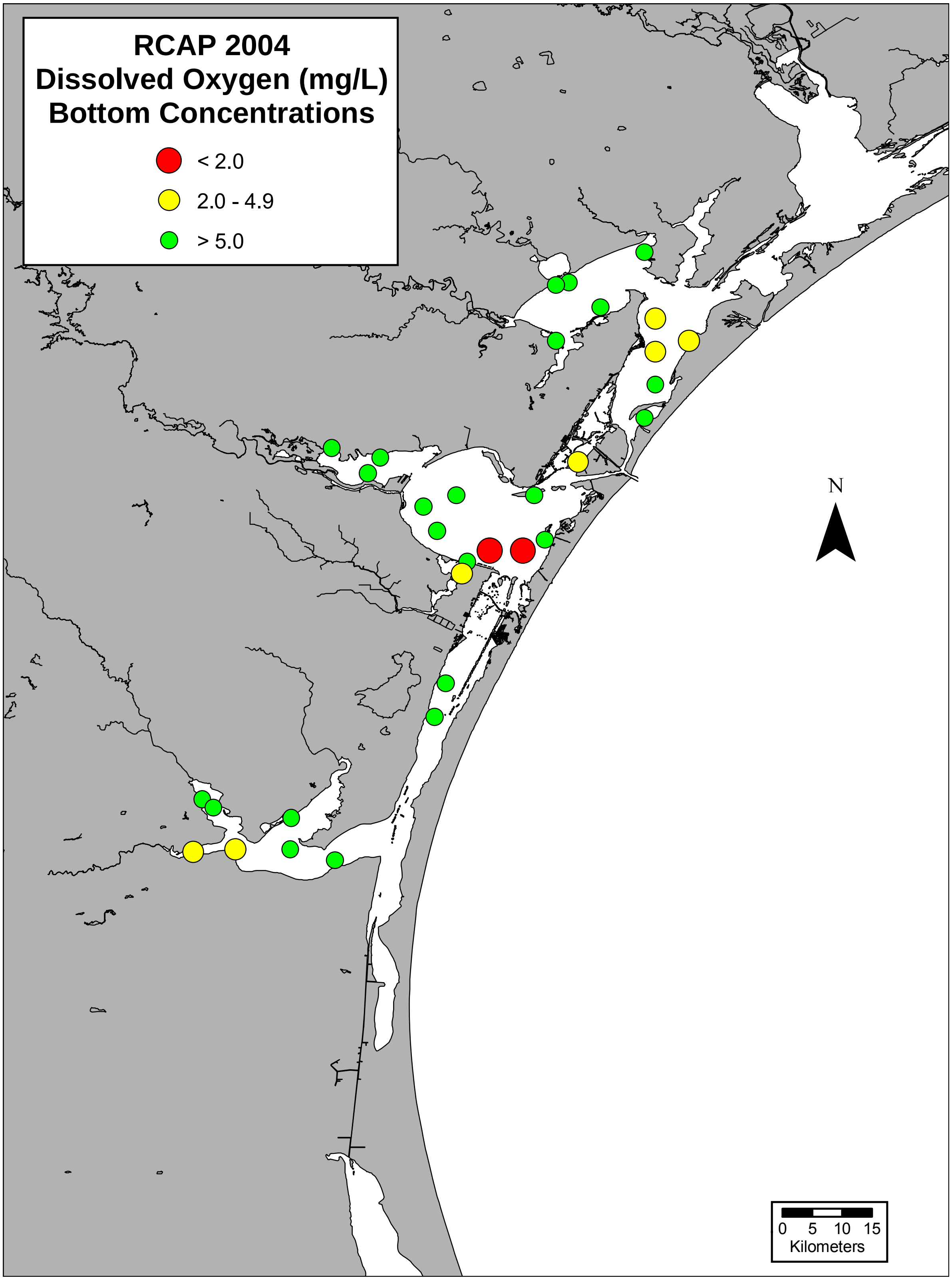

Fig. 3.5. Bottom dissolved oxygen concentrations (mg/L) at RCAP 2004 sampling sites (sites in Baffin Bay coded as yellow while <5.0 mg/L did meet the TCEQ established criterion of 4.0 mg/L for this Segment).

Individual near-surface DO concentrations ranged from 4.55 mg/L at Site 330 in Oso Bay to 7.78 mg/L at Site 352 located in Nueces Bay (Segment 2482) (Fig. 3.4; Tables 6.2.1 and 6.3.3). Mean near-surface DO ranged from 4.55 mg/L Oso Bay to 7.38 mg/L in Nueces Bay (Table 6.3.3). Mean near-bottom salinity at sites where multiple depth sampling occurred (n = 25) ranged from 3.67 mg/L in Aransas Bay to 7.01 mg/L in Nueces Bay (Table 6.3.3).

The mean difference between near-surface and near-bottom DO concentrations was <1.56 mg/L in Redfish Bay, 1.34 mg/L in Corpus Christi Bay, and <0.15 mg/L for all Segments where multiple depth sampling occurred. The exception was in Aransas Bay where the difference was 3.26 mg/L between the surface and bottom DO concentrations recorded (Tables 6.2.1 and 6.2.2 and 6.3.3). Comparison of all sites (n = 25) where multiple-depth sampling occurred showed statistically significant differences (p = <0.01) between near-surface and near-bottom DO concentrations.

3.3.2. TCEQ Routine Conventional Water Chemistry

Excessive nutrient concentrations remain a major concern in estuarine waters throughout the United States as persistent high nutrient levels may result in estuarine eutrophication and produce undesirable effects, such as increased incidents of algal blooms, which often result in low dissolved oxygen levels and harmful biotic conditions (Bricker et al. 1999; CENR 2003). In the absence of established criteria, TCEQ continues to utilize screening levels for nutrients (ammonia, nitrate + nitrite, orthophosphate, total phosphorus), and chlorophyll *a*. These screening levels aid in identifying aquatic life use concerns within a segment based on percent exceedance derived from long-term SWQM data. Screening Level Estuary 2002 (SLE 2002) concentrations apply to all sites sampled in RCAP 2002, 2003, and 2004.

3.3.2.1. Nitrogen

A primary limiting nutrient in estuarine systems, nitrogen levels control rates of primary production, with high input levels often producing significant increases in phytoplankton and macrophyte production. Some limits suggested for avoiding algal blooms and for maintaining designated aquatic life uses in estuaries range between 0.10 mg/L for maximum diversity, to 1.00 mg/L for moderate diversity (NOAA/EPA 1988; AWWA 1990; Rabalais 1992; Bricker et al. 1999).

Applying the TCEQ screening level for ammonia of 0.10 mg/L, showed relatively low near-surface ammonia concentrations recorded during RCAP 2004 for all but one site. As opposed to RCAP 2003, when four sites located in the Baffin Bay Complex (Segment 2492) exceeded the screening level, only one location (Site 329 located in the Baffin Bay Complex) exceeded the screening level in RCAP 2004 (Fig. 3.6; Tables 6.4.1 and 6.5.1). Concentrations at all 32 sites ranged from 0.002 mg/L to 0.143 mg/L; with a mean of 0.014 mg/L. Table 3.3 lists the number of sampling sites exceeding respective screening levels during RCAP 2004. While there was only one high concentration in the Baffin Bay Complex in RCAP 2004, one or more sites have exceeded the screening level for ammonia in this segment since RCAP inception. Mean concentrations in other segments sampled for RCAP 2004 were typically <0.025 mg/L (Table 6.5.1).

Individual near-surface concentrations of nitrate + nitrite ranged from 0.004 mg/L to a high of 0.103 mg/L at Site 329 in the Baffin Bay Complex. The overall mean for all 32 sites was

0.018 mg/L and there were no sites exceeding the screening level in RCAP 2004, as opposed to two sites exceeding the screening level in RCAP 2003 and no screening level exceedances in RCAP 2002 (Fig. 3.7; Table 3.3; Tables 6.4.4 and 6.5.7). Mean concentrations of nitrate + nitrite were typically <0.03 mg/L for all segments except Oso Bay (Segment 2485) which had a concentration of 0.053 mg/L.

Table 3.3. Total number of sampling sites (n) and the number of applicable TCEQ screening level exceedances seen for nutrients and chlorophyll *a* within each TCEQ Segment sampled for RCAP 2004. No value indicated by – means no exceedances existed for this parameter.

Segment Number	Segment Name	n	Ammonia	Nitrate + Nitrite	Ortho P	Total P	Ch *a*
2471	Aransas Bay	5	-	-	-	-	-
2472	Copano/Port/Mission Bays	5	-	-	2	-	1
2481	Corpus Christi Bay	8	-	-	-	-	-
2482	Nueces Bay	3	-	-	2	-	2
2483	Redfish Bay	1	-	-	-	-	-
2485	Oso Bay	1	-	-	-	-	1
2491	Laguna Madre	2	-	-	-	-	-
2492	Baffin Bay/Alazan Bay/ Cayo del Grullo/Laguna Salada	7	1	-	-	-	3

3.3.2.2. Phosphorus

Total phosphorous measures the various forms of phosphorus (particulate and dissolved) found in water. Particulate phosphorus is bound to mineral and organic sediment while dissolved phosphorus exists in the water solution. Particulate phosphorus availability to plants and algae varies from 10% to 90% of total phosphorus inputs where as the dissolved portion is 100% bioavailable. Combined, the bioavailable portion of particulate and dissolved phosphorus represents the phosphorus that promotes surface water eutrophication (NRCS 1994). Recommended levels of phosphorus to avoid algal blooms are 0.01 mg/L to 0.10 mg/L or a 10:1 N:P ratio (NOAA 1998; Bricker et al. 1999).

Total Phosphorus (TP) near-surface concentrations for RCAP 2004 ranged from 0.024 mg/L to 0.157 mg/L, with an overall mean of 0.075 mg/L. There were no sites exceeding the TCEQ screening level of 0.22 mg/L in RCAP 2004 (Table 3.3) or in RCAP 2003, as opposed to one site in RCAP 2002. Mean concentrations for all segments were <0.139 mg/L and higher concentrations existed in the Copano Bay Complex (Segment 2472) and Nueces Bay (Segment 2482) (Fig. 3.8; Tables 6.4.5 and 6.5.9).

Ortho-Phosphate (OP), or dissolved inorganic phosphate, near-surface concentrations ranged from <0.015 mg/L to 0.228 mg/L (Fig. 3.9; Tables 3.3; 6.4.6; and 6.5.10). Mean concentrations for all segments in RCAP 2004 were typically <0.100 mg/L. There were four sites (2 in Nueces Bay and 2 in the Copano Bay Complex) exceeding the TCEQ screening level of 0.16 mg/L in RCAP 2004, as opposed to three sites in RCAP 2003, and no sites in RCAP 2002. This trend in increasing values is seen when comparing the overall mean site concentrations for all events; 0.031 mg/L for RCAP 2002, versus 0.054 mg/L in RCAP 2003, and 0.087 mg/L in RCAP 2004.

3.3.2.3. Chlorophyll *a*

Chlorophyll *a* concentrations are an indicator of phytoplankton biomass in estuarine waters. Due to the rapid response of phytoplankton to nutrient level increases, high concentrations may possibly indicate poor water quality. Therefore, many monitoring programs utilize chlorophyll *a* concentrations to evaluate water quality. However, it is important to remember that short-term elevated levels do not necessarily indicate poor water quality as much as persistent long-term elevated levels. Long-term elevated levels of chlorophyll *a* may reflect increased nutrient inputs, with increasing trends being a strong indicator of estuarine eutrophication (Bricker et al. 1999; CENR 2003).

From data collected for RCAP 2004, persistent elevated chlorophyll *a* concentrations, relative to TCEQ screening levels, continue to indicate possible *Secondary Concerns*. Compared to the 11.50 µg/L TCEQ screening level, seven sites exceeded the screening level in four of eight segments sampled for RCAP 2004 (Fig. 3.10; Tables 3.3; 6.4.7 and 6.5.11). However, the number of exceedances is declining from 14 exceedances in RCAP 2002, to eight in RCAP 2003, and only seven in RCAP 2004. Exceedances and higher concentrations do however routinely persist in Nueces Bay and the Baffin Bay Complex. Chlorophyll *a* concentrations ranged from 2.84 µg/L to 31.60 µg/L, and the overall mean concentration for all 32 sites was 9.07 µg/L in RCAP 2004. This was up slightly from RCAP 2003 when the mean concentration for all 32 sites sampled was 8.76 µg/L and slightly below the 9.24 µg/L seen in RCAP 2002 when sampling took place at 50 sites. Mean segment concentrations for RCAP 2004 exceeded the screening level in Nueces Bay, Oso Bay, and the Baffin Bay Complex (Table 6.5.11).

Comparison of historical RCAP data continues to indicate elevated chlorophyll *a* concentrations may be short-term and possibly correspond with increased nutrient inputs from inflow events. During all RCAP 2000 sampling events (4), elevated chlorophyll *a* concentrations occurred in known areas of historical concern; the Corpus Christi Inner Harbor (Segment 2484), which was not sampled during later events, and Oso Bay (Segment 2485).

During the RCAP 2001 events (4), the majority of elevated concentrations occurred primarily in the Baffin Bay Complex (Segment 2492) during the Summer and Fall 2001 sampling events, with the Fall 2001 event coinciding with increased inflows to the system. RCAP 2002 chlorophyll *a* data also indicated a majority of sites exceeding screening levels in areas receiving greater amounts of freshwater inflow. For RCAP 2003, the majority of sites exceeding the screening levels were in the Baffin Bay Complex and coincided with salinity decreases, indicating freshwater inputs to the system. Once again, in RCAP 2004 the majority of sites with exceedances were areas receiving higher freshwater inflows as evident by the lower salinities recorded (Figs. 3.2 and 3.10).

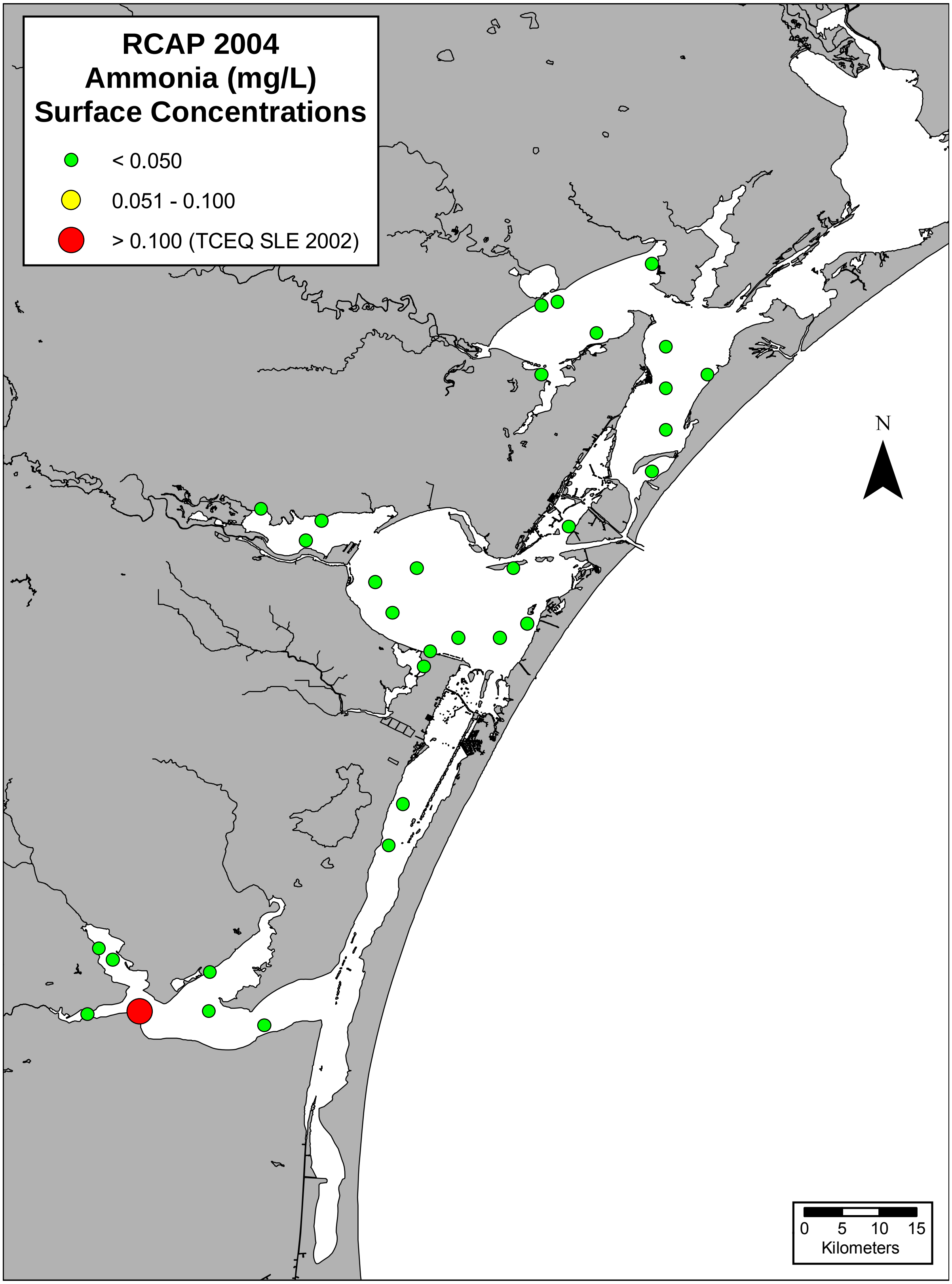

Fig. 3.6. Ammonia surface concentrations (mg/L) at RCAP 2004 sampling sites as evaluated according to TCEQ Screening Level Estuary 2002 (SLE 2002) guidelines.

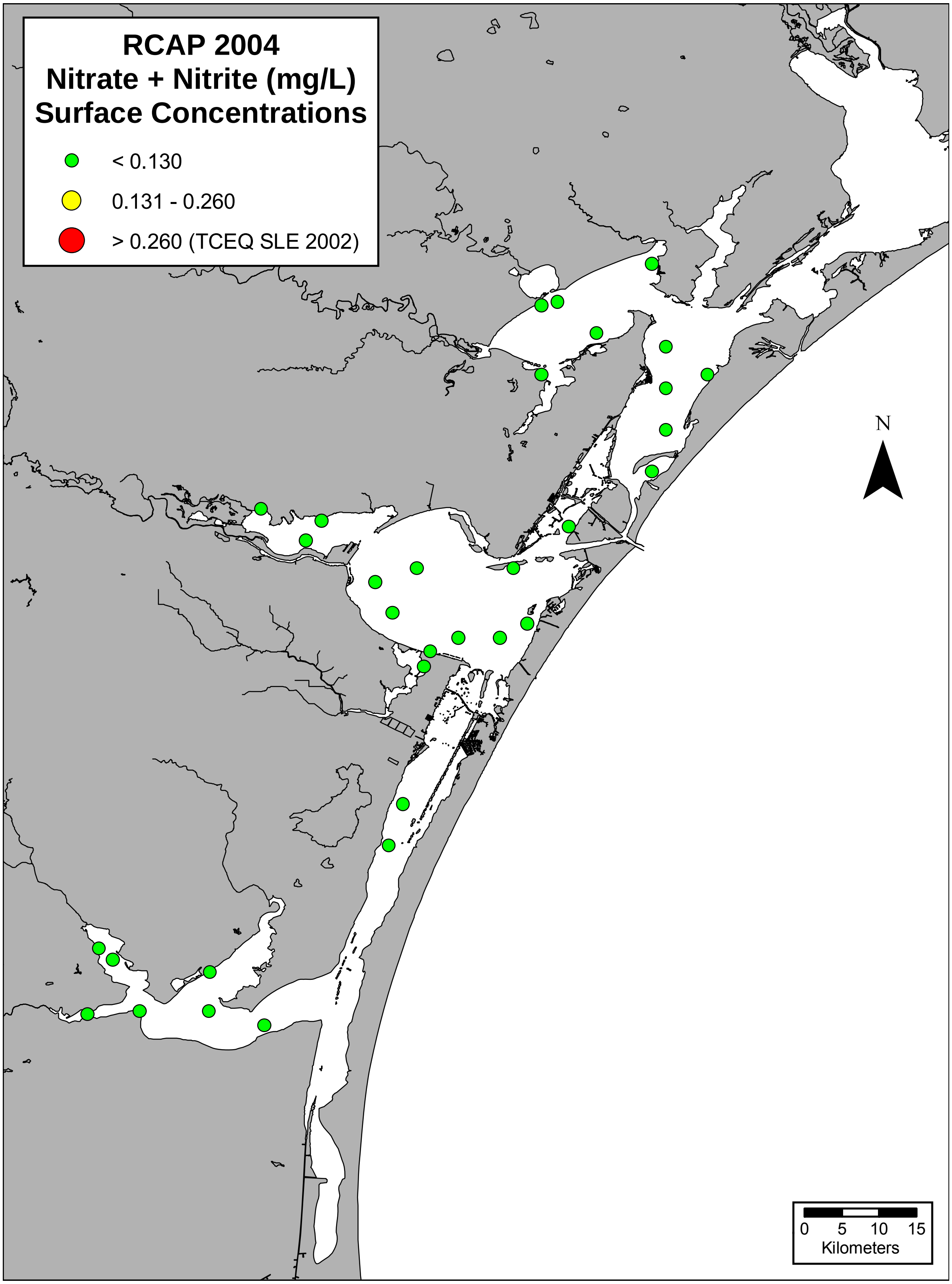

Fig. 3.7. Nitrate + Nitrite surface concentrations (mg/L) at RCAP 2004 sampling sites evaluated according to TCEQ Screening Level Estuary 2002 (SLE 2002) guidelines.

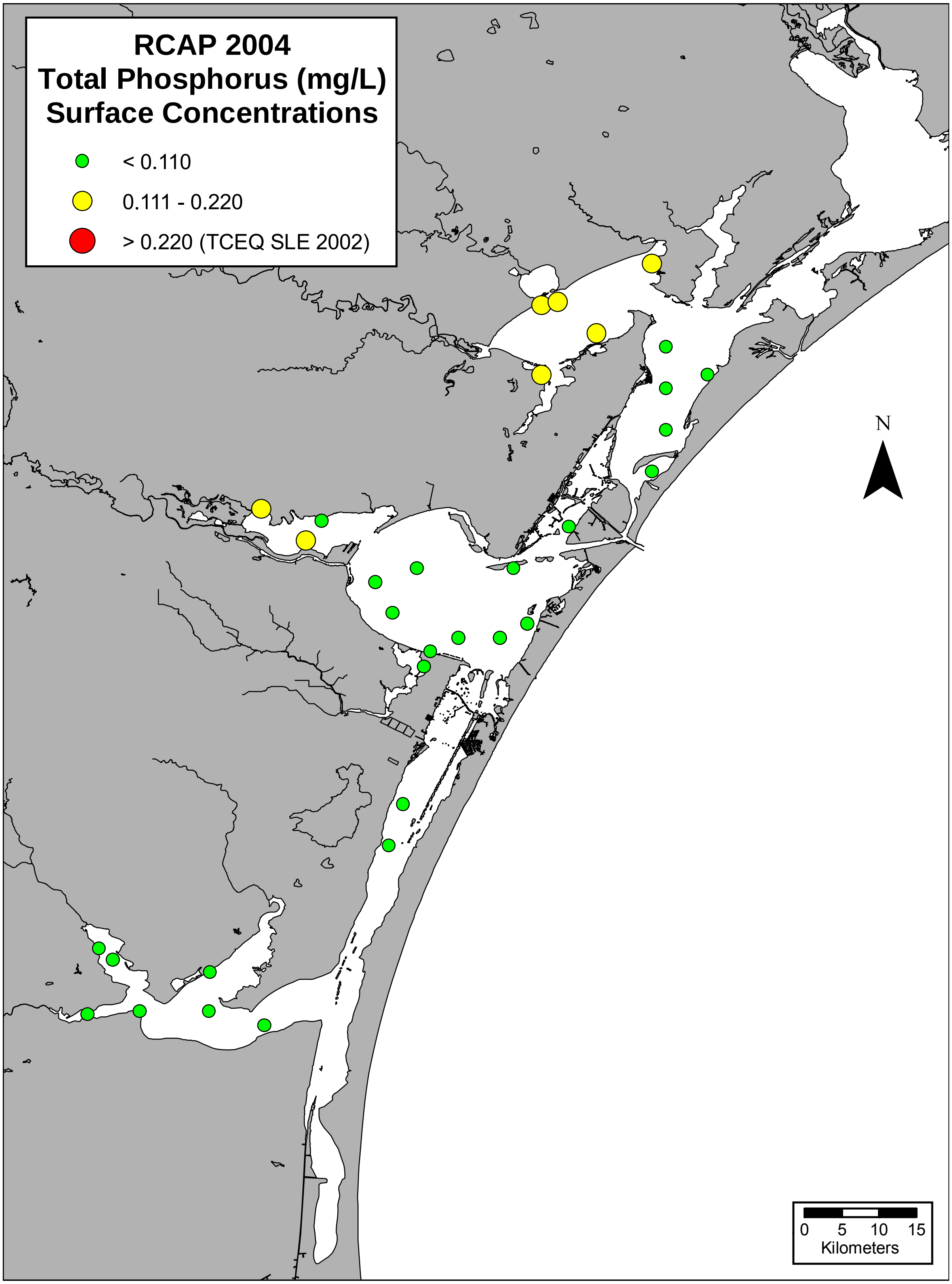

Fig. 3.8. Total Phosphorus surface concentrations (mg/L) at RCAP 2004 sampling sites evaluated according to TCEQ Screening Level Estuary 2002 (SLE 2002) guidelines.

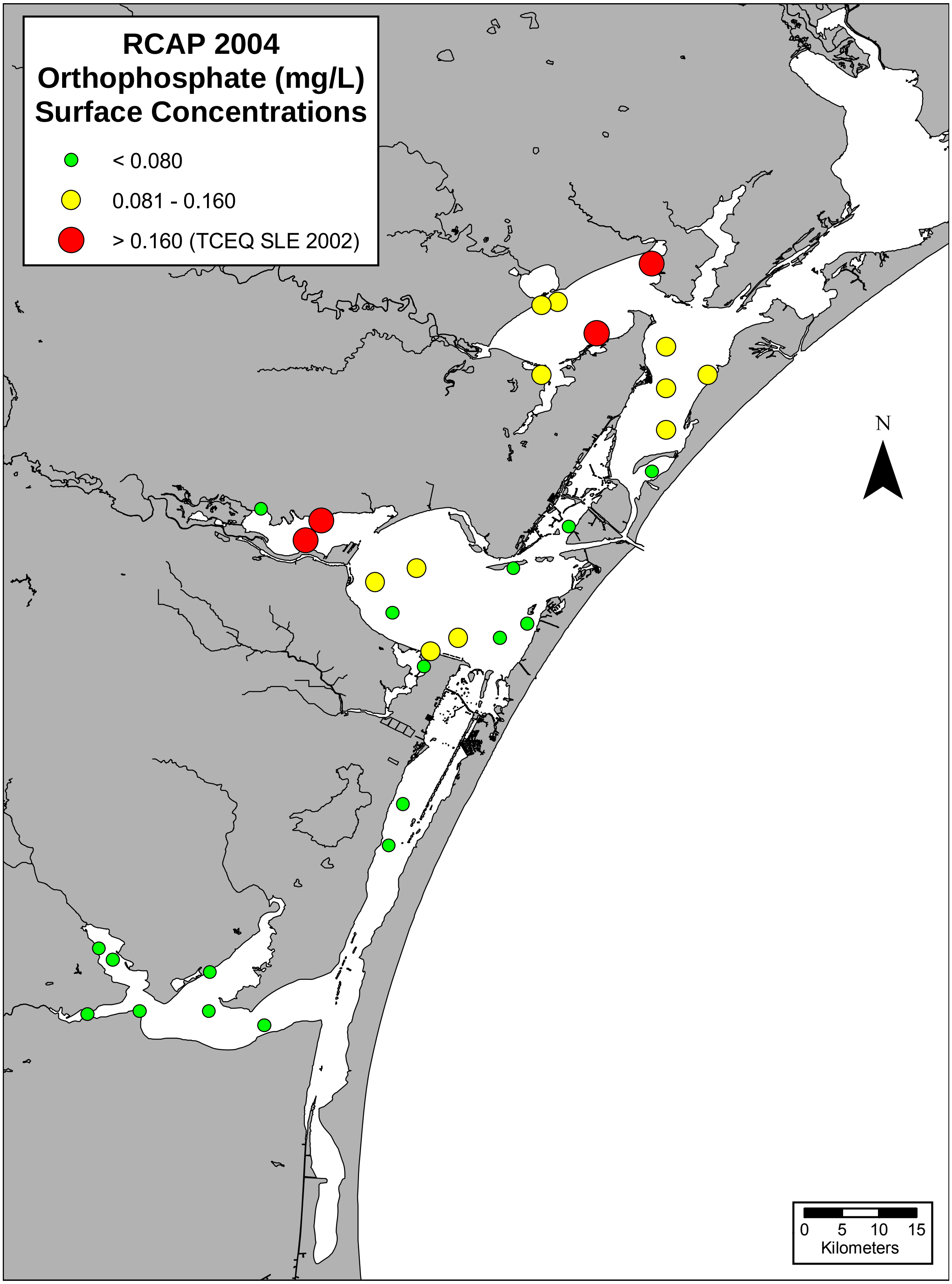

Fig. 3.9. Orthophosphate surface concentrations (mg/L) at RCAP 2004 sampling sites evaluated according to TCEQ Screening Level Estuary 2002 (SLE 2002) guidelines.

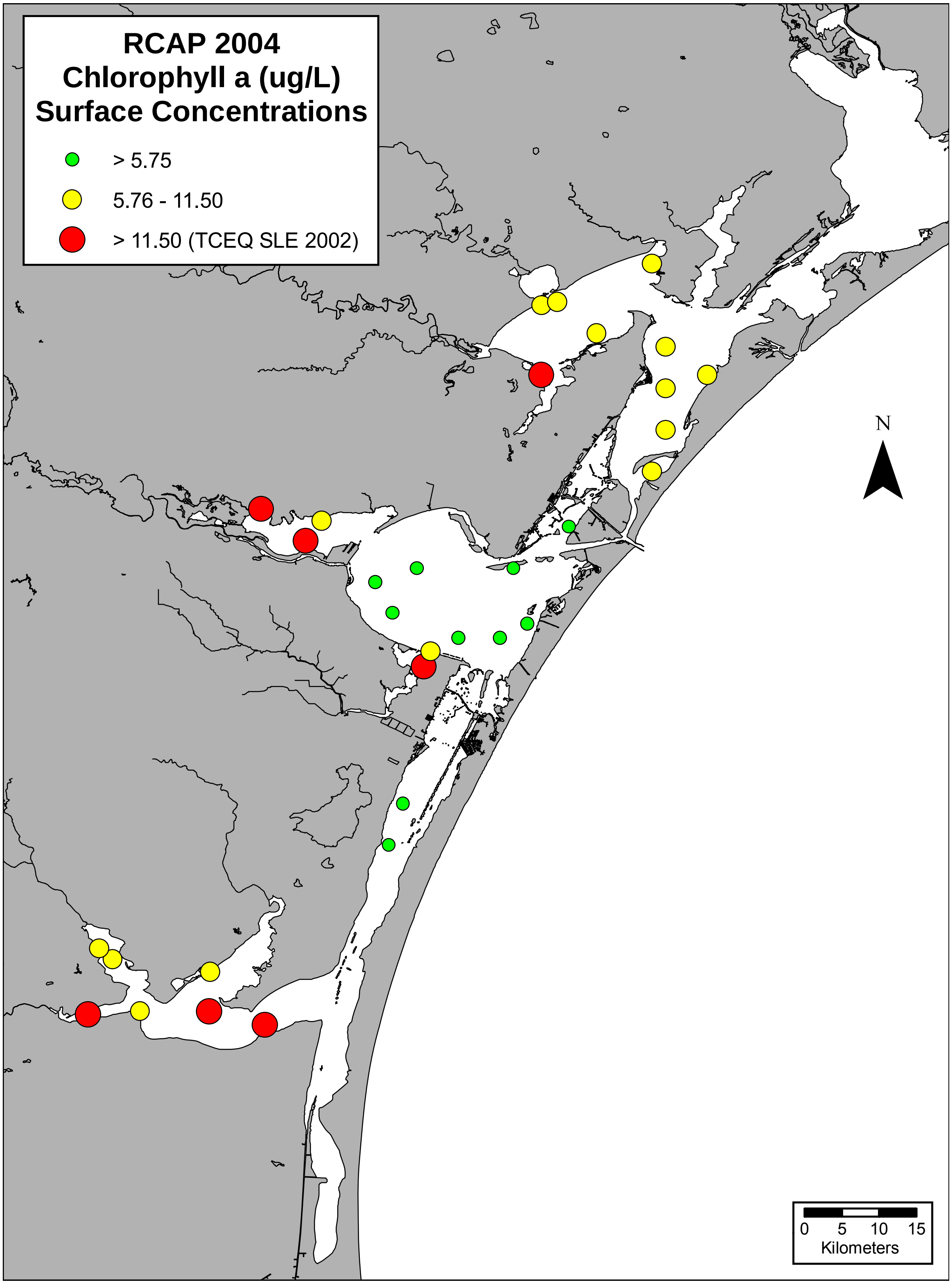

Fig. 3.10. Chlorophyll *a* surface concentrations (µg/L) at RCAP 2004 sampling sites evaluated according to TCEQ Screening Level Estuary 2002 (SLE 2002) guidelines.

3.3.3. EPA NCCR II Water Quality Index

According to EPA, the NCCR II Water Quality Index (WQI) only intends to characterize acutely degraded water quality conditions and does not identify sites that may experience infrequent hypoxic events or nutrient enrichment on a consistent basis (USEPA 2004). Therefore, the EPA position is that, "a rating of a poor WQI means that the site is likely to have consistently poor condition during the monitoring period. If designated fair or good, the site did not experience poor condition on the date sampled, but could be characterized by poor condition for short time periods". In addition, to assess WQI variability at a specific site will require increased or supplemental sampling (USEPA 2004).

3.3.3.1. Dissolved Oxygen

While a limited number of TCEQ defined segments (Baffin Bay Complex - Segment 2492) carry a <5.0 mg/L dissolved oxygen criterion, EPA and TCEQ generally evaluate near-surface DO along the same guidelines. As seen in Section 3.3.1.8, near-surface DO concentrations within the RCAP 2004 area rank as very good with no recorded instances of hypoxia at the near-surface level. Three sites (Sites 330, 327, and 329) did record near-surface DO concentrations between 4.0 mg/L and 5.0 mg/L (lowest concentration was 4.47 mg/L) but were sites sampled in the early morning or in shallow water (0.70 m) when lower DO concentrations might be expected (Fig. 3.4; Tables 6.2.1 and 6.3.3). Based on EPA NCCR II guidelines listed in Table 3.1, for the 32 sites sampled in RCAP 2004, near-surface DO was good at 90.6% and fair at 9.4% of the sites sampled. General comparisons to past events show near-surface DO concentrations typically fell in this range for RCAP 2003 and RCAP 2002.

However, we continue to stress that both programs may be overlooking an important feature by not incorporating near-bottom DO data into the assessment process. As previously stated in Section 3.3.1.8, in RCAP 2004 six sites had low near-bottom DO concentrations. Three sites in Aransas Bay (Segment 2471) were <3.0 mg/L, one site in Redfish Bay (Segment 2483) was <4.0 mg/L, and two sites in Corpus Christi Bay (Segment 2481) were considered hypoxic, with DO concentrations of <2.0 mg/L (Fig. 3.5; Tables 6.2.2 and 6.3.3). We strongly recommended that continued monitoring occur within the Corpus Christi Bay "hypoxic zone" identified by researchers at the University of Texas Marine Science Institute at Port Aransas.

3.3.3.2. Dissolved Inorganic Nitrogen

EPA NCCR II guidelines (Table 3.1) evaluate near-surface Dissolved Inorganic Nitrogen (DIN) based on the combined concentrations of ammonia, nitrate, and nitrite samples collected and filtered in the field. EPA considers DIN as one of the estuarine eutrophication indicators. However, reference concentrations used in Gulf Coast and East Coast evaluations are lower than NOAA concentrations reported in Bricker et al. (1999) as EPA believes that summer does not represent a period when nutrient values would reach a maximum due to phytoplankton uptake from spring to summer for chlorophyll production.

According to these guidelines, RCAP 2004 sampling showed 31 sites achieved a rating of good (96.9%), with one site fair (3.1%), and no sites listed as poor (Table 3.4; Fig. 3.11). DIN concentrations ranged from 0.003 mg/L to 0.261 mg/L. The mean concentration for all sites sampled was 0.021 mg/L. RCAP 2004 concentrations were similar to those concentrations seen in RCAP 2002 when the range was 0.002 mg/L to 0.281 mg/L, the mean was 0.025

mg/L for the 49 sites sampled (one site had missing data), and all sites rated as good. This is in contrast to RCAP 2003 in which 27 sites were good (84.4%), 2 sites fair (6.2%), and 3 sites poor (9.4%). RCAP 2003 concentrations ranged from <0.001 mg/L to 3.302 mg/L. An extremely high concentrations recorded at one site in Hynes Bay (Segment 2462) produced an overall mean concentration for all sites sampled in RCAP 2003 of 0.168 mg/L.

3.3.3.3. Dissolved Inorganic Phosphorus

EPA NCCR II guidelines (Table 3.1) evaluate near-surface Dissolved Inorganic Phosphorus at considerably lower concentrations then TCEQ. Along with DIN, EPA also considers DIP as an estimator of eutrophication and gives the same reasoning for reference concentrations being lower than reported in Bricker et al. (1999).

For RCAP 2004 no sites rated as good, 9 sites (28.1%) ranked as fair, and 23 sites (71.9%) ranked as poor (Table 3.4; Fig. 3.12). DIP concentrations ranged from 0.015 mg/L to 0.280 mg/L, with an overall mean of 0.087 mg/L. This is in sharp contrast to RCAP 2003 when only one site (3.1%) ranked as good, 23 sites (71.9%) ranked as fair, and eight (25.0%) sites ranked as poor. RCAP 2003 concentrations ranged from 0.009 mg/L to 0.234 mg/L, with an overall mean of 0.054 mg/L. During RCAP 2002 concentrations ranged from <0.001 mg/L to 0.137 mg/L. with an overall mean of 0.031 mg/L and 16 sites (32.7%) achieved a rating of good, 20 sites (40.8%) ranked as fair, and 13 sites (26.5%) ranked as poor. As previously stated a trend in increasing values is seen when comparing the overall mean site concentrations for all events; 0.031 mg/L for RCAP 2002, versus 0.054 mg/L in RCAP 2003, and 0.087 mg/L in RCAP 2004.

Elevated DIP concentrations continue to rank the region as less than favorable, according to EPA guidelines, but may still be indicative of short-term nutrient inputs from freshwater inflow events and not reflective of long-term eutrophication within the system.

3.3.3.4. Chlorophyll *a*

In the absence of established criteria, TCEQ uses a screening level of >11.50 µg/L to indicate *Secondary Concerns* for elevated chlorophyll *a* concentrations. Based on this screening level, *Secondary Concerns* may continue to be justified for some areas in RCAP 2004. In comparison, EPA NCCR II guidelines evaluate near-surface chlorophyll *a* concentrations based on recommendations proposed in Bricker et al. (1999), with the poor, or concerned, range being concentrations >20.0 µg/L (Table 3.1). Based on the EPA NCCR II guidelines, for the 32 sites sampled in RCAP 2004, 8 (25.0%) achieved a good rating, 22 (68.7%) ranked as fair, and 2 (6.3%) ranked as poor (Table 3.4; Fig. 3.13). Near-surface chlorophyll *a* concentrations ranged from 2.84 µg/L to 31.6 µg/L. Overall mean concentration for all sites was 9.06 µg/L (Tables 6.4.7 and 6.5.11).

Please see Section 3.3.2.3 for a discussion of historical chlorophyll *a* concentrations during all RCAP events, as elevated concentrations may continue to represent short-term influences from freshwater inflow events, in which nutrient inputs influence phytoplankton responses, which again occurred prior to sampling for RCAP 2004.

Table 3.4. Results of the individual parameter and combined EPA Water Quality Index by site for RCAP 2004. DO= Dissolved Oxygen, DIN= Dissolved Inorganic Nitrogen, DIP= Dissolved Inorganic Phosphorus, Ch *a* = Chlorophyll *a*, WQI= Water Quality Index. See Fig. 2.2 for station location and Table 3.1 for color code guidelines and Water Quality Index determination.

Segment	Site	DO	DIN	DIP	Ch *a*	EPA WQI
2471	337					
2471	340					
2471	341					
2471	344					
2471	353					
2472	332					
2472	338					
2472	343					
2472	356					
2472	357					
2481	333					
2481	339					
2481	346					
2481	348					
2481	350					
2481	351					
2481	354					
2481	355					
2482	331					
2482	349					
2482	352					
2483	328					
2485	330					
2491	335					
2491	347					
2492	327					
2492	329					
2492	334					
2492	336					
2492	342					
2492	345					
2492	358					

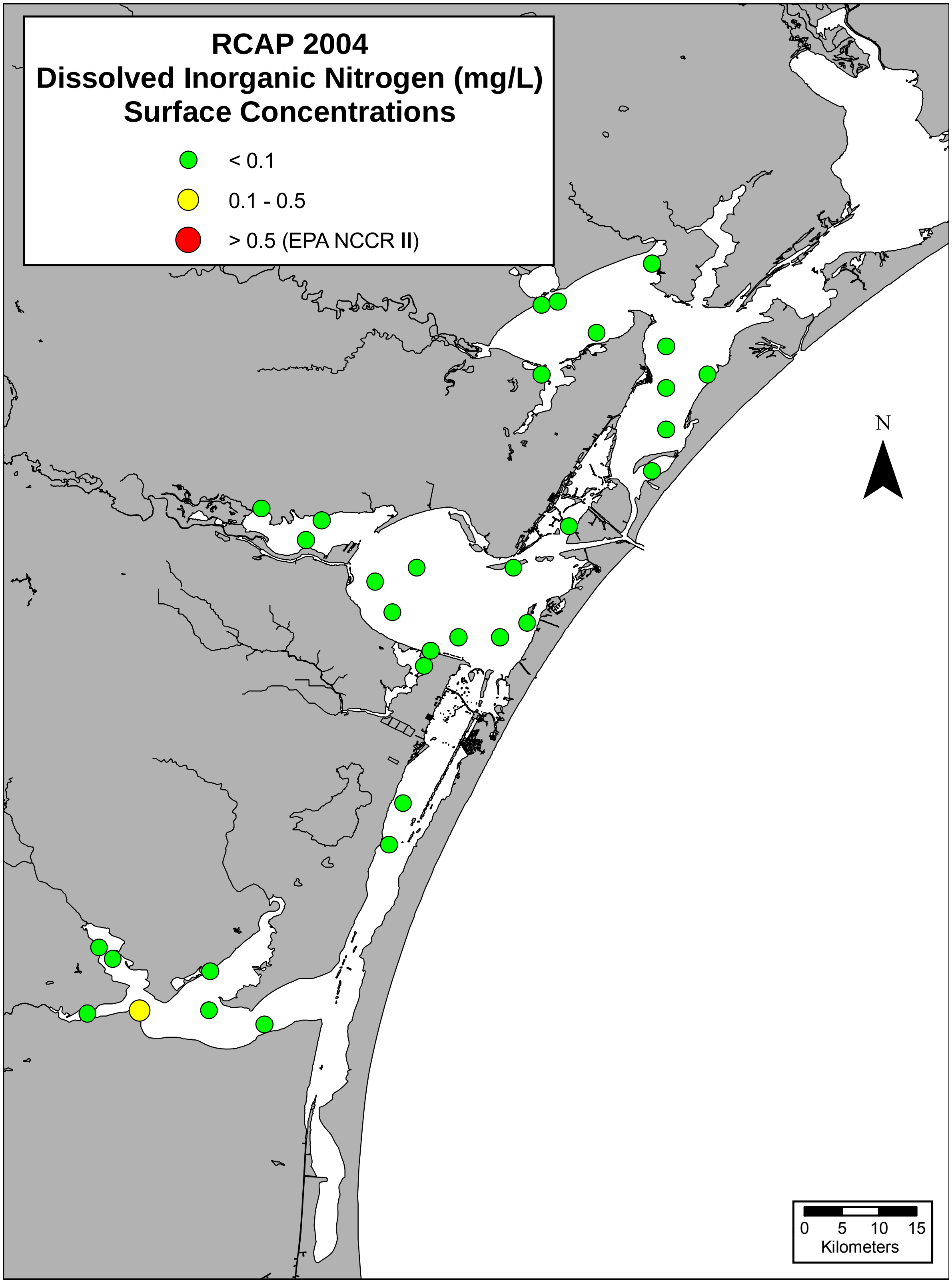

Fig. 3.11. Dissolved Inorganic Nitrogen surface concentrations (mg/L) at RCAP 2004 sampling sites evaluated according to EPA NCCR II guidelines.

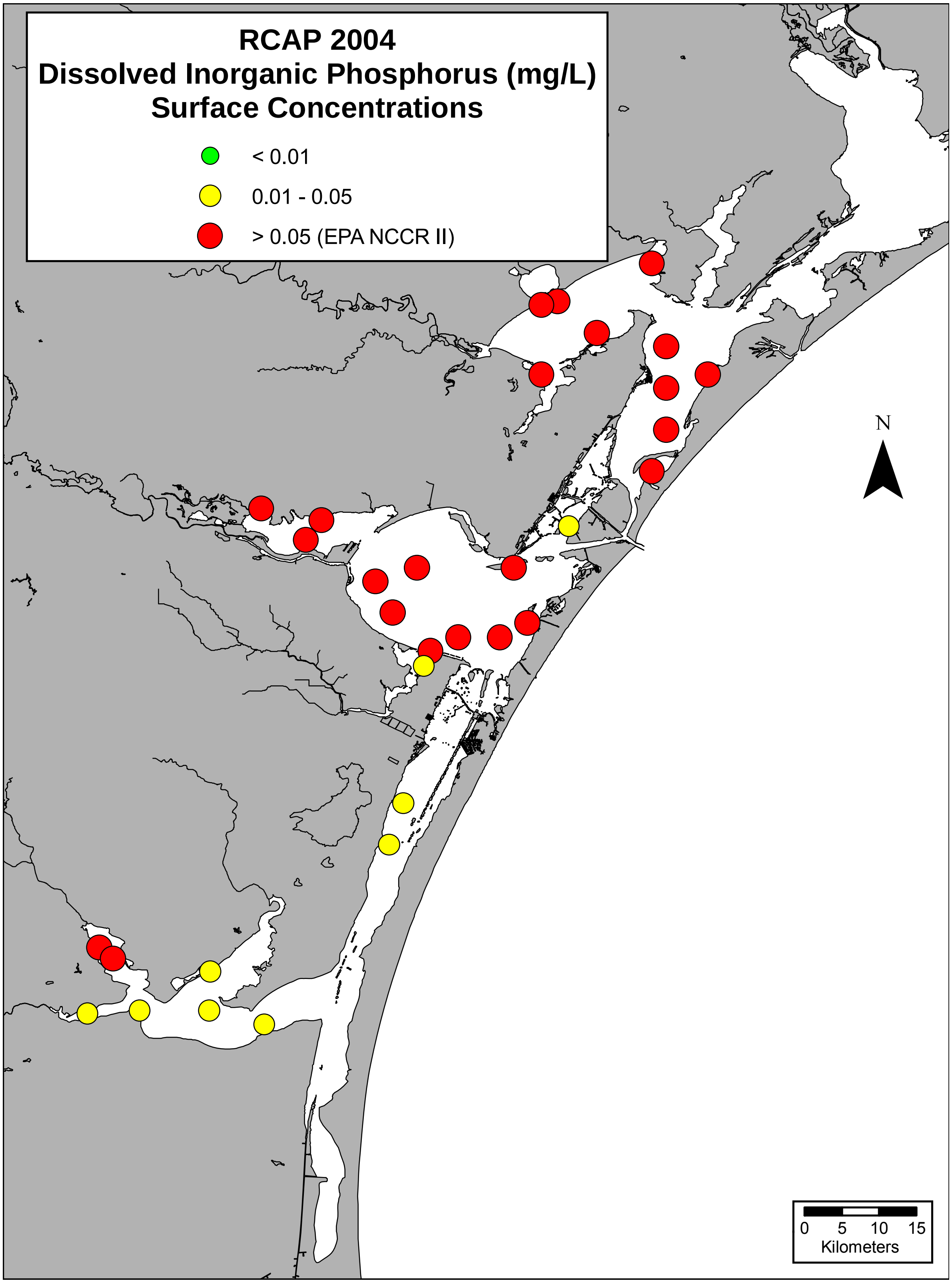

Fig. 3.12. Dissolved Inorganic Phosphorus surface concentrations (mg/L) at RCAP 2004 sampling sites evaluated according to EPA NCCR II guidelines.

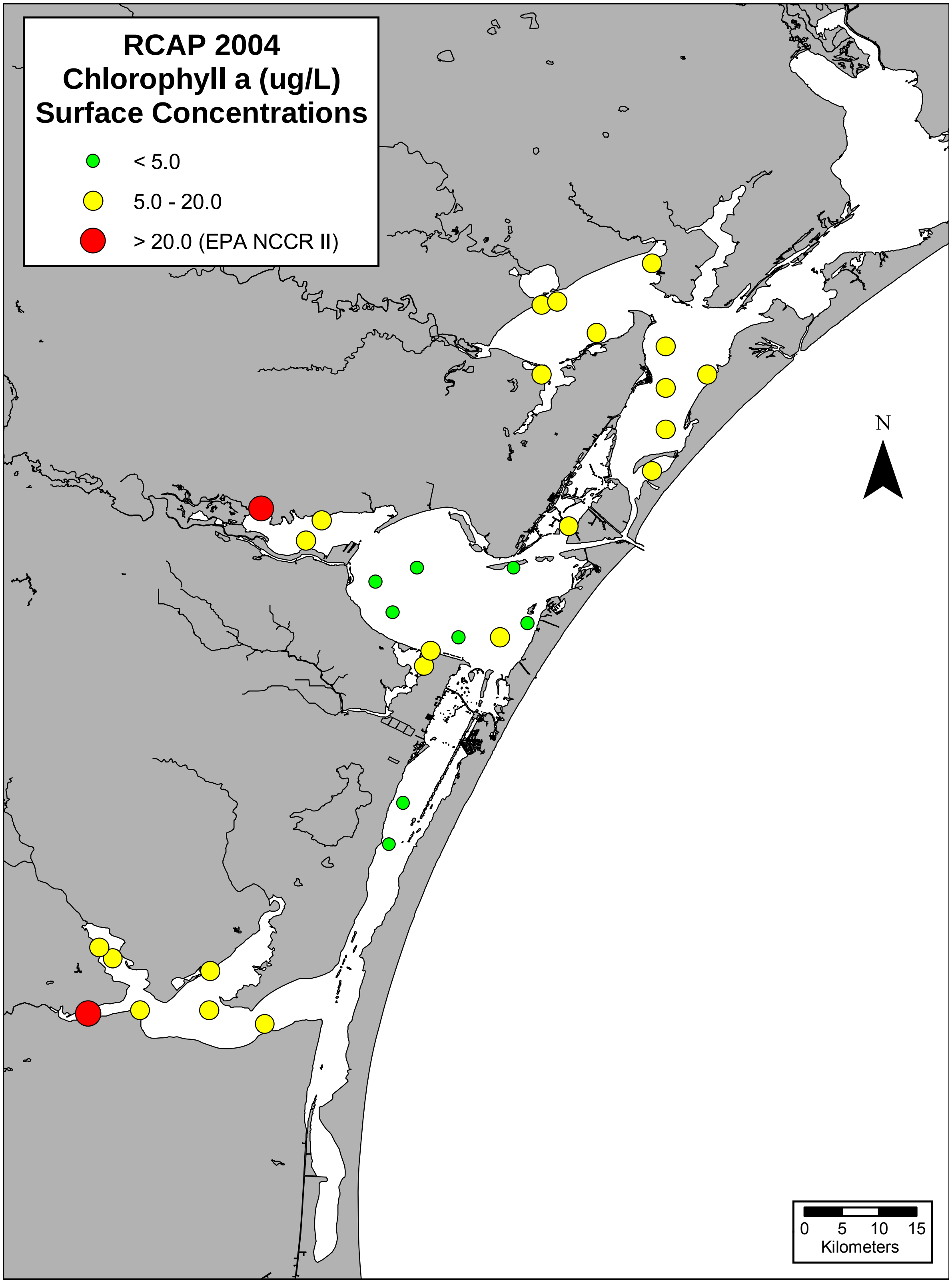

Fig. 3.13. Chlorophyll *a* surface concentrations (µg/L) at RCAP 2004 sampling sites evaluated according to EPA NCCR II guidelines.

3.3.4. Microbiological Indicators

Disease causing microorganisms, or pathogens, can adversely affect estuarine systems; resulting in restrictions of shellfish harvesting areas, fish kills, and adverse effects on human health during recreational use involving primary contact (i.e., wading, swimming, fishing, etc) with water (Heilman 2000; USEPA 2002).

TCEQ analyzes concentrations of *Escherichia coli* and fecal coliform in freshwater, and enterococci in marine or tidal water to determine Contact Recreation Use (CRU) support. Existence of these naturally occurring organisms in high numbers within the water column indicates contamination by fecal matter originating from warm-blooded animals, including humans. TCEQ guidance stresses that full CRU support does not necessarily guarantee that waters are completely free of disease causing organisms (TCEQ 2003). In addition, the national EPA Beachwatch Program monitors Texas beaches for enterococci concentrations to determine closures based on elevated bacterial concentrations.

Support of the TCEQ CRU utilizes a 10-sample minimum per individual site. For routinely monitored bacteria data, the long-term geometric average for enterococci is 35-colony forming units/100 ml (CFU/100ml) in tidal water. Due to various interpretations, an enterococci criterion of 89 CFU/100ml applies to individual samples under the TCEQ SWQM program. However, the TCEQ TMDL program uses the same criteria as the EPA Beachwatch program, which is 104 CFU/100ml. The CRU is not supported if the geometric average of samples collected exceeds the mean criterion or if the criteria for individual samples are exceeded >25% of the time. As RCAP sampling only occurs one time each summer at random locations, determination of CRU support is not applicable. However, data collected still continues to provide CBBEP and TCEQ information for assessing conditions over the region.

RCAP 2004 sampling utilized the approved TCEQ IDEXX method (SWQM monitoring) for the determination of enterococci concentrations. TCEQ adopted IDEXX for simplicity and ease of use by field personnel, as opposed to the more labor-intensive EPA 1600 laboratory filtration method. While some concerns exist as to the possibility that IDEXX may under or over report actual bacterial concentrations present, from a TCEQ regulatory perspective the method tends to provide adequate concentration determinations and would only cause concern when concentrations were located closely to the criteria values.

For the sites and areas sampled during RCAP 2004, bacterial conditions continue to be rated as very good, as the majority of the 32 sites yielded concentrations of <10 CFU/100 ml. Only one site, Site 330 in Oso Bay (Segment 2485), exceeded the individual 104 CFU/100 ml criterion with a concentration of 121 CFU/100 ml (Fig. 3.14; Table 6.6.1). Historically, these low concentrations are similar to those recorded in RCAP 2003, in which no sites exceeded the criterion. In RCAP 2002, one site in Nueces Bay and one site in Corpus Christi Bay at the confluence with Nueces Bay exceeded the criterion but the extremely elevated concentrations related directly to the large inflow amounts received during the flooding event prior to RCAP 2002 sampling.

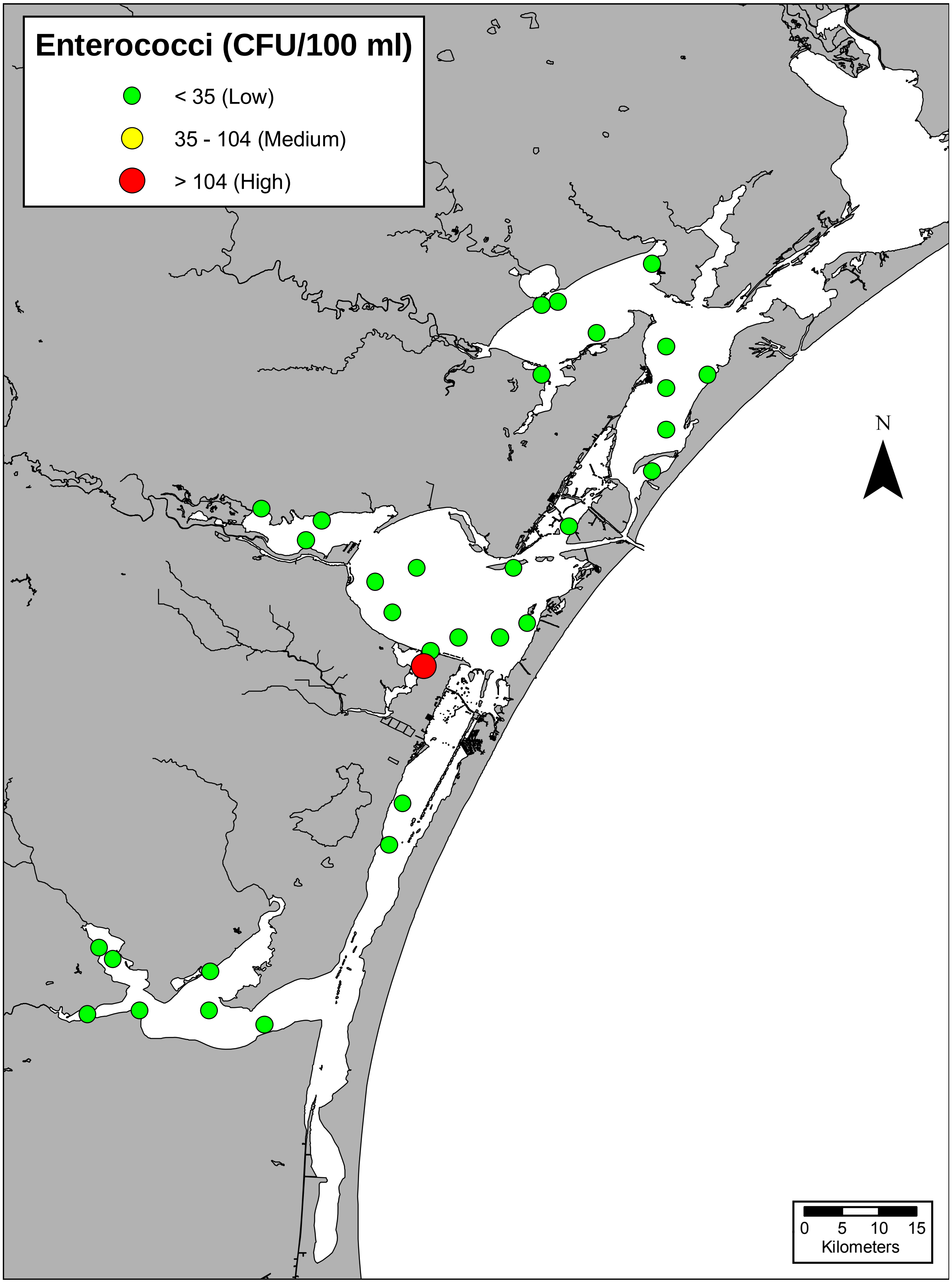

Fig. 3.14. Enterococci concentrations (CFU/100 ml) at RCAP 2004 sampling sites evaluated according to TCEQ TMDL and EPA Beachwatch Criteria guidelines.

3.4 Summary

The initial attempt at providing data for comparisons on a local, regional, and national level began with the RCAP 2002 assessment. Unfortunately, the problem in making a standardized assessment still exists because of the different ways that TCEQ and EPA evaluate water quality within the CBBEP region. As an evolving process, the collection and assimilation of additional RCAP data is aiding in developing indicators that will give us a better picture as to what may represent healthy or degraded conditions or habitat within the CBBEP region.

Field data collected continues to be representative of the CBBEP region, with values recorded during RCAP 2004 typical for the summer index period. In contrast to RCAP 2002, salinity concentrations recorded in RCAP 2003 showed increases within most Segments as major inflow events ceased towards the end of 2002; but declined in RCAP 2004 as inflows to the system once again increased. Freshwater inflows remain as one of the most critical factors for sustaining long-term estuarine health within the CBBEP region and it is important to document the stress to aquatic organisms that these dramatic short-term shifts in salinity can create (Montagna et al. 2002).

Dissolved oxygen continues to represent one of the most essential water quality parameters utilized by both TCEQ and EPA in assessments of aquatic life use and the health of a water body. While a few near-surface dissolved oxygen concentrations fell in the “biologically stressful” range of >2.0 mg/L but <5.0 mg/L, based on one-time grab sampling, overall near-surface dissolved oxygen quality for the CBBEP region can be considered very good (see Fig. 3.4). However, analysis of RCAP 2004 near-bottom DO data revealed a different picture with six sites having low near-bottom DO concentrations, of which two were hypoxic (see Fig. 3.5). Future events, and all monitoring programs, should incorporate the monitoring of near-bottom DO concentrations to provide a complete picture of the system.

As previously stated, in the continued absence of established nutrient criteria, state and federal monitoring entities employ screening levels based on different methodologies. According to TCEQ screening levels, some nutrient values exceeded screening levels (see Figs. 3.6 through 3.9 and Table 3.3) in RCAP 2004. While the one exceedance for ammonia in Baffin Bay (Segment 2492) warrants little concern, there was a clustering of ammonia exceedances in Baffin Bay during RCAP 2003, and one exceedance in RCAP 2002. Concerning total phosphorus concentrations, while not on the 2002 305(b) list for *Secondary Concerns* (see Section 3.2.1), the elevated levels recorded in Nueces Bay (Segment 2482) during RCAP 2000 and RCAP 2002, were again elevated in RCAP 2004. The Copano Bay Complex (Segment 2472) is on the 305(b) list for *Secondary Concerns* regarding total phosphorus, and while a few levels were elevated in RCAP 2000, elevated levels did not occur again until RCAP 2004. (Fig. 3.8). However, the increasing trend seen in orthophosphate concentrations (overall mean site concentrations; 0.031 mg/L for RCAP 2002, versus 0.054 mg/L in RCAP 2003, and 0.087 mg/L in RCAP 2004) may warrant some concern, as there were 4 exceedances and 11 elevated concentrations occurring in four of the eight segments sampled for RCAP 2004 (Table 3.3; Fig. 3.9). Presently the 2002 305(b) list does not list orthophosphate for *Secondary Concerns* in any of these segments sampled for RCAP 2004.

As stated in past RCAP reports, based on TCEQ screening levels, *Secondary Concerns* may exist for excessive algal growth, or chlorophyll *a* concentrations, within those segments listed on the 2002 305(b) list (see Section 3.2.1 and see Fig. 3.10). We still feel that the screening level (>11.50 µg/L) for this region may not be warranted and that elevated concentrations may relate to natural phytoplankton responses to increased nutrients into the receiving waters from inflow events prior to sampling. This fact coupled with the optimal conditions of high temperatures and increased light levels that occur during the south Texas summer are conditions that often produce high chlorophyll *a* concentrations (Monbet 1992), which appear to be typical for this area.

Continued use of EPA NCCR II guidance, which looks at near-surface Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorus (DIP) concentrations, typically yields a more unfavorable assessment of the region than evaluation using TCEQ Screening Levels. In the case of DIN, the region rated better in RCAP 2004; with 31 sites (96.9%) rated as good and one site (3.1%) rated as fair (see Table 3.4 and Fig. 3.11). This is in contrast to RCAP 2003 when sampling produced 27 sites (84.4%) rated as good, 2 sites (6.2%) rated as fair, and 3 sites (9.4%) rated as poor. Data for RCAP 2004 was similar to data collected in RCAP 2002 when DIN concentrations were primarily <0.10 mg/L.

EPA NCCR II guidance concerning DIP concentrations is more restrictive than TCEQ methodologies used to establish criteria ranges. While the point may be debatable, as to which concentration range to use, EPA is attempting to use a range for all Gulf Coast states so that conditions are comparable throughout the region. Comparing RCAP 2002 DIP concentrations with concentrations from RCAP 2003 revealed that approximately the same percentage (26.5% versus 25.0%) of sites exceeded EPA NCCR II guidelines for DIP and rated as poor. This is in sharp contrast to RCAP 2004 when 23 (71.9%) of the sites sampled rated as poor and 9 (28.1%) of the sites rated as fair (see Table 3.4 and Fig. 3.12). As stated earlier, the increasing number of sites with elevated DIP, or orthophosphate, concentrations may signify a trend, which requires continued monitoring.

Chlorophyll *a* concentrations for RCAP 2004 looked similar to past RCAP events with 8 sites (25.0%) listed as good, 22 sites (68.8%) listed as fair, and 2 sites (6.2%) listed as poor (see Table 3.4 and Fig. 3.13). In RCAP 2003 10 sites (31.3%) ranked as good, 21 sites (65.6%) received a fair ranking, and one site (3.1%) ranked as poor. RCAP 2002 showed 16 sites (32.7%) ranking as good, 30 sites (61.2%) received a fair rating, and 2 sites (6.1%) ranked as poor. One site in RCAP 2002 had missing data. While the upper end of the EPA range is higher than the TCEQ screening levels (>20.00 µg/L versus 11.50 µg/L) we still consider the lower end of the fair category (5.00 µg/L to 20.00) as to low based on the historical concentrations observed for this region. For comparative purposes, in RCAP 2002, of the 30 sites receiving a fair ranking, 17 of the sites had chlorophyll *a* concentrations between 5.00 µg/L and 9.00 µg/L, with five of those sites having concentrations between 5.00 µg/L and 6.00 µg/L. The same picture was evident in RCAP 2003; 21 sites received a fair rating, with 10 of those sites having chlorophyll *a* concentrations between 5.00 µg/L and 9.00 µg/L and five of those sites having concentrations between 5.00 µg/L and 6.00 µg/L. For RCAP 2004 there were 22 sites receiving a fair ranking. Of those, 12 sites had chlorophyll *a* concentrations between 5.00 µg/L and 9.00 µg/L with two of those sites having concentrations between 5.00 µg/L and 6.00 µg/L.

The authors feel that EPA should use a modified scale for this region of Texas based on the extreme climate conditions (air temperatures routinely above 35.0 °C during the summer), and intense light levels. Based on analysis of all chlorophyll *a* data collected for RCAP, approximately 79.1% of all concentrations are <11.50 μg/L. The authors feel that perhaps the new scale should be <11.50 μg/L would be considered as good, 11.50 μg/L to 20.00 μg/L would be rated as fair, and >20.00 μg/L would be considered as poor.

Overall, the combined EPA Water Quality Index (not including the Water Clarity Index) for RCAP 2004 ranked 2 (6.2%) sites as good, 28 (87.5%) sites as fair, and 2 sites as poor, with primarily a combination of DIP and chlorophyll *a* concentrations the justification for a fair ranking (see Table 3.4). EPA guidelines for NCCR II developed criteria for DIP and DIN as possible estimators of eutrophication. However, the authors question the utility of DIN as an estimator of possible eutrophication within the CBBEP region for all RCAP events. In RCAP 2002, all DIN concentrations were <0.10 mg/L and did not correspond with high chlorophyll *a* concentrations. For RCAP 2003 high levels of DIN did correspond with high levels of chlorophyll *a* in one site Hynes Bay (Site 295) and relatively moderate levels at two sites (Sites 318 and 322) in the Baffin Bay Complex. In RCAP 2004, only one site (Site 329) in the Baffin Bay Complex had a moderate DIN concentration that corresponded with a low to moderate chlorophyll *a* concentration (8.75 μg/L). All other DIN concentrations were <0.10 mg/L during RCAP 2004.

Regarding DIP comparisons, no clear association with high levels of chlorophyll *a* existed for RCAP 2002. Of the 13 sites rated as having poor DIP concentrations (>0.05 mg/L), five had low (good or <5.00 μg/L) concentrations of chlorophyll *a*, seven had moderate (fair or >5.00 μg/L and <20.00 μg/L) concentrations, of which 4 were <9.00 μg/L, and only one had high (poor or >20.00 μg/L) chlorophyll *a* concentrations. For RCAP 2003, of the eight sites having poor DIP concentrations one had low (good) concentrations of chlorophyll *a*, six had moderate (fair) concentrations and only one had high (poor) chlorophyll *a* concentrations. Of six sites listed as fair, only one site would have exceeded the TCEQ screening level of 11.50 μg/L, with three sites having chlorophyll *a* concentrations <9.00 μg/L, two sites <10.00 μg/L, and one site was 12.80 μg/L. In RCAP 2004 there were 23 sites rated as being poor regarding DIP concentrations; 6 sites had low (good) concentrations of chlorophyll *a*, 16 had moderate (fair) concentrations, and one site had high (poor) concentrations of chlorophyll *a*. Of the 16 sites listed as fair, only two sites would have exceeded the TCEQ standard of 11.50 μg/L, with 9 sites having chlorophyll *a* concentrations <9.00 μg/L and five sites having concentrations less than the TCEQ screening level of 11.50 μg/L. As stated in previous RCAP reports by Nicolau and Nuñez (2004; 2005a; 2005b), the effectiveness of DIN and DIP as indicators of high phytoplankton concentrations indicative of possible eutrophication for South Carolina sites monitored for the NCA program have been questioned by Van Dolah et al. (2004). Additional data assessment of CBBEP and Texas coastal waters is still necessary with the hope that additional data may provide concentration ranges more applicable within our estuaries.

Many water body segments in Texas are still undergoing assessment by the TCEQ TMDL group for bacteria impairments related to the Oyster Water Use (Fecal Coliform criteria). The continuation of bacteria sampling in RCAP 2004 provided data using the new criterion, enterococci, in the assessment of the Contact Recreation Use (CRU) for water within the CBBEP region. Analysis of RCAP 2004 data continues to indicate that for the areas and sites sampled, based on the current CRU single sample criteria of 104 CFU/100ml, water quality regarding enterococci concentrations is very good throughout the CBBEP region.

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4.0 SEDIMENT MONITORING

4.1 Introduction

As stated in previous RCAP reports by Nicolau and Nuñez (2004; 2005a; 2005b), while natural processes may provide low-level environmental inputs of certain trace metals, anthropogenic activities usually have a greater effect on the estuarine environment. Environmental concerns always exist regarding potential sediment contamination with toxic chemicals due to the discharges of a wide variety of metal and organic substances.

When contaminants enter estuarine systems, they bind to suspended particulates in the water column then settle out, or sink, to the underlying sediments. When found, most contaminants usually occur in elevated concentrations in the upper few centimeters of sediments. Sediments consisting of fine grains (Silt-Clay) or enriched with organic matter (Total Organic Carbon or TOC) may influence the degree of contamination. Concerns also exist regarding the possible re-suspension and transport of sediment contaminants across wide areas (Kennish 1992; GBEP 2002; USEPA 2004; SFEI 2004). As sediments also provide biological habitat, potential effects may result when benthic deposit-feeding organisms ingest sediment particles. While not all sediment contaminants are biologically available, some have the potential to yield possibly harmful effects to humans through bioaccumulation and possible biomagnification through the food web (Kennish 1992).

Regulatory agencies, and informed citizens, consider contaminated sediments as a primary indicator reflecting poor conditions in a water body. Researchers, resource managers, and regulatory officials utilize a multitude of methodologies for assessing coastal sediments, which often yield differing results, so the need for accurate, reliable, and substantial amounts of data, utilizing multiple evaluation techniques, is necessary to make informed decisions. Therefore, sediment and biological monitoring constitute a major portion of RCAP by providing data for long-term status and trends analysis.

4.2 Sampling Design and Data Evaluation

Sediment sampling for RCAP 2004 took place from July 20th through August 11th 2004 at 32 randomly selected sites throughout the CBBEP region as described in Chapter 2.0. Table 6.1.1 in the *Data Tables* chapter and Fig. 2.2 provide site information and location.

RCAP 2004 sediment contaminant analysis consisted of 15 trace metals, 20 Polychlorinated Biphenyls (PCBs), 6 DDT metabolites and 13 chlorinated pesticides other than DDT, and 23 Polycyclic Aromatic Hydrocarbons (PAHs) (Table 2.1). The *Data Tables* in Chapter 6.0 provide actual concentration values for each contaminant recorded at an individual site location (Metals-Table 6.7.1; PCB–Table 6.9.1; DDT-Table 6.9.2; Chlorinated Pesticides–Table 6.9.3; PAHs–Table 6.9.4) and summary descriptive results for metals in sediments for each TCEQ Segment (Table 6.8.1 through 6.8.6).

RCAP 2004 data analysis and evaluation continued to utilize all, or a subset of the contaminants listed above. Assessment used three different methods: 1) the TCEQ Sediment Quality Screening Level regulatory approach, 2) according to guidelines utilized in the EPA NCCR II (USEPA 2004), and 3) the Sediment Contaminant Distribution approach utilizing the Sediment Quality Guideline Quotient (SQGQ) method.

4.2.1. TCEQ Sediment Quality Screening Levels

Regulatory criteria still does not exist for the majority of sediment contaminants. However, TCEQ continues to employ sediment-screening levels to assess *Secondary Concerns*; previously defined as parameters for which no adopted standard exists that exhibit elevated concentrations exceeding these screening levels.

Screening levels established by TCEQ utilize long-term data based on the 85th percentiles of all TCEQ Surface Water Quality Monitoring (SWQM) data and the Probable Effects Level (PEL) guidelines developed by NOAA through its National Status and Trends Program. TCEQ revises the sediment 85th percentiles on an annual basis while NOAA sediment guidelines derive from a multitude of nationwide datasets of sediment contamination and corresponding biological effects compiled by Long et al. (1995). A *Secondary Concern* is identified by TCEQ if the 85th percentiles and PELs are exceeded greater than 25% of the time based on the number of exceedances for a given sample size (TCEQ 2003).

Depending on the effects level used, a wide range of interpretations is possible using these guidelines. Not considered regulatory criteria or standards, these screening levels and guidelines serve as a non-regulatory interpretive aid for sediment chemical data. Based on comparable datasets, but calculated differently (Long et al. 1995; MacDonald et al. 1996), the classification of these levels and their corresponding increasing effect thresholds employs the following terminology:

Threshold Effects Level	TEL	*Rare* adverse effects observed
Effects Range Low	ERL	Effects begin to occur in sensitive species
Probable Effects Level	PEL	*Frequent* adverse effects observed
Effects Range-Median	ERM	Median concentration of the compiled toxic data

4.2.2. EPA NCCR II Sediment Quality Index

Evaluation of RCAP 2004 sediment data used the EPA NCCR II guidelines (Table 4.1) for assessing individual sites to provide continuity between locally collected data and the ongoing EMAP-NCA program for assessing coastal waters and to see if the broad based EPA regional approach is applicable in all estuarine systems. The EPA Sediment Quality Index (SQI) utilizes a combined approach (Sediment TOC, Sediment Contaminants, and Sediment Toxicity) to assess sediment conditions, with sediment toxicity from organic matter enrichment assessed by measuring TOC, and Sediment Contaminants assessed in relation to ERL and ERM values as previously defined in Section 4.2.1 and listed in Table 4.2.

4.2.2.1. Sediment Toxicity Test Methods and Analysis

Sediment toxicity analysis followed EPA procedures for ten-day solid phase tests conducted with the amphipod, *Ampelisca abdita*, with test organisms purchased from Brezina and Associates, San Pablo Bay, CA (USEPA 1995). EPA approved the following modifications: amphipods were acclimated for 24 hours, instead of 48, after arrival at the laboratory; sediments were stored at 4°C, in the dark, for 30 to 60 days prior to use in experiments, rather than a maximum of 30 days. The latter modification occurred due to lower than acceptable control survival in the first test conducted, thus requiring a second test using sediment stored under refrigeration for a longer period. Control sediment, collected from Aransas Bay, Texas, was sieved through 500-µm mesh prior to addition to the test jars. The remaining test sediments were not sieved, but visible large organisms were removed prior to test initiation. Five replicates were prepared for each treatment, with addition of 200 ml sediment and 600 ml seawater at 30 ppt salinity in each test jar. Test containers were placed in controlled temperature chambers at 20 ± 1°C, with mild aeration in each jar, and allowed to equilibrate overnight under test conditions prior to addition of organisms.

Animals to be used in the test were sequentially sieved. Organisms that passed through a 1 mm mesh screen, but retained by a 0.7 mm screen, were used in the experiment. Twenty amphipods were added to each replicate, and the length of 20 randomly selected organisms was measured at test initiation. Amphipods had an average length of 3.125 mm (± 0.51). Constant lighting conditions existed throughout the duration of the test. Temperature, aeration, lighting, and number of organisms on the sediment surface, water column or water surface film were monitored daily. Dead organisms were removed and recorded, and floating animals were gently pushed into the water column with a glass rod. At test termination, sediments were sieved and retained material was preserved in 5% buffered formalin with rose Bengal. Dyed amphipods were sorted later and counted under a dissecting microscope.

Table 4.1. EPA NCA guidelines for assessing Sediment TOC (% dry weight), Sediment Toxicity, and Sediment Contaminants for determining the Sediment Quality Index (SQI), by site (USEPA 2004).

Rating		**TOC (% dry weight) Guidelines**
Good (Low)	Green	TOC concentration <2.0%.
Fair (Moderate)	Yellow	TOC concentration between 2.0% and 5.0%.
Poor (High)	Red	TOC concentration >5.0%.
Rating		**Sediment Toxicity Guidelines**
Good	Green	The amphipod survival rate is greater than or equal to 80%.
Poor	Red	The amphipod survival rate is less than 80%.
Rating		**Sediment Contaminant Guidelines**
Good	Green	No ERM concentrations are exceeded, and less than five ERL concentrations are exceeded.
Fair	Yellow	Five or more ERL concentrations are exceeded.
Poor	Red	An ERM concentration is exceeded for one or more contaminants.
Rating		**Sediment Quality Index (SQI) Guidelines**
Good	Green	None of the individual components are poor, and sediment contaminants indicator is good.
Fair	Yellow	No measures are poor, and the sediment contaminants indicator is fair.
Poor	Red	One or more of the of the component indicators is poor.

Table 4.2. List of metal concentrations in parts per million (ppm) and organic contaminant concentrations in parts per billion (ppb) along with corresponding ERL and ERM, values used in the NCCR II analysis and the PEL values used in SQGQ analysis.

Metals (ppm)	ERL	ERM	PEL
Arsenic	8.2	70.0	41.60
Cadmium	1.2	9.6	4.21
Chromium	81.0	370.0	160.40
Copper	34.0	270.0	108.20
Lead	46.7	218.0	112.18
Mercury	0.15	0.71	0.70
Nickel	20.9	51.6	42.4
Silver	1.0	3.7	1.77
Zinc	150	410.0	271.00
Organics (ppb)			
Acenaphthene	16.0	500.0	88.90
Acenapthylene	44.0	640.0	127.87
Anthracene	85.3	1,100.0	245.00
Flourene	19.0	540.0	144.35
2-Methylnaphthalene	70.0	670.0	201.00
Napthalene	160.0	2,100.0	390.64
Phenanthrene	240.0	1,500.0	543.53
Benzo(a)anthracene	261.0	1,600.0	692.53
Benzo(a)pyrene	430.0	1,600.0	763.22
Chrysene	384.0	2,800.0	845.98
Dibenzo(a,h)anthracene	63.4	260.0	1,34.61
Fluoranthene	600.0	5,100.0	1,493.54
Pyrene	665.0	2,600.0	1,397.60
Low molecular weight PAHs	552.0	3,160.0	1,442.00
High molecular weight PAHs	1,700.0	9,600.0	6,676.14
Total PAHs	4,020.0	44,800.0	16,770.40
4,4'-DDE	2.2	27.0	374.00
Total DDT	1.6	46.1	51.70
Total PCBs	22.7	180.0	188.79

Water quality measurements, consisting of dissolved oxygen (DO), pH, salinity, and ammonia were made in every replicate on days 0 and 10. DO was measured with an YSI® meter, model 59; pH, ammonia and sulfide were measured with an Orion® meter, model 290A, and the respective probes; salinity was measured with a Reichert® refractometer. Un-ionized ammonia (expressed as nitrogen) concentrations (NH_3) were calculated for each sample using the respective salinity, temperature, pH, and total ammonia ($NH_4 + NH_3$) measurements.

96-hour reference toxicant tests in aqueous phase were conducted concurrently to the sediment test. Sodium dodecyl sulfate (SDS) was used as the reference toxicant. Results of the SDS test were compared to a control chart containing data from previous experiments conducted in our laboratory (Environment Canada 1990).

One-tailed paired T-tests were run between sediment duplicates and between control and reference sediment data using TOXSTAT 3.3 (Gulley et al. 1991). Toxicity results with duplicate samples (stations 0018, 0022 and 0024) did not differ significantly from each other ($p = 0.01$ and 0.05). Therefore, the duplicate result was removed from the dataset prior to further analyses. The control and reference sample were also not significantly different at from each other $\alpha = 0.05$ and 0.01. Control and reference were pooled for further analyses. Statistical comparisons among treatments were made using ANOVA with the aid of SAS (SAS 1989).

4.2.3. Sediment Contaminant Distribution

As in previous RCAP analyses, RCAP 2004 sediment contaminant characterization continued to utilize the Sediment Quality Guideline Quotient (SQGQ) in order to determine the Sediment Contaminant Distribution (SCD) for the region. The purpose of this method is to identify the distribution patterns of the sediment contaminant and associated loadings within the CBBEP.

The SQGQ is a method increasingly utilized to quantify potentially harmful mixtures of contaminants present in varying concentrations (Hyland et al. 1999). The purpose of this method is to identify sites that may not necessarily have individual contaminant exceedances, but could cumulatively have concentrations that may negatively affect the biota of the system. This approach follows methods described in Long et al. (2003) and incorporates multiple RCAP 2004 contaminants also used in EPA NCCR II sediment assessments (Table 4.2). Calculating the SQGQ for each individual site involves first obtaining the ratio for each contaminant variable by dividing the variable concentration by its respective PEL (Texas screening value), then summing up the individual quotients and dividing by the total number of contaminant variables to arrive at a final collective quotient.

RCAP 2002 acted as the “baseline” year for determining the SQGQ categories used for future RCAP sampling events. For RCAP 2002 the upper and lower bound of the 95% Confidence Interval (CI) resulted in SQGQ breaks occurring at 0.029 for the lower bound CI and 0.045 for the upper bound CI. This would have produced three SQGQ categories: <0.029 Good (green), 0.029 to 0.045 Fair (yellow), and >0.045 Poor (red). However, due to the relatively low contaminant concentrations seen at most RCAP 2002 sites we modified the approach and characterized the sites as follows; <0.045 Good and >0.045 as Fair, or “Moderately”, contaminated. Site 258 was the only extreme outlier identified (SQGQ 0.177) in RCAP 2002 and was thereby characterized with “High” sediment contamination.

4.2.4. Benthic Community

Benthic analysis included common measures of community composition such as richness, density, biomass, and diversity. In addition, benthic community evaluation utilized the EPA Benthic Condition Index (EPA-BCI) for Gulf of Mexico Estuaries (Engle and Summers 1999) according to the guidelines in Table 4.3. Development of the index aids in assessing the health of the macrobenthic community. The purpose of the index is to reflect conditions of both water and sediment quality and serves as an independent variable used for the assessment of estuarine condition by EPA in NCCR II. If calculated correctly, a poor benthic condition should often co-occur with poor sediment or water quality (USEPA 2004). Community characterizations also included mean community measures for TCEQ designated segments and benthic community assemblages.

Table 4.3. EPA NCA guidelines for determining the Benthic Index (Gulf Coast), by site (USEPA 2004).

Rating		Benthic Index (Gulf Coast) Guidelines
Good		Benthic Index score is >5.0
Fair		Benthic Index score is between 3.0 and 5.0
Poor		Benthic Index score is <3.0

Identification of benthic community assemblages utilized the PRIMER v6.0 (Plymouth Routines in Multivariate Ecological Research) software program developed by Clark and Warwick (2001). Community characterization begins with the Bray-Curtis Similarity Matrix, which replaces the original data with pairwise similarity coefficients that reflect aspects of similarity (species composition and densities) in a community. Delineation of Benthic Assemblages and Species Groups from this matrix incorporated hierarchical clustering and the ordination technique referred to as Non-metric Multidimensional Scaling (MDS). The two techniques are then compared in order to cross check for adequacy and mutual consistency of both representations. Cluster analysis aims to find the “natural groupings” of sites by describing the patterns of occurrences of each species across a given set of samples with a dendrogram constructed for graphic illustration of the clustering. MDS constructs a configuration of the samples in an attempt to satisfy all the conditions imposed by the rank similarity matrix (Clark and Warwick, 2001).

The BIOENV procedure identified factors distinguishing Benthic Assemblages from each other. This program selects the environmental variables that best explain community patterns, by maximizing the rank correlation between biological (Bray-Curtis Similarity Matrix) and physiochemical (Euclidean Similarity Matrix) similarity matrices (Clarke and Warwick 2001). The SIMPER procedure identified the top contributing species for both the TCEQ Segments and the Benthic Assemblages. This procedure indicates which species are responsible for the observed clustering pattern (Benthic Assemblage), or the differences between sets of samples defined *a priori* (TCEQ Segments) (Clarke and Warwick 2001).

4.3 Results and Discussion

4.3.1. Sediment Characteristics

Total Organic Carbon (TOC) is one of three components (TOC, Sediment Toxicity, and Sediment Contaminants) utilized by EPA in assessing estuarine sediment quality for the National Coastal Condition Report (USEPA 2004). TOC provides a relative measure of organic matter contained in sediments and typically, elevated TOC percentages are associated with sediments high in slit/clay content. During RCAP 2004, Spearman's correlation coefficient identified a positive correlation between TOC and Silt-Clay content (r=0.739, p<0.001), with the Silt-Clay content of moderately enriched sites >89.0%.

TOC concentrations ranged from a low of <0.03% found at Sites 335 and 347 (Upper Laguna Madre-Segment 2491), Site 331 (Nueces Bay-Segment 2482), and Site 339 (Corpus Christi Bay-Segment 2481), to a high of 3.14% at Site 357 (Copano Bay Complex-Segment 2492) (Fig. 4.1; Fig. 4.2; Table 6.7.1). The lowest mean TOC enrichment per segment value of 0.03% occurred in the Upper Laguna Madre (Table 6.8.1). While several individual sites exhibited moderate enrichment, unlike RCAP 2002, and similar to RCAP 2003, no Segment in RCAP 2004 was characterized as moderately enriched, as all mean Segment values were <2.0% (Table 4.4; Table 6.8.1). The CBBEP region rates as very good concerning TOC enrichment as the overall mean TOC concentration in RCAP 2004 was 0.79% (n= 32); down from 0.95% (n=32) in RCAP 2003 and 1.71% (n=50) in RCAP 2002.

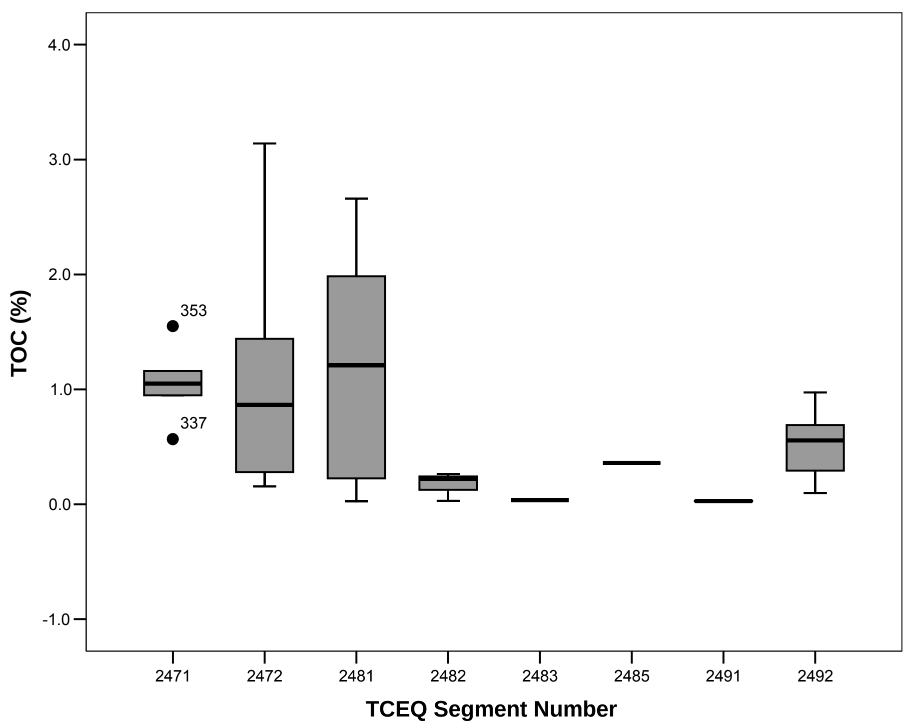


Fig. 4.1. Box and whisker plots of TOC (%) for TCEQ segments during RCAP 2004. Boxes are interquartile ranges; horizontal lines within boxes are medians; whisker endpoints are high and low extremes.

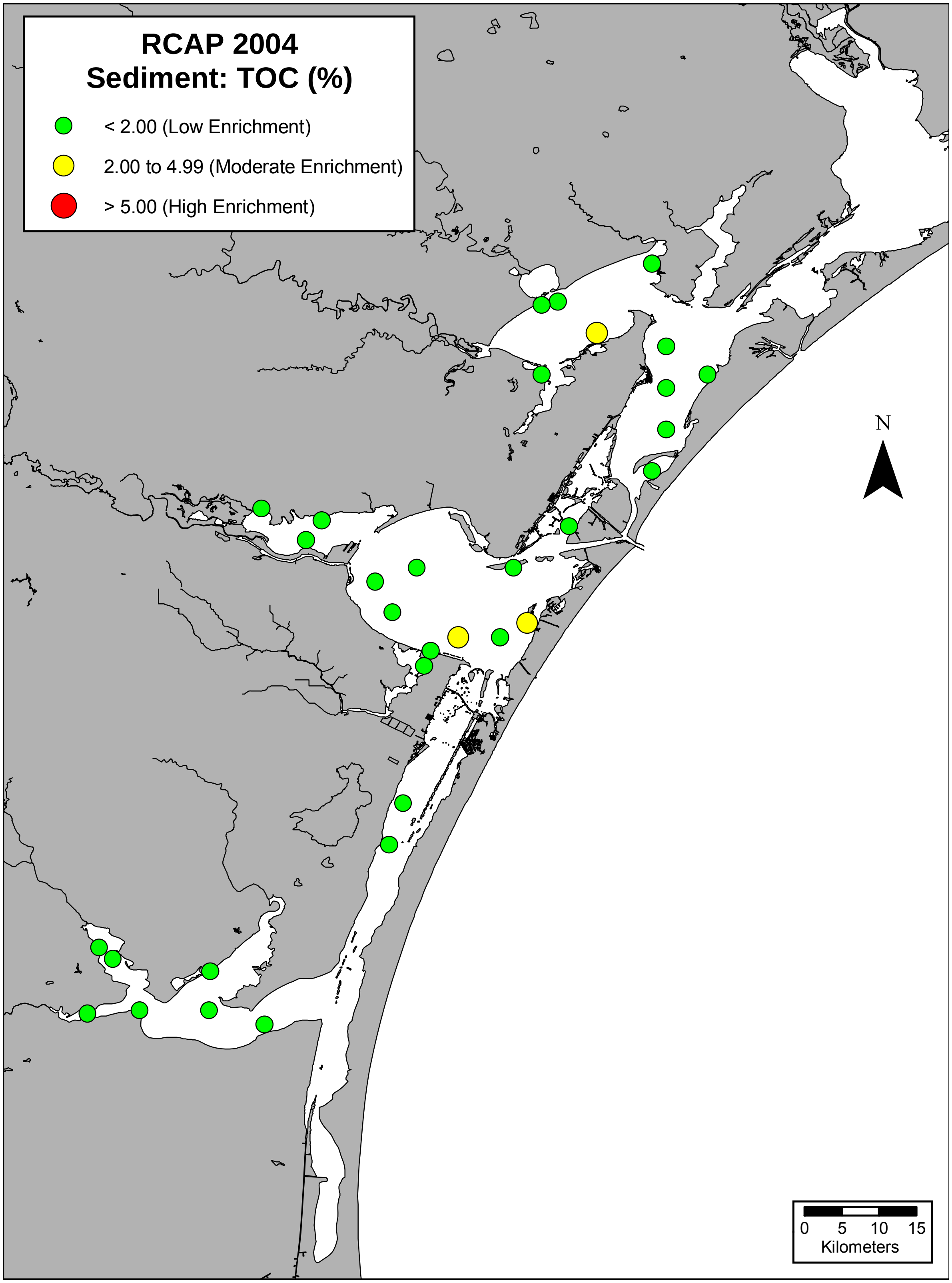


Fig. 4.2. Total Organic Carbon sediment concentrations (% dry weight) for RCAP 2004 sampling sites.

The percentage of mud (Silt-Clay) within sediments is also an important aspect in the assessments of estuarine condition. Typically, as sediment grain size decreases, the risk of contamination increases due to the strong affinity metals have to adsorb to Silt-Clay particles. Sediment grain size is also a contributing factor effecting the distribution of marine benthic organisms. As expected with a randomized sampling design, considerable variability often occurred in most Segments (Fig. 4.3; Fig 4.4).

As seen in previous years, individual Silt-Clay proportions in RCAP 2004 ranged from 2.72% to 95.69% (Fig. 4.3; Fig. 4.4; Table 6.8.1). While Corpus Christ Bay had the greatest number of sites characterized with mud (>75% Silt-Clay), Aransas Bay (Segment 2471) had the highest mud content mean percentages (>78%) (Table 4.4; Table 6.8.1). Aransas Bay and the Baffin Bay Complex (Segment 2492) had the greatest number of sites characterized as muddy sand (50% - 75% Silt-Clay) and the Upper Laguna Madre, Baffin Bay Complex, and Corpus Christi Bay had equal number of sites characterized with a low Silt-Clay content (<25%) (Table 4.4). Mean Silt-Clay proportions for Segments ranged from 3.77% to 78.40% with highest and lowest mean values recorded in Aransas Bay and the Upper Laguna Madre, respectively (Table 6.8.1).

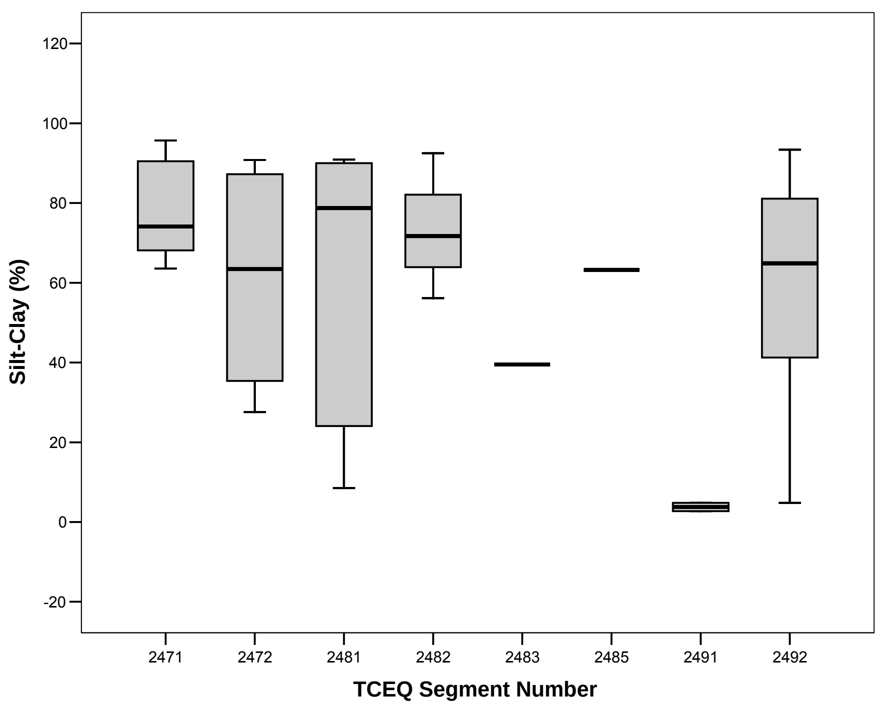


Fig. 4.3. Box and whisker plots of Silt-Clay (%) for TCEQ segments during RCAP 2004. Boxes are interquartile ranges; horizontal lines within boxes are medians; whisker endpoints are high and low extremes.

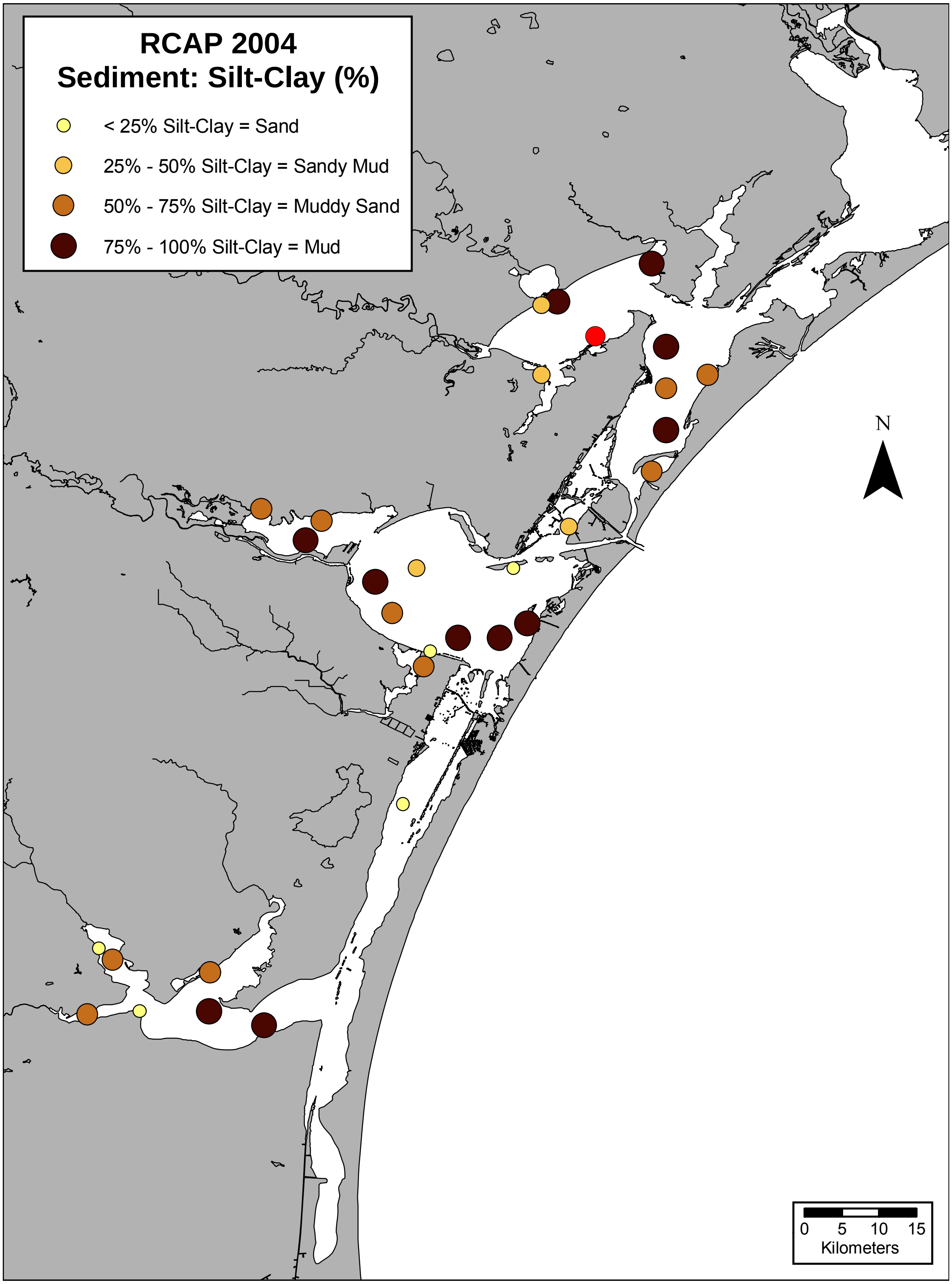


Fig. 4.4. Silt-Clay sediment concentrations for 31 RCAP 2004 sampling sites (● Site 337 in Copano Bay had no data due to a missing sample).

Table 4.4. Sediment characteristics distribution listing total number of sampling sites within TCEQ designated Segments for RCAP 2004 and number of sites associated with % TOC and % Silt-Clay categories.

Segment	Segment Name	n	% TOC			% Silt-Clay			
			<2% (Low)	2% - 5% (Mod)	>5% (High)	<25% (Sand)	25% – 50% (Sand-Mud)	50% – 75% (Mud-Sand)	>75% (Mud)
2471	Aransas Bay	5	5	-	-	-	-	3	2
2472	Copano Bay/Port Bay/ Mission Bay*	5	4	1	-	-	2	-	2
2481	Corpus Christi Bay	8	6	2	-	2	1	1	4
2482	Nueces Bay	3	3	-	-	-	-	2	1
2483	Redfish Bay	1	1	-	-	-	1	-	-
2485	Oso Bay	1	1	-	-	-	-	1	-
2491	Laguna Madre	2	2	-	-	2	-	-	-
2492	Baffin Bay/Alazan Bay/ Cayo del Grullo/Laguna Salada	7	7	-	-	2	-	3	2

*****Site 357 = No data due to missing sample.

4.3.2. TCEQ Sediment Quality Screening Levels

As previously stated, a *Secondary Concern* is identified by TCEQ if the 85th percentiles and PELs are exceeded greater than 25% of the time based on the number of exceedances for a given sample size (TCEQ 2003). TCEQ requires a minimum of 10 samples within a Segment in order to apply the 25% temporal exceedance of the screening level necessary to justify a *Secondary Concern*. While not applicable to this one-time sampling event, as no Segment had 10 sites sampled, no Segment had *Secondary Concerns* based on exceedances of the 85th percentiles and PELs. Table 4.5 lists RCAP 2004 sites whose contaminant concentrations exceeded the 85th percentile along with sites above the Threshold Effects Levels (TEL). While TCEQ does not use concentrations above TEL values in identifying *Secondary Concerns*, TEL values aid in providing a baseline reference indicating that possible harmful concentrations may be occurring.

Unlike RCAP 2002, no sites had concentrations above respective PEL values in RCAP 2003 and RCAP 2004. However, some minor concerns may exist; as cadmium, chromium, lead, and zinc consistently have had concentrations above TCEQ 85th percentile screening levels at multiple sites during all RCAP sampling events. In addition, DDT occasionally has concentrations above TEL screening levels, especially in areas receiving greater amounts of freshwater inflow such as Mesquite Bay (Segment 2463), the Copano Bay Complex (Segment 2472), Aransas Bay (Segment 2471), Oso Bay (Segment 2485), and Nueces Bay (Segment 2482).

Table 4.5. RCAP 2004 sampling sites with sediment contaminants exceeding respective screening levels.

	Contaminant	Screening Level	Site (s)
Metals	Arsenic	TEL and 85th Percentile	342
	Cadmium	TEL and 85th Percentile	341, 352
	Chromium	85th Percentile	333, 337, 342, 345, 348, 350, 352, 353, 354, 355, 357
	Lead	85th Percentile	333, 348, 352, 355
	Zinc	TEL and/or 85th Percentile	333, 341, 348, 350, 352, 354, 355
Organics	4,4’-DDT	TEL	338, 343
	Total DDT	TEL	343

4.3.3. EPA NCCR II Sediment Quality Index

The EPA Sediment Quality Index (SQI) for NCCR II utilizes a combined approach (Sediment TOC, Sediment Contaminants, and Sediment Toxicity) to assess sediment conditions (Table 4.1). During RCAP 2004, most sites had good (three sites listed as fair) sediment quality based on TOC, while all sites had good sediment quality based on Sediment Contaminants (Table 4.6). TOC and Sediment Contaminant results were similar to RCAP 2003, and improved from RCAP 2002, when two sites had poor sediment quality due either to TOC enrichment or sediment contaminants (based on ERL and ERM exceedances).

Regarding the third category, sediment toxicity, no RCAP 2004 sites received a classification of poor sediment quality due to the expression of toxic effects (Fig 4.5, Table 4.6). This is as opposed to 8 sites in RCAP 2003 and 18 sites in RCAP 2002. For RCAP 2004, amphipod (*Ampelisca abdita*) survival in sediments collected ranged from 84% to 98%, with control and reference sediment survival ranging from 93% to 92%, respectively (Table 6.10.1). No statistically significant difference among samples was detected by ANOVA. This data suggests that the sediments collected on the south Texas coast for RCAP 2004 had no bioavailable contaminants at acutely toxic levels to benthic amphipods.

Water quality was good in all test treatments and replicates. Minimum mean DO for any given treatment was 88.5%, mean pH ranged from 8.05 to 8.45, and mean salinity ranged from 26.6 to 30.8 ppt at test start and 25.0 to 31.2 ppt at test end. Porewater salinity is likely to have varied among samples from different locations, thus causing these differences in overlying water salinity due to equilibration with the porewater during the test period.

The concentration of ammonia in the overlying water decreased during the experiment, with few exceptions. Final total ammonia concentrations in most test chambers was below the detection limit (<0.10 mg/L). Measurable ammonia concentrations at test start ranged from 0.23 to 2.09 mg/L. Final concentrations in the seven samples with measurable ammonia ranged from 0.63 to 4.19 mg/L. Conversion of these values to unionized ammonia results in a range from 8.8 to 81.1 μg/L at test start and 7.7 to 205.7 μg/L in the chambers with measurable concentrations at test end. Kohn et al. (1994) found a 96-h LC50 of 830 μg NH3/L for *A. abdita* in aqueous phase tests. Therefore, ammonia is unlikely to have acted as a stressor in the current experiment. The reference toxicant tests conducted with SDS in aqueous phase resulted in a 96-h LC50 of 6.4 mg/L with 95% confidence limits between 5.8 and 7.0 mg/L. This value was within the acceptable limits established by our laboratory's control chart (Environment Canada 1990).

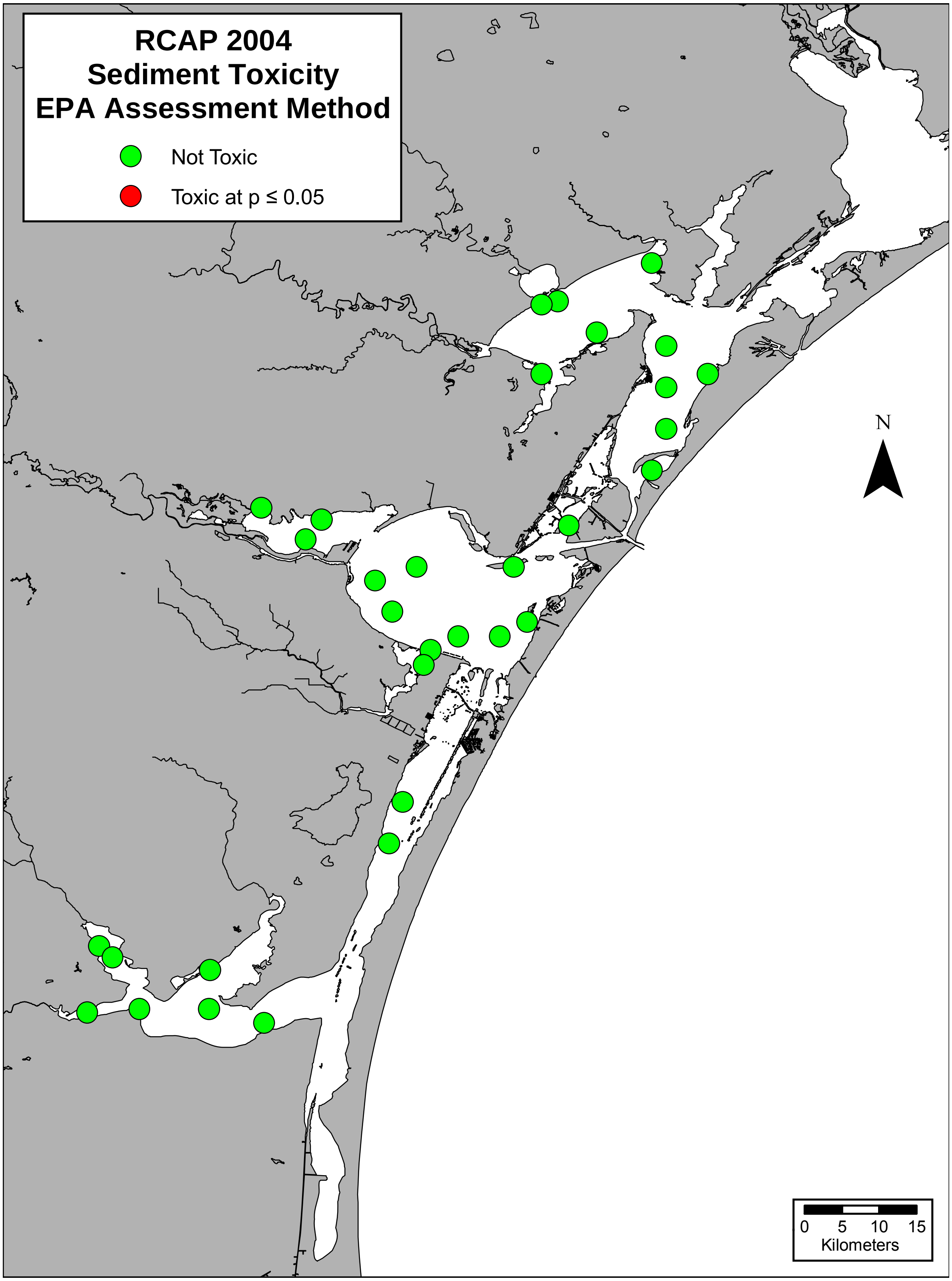


Fig. 4.5. RCAP 2004 sampling sites exhibiting toxic effects based on EPA assessment methods.

Table 4.6. Results of individual parameter and combined EPA Sediment Quality Index (SQI) by site for RCAP 2004, as defined by EPA NCCR II guidelines in Table 4.1.

Segment *	Site	TOC	Sediment Toxicity	Sediment Contaminant	EPA SQI
2471	337				
2471	340				
2471	341				
2471	344				
2471	353				
2472	332				
2472	338				
2472	343				
2472	356				
2472	357				
2481	333				
2481	339				
2481	346				
2481	348				
2481	350				
2481	351				
2481	354				
2481	355				
2482	331				
2482	349				
2482	352				
2483	328				
2485	330				
2491	335				
2491	347				
2492	327				
2492	329				
2492	334				
2492	336				
2492	342				
2492	345				
2492	358				

* 2471 (Aransas Bay), 2472 (Copano Bay/Port Bay/Mission Bay), 2481 (Corpus Christi Bay), 2482 (Nueces Bay), 2483 (Redfish Bay), 2485 (Oso Bay), 2491 (Laguna Madre), 2492 (Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada).

4.3.4. Sediment Contaminant Distribution

For RCAP 2004, sediment contamination throughout the region was generally low, as was the case in RCAP 2003 and RCAP 2002. SQGQ analysis for RCAP 2004 incorporated the same subset of contaminants analyzed for previous RCAP events. The subset consisted of the 28 contaminants (see Table 4.2) used in the EPA NCCR II sediment contaminant assessment (see guidelines in Table 4.1) (EPA 2004). As previously stated, calculating the SQGQ sites involved first obtaining the ratio for each of the 28 contaminants at a site by dividing the variable concentration by its respective PEL value, then summing up the individual quotients and dividing by 28 to arrive at a final collective quotient for that site.

For RCAP 2004, individual SQGQ site values ranged from 0.003 to 0.083 with a mean of 0.044. In contrast, RCAP 2003 values ranged from 0.006 to 0.059 with a mean of 0.031 and RCAP 2002 values ranged from 0.002 to 0.076 with a mean of 0.037. The highest individual quotient value for RCAP 2004 occurred at Site 352 in Nueces Bay (Segment 2482) and the lowest at Site 347 in the Upper Laguna Madre (Segment 2491). Overall, higher individual SQGQ values occurred at sites located in Corpus Christi Bay (Segment 2481).

Mean SQGQ values within TCEQ segments ranged from 0.003 and 0.054 (Table 4.7) with two segments only represented by one site. In those instances, we reported the individual SQGQ value for that site as the mean. As opposed to RCAP 2002 and RCAP 2003, which found highest mean SQGQ values in the Copano Bay Complex (Segment 2474), the highest mean SQGQ value for RCAP 2004 was in Aransas Bay (Segment 2471) and Nueces Bay. Lowest mean SQGQ values occurred in the Upper Laguna Madre for the third straight year. Mean SQGQ values recorded in RCAP 2004 were higher for most segments than RCAP 2003 and more similar to RCAP 2002 reported values. Box-plots in Fig. 4.6 indicate the variability seen within some segments.

RCAP 2004 Sediment Contaminant Distribution (SCD) rankings utilized the same breaks as defined in the RCAP 2002 sediment assessment, and identified 14 sites as fair, or "moderately" contaminated; with SQGQ values >0.045 (Fig. 4.7). Based on RCAP assessment procedures 13 sites classified as "moderately" contaminated for metals and 1 site for DDT. Sites classified as "moderately" contaminated occurred in five of the eight TCEQ segments sampled. As seen in past RCAP sampling events, concentrations of PCBs, DDT, Total Chlorinated Pesticides, and PAHs were extremely low or undetectable throughout the region.

As previously stated, high SQGQ values derive from the cumulative effect of all concentrations of sediment containments analyzed. Therefore, we expected that sites exceeding screening levels would correlate with higher SQGQ values. Of the 14 sites listed in Table 4.5 that showed screening level exceedances, 13 had corresponding higher SQGQ values. There were two exceptions. Site 343, located at the mouth of Mission Bay and adjacent to Site 338, which is also on the list for DDT, did not have a high SQGQ value, as metals concentrations were low and is shown on Fig. 4.7 as having low concentrations. Site 349 in Nueces Bay is not on the exceedance list (Table 4.5) but cumulatively had higher concentrations of metals (minor PAHs) and is shown on Fig. 4.7 as "moderately" contaminated for metals.

Table 4.7. Mean SQGQ values for TCEQ designated Segments during RCAP 2004.

Segment	Segment Name	n	Min	Max	Mean
2471	Aransas Bay	5	0.043	0.068	0.054
2472	Copano Bay/Port Bay/Mission Bay	5	0.016	0.065	0.041
2481	Corpus Christi Bay	8	0.008	0.079	0.052
2482	Nueces Bay	3	0.024	0.083	0.054
2483	Redfish Bay	1	-	-	0.043
2485	Oso Bay	1	-	-	0.039
2491	Laguna Madre	2	0.003	0.004	0.003
2492	Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada	7	0.003	0.064	0.036

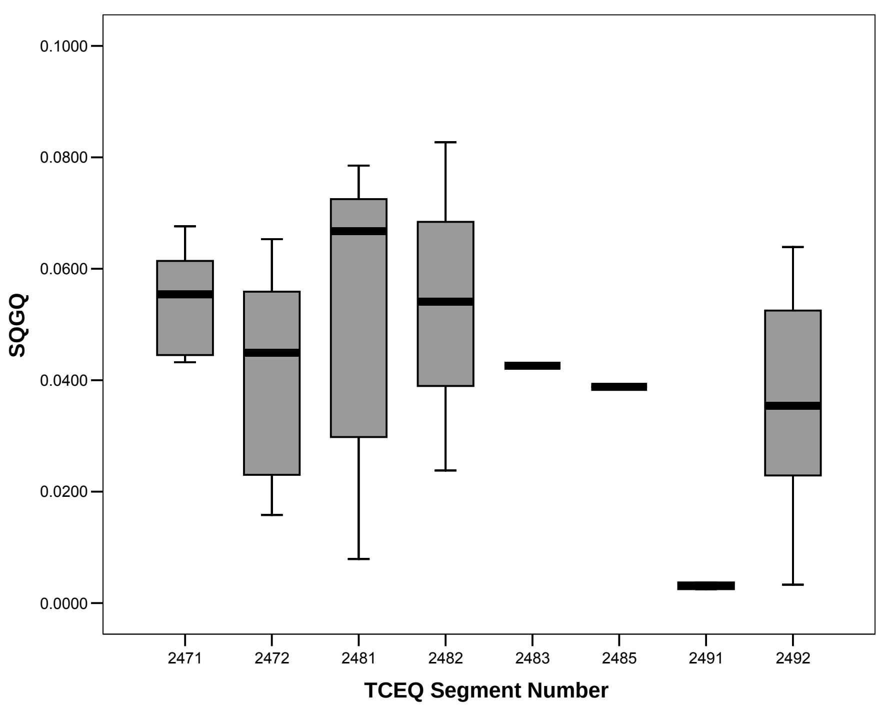


Fig. 4.6. Box and whisker plots of SQGQ values for TCEQ segments during RCAP 2004. Boxes are interquartile ranges; horizontal lines within boxes are medians; whisker endpoints are high and low extremes.

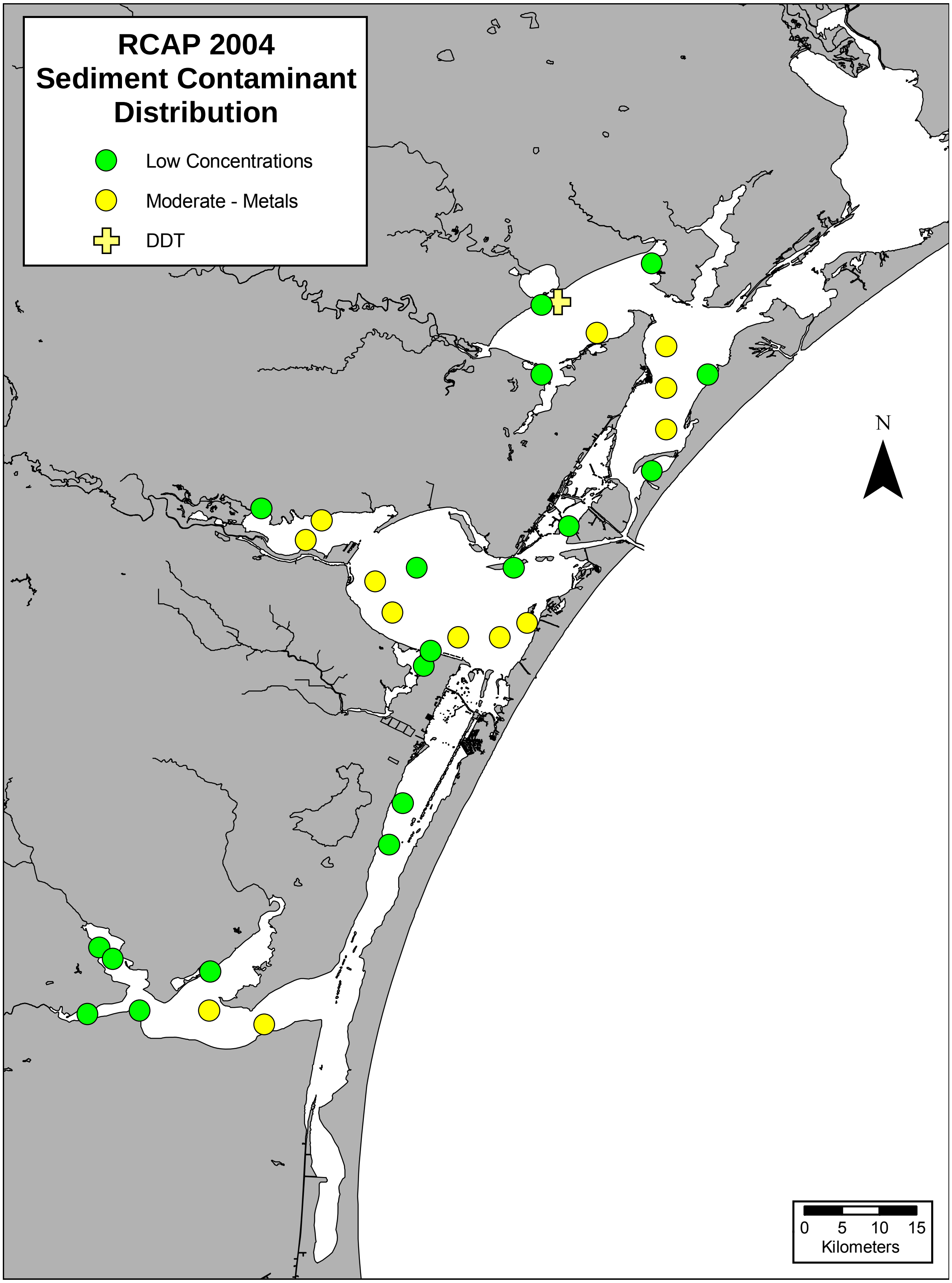


Fig. 4.7. Sediment contaminant distribution for RCAP 2004 sampling sites derived by SQGQ.

4.3.5. Benthic Community

Benthic analysis for RCAP 2004 identified 103 species totaling 3822 individuals within the sampling area (32 sites) as opposed to 114 species totaling 3000 individuals in RCAP 2003 (32 sites), and 173 species totaling 4775 individuals in RCAP 2002 (50 sites).

Before RCAP 2004, annelids typically dominated sample collections, comprising 61.9% of all organisms collected in RCAP 2003 and 72.2% in RCAP 2002. Polychaetes represented the majority of the annelids collected and no one particular species numerically dominated. However, in RCAP 2004 arthropods dominated sample collections, representing 54.0% of all organisms collected. Two species of amphipods accounted for 91.9% of the crustaceans collected with *Ampelisca abdita* accounting for 47.0% and *Corophium louisianum* accounting for 44.9%. Polychaetes accounted for 34.5% of all organisms collected with no one species dominating collections, while molluscs accounted for 6.4%, with the bivalve, *Mulinia lateralis*, yielding 38.3% of the molluscs collected. Collectively the three dominant phyla represented 94.8% of all organism collected. The remaining 5.2% of organisms collected included representatives from the phyla Hemichordata, Nemertea, Sipuncula, Cnidaria, and Echinodermata.

Across the region at all 32 RCAP 2004 sites, richness ranged from 1 to 42 with a mean of 11 species collected and was negatively correlated with Silt-Clay (-0.582, p=0.001) and positively correlated with salinity (0.657, p<0.001). Mean number of species collected was slightly lower than RCAP 2003 (32 sites) when the mean was 13 and RCAP 2002 (50 sites) when the mean was 16 species collected. Density ranged from 25 to 27,704 n m^{-2} with a mean of 2945 n m^{-2}, which was higher than RCAP 2003 when the mean was 2313 n m^{-2} and RCAP 2002 when the mean was 2356 n m^{-2}. Higher mean values relate directly to a greater number of organisms (amphipod crustaceans) collected at two sites (336 and 358) in the Baffin Bay Complex (Segment-2492). Biomass ranged from <0.01 g m^{-2} to 11.80 g m^{-2} with a mean of 1.73 g m^{-2}) and was negatively correlated with Silt-Clay (-0.495, p=0.005) and positively correlated with salinity (0.543, p=0.001). Mean biomass was lower than RCAP 2003 when the mean was 2.44 g m^{-2} and RCAP 2002 when the mean biomass was 3.96 g m^{-2}. The EPA-BCI resulted in values ranging from -3.01 to 8.41 with a mean of 5.13. Mean EPA-BCI values were higher than RCAP 2003 with a mean of 4.76 but slightly lower than RCAP 2002 when the mean was 5.27. Table 4.8 list benthic community characteristics by TCEQ Segment.

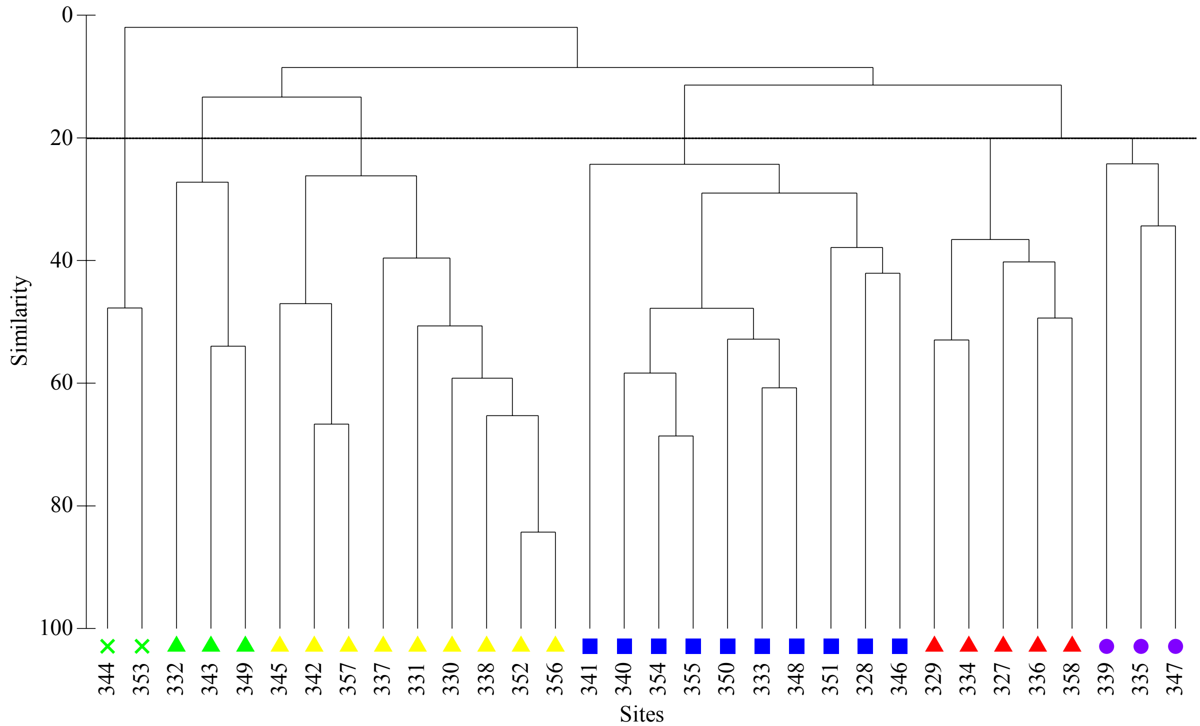
Benthic community assemblage grouped together sites into clusters by constructing a dendrogram using a Bray-Curtis similarity matrix that reflected aspects of similarity (species composition and densities). Groups were super-imposed over an MDS plot to cross-check the adequacy and consistency of both representations (Fig. 4.8). Both cluster analysis (at 20.0%) and the MDS plot (Stress = 0.15) revealed that the 32 sites sampled during RCAP 2004 could be attributed to six assemblages. Mean similarities of sites within each assemblage ranged from 24.2% to 47.7%. Box-plots for richness, density, and biomass in Fig. 4.9 show the spread within the assemblages. The BIOENV analysis indicated the best correlation between abiotic and biotic data was the combination of depth, salinity, and Silt-Clay (r_w = 0.259). Although significant, the relatively low correlation suggests that some unmeasured variable is effecting the benthic distribution in addition to the aforementioned variables. Box-plots in Fig. 4.10 show the spread of the abiotic factors within the assemblages. Factors that the BIOENV procedure identified as affecting assemblage distribution resulted in classifications six assemblages listed below, with Fig. 4.11 providing a geographical distribution of these assemblages:

1. **D**eep Depth **P**olyhaline **M**ud Assemblage (**DPM**)
2. **M**id Depth **M**esohaline **Sandy M**ud Assemblage (**MMSM**)
3. **M**id Depth **M**esohaline **Mud** Assemblage (**MMM**)
4. **D**eep Depth **P**olyhaline **M**uddy **S**and Assemblage (**DPMS**)
5. **S**hallow Depth **M**esohaline **S**andy **M**ud Assemblage (**SMSM**)
6. **M**id Depth **E**uhaline **S**and Assemblage (**MES**)

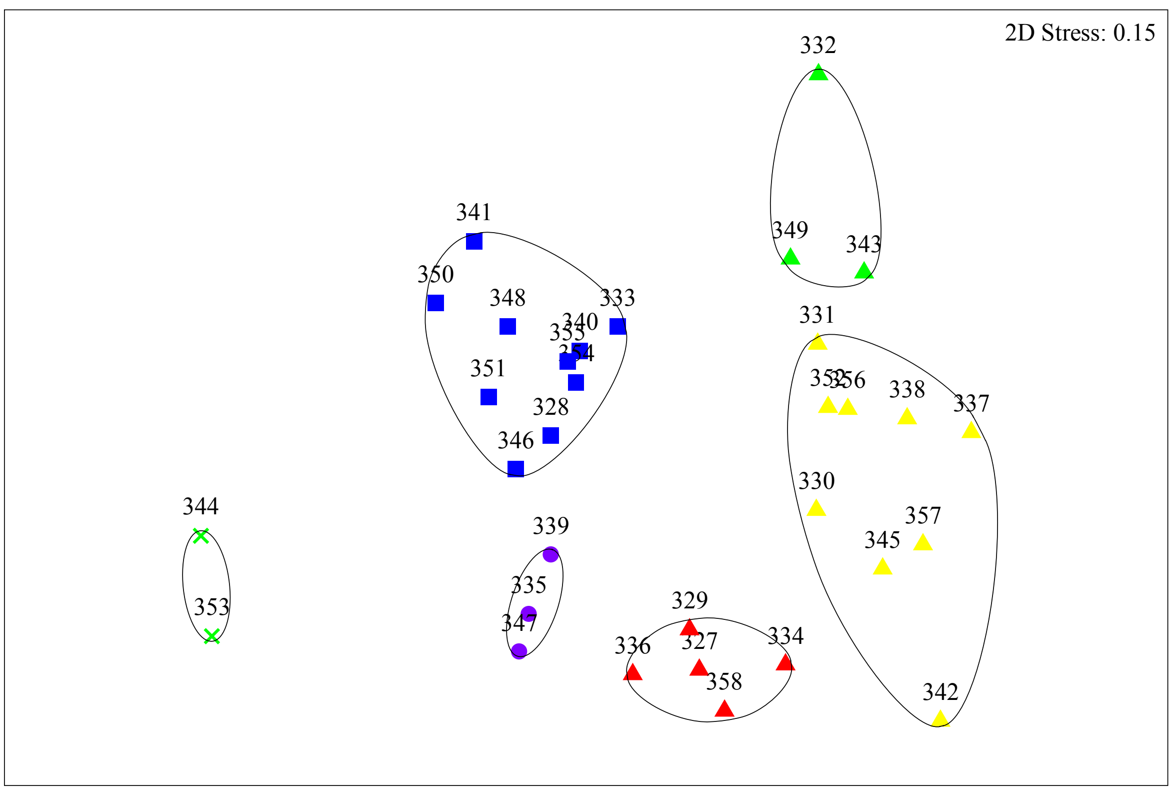
Table 4.8. Benthic community characteristics, EPA Benthic Condition Index, and dominant species percent contribution as related to density and distribution, listed by TCEQ Segment. Numbers for community characteristics are ranges with mean values in parentheses with AC = Arthropod Crustacean, AP = Annelid Polychaete, HE = Hemichordata, MB = Mollusc Bivalve, and N = Nemertean.

Segment *	Species Richness	Density (m^{-2})	Biomass ($g\ m^{-2}$)	Species Diversity	EPA Benthic Index	Dominant Species and Percent Contribution (Density and Distribution)	
2471 (n=5)	1 – 17 (6)	25 – 2319 (592)	0.01 – 1.63 (0.49)	0.00 – 3.26 (1.45)	-3.01 – 5.74 (2.91)	*Paraprionospio pinnata* (AP) *Scoloplos robustus* (AP) *Aricidea fragilis* (AP)	79.5
2472 (n=5)	2 – 3 (3)	49 – 715 (262)	0.01 – 0.56 (0.16)	0.92 – 1.41 (1.09)	1.99 – 4.87 (3.70)	*Streblospio benedicti* (AP) *Mediomastus* sp. (AP)	90.6
2481 (n=8)	12 - 24 (17)	1850 – 3404 (2597)	1.02 – 4.81 (2.92)	2.29 – 3.65 (3.03)	4.96 – 7.11 (6.06)	*Aricidea fragilis* (AP) *Hemichordata* 'acorn worm' (HE) *Paleanotus heteroseta* (AP)	60.3
2482 (n=3)	3 – 6 (4)	247 – 1184 (740)	0.01 – 0.31 (0.15)	0.84 – 2.35 (1.37)	0.96 – 6.92 (2.95)	*Mediomastus* sp. (AP) *Streblospio benedicti* (AP) Nemertean (N)	90.1
2483 (n=1)	- (21)	- (3454)	- (1.76)	- (3.40)	- (6.00)	*Tharyx cf. annulosus* (AP) *Paraonides cf. Lyra* (AP) *Mediomastus* sp. (AP)	55.7
2485 (n=1)	– (5)	– (148)	– (0.03)	– (2.25)	– (5.85)	*Ampelisca abdita* (AC) *Corophium louisianum* (AC) Nemertean (N)	66.7
2491 (n=2)	22 – 42 (32)	1875 – 6710 (4293)	3.91 – 11.80 (7.85)	3.94 – 4.70 (4.32)	6.97 – 8.41 (7.69)	*Magelona pettiboneae* (AP) *Branchioasychis americana* (AP) *Tellina* sp. (MB)	59.5
2492 (n=7)	1 – 19 (8)	25 – 27,704 (7834)	0.00 – 6.57 (1.55)	0.00 – 3.10 (1.31)	5.37 – 8.37 (6.64)	*Ampelisca abdita* (AC) *Mulinia lateralis* (MB) *Corophium louisianum* (AC)	95.0

* 2471 (Aransas Bay), 2472 (Copano Bay/Port Bay/Mission Bay), 2481 (Corpus Christi Bay), 2482 (Nueces Bay), 2483 (Redfish Bay), 2485 (Oso Bay), 2491 (Laguna Madre), 2492 (Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada).



a)



b)

Fig. 4.8. Benthic assemblages determined by a) cluster analysis with results superimposed onto a b) MDS plot to cross check for adequacy and mutual consistency of both representations.

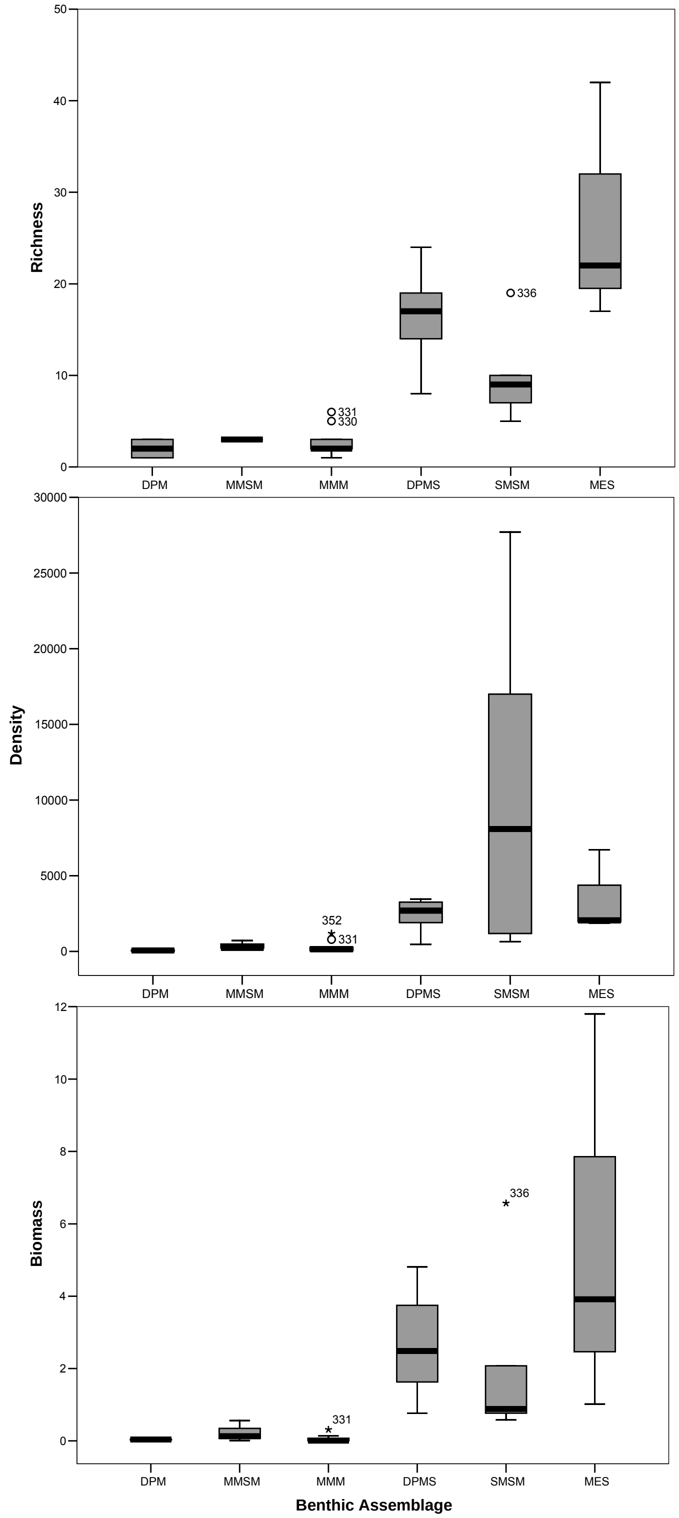


Fig. 4.9. Box and whiskers plots of biotic factors a) Richness, b) Density, and c) Biomass by benthic assemblage. Boxes are interquartile ranges; horizontal lines within boxes are medians; whisker endpoints are high and low extremes.

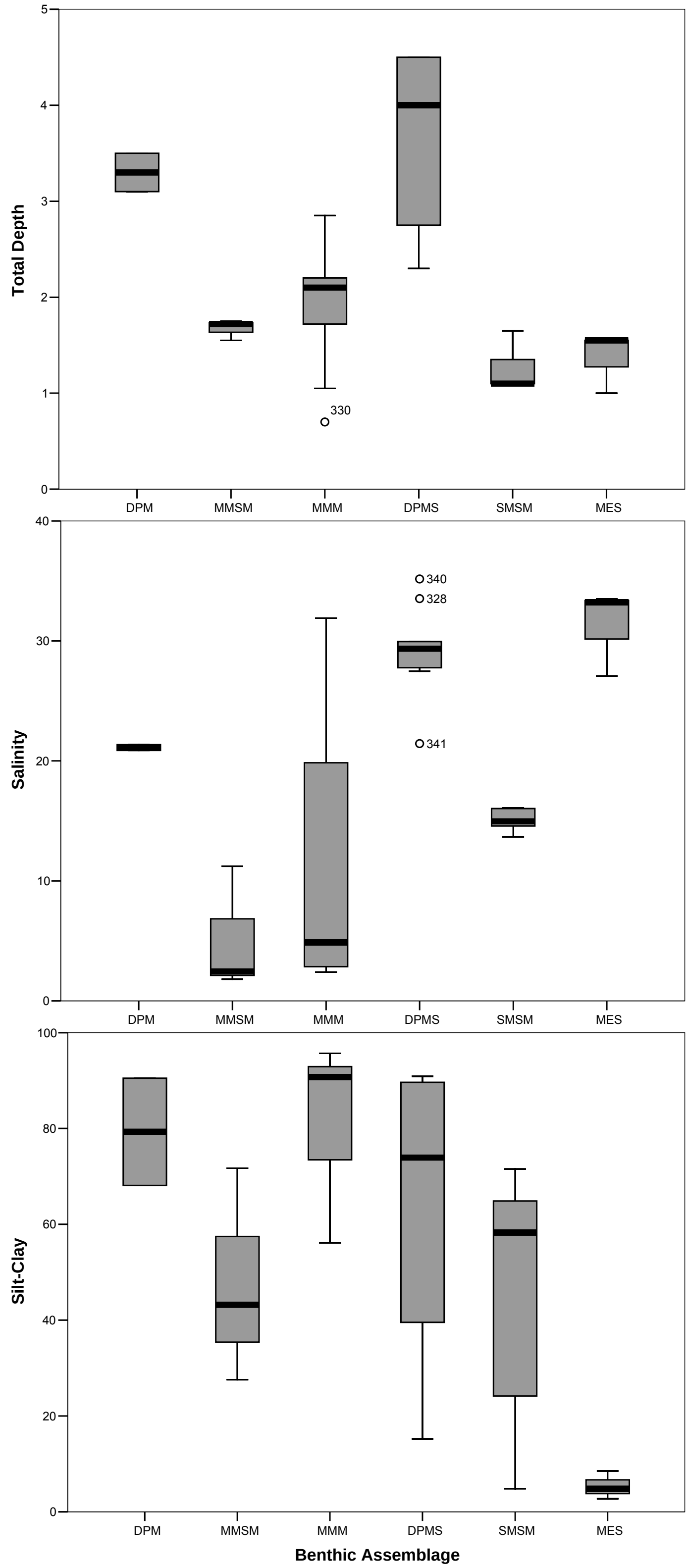


Fig. 4.10. Box and whisker plots of abiotic factors a) Total Depth, b) Salinity, and c) Silt-Clay content by benthic assemblage. Boxes are interquartile ranges; horizontal lines within boxes are medians; whisker endpoints are high and low extremes.

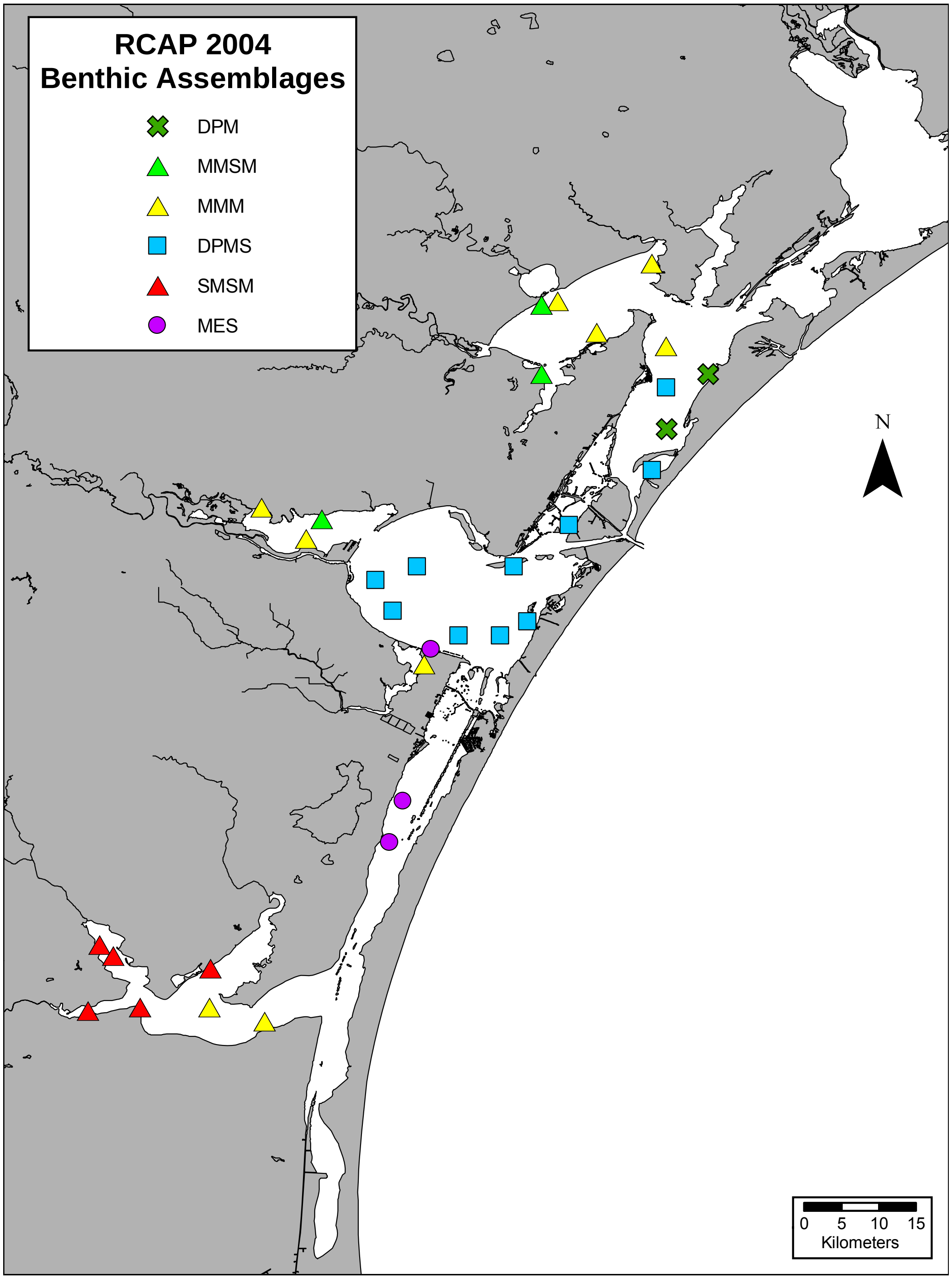
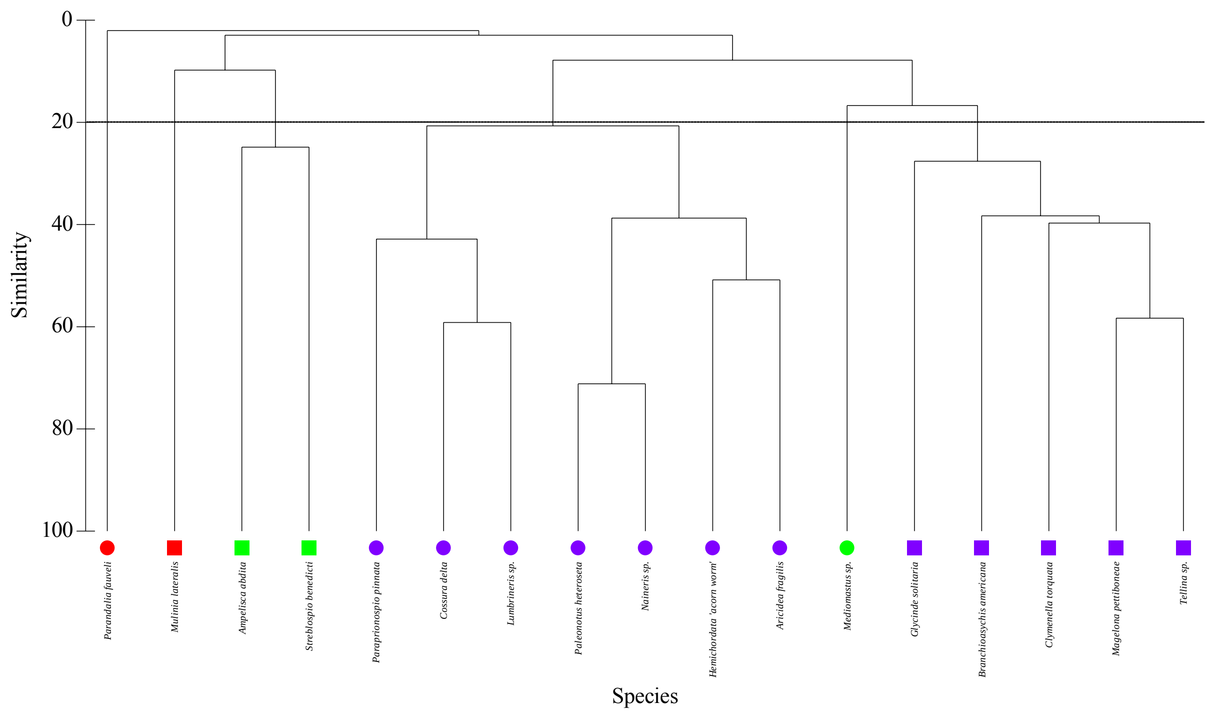
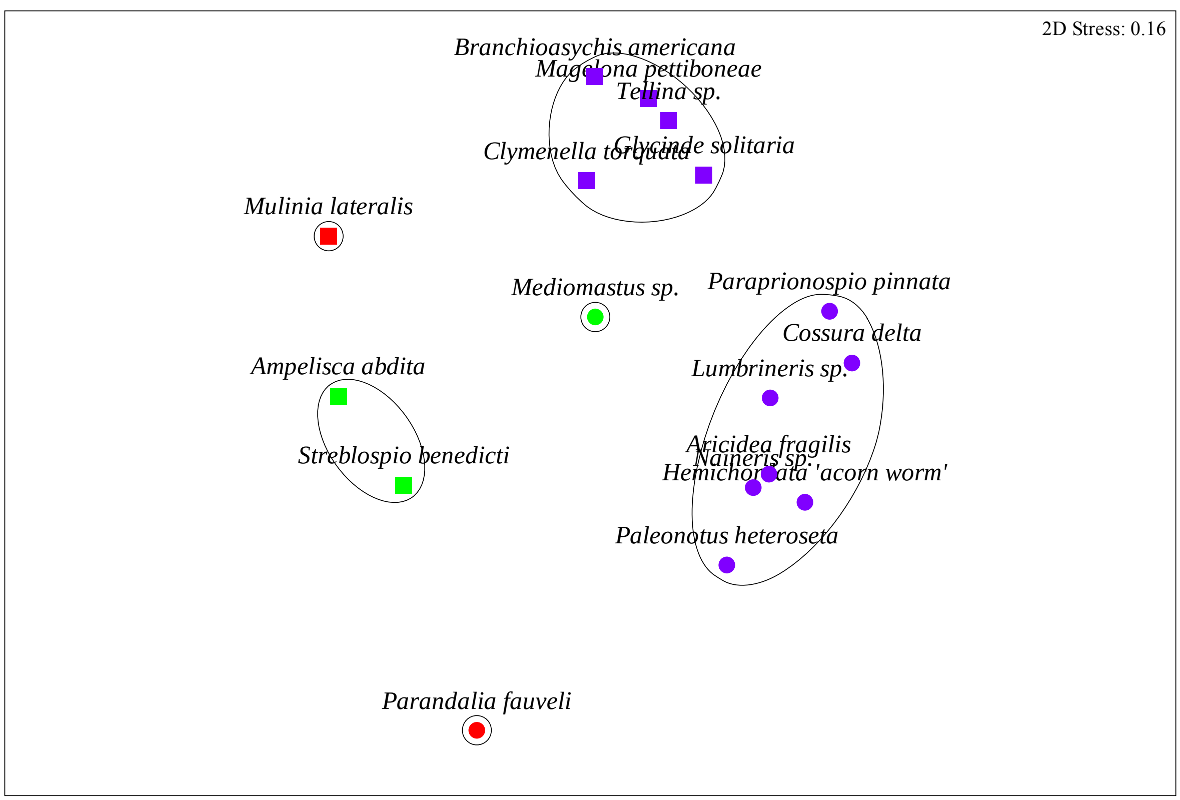


Fig. 4.11. Benthic assemblage distribution for RCAP 2004.

The SIMPER procedure identified species contributing the greatest to similarity within an assemblage and dissimilarity between assemblages. The species contributing >70% of inter-group similarity within the benthic assemblages reduced the matrix from 103 species to 17 species. Inverse cluster analysis performed on the reduced matrix identified the species most representative of the assemblages. Cluster analysis and the MDS plot (Stress = 0.16) revealed the 17 species categorized into six Species Groups represented by three groups containing multiple species and three groups containing a single species (Fig. 4.12; Table 4.9).



a)



b)

Fig. 4.12. Species groups determined by a) cluster analysis with results super-imposed onto a b) MDS plot to cross check for adequacy and mutual consistency of both representations.

Table 4.9. Mean density (n m^{-2}) of taxa within each benthic assemblage by species group. Numbers in parentheses denote the percentage of occurrence within the benthic assemblage groups. Species contributing to over 70% of inter-group similarity within the benthic assemblages are in bold.

Species	Benthic Assemblage					
	SMSM (n=5)	**DPMS (n=10)**	**MMM (n=9)**	**MMSM (n=3)**	**MES (n=3)**	**DPM (n=2)**
Species Group 1						
Parandalia fauveli	-	49.3 (10)	123.4 (11)	**296.0 (100)**	-	-
Species Group 2						
Mulinia lateralis	**2245.0 (100)**	-	-	-	49.3 (67)	-
Species Group 3						
Ampelisca abdita	**22992.4 (100)**	49.3 (20)	222.0 (44)	-	**641.4 (100)**	-
Streblospio benedicti	4095.2 (20)	172.7 (40)	**518.1 (67)**	98.7 (33)	-	-
Species Group 4						
Paraprionospio pinnata	49.3 (40)	320.7 (40)	-	-	-	**49.3 (100)**
Cossura delta	-	**616.8 (70)**	-	-	-	-
Lumbrineris sp.	-	**1134.8 (100)**	-	-	-	-
Paleonotus heteroseta	-	**2960.4 (60)**	-	-	24.7 (33)	-
Naineris sp.	-	**2097.0 (70)**	-	-	49.3 (33)	-
Hemichordata 'acorn worm'	-	**2417.7 (60)**	-	-	24.7 (33)	-
Aricidea fragilis	-	**2787.7 (90)**	-	-	690.8 (33)	-
Species Group 5						
Mediomastus sp.	197.4 (20)	838.8 (60)	**1455.5 (78)**	-	641.4 (33)	-
Species Group 6						
Glycinde solitaria	172.7 (40)	123.4 (40)	-	-	**246.7 (100)**	-
Branchioasychis americana	-	863.5 (10)	-	-	**370.1 (67)**	-
Clymenella torquata	-	690.8 (30)	-	-	**345.4 (100)**	-
Magelona pettiboneae	-	49.3 (10)	-	-	**690.8 (67)**	-
Tellina sp.	-	49.3 (20)	-	-	**394.7 (100)**	-

DPM (Deep Depth, Polyhaline, Mud)
DPMS (Deep Depth, Polyhaline, Muddy Sand)
MES (Mid Depth, Euhaline, Sand)
MMM (Mid Depth, Mesohaline, Mud)
MMSM (Mid Depth, Mesohaline, Sandy Mud)
SMSM (Shallow Depth, Mesohaline, Sandy Mud)

Based on a weight-of-evidence approach, biotic measures of richness, density, biomass, and the EPA Benthic Condition Index were combined with SCD rankings and sediment toxicity within the assemblages to assess sediment quality. Using RCAP 2002 as a benthic assessment baseline, sites characterized as having low richness, density, and biomass if measures fell below the 25th percentile and high if measures were above the 75th percentile. Sites with low benthic measures, moderate to high SCD rankings and/or expressing toxic effects, were evaluated and reported within the assemblages.

Shallow Depth, Mesohaline, Sandy Mud (SMSM)

The SMSM assemblage grouped together five sites all located in the Baffin Bay Complex (Segment 2492). Of the five sites, the majority were located in Alazan Bay, Cayo del Grullo, and the Laguna Salada, not in the main stem of Baffin Bay (see Fig. 4.8 and Fig. 4.11). Sites in this assemblage were typically shallower than the other sites, ranging from 1.10 m to 1.65 m with a mean of 1.26 m. Salinities ranged from 13.67 PSU to 16.09 PSU with a mean of 15.07 PSU, classifying it as a mesohaline assemblage. Sediments in this assemblage ranged from 4.80% to 71.56% Silt-Clay with a mean of 44.74%, classifying this assemblage as a sandy mud assemblage (see Fig. 4.10).

Mean benthic density was 10,924 n m^{-2} and ranged from 641 n m^{-2} to 27,704 n m^{-2}. Biomass ranged from 0.058 g m^{-2} to 6.57 g m^{-2} with a mean of 2.18 g m^{-2}. Mean species richness was 10 species collected and ranged from 5 to 19 species collected (see Fig. 4.9). Species diversity ranged from 0.63 to 3.10 with a mean of 1.65. EPA-BCI benthic condition was good at all stations (Table 4.10). Inverse cluster analysis identified two groups, Species Group 2 and 3, as containing the primary species contributing the greatest similarity within the SMSM assemblage (see Fig. 4.12 and Table 4.9). Although Species Group 3 is not exclusively associated with this assemblage, one species, *Ampelisca abdita*, was found in high densities at several sites and occurred at all sites within the assemblage.

Table 4.10. Benthic community characterization in relation to sediment contaminant characteristics within the SMSM assemblage. Bold represents sites characterized with reduced benthic community measures. SAV indicates presence or absence of submerged aquatic vegetation.

Segment*	Site	Richness	Density	Biomass	EPA-BCI	Toxic	TOC	SCD	SAV	Silt-Clay
2492	327	Moderate	High	Moderate					*	Muddy Sand
2492	329	Moderate	Moderate	Moderate						Sand
2492	**334**	**Low**	**Low**	**Moderate**						**Muddy Sand**
2492	336	Moderate	High	High						Sand
2492	358	Moderate	High	Moderate						Muddy Sand

* 2492 (Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada).

In past RCAP events, many sites within the Baffin Bay Complex typically had reduced benthic community measures, which often, but not always, co-occurred with elevated SCD, TOC, or toxicity levels. However, the reduction in measures most likely related to the fact that evaporation typically exceeds precipitation within the region; resulting in a hypersaline environment extremely stressful to benthic organisms. This changed in RCAP 2004 as increased inflows since RCAP sampling began in this region have reduced salinities from >50 PSU in 2001 to <20 PSU at the time of RCAP 2004 sampling (see Table 3.2). Increased numbers of species collected, higher densities and greater biomass, reflect the changes to the system from these lowered salinities. While Site 334 exhibited characteristics of a stressed benthic community, there were no clear associations as to why this site was different from the rest. The sites location in Alazan Bay and higher gravel/shell hash in the sediment may just represent a habitat that was not conducive to benthic organisms.

Deep Depth, Polyhaline, Muddy Sand (DPMS)

The DPMS assemblage grouped together 10 sites with the majority (seven) of sites located in Corpus Christi Bay (Segment 2481) (see Fig. 4.8 and Fig. 4.11). Sites in this assemblage were in deep water, ranging from 2.30 m to 4.50 m, with a mean of 3.70 m. Salinities ranged from 21.45 PSU to 35.17 PSU with a mean of 29.28 PSU, classifying it as a polyhaline assemblage. Sediments in this assemblage ranged from 15.23 % to 90.89 % Silt-Clay, with a mean of 65.37%; classifying this assemblage as a muddy sand assemblage (Fig. 4.10).

Mean benthic density was 2497 n m^{-2}, ranging from 469 n m^{-2} to 3454 n m^{-2} while biomass ranged from 0.76 g m^{-2} to 4.81 g m^{-2} with a mean benthic biomass of 2.65 g m^{-2}. Mean species richness was 17 species collected and ranged from 8 to 24 species collected (see Fig. 4.9). Species diversity ranged from 2.29 to 3.65 and had the second highest mean diversity of 3.03. Benthic condition within the assemblage was good, with only one site barely characterized as fair, receiving an EPA-BCI ranking of 4.96 (> 5.00 is good) (Table 4.11). Inverse cluster analysis identified Species Group 4 as the primary group contributing to the similarity of this assemblage (see Fig. 4.12 and Table 4.9). Other Species Groups such as 3, 5, and 6 contributed to this assemblage; however, Species Group 4 contained the highest densities and percent occurrence and was found almost exclusively in this Benthic Assemblage.

Table 4.11. Benthic community characterization in relation to sediment contaminant characteristics within the DPMS assemblage. Bold represents sites characterized with reduced benthic community measures. SAV indicates presence or absence of submerged aquatic vegetation.

Segment*	Site	Richness	Density	Biomass	EPA-BCI	Toxic	TOC	SCD	SAV	Silt-Clay
2471	340	Moderate	Moderate	Moderate						Muddy Sand
2471	341	Moderate	Low	Moderate						Muddy Sand
2481	333	Moderate	High	Moderate						Mud
2481	346	Moderate	High	Moderate						Sand
2481	348	Moderate	Moderate	Moderate						Mud
2481	350	Moderate	High	Moderate						Muddy Sand
2481	351	Moderate	Moderate	Moderate						Sandy Mud
2481	354	Moderate	High	Moderate						Mud
2481	355	Moderate	High	Moderate						Mud
2483	328	Moderate	High	Moderate						Sandy Mud

* 2471 (Aransas Bay), 2481 (Corpus Christi Bay), 2483 (Redfish Bay).

The DPMS assemblage consisted of sites with relatively stable benthic communities primarily located in Corpus Christi Bay. Salinities were polyhaline with minimal variability. No evidence of significant benthic impairment existed where fair, or moderate, SCD values occurred. Moderate SCD values relate to TEL and 85th percentile exceedances for Cadmium, 85th percentile exceedances for Chromium and Lead, and TEL and/or 85th percentile exceedances for Zinc (see Table 4.5).

Mid Depth, Mesohaline, Mud (MMM)

The MMM assemblage was the most geographically diverse assemblage. Nine sites grouped together from the Copano Bay Complex (Segment 2472) and Aransas Bay (Segment 2471) in the north, to Nueces Bay (Segment 2482) and Oso Bay (Segment 2485) in the central portion, to the Baffin Bay Complex (Segment 2492) in the southern portion of the CBBEP region (see Fig. 4.8 and Fig. 4.11). Depths ranged from 0.70 m to 2.85 m with a mean of 1.87 m. With such a broad geographic distribution bottom salinity concentrations tended to be highly variable, ranging from 2.63 PSU to 31.91 PSU with a mean of 13.37 PSU, classifying this as a mesohaline assemblage. Silt-Clay content within this assemblage ranged from 56.12% to 95.69% and produced a mean of 83.26%, classifying this as a mud assemblage (see Fig. 4.10).

Mean benthic density was 342 n m^{-2} and ranged from 25 n m^{-2} to 1184 n m^{-2}. Biomass ranged from <0.01 g m^{-2} to 0.31 g m^{-2}. Mean species richness was 3 species collected and ranged from 1 to 6 species collected (see Fig. 4.9). Species diversity ranged from 0.00 to 2.35 with a mean of 1.05. EPA-BCI benthic condition ranged from good to poor, with the four of the nine sites characterized as good, two as fair, and three as poor (Table 4.12). Inverse cluster analysis identified Species Groups 3 and 5 as the primary groups contributing to the assemblage (see Fig. 4.12 and Table 4.9). Although these species groups are not exclusively associated with the MMM assemblage, densities and frequencies of occurrence were relatively high.

Table 4.12. Benthic community characterization in relation to sediment contaminant characteristics within the MMM assemblage. Bold represents sites characterized with reduced benthic community measures. SAV indicates presence or absence of submerged aquatic vegetation and ND = No Data collected.

Segment*	Site	Richness	Density	Biomass	EPA-BCI	Toxic	TOC	SCD	SAV	Silt-Clay
2471	**337**	**Low**	**Low**	**Low**						**Mud**
2472	**338**	**Low**	**Low**	**Low**						**Mud**
2472	**356**	**Low**	**Low**	**Low**						**Mud**
2472	**357**	**Low**	**Low**	**Low**						**ND**
2482	331	Moderate	Moderate	Low						Muddy Sand
2482	**352**	**Low**	**Moderate**	**Low**						**Mud**
2485	**330**	**Low**	**Low**	**Low**						**Muddy Sand**
2492	**342**	**Low**	**Low**	**Low**						**Mud**
2492	**345**	**Low**	**Low**	**Low**						**Mud**

* 2471 (Aransas Bay), 2472 (Copano Bay/Port Bay/Mission Bay), 2482 (Nueces Bay), 2485 (Oso Bay), 2492 (Baffin Bay/Alazan Bay/Cayo del Grullo/Laguna Salada).

Of all the assemblages the MMM assemblage had the greatest number of sites possessing characteristics of a stressed benthic community (Table 4.12). Eight of the nine sites had extremely low species richness, density, and biomass and the one remaining site (Site 331 in Nueces Bay) had species richness and density values that just barely classified as moderate. Six sites had moderate SCD rankings, which related to increased metal concentrations (see Fig. 4.7). Moderate SCD values relate to TEL and 85^{th} percentile exceedances for Arsenic, and Cadmium, 85^{th} percentile exceedances for Chromium and Lead, and TEL and/or 85^{th} percentile exceedances for Zinc (see Table 4.5).

As seen in past RCAP events, sites in the MMM assemblage are typically located in areas where dramatic salinity shifts commonly occur. Within the CBBEP region, the northern and central sites are often located near freshwater inputs, subjecting these communities to salinity reductions during significant freshwater inflows as was seen prior to RCAP 2004 sampling. While the southern sites in the Baffin Bay complex, which have typically been hypersaline in past years, experienced lower salinities in RCAP 2004. As a result, the possibility suggested in past reports is that the bioeffects are partially due to co-varying stressors, other than anthropogenic inputs (Hyland et al. 2003).

Mid Depth, Mesohaline, Sandy Mud (MMSM)

The MMSM assemblage also grouped together sites typically near sources of freshwater inflows (see Figs. 4.7, 4.8, and Fig. 4.11), in Copano Bay/Port Bay/Mission Bay (Segment 2472) and Nueces Bay (Segment 2482). Sites differed from the MMM assemblage due to lower salinities and grain size content. Depths ranged from 1.55 m to 1.75 m with a mean of 1.67 m. Salinity concentrations ranged from 1.81 PSU to 11.22 PSU with a mean of 5.16 PSU, classifying this as a mesohaline assemblage. Silt-Clay ranged from 27.56% to 71.72% with a mean of 47.50%, classifying this as primarily a sandy-mud assemblage (see Fig. 4.10).

Mean benthic density was 342 n m^{-2} and ranged from 197 n m^{-2} to 715 n m^{-2}. Biomass ranged from 0.01 g m^{-2} to 0.56 g m^{-2} with a mean of 0.23 g m^{-2}. Species richness was similar with 3 species collected at each site (see Fig. 4.9). Species diversity ranged from 0.92 to 1.41 and the EPA-BCI ranged from fair to poor (Table 4.13). The inverse cluster analysis identified Species Group 1, as the primary species contributing the greatest to similarity within the assemblage (see Fig. 4.12 and Table 4.9). As indicated for the MMM assemblage, the sites in this assemblage may also show bioeffects that are partially due to co-varying stressors, other than anthropogenic inputs (Hyland et al. 2003).

Table 4.13. Benthic community characterization in relation to sediment contaminant characteristics within the MMSM assemblage. Bold represents sites characterized with reduced benthic community measures. SAV indicates presence or absence of submerged aquatic vegetation.

Segment*	Site	Richness	Density	Biomass	EPA-BCI	Toxic	TOC	SCD	SAV	Silt-Clay
2472	332	Low	Moderate	Moderate					*	Sandy Mud
2472	**343**	**Low**	**Low**	**Low**						**Sandy Mud**
2482	**349**	**Low**	**Low**	**Low**						**Muddy Sand**

* 2472 (Copano Bay/Port Bay/Mission Bay), 2482 (Nueces Bay).

Site 332 at the mouth of Port Bay in the Copano Bay Complex had a fair EPA-BCI ranking, showed no expression of toxicity or elevated SCD concentrations and had good TOC concentrations (Table 4.13). However, low species richness and barely moderate density and biomass perhaps indicate a stressed benthic community. Measures of density and biomass were higher at this site then the other two locations in this assemblage and this site was the only one with signs of seagrass present. Site 343 at the mouth of Mission Bay in the Copano Bay Complex also exhibited characteristics of a stressed benthic community consisting of low richness, densities, and biomass and had TEL exceedances for 4,4'-DDT and Total DDT (see Table 4.5). Site 349 in Nueces Bay had the most factors indicating a stressed benthic community with a poor EPA-BCI and a moderate SCD ranking. The moderate SCD characterization at this site is due to increased metal loadings (see Fig 4.7). While no one metal concentration at this site exceed any of the screening levels (see Table 4.5) it was the presence of higher concentrations of all metals that resulted in this ranking (see Table 6.7.1). In addition, of the eight sites that had barely detectable PAH concentrations, Site 349 recorded the third highest value.

Mid Depth, Euhaline, Sand (MES)

The MES assemblage grouped together the only two sites located in the Upper Laguna Madre (Segment 2491) and one site located in Corpus Christi Bay (Segment 2481) just outside the mouth of Oso Bay (see Figs. 4.7, 4.8, and 4.12). Depths ranged from 1.00 m to 1.55 m with a mean of 1.37 m. Salinity concentrations ranged from 27.08 PSU to 33.50 PSU with a mean of 31.27 PSU, classifying this as a euhaline assemblage. Silt-Clay ranged from 2.72% to 8.52% with a mean of 5.35%, classifying this as a sand assemblage (see Fig. 4.10).

Mean benthic density was 3544 n m^{-2}. Density ranged from 1875 n m^{-2} to 6710 n m^{-2} and biomass ranged from 1.02 g m^{-2} to 11.80 g m^{-2} with a mean of 5.58 g m^{-2}. Mean species richness was the highest of all assemblages with 27 species collected and ranged from 17 to 42 species collected (see Fig 4.9). Species diversity ranged from 3.17 to 4.70 with the highest mean of all assemblages of 3.97. The benthic condition was good at all stations (Table 4.14). Inverse cluster analysis identified Species Group 6 as the primary group contributing to the similarity of this assemblage (see Fig 4.12 and Table 4.9). Although this group was also associated with the DPMS Assemblage, the highest densities and percent occurrence occurred primarily in the MES assemblage.

Table 4.14. Benthic community characterization in relation to sediment contaminant characteristics within the MES assemblage. Bold represents sites characterized with reduced benthic community measures. SAV indicates presence or absence of submerged aquatic vegetation.

Segment*	Site	Richness	Density	Biomass	EPA-BCI	Toxic	TOC	SCD	SAV	Silt-Clay
2481	339	Moderate	Moderate	Moderate						Sand
2491	335	Moderate	Moderate	Moderate					*	Sand
2491	347	High	High	High					*	Sand

* 2481 (Corpus Christi Bay), 2491 (Laguna Madre).

Deep Depth, Polyhaline, Mud (DPM)

The DPM assemblage grouped together two sites located in Aransas Bay (Segment 2471) (see Fig. 4.8 and Fig. 4.11). Depths ranged from 3.10 m to 3.50 m with a mean of 3.30 m. Salinities ranged from 20.88 PSU to 21.36 PSU with a mean of 21.12 PSU, classifying it as a polyhaline assemblage. Sediments ranged from 68.12% Silt-Clay to 90.49% with a mean of 79.31%, classifying this assemblage primarily as a mud assemblage (see Fig. 4.10).

Mean benthic density was 62 n m^{-2} and ranged from 25 n m^{-2} to 99 n m^{-2} while biomass ranged from of 0.03 g m^{-2} to 0.04 g m^{-2}. Species richness ranged from 1 to 3 species collected and diversity ranged from 0.00 to 1.50 (see Fig. 4.9). Inverse cluster analysis identified no species group association within this assemblage. However, the top contributing species associated with this assemblage was *Paraprionospio pinnata* (see Fig. 4.12 and Table 4.9).

Both Site 344 and 353 exhibited low benthic richness, density and biomass and had fair and poor EPA-BCI values, respectively (Table 4.15). As seen in past years for Aransas Bay, reduced benthic measures at Site 353 could be attributed heavy shrimp trawling activity that often occurs in this area. This activity often disturbs the bottom sediments and can result in a benthic community characterized as stressed. Site 353 also received a fair, or "moderate", SCD ranking due to a Chromium concentration above the 85^{th} percentile screening level (see Table 4.5). Elevated Chromium concentrations above the 85^{th} percentile also occurred in RCAP 2003 at a site located in the same region of Aransas Bay.

Table 4.15. Benthic community characterization in relation to sediment contaminant characteristics within the DPM assemblage. Bold represents sites characterized with reduced benthic community measures. SAV indicates presence or absence of submerged aquatic vegetation.

Segment*	Site	Richness	Density	Biomass	EPA-BCI	Toxic	TOC	SCD	SAV	Silt-Clay
2471	**344**	**Low**	**Low**	**Low**						**Muddy Sand**
2471	**353**	**Low**	**Low**	**Low**						**Mud**

* 2471 (Aransas Bay)

As previously stated, the benthic community characterization resulted in the delineation of six assemblages, with the BIOENV procedure identifing salinity, depth, and sediment grain-size as the primary natural factors responsible for benthic community distribution. As suggested, the poor correlation associated with the BIO-ENV test may indicate that there may be other unmeasured factors effecting benthic distribution. During the RCAP 2004 study, patterns of stress occurred within the benthic assemblages at 13 or approximately 41% of the sites sampled. Of the 13 sites, only seven sites had elevated SCD concentrations and one site had elevated SCD and TOC concentrations. Of these eight sites two each were located in the Copano Bay Complex (Segment 2472), Aransas Bay (Segment 2471), Nueces Bay (Segment 2482), and the Baffin Bay Complex (Segment 2492).

As expected, many benthic assemblages for RCAP 2004 shared similar characteristics as those of the RCAP 2003 and RCAP 2002 assemblages. Typically, the assemblages grouped together sites located in often naturally stressed areas, as reflected in the benthic communities.

Often these assemblages consist of organisms characterized as pollution-tolerant or pollution-sensitive species, which are indicative of environmental stress and/or possible organic enrichment. Since these assemblages are located in dynamic portions of the estuaries, other unmeasured factors ought to be considered as negatively impacting the benthic community, such as biological interactions and/or physical factors; including upwelling of bottom waters due to high winds, bottom water currents, and/or storm events (Balthis et al. 2002; Hyland et al. 2003). However, as stated in past RCAP reports, co-occurring moderate SCD rankings and/or past expressions of sediment toxicity at sites (no sites listed for RCAP 2004) exhibiting the greatest evidence of benthic stress and poor EPA-BCI scores should not be ignored (Nicolau and Nuñez 2005a; Nicolau and Nuñez 2005b).

The DPMS assemblage, primarily located in Corpus Christi Bay (Segment 2481), shared the same benthic characteristics and SCD rankings as the DEMS and DPMS assemblage of the RCAP 2003 and RCAP 2002 studies, respectively. While salinity may differ from year to year this assemblage remains relatively constant and is characteristic of a stable environment with little environmental variability; resulting in a more complex benthic community (Nuñez 2004; Nicolau and Nuñez 2004; Nicolau and Nuñez 2005a; Nicolau and Nuñez 2005b). Similar SQGQ values associated with SCD rankings occurred in other assemblages in each of the respective sampling years. However, the impact to the benthic community in this stable assemblage has been minimal. This suggests that similar contaminant loadings in a dynamic system may have a greater impact on a benthic community than that of a stable system.

4.4 Summary

As seen in RCAP 2002 and RCAP 2003, sediment contamination was low for RCAP 2004 and the region rates as good according to TCEQ protocols. However, as was the case in previous RCAP sampling events, different methodologies used by TCEQ and EPA produced different assessments. In contrast to RCAP 2002 sampling results, data analysis produced similar results to RCAP 2003 with no cases of high (poor) TOC levels existing at sites sampled for RCAP 2004. While three cases of moderate (fair) levels existed, EPA would consider the results for the region as good according to NCCR II guidance (see Table 4.1; Fig. 4.1; Fig. 4.2; Table 4.4). Percentage of Silt-Clay conformed to expected values for sites sampled, although within some TCEQ Segments, and as expected, there was considerable variability (see Table 4.4; Fig. 4.3; Fig. 4.4).

Concerning sediment metal and organic contaminants, according to TCEQ screening levels, no *Secondary Concerns* exists. Unlike RCAP 2002, when one site exhibited elevated concentrations of PCBs and Total DDT, no sites had concentrations above respective PEL values in RCAP 2004. However, some concerns may exist as various sites throughout the region continually have concentrations above the TCEQ 85th percentile screening levels for arsenic, cadmium, chromium, lead, and zinc. These metals also had concentrations above the 85th percentiles during the RCAP 2002 and RCAP 2003 studies.

Following NCCR II assessment guidelines (Table 4.1) for RCAP 2004 produced no sites with poor sediment quality due to sediment contaminants based on ERL and ERM exceedances and for the first time no sites had poor sediment quality due to the expression of toxic effects. As a fundamental part of the EPA Sediment Quality Index (TOC, Sediment Toxicity, and Sediment Contaminants) used in the EPA NCCR II report, the expression of toxic effects in sediment ranked eight of the 32 RCAP 2003 sites and 18 of the 50 RCAP 2002 sites as having poor sediment quality. In both RCAP 2002 and RCAP 2003, the amphipod toxicity test continued to produce conflicting results, with no straightforward cause-effect relationship appearing to exist, as none of the sites sampled had co-occurring toxicity and elevated sediment contaminants. While unmeasured chemicals or other confounding factors such as elevated ammonia concentrations during the testing process, and/or habitat preference of the test organism may have influenced sediment toxicity results, the lack of co-occurring sediment contamination and toxicity raised questions that for RCAP 2004 are not an issue.

Use of the Sediment Quality Guideline Quotient (SQGQ) in RCAP 2004 continued to provide an alternate method of investigating potential contaminant impacts that address cumulative effects of multiple contaminants, as opposed to a single sediment screening level assessment. This process produced 14 sites with "Moderate" contaminant levels relative to the other RCAP 2004 sites sampled. These "moderately" contaminated sites occurred in five of the eight TCEQ segments sampled during RCAP 2004. These sites primarily had one or more contaminants above respective the TCEQ 85th percentile or TEL (TELs not used by TCEQ) screening levels. Similar contaminants had increased concentrations in the same segments during RCAP 2002 and RCAP 2003. As observed during RCAP 2002 and RCAP 2003, increased contaminant deposition occurred in Copano Bay (Segment 2472) Aransas Bay (Segment 2471), Corpus Christi Bay (Segment 2481), Nueces Bay (Segment 2482), and Baffin Bay (Segment 2492). Typically, the contaminants contributing the most to elevated concentrations are metals. Overall, PCBs, DDT, Total Chlorinated Pesticides, and PAHs are of little concern as the majority of the concentrations at most sites are at or near minimum detection limits.

Benthic community characterization for RCAP 2004 resulted in the delineation of six assemblages, with many benthic assemblages sharing similar characteristics as those in RCAP 2003 and RCAP 2002, respectively. Typically, sites within the assemblages are located in often naturally stressed areas and consist of organisms characterized as pollution-tolerant or pollution-sensitive species, which are indicative of environmental stress and possible organic enrichment. Since these assemblages are located in dynamic portions of the estuaries, other unmeasured factors ought to be considered as negatively affecting the benthic community. However, as stated in previous reports, co-occurring moderate SCD rankings and/or past expressions of sediment toxicity at sites exhibiting the greatest evidence of benthic stress and attaining poor EPA-BCI scores should not be ignored.

The one constant assemblage over the years is primarily located in Corpus Christi Bay (Segment 2481) and tends to differ from year to year depending on salinity. The DPMS assemblage of RCAP 2004 shared the same benthic characteristics and SCD rankings as the respective assemblages of the previous RCAP sampling events. Characteristically more stable and exhibiting little environmental variability, this system tends to produce complex benthic communities. Similar SQGQ values associated with SCD rankings occurred in other assemblages in each of the respective sampling years but the impact to the benthic community in this assemblage has been minimal. This may suggest that similar contaminant loadings in a dynamic system may have a greater impact on a benthic community than that of a stable system. The complex process of understanding sediment interactions within the CBBEP region continues to evolve, and we expect that additional data collection and refinement of the methods will lead to improved indices.

4.5 References

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5.0 TISSUE MONITORING

5.1 Introduction

Pathways that contaminants may enter into marine organisms involve direct uptake from contaminated waters and/or sediments or consumption of already contaminated organisms (USEPA 2004). Once an organism acquires theses contaminants, the tendency to remain in the animal tissues or increase through subsequent contamination can be significant. This same bioaccumulation pattern can also happen when humans eat contaminated tissue thereby effecting human health. Contaminants of concern consist of Mercury (methyl-mercury), metals such as copper, chromium, or zinc (currently found in elevated levels in oyster tissue in Nueces Bay), PAHs, PCBs, and DDT and other pesticides.

5.2 Sampling Design and Data Evaluation

Tissue sampling (whole-body) for RCAP 2004 took place on various days from July 20th through August 11th 2004 at 31 of 32 (1 site not sampled due to shallow water) randomly selected sites throughout the CBBEP region as described in Chapter 2.0. Table 6.1.1 in the *Data Tables* chapter and Fig. 2.2 provide site information and location. A complete list of parameters measured during the RCAP 2004 sampling event is in Table 2.1. The *Data Tables* in Chapter 6.0 provide the type of fish analyzed at each site (Table 6.11.1) and individual concentration values for tissue metals and tissue organic parameters measured (Table 6.12.1 and 6.13.1 through 6.13.4). Tissue analysis involved processed whole-body tissue rather than fillets to provide a better idea of possible bioaccumulation. If a screening level or concentration range existed, then data evaluation followed two different approaches; 1) the TCEQ regulatory approach and 2) according to guidelines utilized in the EPA NCCR II (USEPA 2004).

5.2.1. TCEQ Criteria and Screening Levels

Currently, regulatory criteria do not exist for the majority of tissue contaminants. However, TCEQ does employ screening levels developed from human health criteria in the TSWQS for lead and 31 organic substances to assess the concentration of toxicants in edible fish tissue. Screening levels for an additional six metals include arsenic (inorganic arsenic screen is based on 10% of total arsenic value), cadmium, chromium, copper, mercury, and selenium which come from Texas Department of State Health Services (TDSHS) screening levels used to issue consumption advisories. Screening levels aid in identifying *Secondary Concerns* for those parameters for which no adopted standard exists that exhibit elevated concentrations greater than 25% of the time based on the number of exceedances for a given sample size (TCEQ 2003). TCEQ and TDSHS do not screen or issue advisories based on whole-body fish tissue. Results presented serve as a point of reference for comparison of possible tissue contamination within the CBBEP region.

5.2.2. EPA NCCR II Guidelines

Evaluation of RCAP 2004 tissue contaminant data used the EPA NCCR II guidelines for assessing individual sites as listed in Table 5.1 and based on the risk guidelines for recreational fishers provided in Table 5.2. EPA recognizes that these assessments do not often involve widely consumed fish species of market length. However, if the fish contaminant data exceeds the risk-based concentrations ranges in Table 5.2 for consumption of four 8-ounce meals per month for any contaminant then the site is assessed as impaired for human use (USEPA 2004). Furthermore, no guidance exists to asses the ecological risk of whole-body contaminants, but EPA Advisory Guidance often serves as a basis for estimating consumption advisories even when data are based on whole-fish or organ-specific body burdens. Use of this evaluation approach in the RCAP is to provide continuity between locally collected data and the ongoing NCA program for assessing coastal waters.

Table 5.1. EPA NCA guidelines for assessing fish tissue contaminants, by site (USEPA 2004).

Rating		Fish Tissue Contaminant Guidelines
Good	(green)	The index score falls below the range of the guidance criteria for a risk-based consumption associated with four 8-ounce meals per month.
Fair	(yellow)	The index score falls within the range of the guidance criteria for a risk-based consumption associated with four 8-ounce meals per month
Poor	(red)	The index score exceeds the maximum value of the range of the guidance criteria for a risk-based consumption associated with four 8-ounce meals per month

Table 5.2. EPA NCA risk guidelines for recreational fishers. Multiple screening values are for noncancer health endpoints, respectively (USEPA 2004). Metals are in parts per million (ppm) and organics are in parts per billion (ppb).

Metals	Screening Value (ppm)	Concentration Range (ppm) (noncancer)
Arsenic (Inorganic)[a]	1.2	3.5 – 7.0
Cadmium	4.0	0.35 – 0.70
Mercury	0.4	0.12 – 0.23
Selenium	20.0	5.9 – 12.0
Organics	**Screening Value (ppb)**	**Concentration Range (ppb) (noncancer)**
Chlordane	2000	590 - 1200
DDT (Total)	2000	59 - 120
Dieldrin	200	59 - 120
Endosulfan	24000	7000 - 14000
Endrin	1200	350 - 700
Heptachlor epoxide	52	15 - 31
Hexachlorobenzene	3200	940 - 1900
Lindane	1200	350 - 700
Mirex	800	230 - 470
Toxaphene	100	290 - 590
PAH (Total)	5.47	-
PCB (Total)	80	23 - 47

[a] EPA estimates inorganic arsenic at 2% of total arsenic as opposed to TCEQ/TDSHS using 10% of total arsenic.

5.3 Results and Discussion

The approach EPA NCA uses in the collection of data for the NCCR II report continues to make RCAP tissue contaminant data difficult to assess in Texas, as existing standards and methods are not comparable (e.g. whole-body versus edible tissue). Analysis of edible tissue (filets) took place at five sites in RCAP 2004 but data results were not noticeably different from those of whole-body samples.

As observed in past RCAP sampling events, the concentration of metals in whole-body tissue was lower than all TCEQ/TDSHS applicable screening levels for RCAP 2004. However, one site sampled during RCAP 2004 exceeded the EPA risk based guidance range used in the NCCR II for mercury in fish tissue (Table 6.12.1; Fig.5.1). Contaminant exceedances existed for mercury in the hardhead catfish (*Arius felius*). As seen in past RCAP sampling events, most sites had very low concentrations of aluminum, chromium, mercury, and iron. A limited amount of nickel, lead and selenium followed by zinc and copper occurred at some locations, with many sites having metals concentration values that were non-detectable (Table 6.12.1).

Detectable PCB concentrations occurred in whole-body tissue at only one site (Site 336 in the Cayo del Grullo of the Baffin Bay Complex-Segment 2492) during RCAP 2004 sampling (6.13.1), as opposed to one site (Copano Bay Complex-Segment 2472) in RCAP 2003, and eight sites throughout the region during RCAP 2002. As was previously observed, concentrations for RCAP 2004 were below screening levels. Detectable concentrations of DDT occurred at three sites; with one site located in the Copano Bay Complex and two sites in the Baffin Bay Complex (Table 6.13.2). As seen with PCB the highest values were below screening levels. Total Chlorinated Pesticides, other than DDT, registered in whole-body tissue samples at one site (Site 342 in the Baffin Bay Complex) in RCAP 2004, and consisted of small detectable amounts of Lindane (Table 6.13.3). No detectable concentrations of PAHs occurred in any of the 31 sites sampled (Table 6.13.4).

5.4 Summary

Although not applicable, the results of whole-body tissue analysis were compared to screening levels normally used for edible tissue as a basis for determining extent of possible contamination and bioaccumulation in tissue. Based on TCEQ/TDSHS screening levels the region ranks as good, since most contaminants were non-detectable or well below any applicable screening level. When evaluating the CBBEP region according to EPA guidelines the CBBEP region also rated as good as only one site exceeded the maximum concentration range value (>0.23 ppm) for mercury. While the presence of mercury in edible fish tissue can be a major concern for public health, overall RCAP data does not suggest that mercury in estuarine fish tissue represents an increasing trend within the area.

As seen in RCAP 2002 and 2003 no specimens collected in RCAP 2004 showed evidence of lesions or tumors during the external gross pathology examination performed on-board TPWD vessels during sampling. Future events and reevaluation of sampling and analysis protocols may produce results that are comparable to existing state guidelines and /or federal guidelines.

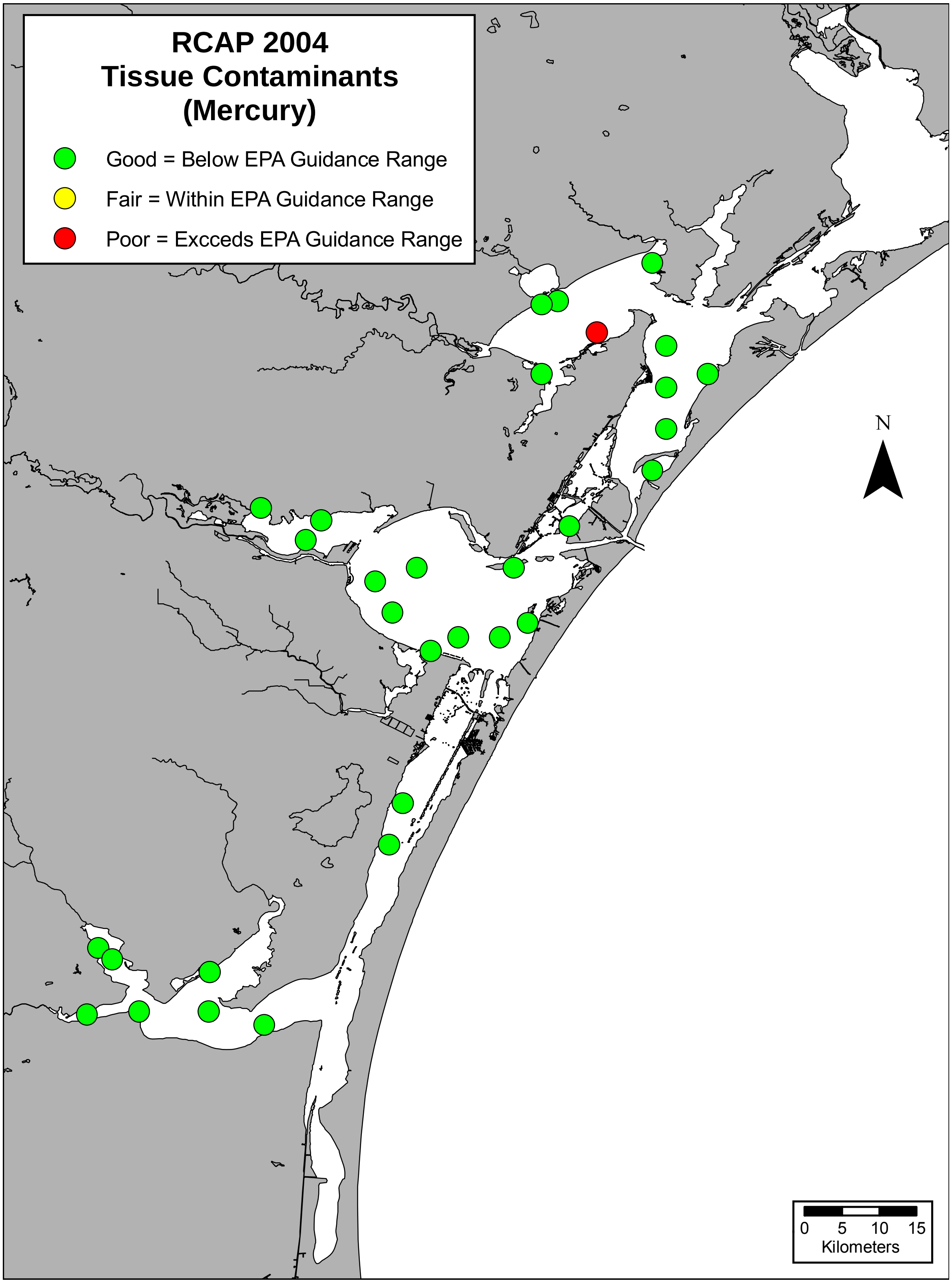

Fig. 5.1. Results of mercury tissue contaminant evaluation according to EPA guidance ranges (see Table 5.2) at 31 of 32 RCAP 2004 sampling sites.

5.5 References

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