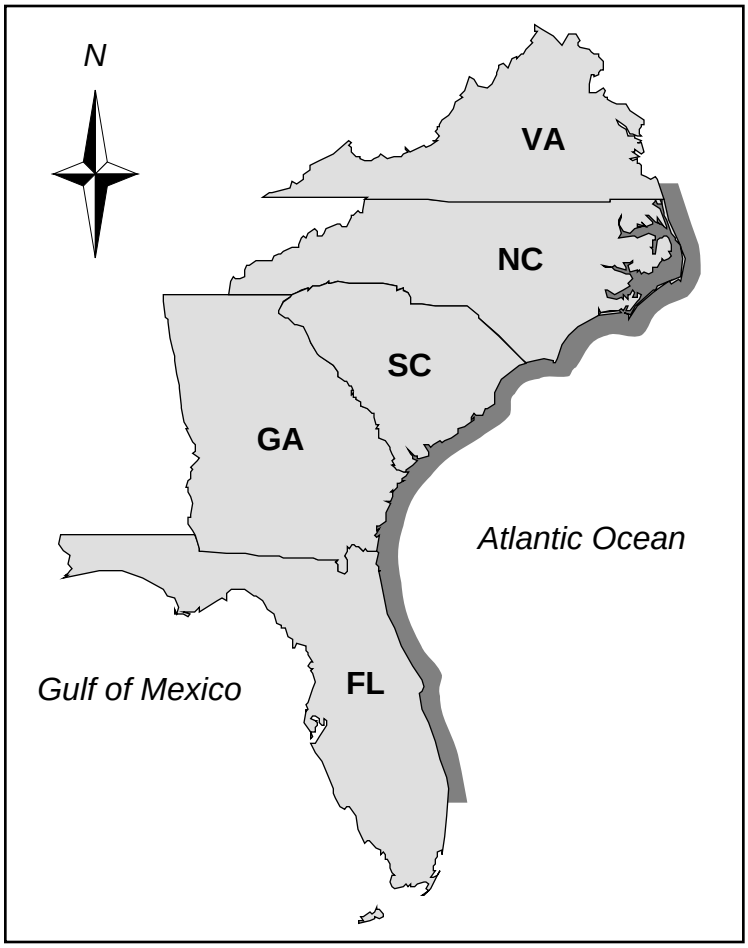
NOAA Technical Memorandum NOS ORCA 123

ENVIRONMENTAL QUALITY OF ESTUARIES OF THE CAROLINIAN PROVINCE: 1995

Annual Statistical Summary for the 1995 EMAP-Estuaries Demonstration Project in the Carolinian Province



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NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service
Office of Ocean Resources Conservation and Assessment
Coastal Monitoring and Bioeffects Assessment Division

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Environmental Quality of Estuaries of the Carolinian Province: 1995

(Annual Statistical Summary for the 1995 EMAP-Estuaries Demonstration Project in the Carolinian Province)

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Notice

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PREFACE

This document is the second annual statistical summary for the Carolinian Province estuaries component of the nationwide Environmental Monitoring and Assessment Program (EMAP). EMAP-Estuaries in the Carolinian Province is jointly sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA). The program is being administered through the NOAA Carolinian Province Office in Charleston, South Carolina and implemented through partnerships with a combination of federal and state agencies, universities, and the private sector.

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Note: Co-authors are listed alphabetically after senior author.

DISCLAIMER

This report provides a summary of ecological conditions in estuaries of the Carolinian Province based on data collected during the sampling period July 5 – September 14, 1995 using the sampling design and protocols established for the nationwide Environmental Monitoring and Assessment Program (EMAP). The EMAP-Estuaries scientific design incorporates a broad-based sampling scale in which a large regionally extensive population of estuaries is sampled each year. Usually a single randomly selected station was sampled in each estuary. This design is intended to support probability-based estimates of the percent area of degraded vs. nondegraded estuaries across the region (or smaller subpopulations of estuaries). However, the design is limited in its ability to support detailed characterizations of pollutant distributions and sources within individual estuarine systems. Such assessments would require finer-scale sampling designs applied in the particular areas of concern. Furthermore, the 1995 data represent only the second year of sampling. Although a comparison of conditions between 1995 and the previous year is included in the report, it is not possible at this point in the program to report on long-term temporal changes or trends. Collection of data over several years should provide a better understanding of whether the conditions in estuaries within the region are getting better or worse with time. The statistical power to detect such changes also should be enhanced as additional measurements from multiple years of sampling are included in the database. Such limitations of the present data must be recognized should the information be used for policy, regulatory, or legislative purposes.

ACKNOWLEDGMENTS

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EMAP-Estuaries in the Carolinian Province is a comprehensive, interdisciplinary monitoring program that has depended upon the help of many individuals from multiple institutions to complete the effort represented in this report. Everyone's dedication and cooperation are greatly appreciated. While the overall success has been due to the combined efforts of all of these individuals, special recognition is extended to the following contributors who played major roles in the corresponding components of the program:

Program Management and Coordination — Andrew Robertson (NOAA/NOS–ORCA); Kevin Summers (EPA–Gulf Ecology Division); Fred Holland (SC Department of Natural Resources); Steve Ross (NC National Estuarine Research Reserve); Tracy Wheeler (University of NC–Wilmington); Jan Landsberg and Richard Paperno (FL Department of Environmental Protection).

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Demersal Analyses — *VA/NC Samples*: Steve Ross (NC National Estuarine Research Reserve); Kevin Stokesbury (University of NC-Wilmington). *SC/GA Samples*: Paulette Powers and George Steele (SC Department of Natural Resources); Charles Keppler and Mike Wert (University of Charleston SC). *FL Samples*: Richard Paperno (FL Department of Environmental Protection). *Pathology Confirmations*: Jack Fournie (EPA–Gulf Ecology Division), Miriam Rodon-Naveira (EPA-RTP, NC), and Edward Noga (NC State University).

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ABSTRACT

A study was conducted to assess the environmental condition of estuaries in the EMAP Carolinian Province (Cape Henry, VA – St. Lucie Inlet, FL). A total of 87 randomly located stations was sampled from July 5 – September 14, 1995 in accordance with a probabilistic sampling design. Wherever possible, synoptic measures were made of: (1) general habitat condition (depth, physical properties of water, sediment grain-size, organic carbon content), (2) pollution exposure (sediment contaminant concentrations, sediment toxicity, low dissolved oxygen conditions in the water column, ammonia and sulfide in sediment porewater), (3) biotic conditions (diversity and abundance of macroinfauna and demersal biota, pathological disorders in demersal biota), and (4) aesthetic quality (presence of anthropogenic debris, visible oil, noxious sediment odor, water clarity). Percentages of degraded vs. undegraded estuarine area were estimated based on these various environmental indicators. The data also were compared to results of a related EMAP survey conducted in 1994 in this same region as part of a multi-year monitoring effort.

High concentrations of contaminants in sediments were found at 25 of 86 sites with samplable substrates, representing 30% of the province area. The 1994 estimate of contaminated area was much less (12%). PCBs and pesticides (lindane, dieldrin, and DDT and derivatives) were the most dominant sediment contaminants over the two-year period. Analysis of chemical contaminants also was conducted on edible tissues of spot, croaker, blue crab, and penaeid shrimp obtained from a subset of 14 stations throughout the province, including sites where high levels of sediment contamination had been found. All measured analytes in these samples were below corresponding FDA tissue guidelines — i.e., "Action Levels" for PCBs, pesticides, and mercury and "Levels of Concern" in shellfish for five additional metals (arsenic, cadmium, chromium, lead, and nickel).

About 82% of the province area, represented by 76 of the 87 stations, showed some evidence of environmental disturbance based on any one biotic, exposure, or aesthetic indicator. However, co-occurrences of adverse biological and exposure conditions were found in a much smaller proportion of the province — 29% (represented by 20 stations). Over half of these sites (12) were in North Carolina, as were most degraded sites during the previous 1994 survey. The majority of these sites were characterized by degraded infaunal assemblages accompanied by high sediment contamination and/or sediment toxicity based on *Mercenaria* ("seed clam") and Microtox® assays.

Selected data on sediment contamination, sediment toxicity, and macroinfaunal composition (from both years) also were examined to evaluate conditions of Carolinian Province estuaries from the perspective of sediment quality. Each year a sizable portion of the province — 36% in 1994 and 51% in 1995 — showed some evidence of either degraded benthic assemblages, contaminated sediment in excess of reported bioeffect guidelines, or high sediment toxicity (significant toxicity in ≥ 50% of assays at a station). Yet, co-occurrences of a degraded benthos and adverse exposure conditions (sediment contamination and/or toxicity) were much less extensive. Such conditions were found at 16 of 82 stations with samplable substrates in 1994 (representing 17% of the province area) and 17 of 86 stations in 1995 (25% of province). Only four sites in 1994 (5% of province) and three sites in 1995 (7% of province) had degraded infauna accompanied by both sediment contamination and toxicity (defined as above) suggesting that strong contaminant-induced effects on the benthos, based on

such combined weight-of-evidence, are perhaps limited to a fairly small percentage of estuarine area province-wide.

The broad-scale sampling design of EMAP was not intended to support detailed characterizations of potential pollutant impacts within individual estuarine systems. Thus, some estuaries classified as undegraded may have degraded areas outside the immediate vicinity of the randomly sampled sites. Such localized impacts (not accounted for in the above estimates) were detected in this study at additional nonrandom supplemental sites sampled near anticipated contaminant sources. A strength of the EMAP probability-based sampling design, however, is its ability to support unbiased estimates of ecological condition with known confidence at regional scales. Further sampling in the Carolinian Province should improve the accuracy of these estimates and provide a basis for beginning to assess how the overall quality of these estuaries is changing with time.

1. INTRODUCTION

1.1 Background and Purpose of the Study

In 1993, NOAA and EPA formalized an agreement to conduct a joint study of the quality of estuaries of the Carolinian Province, one of 12 coastal regions established under the nationwide Environmental Monitoring and Assessment Program (EMAP). A detailed program plan for estuaries and other near-coastal components of EMAP is described by Holland (1990). While the study was conducted as part of the estuaries component of EMAP, an emphasis was placed on bringing together resources and methods of both EMAP and NOAA's National Status and Trends (NS&T) program. The integrative approach to monitoring these coastal resources fulfills a key directive under the 1992 National Coastal Monitoring Act (Sec. 501 *Et Seq*, 33 U.S.C. 2801) for NOAA, EPA and other federal agencies to establish a comprehensive national program for consistent monitoring of the nation's coastal environments and ecosystems.

The Carolinian Province extends from Cape Henry, Virginia through the southern end of the Indian River Lagoon along the east coast of Florida (Figure 1-1). The estuarine resources of this region are diverse and extensive, covering an estimated 11,622 km^2. There is an increasing need for effective management of these resources given a predicted influx of people and businesses to southeastern coastal states over the next few decades and the ensuing pressures on the coastal zone of this region. Culliton et al. (1990) estimated that the coastal population of the southeastern United States will have increased by 181% over the 50-year period from 1960 to 2010 (the largest increase in the country). The Carolinian monitoring program is intended to provide valuable information on the overall health of southeastern estuaries in addition to a reliable baseline for evaluating how conditions of these resources are changing with time. The program also provides an opportunity to refine methods for conducting future monitoring and assessment studies in this and other regions.

An initial pilot study was conducted in the Carolinian Province in 1993 to collect background information on ranges of environmental variables and to determine appropriate indicators of environmental quality to include in subsequent monitoring efforts. Results of the pilot study are summarized by Ringwood et al. (1996). A full province-wide monitoring effort began in 1994. This effort incorporates approaches suggested in the pilot study but is based primarily on the overall EMAP-E sampling design and protocols to ensure data comparability with other provinces. Results of the 1994 study are reported by Hyland et al. (1996). The following report provides a summary of ecological conditions of estuaries of the Carolinian Province based on data collected during the second monitoring period (summer 1995).

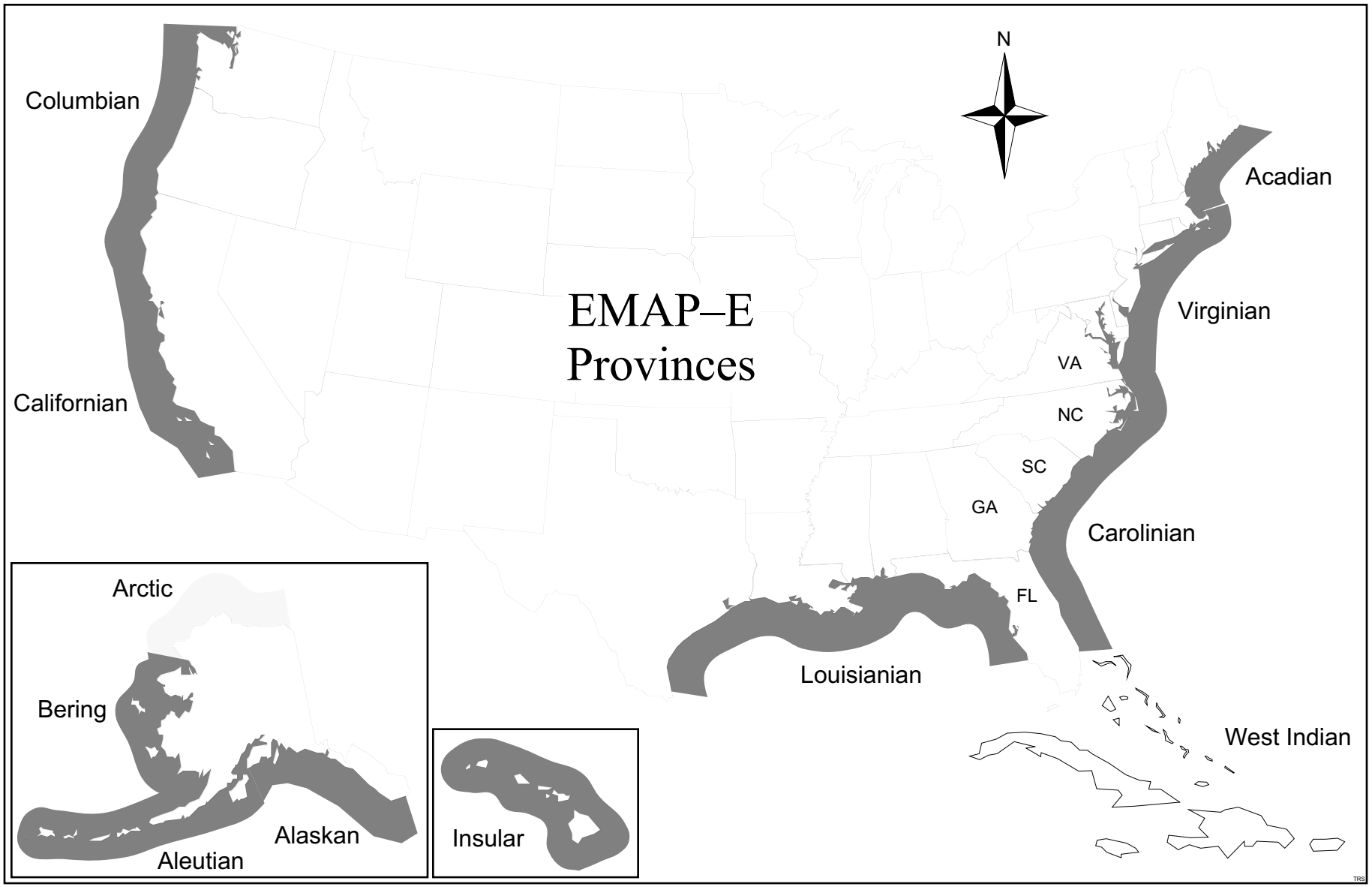

FIGURE 1-1. EMAP-E provinces

1.2 Objectives

The objectives of this program are to:

1. Assess the condition of estuarine resources of the Carolinian Province based on a variety of synoptically measured indicators of environmental quality;

2. Establish a baseline for evaluating how the condition of these resources are changing with time; and

3. Develop and validate improved methods for use in future coastal monitoring and assessment efforts.

These objectives are being addressed using a probability-based sampling design, under which a large regionally extensive population of randomly selected sites is sampled from year to year. This design makes it possible to produce unbiased estimates of the percent area of degraded vs. nondegraded estuaries, based on a series of synoptically measured indicators of environmental quality. With such capability, the above objectives may be addressed by asking the following kinds of related assessment questions:

- What proportion of estuarine bottom waters in the Carolinian Province experiences hypoxia?

- What proportion of estuarine sediments in the Carolinian Province contains concentrations of anthropogenic chemical contaminants above reported bioeffect levels?

- What proportion of estuaries in the Carolinian Province contains sediments that are toxic to standard test populations of marine organisms?

- What proportion of estuarine sediments in the Carolinian Province has a benthic community structure indicative of polluted environments?

- What proportion of estuaries in the Carolinian Province has demersal fish and invertebrate community structure indicative of polluted environments?

- What is the incidence of gross external pathologies among demersal fish and invertebrate species in the Carolinian Province?

- What is the incidence of chemical contaminant loading in the tissues of commercially and recreationally important fishes and invertebrates in the Carolinian Province?

- What proportion of Carolinian Province estuaries is aesthetically degraded (e.g., contains anthropogenic marine debris, oil sheens, or sediments with noxious odors)?

- Are there co-occurrences of degraded biological and adverse exposure conditions?

- How are the conditions of these estuaries changing with time?

- How do indicators of environmental quality for southeastern estuaries compare to those of other regions?

Methods used to answer these kinds of questions are described in Section 2 of this report. Section 3 presents results for each of the various types of indicators. Conclusions are given in Section 4. The appendices list data by station for key biological and abiotic environmental variables. Users also may obtain data electronically by accessing the EMAP Internet web site (http://www.epa.gov/emap/).

2. METHODS

2.1 Sampling and Statistical Design

An overall goal of EMAP is to make statistically unbiased estimates of ecological condition with known confidence. To approach this goal, a probabilistic sampling framework was established among the overall population of estuaries comprising the Carolinian Province. Under this design, each sampling point is a statistically valid probability-based sample. Thus, percentages of estuarine area with values of selected indicators above or below suggested environmental guidelines can be estimated based on the conditions observed at individual sampling points. Statistical confidence intervals around these estimates also can be calculated. Moreover, these estimates can be combined with those for other regions that were sampled in a consistent manner to yield national estimates of estuarine condition. The following section describes how stations were selected using this probabilistic sampling design (also see Rathbun 1994). Supplemental sites, selected nonrandomly in suspected polluted areas, were included in the survey and are discussed below as well.

Sampling sites in 1995 consisted of 88 base stations and 21 supplemental stations (Table 2-1). Base stations were randomly selected sites that made up the probability-based monitoring design. Data collected from these sites were used to produce unbiased estimates of estuarine condition throughout the province based on the various synoptically measured indicators of environmental quality. Eighty-seven of the base stations were in samplable estuaries and one was in an unsamplable estuary (station CP95137 in Rattan Bay, NC; see Section 2.6). The province-wide distribution of base sites is shown in Figure 2-1.

Supplemental stations were selected nonrandomly in areas for which there was some prior knowledge of the ambient environmental conditions. These sites, which represented both pristine areas and places with histories of anthropogenic disturbance, were used to test the discriminatory power of various ecological indicators included in the program. Data from supplemental sites were not included in the probabilistic spatial estimates.

As in other EMAP-E provinces (Strobel et al. 1994, Summers et al. 1993), the sampling design for base sites in the Carolinian Province was stratified based foremost on physical dimensions of an estuary. Estuaries were divided into three classes: large estuaries (area > 260 km^2 and length/width aspect ratio < 20), small estuaries (area 2.6–260 km^2), and large tidal rivers (tidally influenced portion of a river with detectable tides > 2.5 cm, area > 260 km^2 and length/width aspect ratio > 20). This classification scheme resulted in the identification of 200 estuaries with an overall surface area of 11,622 km^2 (Table 2-2). The total is composed of three large estuaries, three large tidal rivers, and 194 small estuaries with corresponding subpopulation areas of 5,581 km^2, 1,134 km^2, and 4,907 km^2, respectively. Currituck, Albemarle, and Pamlico Sounds — all in North Carolina — are the three large estuaries. The three large tidal rivers are the Neuse and Pamlico Rivers in North Carolina and the Indian River in Florida. Small estuaries for 1995 (49 of the total 194) are listed in Table 2-1.

Stratification of the overall sampling area into classes of estuaries with similar attributes is necessary in order to minimize within-class sampling variability. Also, it is not feasible to sample all of the different types of estuaries that exist within a broad geographic region at the

TABLE 2-1. Carolinian Province summer 1995 sampling sites with target station coordinates. In the EMAP station number, RR = Large Tidal River, RP = Large Tidal River Replicate, SR = Small Estuary, SP = Small Estuary Replicate, and LR = Large Estuary. In area column, R = Replicate Station and NA = Not Applicable. Area refers to area of estuary (for small estuaries), area of river segment (for large tidal rivers), or area of grid cell (for large estuaries).

CPO Sta. No.	EMAP Sta. No.	State	Estuary	Latitude	Longitude	Area (km^2)
Base Sites						
CP95101	CA95SR01	VA	Back Bay	36°37.27'	75°57.55'	104.9
CP95102	CA95SR02	NC	Coinjock Bay	36°25.27'	75°59.13'	13.7
CP95103	CA95SR04	NC	Chowan River	36°16.42'	76°41.36'	129.3
CP95104	CA95SR03	NC	Little River	36°10.02'	76°14.93'	26.8
CP95105	CA95LR01	NC	Currituck Sound	36°04.55'	75°46.38'	280.0
CP95106	CA95SR07	NC	Kitty Hawk Bay	36°02.48'	75°42.91'	13.0
CP95107	CA95LR02	NC	Albemarle Sound	36°02.33'	76°16.15'	280.0
CP95108	CA95LR04	NC	Albemarle Sound	35°56.42'	76°37.09'	280.0
CP95109	CA95SR05	NC	Little Alligator River	35°56.21'	76°06.09'	17.1
CP95110	CA95SP05	NC	Little Alligator River	35°55.01'	76°04.55'	R
CP95111	CA95SR06	NC	South Lake	35°53.59'	75°52.78'	7.4
CP95112	CA95LR17	NC	Pamlico Sound	35°49.84'	75°40.17'	280.0
CP95113	CA95LR16	NC	Pamlico Sound	35°43.85'	75°40.82'	280.0
CP95114	CA95SR11	NC	Pungo Creek	35°30.86'	76°38.38'	7.8
CP95115	CA95LR15	NC	Pamlico Sound	35°27.87'	75°34.52'	280.0
CP95116	CA95SR10	NC	Pongo River	35°26.96'	76°35.34'	108.3
CP95117	CA95LR14	NC	Pamlico Sound	35°25.87'	75°47.45'	280.0
CP95118	CA95SR08	NC	Wysocking Bay	35°25.30'	76°02.42'	16.3
CP95119	CA95LR13	NC	Pamlico Sound	35°24.26'	75°56.60'	280.0
CP95120	CA95SR12	NC	Durham Creek	35°22.73'	76°49.51'	3.5
CP95121	CA95RR02	NC	Pamlico River	35°22.48'	76°41.35'	150.1
CP95122	CA95RP02	NC	Pamlico River	35°22.32'	76°40.23'	R
CP95123	CA95LR12	NC	Pamlico Sound	35°22.03'	75°36.63'	280.0
CP95124	CA95RR01	NC	Pamlico River	35°21.47'	76°32.70'	208.7
CP95125	CA95LR11	NC	Pamlico Sound	35°21.04'	76°05.33'	280.0
CP95126	CA95SR09	NC	Juniper Bay	35°20.40'	76°15.13'	8.7
CP95127	CA95LR10	NC	Pamlico Sound	35°20.01'	76°18.31'	280.0
CP95128	CA95SP13	NC	Mouse Harbor	35°17.92'	76°29.42'	R
CP95129	CA95SR13	NC	Mouse Harbor	35°16.73'	76°29.44'	6.5
CP95130	CA95LR09	NC	Pamlico Sound	35°16.36'	75°53.21'	280.0
CP95131	CA95LR08	NC	Pamlico Sound	35°13.49'	76°09.11'	280.0
CP95132	CA95LR07	NC	Pamlico Sound	35°13.20'	75°51.15'	280.0
CP95133	CA95LR06	NC	Pamlico Sound	35°11.60'	75°46.73'	280.0
CP95134	CA95SR14	NC	Bonner Bay	35°08.90'	76°35.42'	4.7
CP95135	CA95LR05	NC	Pamlico Sound	35°04.94'	76°00.15'	280.0
CP95136	CA95RR03	NC	Neuse River	35°03.32'	76°30.30'	268.1
CP95137	CA95SR16	NC	Rattan Bay	35°02.78'	76°28.89'	5.0
CP95138	CA95SP14	NC	Bonner Bay	35°09.26'	76°35.97'	R
CP95139	CA95RR04	NC	Neuse River	35°00.52'	76°40.47'	144.3
CP95140	CA95SR15	NC	Adams Creek	34°55.31'	76°39.63'	8.9

TABLE 2-1. (Continued).

CPO Sta. No.	EMAP Sta. No.	State	Estuary	Latitude	Longitude	Area (km^2)
Base Sites (Continued)						
CP95141	CA95SR17	NC	Thorofare Bay	34°54.96'	76°20.16'	9.9
CP95142	CA95SR19	NC	Newport River	34°46.22'	76°41.11'	36.2
CP95143	CA95SR18	NC	Jarrett Bay	34°45.25'	76°29.75'	13.2
CP95144	CA95SR20	NC	White Oak River	34°41.53'	77°06.37'	19.7
CP95145	CA95SR21	NC	Stump Sound	34°28.76'	77°28.35'	10.7
CP95146	CA95SR22	NC	Cape Fear River	33°56.25'	77°58.85'	88.2
CP95147	CA95SP22	NC	Cape Fear River	34°02.01'	77°56.31'	R
CP95148	CA95SR23	NC	Shallotte River	33°55.11'	78°22.31'	4.2
CP95149	CA95SR24	SC	Winyah Bay	33°20.47'	79°16.45'	60.9
CP95150	CA95SR25	SC	South Santee River	33°09.29'	79°21.26'	9.0
CP95151	CA95SP27	SC	Ashley River	32°47.08'	79°57.94'	R
CP95152	CA95SR27	SC	Ashley River	32°47.03'	79°57.70'	13.4
CP95153	CA95SR26	SC	Hamlin Creek	32°46.96'	79°48.26'	3.5
CP95154	CA95SR28	SC	Parrot Point Creek	32°43.89'	79°52.89'	7.5
CP95155	CA95SR29	SC	North Edisto River	32°36.11'	80°14.20'	39.7
CP95156	CA95SR30	SC	South Edisto River	32°35.45'	80°23.90'	27.1
CP95157	CA95SR32	SC	Bull River	32°31.95'	80°34.29'	11.2
CP95158	CA95SR31	SC	Coosaw River	32°30.69'	80°36.34'	42.0
CP95159	CA95SR33	SC	Port Royal Sound	32°15.94'	80°41.66'	40.1
CP95160	CA95SR34	SC	Skull Creek	32°14.89'	80°45.15'	3.6
CP95161	CA95SR35	GA	Tybee Roads	32°04.82'	80°52.79'	48.0
CP95162	CA95SR36	GA	South Channel	32°01.54'	80°54.70'	6.3
CP95163	CA95SR37	GA	Bull River	31°59.17'	80°55.74'	8.5
CP95164	CA95SR38	GA	Ogeechee River	31°51.64'	81°06.51'	29.2
CP95165	CA95SR39	GA	North Newport River	31°41.36'	81°11.49'	28.1
CP95166	CA95SR40	GA	Mud River	31°29.61'	81°17.61'	10.4
CP95167	CA95SR41	GA	Hampton River	31°15.44'	81°19.56'	12.5
CP95168	CA95SR42	GA	Jointer Creek	31°04.32'	81°29.70'	25.5
CP95169	CA95SR43	GA	Cumberland River	30°55.59'	81°27.72'	27.3
CP95170	CA95SR44	FL	South Amelia River	30°33.55'	81°28.19'	9.9
CP95171	CA95SR45	FL	Saint Johns River	30°23.57'	81°33.22'	188.0
CP95172	CA95SR46	FL	Doctors Lake	30°08.11'	81°43.83'	14.3
CP95173	CA95SR47	FL	ICW-Northern	29°33.86'	81°11.09'	7.0
CP95174	CA95SR48	FL	Halifax River	29°14.38'	81°01.59'	28.5
CP95175	CA95RR18	FL	Indian River Lagoon	28°44.38'	80°47.77'	44.4
CP95176	CA95RP17	FL	Indian River Lagoon	28°30.11'	80°44.92'	R
CP95177	CA95RR17	FL	Indian River Lagoon	28°27.82'	80°44.36'	37.4
CP95178	CA95SP49	FL	Newfound Harbor	28°22.06'	80°40.86'	R
CP95179	CA95SR49	FL	Newfound Harbor	28°21.17'	80°40.43'	12.3
CP95180	CA95RR16	FL	Indian River Lagoon	28°17.60'	80°41.11'	37.7
CP95181	CA95RR15	FL	Indian River Lagoon	28°08.50'	80°37.08'	40.4
CP95182	CA95RR14	FL	Indian River Lagoon	27°59.61'	80°32.10'	36.3
CP95183	CA95RR13	FL	Indian River Lagoon	27°49.64'	80°27.04'	32.6

TABLE 2-1. (Continued).

CPO Sta. No.	EMAP Sta. No.	State	Estuary	Latitude	Longitude	Area (km^2)
Base Sites (Continued)						
CP95184	CA95RR12	FL	Indian River Lagoon	27°42.85'	80°23.97'	32.9
CP95185	CA95RR11	FL	Indian River Lagoon	27°34.67'	80°21.41'	33.3
CP95186	CA95RR10	FL	Indian River Lagoon	27°21.91'	80°15.93'	33.7
CP95187	CA95RP10	FL	Indian River Lagoon	27°20.74'	80°16.09'	R
CP95188	CA95RR09	FL	Indian River Lagoon	27°16.24'	80°13.32'	34.1
Supplemental Sites						
CP95ASM	–	SC	Ashley Marina - Ashley River	32°46.81'	79°57.28'	NA
CP95CB_	–	NC	Currituck Bank (NERRS Site)	36°24.00'	75°50.67'	NA
CP95CF_	–	NC	Cape Fear River	34°07.45'	77°55.64'	NA
CP95DIE	–	SC	Diesel Site - Ashley River	32°48.26'	79°57.96'	NA
CP95FOS	–	SC	Fosters Creek - Wando River	32°51.60'	79°51.27'	NA
CP95KIA	–	SC	Kiawah River	32°36.19'	80°07.92'	NA
CP95KOP	–	SC	Kopper's Site - Ashley River	32°49.71'	79°57.91'	NA
CP95LON	–	SC	Long Creek / Bohicket Creek	32°41.08'	80°07.38'	NA
CP95LTH	–	SC	Lighthouse Creek	32°42.14'	79°55.22'	NA
CP95MI_	–	NC	Masonboro Is. (NERRS Site)	34°09.33'	77°51.00'	NA
CP95NMK	–	SC	Newmarket Creek - Cooper R.	32°48.43'	79°56.44'	NA
CP95NV1	–	SC	Navy Base(North) - Cooper R.	32°52.03'	79°57.84'	NA
CP95NV2	–	SC	Navy Base(South) - Cooper R.	32°50.75'	79°55.99'	NA
CP95PR1	–	NC	Pamlico River	35°21.25'	76°39.15'	NA
CP95PR2	–	NC	Pamlico River	35°22.07'	76°37.01'	NA
CP95PR3	–	NC	Pamlico River	35°24.03'	76°45.08'	NA
CP95PR4	–	NC	Pamlico River	35°24.50'	76°46.48'	NA
CP95PR5	–	NC	Pamlico River	35°26.03'	76°49.53'	NA
CP95RC_	–	NC	Rachel Carson Reserve (NERRS)	34°42.67'	76°38.83'	NA
CP95SPY	–	SC	Shipyard Creek - Cooper River	32°50.33'	79°56.69'	NA
CP95ZI_	–	NC	Zeke's Island (NERRS Site)	33°57.33'	77°56.33'	NA

TABLE 2-2. Estuarine resources of the Carolinian Province.

	Province	Large [a]	Small [b]	Tidal [c]
All Years				
Number of Estuaries	200	3	194	3
Area Represented (km^2)	11,622.1	5,581.1	4,907	1,134
In 1995				
Number of Stations	88	16	55 [d]	17 [e]
Area Represented (km^2)	6,991.8	4,480.0	1,377.8	1,134

[a] Area > 260 km^2 and length/width aspect ratio < 20
[b] Area 2.6–260 km^2
[c] Area > 260 km^2 and length/width > 20
[d] Station count includes 6 replicate stations
[e] Station count includes 3 replicate stations

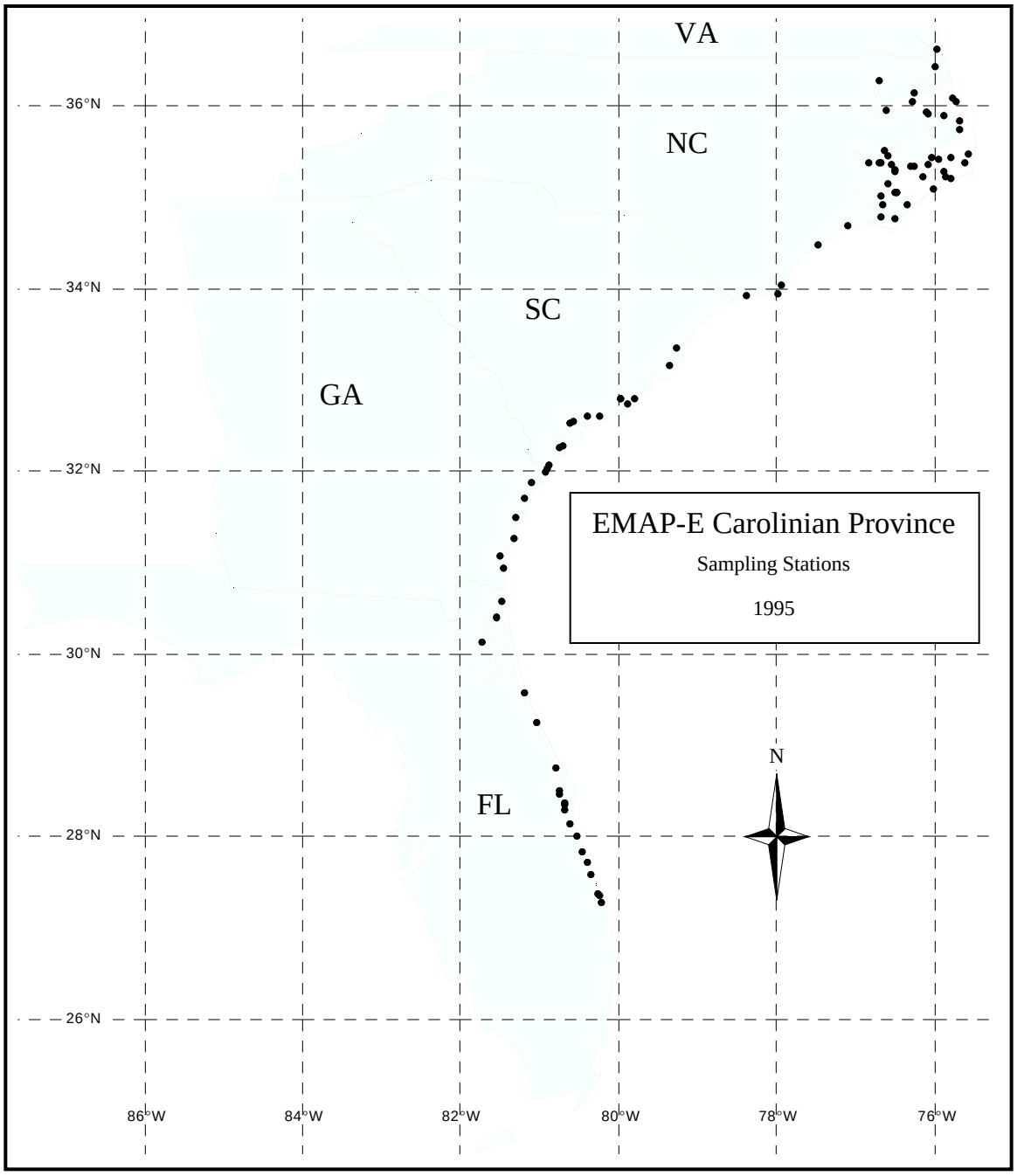

FIGURE 2-1. 1995 Carolinian Province sampling stations.

same spatial scale. Stratification by physical dimensions of an estuary was adopted because: (1) such attributes usually show minimal change over extended periods; (2) alternative classification variables such as salinity, sediment type, depth, and extent of pollutant loadings would result in the definition of classes for which areal extents could vary widely from year to year; (3) data for physically based classes can be aggregated into geographic units that are meaningful from a regulatory or general-interest perspective; and (4) estuarine boundaries can be delineated more readily and accurately from maps or charts of the physical dimensions of coastal areas than from maps of sediment or water-column characteristics.

Base sites in large estuaries were selected at random using a sampling grid approach similar to the one used in the EMAP Louisianian Province (Summers et al. 1993). A triangular lattice was placed initially over the study region and the resulting grid shifted randomly. A tessellation of the grid cells was performed next to partition the province into a series of contiguous hexagonal quadrats each with a surface area of 280 km^2. A station was then selected randomly from each of the hexagons coinciding with large estuaries. As a result of this process, 16 stations were established in large estuaries in 1995: 13 in Pamlico Sound, two in Albemarle Sound, and one in Currituck Sound (Table 2-1).

Base sites in large tidal rivers were selected randomly using a "spine and rib" approach, also similar to the one used in the EMAP Louisianian Province (Summers et al. 1993). The design is basically a linear analog of the sampling grid for large estuaries. Segments of equal length (25 km) were established within the tidally influenced estuarine portions of the rivers (river mouths inland to salinities of ~ 0.5 ‰). Because the Indian River (a bar-built estuary with several inlets along its axis) is tidally influenced throughout its length, ten segments were established along this 250-km large tidal river. For the Neuse and Pamlico Rivers, two segments were established between the mouth of each river and the inland boundary of saltwater influence. A minimum of one sampling station was then selected randomly within each segment of each river. In 1995, three river segments (one in the Pamlico River and two in the Indian River) were also replicated to provide estimates of within-segment spatial variability. As a result of this process, 17 stations were established in large tidal rivers in 1995: 12 in the Indian River, three in the Pamlico River, and two in the Neuse River (Table 2-1).

Base sites in small estuaries were selected using a random list-frame approach. Prior to the first year of sampling, a list frame of all 194 small estuaries was constructed with the individual estuaries ordered from north to south. A random starting point among the estuaries was selected. Beginning with that point, the estuaries were partitioned into spatial strata each composed of four neighboring small estuaries. This process continued until all estuaries on the list frame were partitioned. According to the design, each year over a four-year cycle, a new small estuary is chosen at random from the remaining unsampled estuaries comprising each group of four. An individual sampling site is then selected randomly for each estuary in a given year. Based on this process, 49 small estuaries, each with at least one randomly selected sampling site, were chosen for the summer 1995 sampling effort (Table 2-1). Six of these small estuaries were replicated (total of two sites per estuary) to support estimates of within-estuary variability. A similar list-frame approach was used in the EMAP Louisianian Province (Summers et al. 1993), except that in the latter case the starting position for grouping estuaries was not randomized.

Under the sampling design, a new set of random stations in each of the estuarine classes should be selected and sampled each year over a four-year cycle. The same stations sampled in any given year also are intended to be resampled every four years to facilitate unbiased estimates of temporal trends.

The data discussed in this report are based on samples collected July 5 – September 14, 1995. This time-frame was selected to coincide as much as possible with the index sampling period used in other EMAP-E provinces (typically between July 1 and September 30) and within which estuarine responses to potential anthropogenic and natural stresses are presumed to be the most pronounced.

2.2 Environmental Indicators

A standard series of environmental parameters was measured at each of the base stations to provide a consistent set of synoptic data for making province-wide estimates of estuarine condition. These "core" environmental indicators included measures of general habitat conditions, pollutant exposure, biotic integrity, and aesthetic quality (Table 2-3). Habitat indicators describe the physical and chemical conditions of sample sites, and provide basic information about the overall environmental setting. Exposure indicators provide measures of the types and amounts of pollutants, or other adverse conditions, that could be harmful to resident biota or human health. Biotic condition indicators provide measures of the status of biological resources in response to the surrounding environmental conditions. Aesthetic indicators provide additional measures of environmental quality from a human perceptual perspective. There is a fair amount of overlap among these various indicator categories. For example, some aesthetic indicators (presence of oil sheens, noxious sediment odors, and highly turbid waters) could also reflect adverse exposure conditions. Another example is dissolved oxygen (DO), listed as an exposure indicator because of the potential adverse biological effects of low oxygen concentrations, but which also is clearly a measure of general habitat conditions. These various core environmental parameters included ones used in other EMAP-E provinces (Strobel et al. 1994, Summers et al. 1993) to support regional comparisons and to provide a means for producing combined nationwide estimates of estuarine condition.

TABLE 2-3. Core environmental indicators for the Carolinian Province.

Habitat Indicators

- Water depth
- Water temperature
- Salinity
- Density stratification of water column
- Dissolved oxygen concentrations
- pH
- Percent silt-clay content of sediments
- Percent Total Organic Carbon (TOC) in sediments
- Sediment acid-volatile sulfides (Yr 2 only [*])

Exposure Indicators

- Low dissolved oxygen conditions
- Sediment contaminants (16 inorganic metals, 4 butyltins, 28 aliphatic hydrocarbons, 45 polynuclear aromatic hydrocarbons, 21 polychlorinated biphenyls, 24 pesticides)
- Contaminants in fishes and invertebrates (Yr 2 only)
- Sediment toxicity (*Ampelisca abdita* solid-phase, acute-toxicity test, Microtox® solid-phase, sublethal toxicity test)

Biotic Condition Indicators

- Infaunal species composition
- Infaunal species richness and diversity
- Infaunal abundance
- Benthic infaunal index
- Demersal species composition (fishes and invertebrates)
- Demersal species richness and diversity
- Demersal species abundance
- Demersal species lengths
- External pathological abnormalities in demersal biota

Aesthetic Indicators

- Water clarity (secchi depths)
- Anthropogenic debris (sea surface and in trawls)
- Noxious sediment odors (sulfides, petroleum)
- Oil sheens (sea surface and bottom sediments)

[*] Results not included in this report.

In addition to making the standard EMAP-E measurements, an emphasis was placed on developing and validating other complementary methods to aid in evaluating the quality of southeastern estuaries. Such indicators, some still in the development stage, are listed in Table 2-4. They include sediment bioassays with alternative test species, such as the amphipod *Ampelisca verrilli* as an alternative to *A. abdita* in standard 10-day solid-phase toxicity tests; assays with additional sublethal biological endpoints, such as effects on feeding, growth and fertilization success in key estuarine organisms; additional indices of environmental quality for tidal marshes and estuarine fish assemblages; and the incorporation of additional exposure indicators, such as porewater ammonia and hydrogen sulfide concentrations, to help in the interpretation of sediment toxicity results. Data from some of these "developmental" indicators (i.e., porewater ammonia and sulfide concentrations; results of *A. verrilli* and *M. mercenaria* assays) are used in the present report to help in interpreting conditions at base sites. Additional discussions of their sensitivity and overall utility as monitoring tools are planned for subsequent publications.

2.3 Procedures for Measuring Indicators

2.3.1 Habitat Indicators

2.3.1.1 Water Quality Parameters

Salinity (‰), pH, temperature (°C), dissolved oxygen (DO, mg/L), and water depth (m) were recorded electronically with a "Datasonde 3" (DS3) multiprobe data logger manufactured by Hydrolab Corporation. Both instantaneous and continuous records were made of these variables at each of the base stations. The instantaneous measurements were taken along surface-to-bottom depth profiles, at 1-m intervals for water depths > 3 m, and at 0.5-m intervals for depths < 3 m. Data were recorded on downcasts and upcasts. The continuous measurements were made from a single near-bottom depth at 30-min intervals over a minimum 24-h period. To make these latter measurements, the DS3 unit was placed inside a protective PVC sleeve, outfitted with a pinger, and deployed using either a mooring in the case of deep sites (> 3 m), or a stationary pole for shallower sites (< 3 m). Bottom depth also was recorded at each station with the boat's fathometer.

TABLE 2-4. Environmental indicators under development in the Carolinian Province.

Biotic Condition Indicators
• Benthic index of environmental quality for tidal marshes (incorporating attributes that reflect responses to pollutant stress independent of natural variations in salinity and elevation) *
• Index of environmental quality based on changes in fish parasite assemblages *
Exposure Indicators
• 10-day acute-toxicity sediment bioassay with alternative amphipod species, *Ampelisca verrilli*
• 1-week sublethal bioassay for testing effects of sediment exposure on growth of juvenile clams *Mercenaria mercenaria*
• 96-hour sublethal bioassay for testing effects of sediment exposure on feeding rates of *Ampelisca verrilli* *
• 1-hour sublethal bioassay using gametes of oysters *Crassostrea virginica* and clams *Mercenaria mercenaria* for testing effects of sediment exposure on fertilization success *
• Sediment porewater ammonia and hydrogen sulfide concentrations

* Results not included in this report.

Quality control procedures for water quality measurements included pre-deployment calibration of the Datasonde sensors against standards, and pre- and post-deployment precision checks based on side-by-side comparisons with other calibrated instruments. Maximum acceptable differences for these various quality control steps are summarized in Table 2-5. Range checks also were performed on all downloaded data to identify unacceptable or suspect values (outside expected environmental ranges). Range-check guidelines that were used are summarized by variable in Table 2-6.

2.3.1.2 Sediment Characteristics

At each station, subsamples of composited surface sediment (upper 2 cm) were collected with a 0.04-m^2 Young grab sampler to determine percent water content, percent silt-clay, and percent total organic carbon (TOC). Subsamples for these sediment characteristics were obtained from the same composite source used for the analysis of contaminants and toxicity testing (see next section). Multiple grabs were taken at each station to produce enough composited surface sediment (~ 8 L) to support all of the various kinds of sediment analyses (including toxicity testing and contaminant analysis). To collect this amount of sediment, usually about 20 grabs (range of 11–43) were required at sites in Florida and about 10 grabs (range of 7–13) were required at sites in remaining portions of the province. A 300 mL subsample of the composite was obtained for the analysis of percent water and percent silt-clay, and a 50-mL subsample was obtained for the analysis of percent TOC.

Procedures for analyzing sediment characteristics were based on the general protocols provided in the EMAP-E Laboratory Methods Manual (U.S. EPA 1993, 1994). Percent water was calculated as a loss in the weight of the sample after drying (60 °C) and correcting for

TABLE 2-6. Range-check guidelines for water quality variables.

Variable	Range
Temperature (°C)	19.0 – 33.0
Salinity (‰)	0.5 – 36.0
pH	5.0 – 9.0
Dissolved oxygen (mg/L)	0.3 – 12.0
Depth (m)	0.2 – 15.0

TABLE 2-5. Quality control tolerance ranges for Datasonde instrument calibrations and field measurements.

Frequency of Check	Parameter	Checked Against	Max. Acceptable Difference
Pre-survey Calibration	Temperature	Thermometer	± 1 °C
	Salinity	Standard seawater	± 0.2 ‰
	DO	Manufacturer's setting	± 0.3 mg/L
	% Sat. DO	Manufacturer's setting	± 2.5 % (100–105% range)
	pH	pH buffer solution	± 0.1 pH units
Pre-Deployment Field Comparison	Temperature	Deployed vs. Back-up Datasondes	± 1 °C
	Salinity	Deployed vs. Back-up Datasondes	± 1 ‰
	DO	Deployed vs. Back-up Datasondes	± 0.3 mg/L
	pH	Deployed vs. Back-up Datasondes	± 0.3 pH units
Post-Deployment Field Comparison	Temperature	Deployed vs. Back-up Datasondes	± 1 °C
	Salinity	Deployed vs. Back-up Datasondes	± 1 ‰
	DO	Deployed vs. Back-up Datasondes	± 0.5 mg/L
	pH	Deployed vs. Back-up Datasondes	± 0.5 pH units

salt content. For percent silt-clay, sediment samples were first dispersed with sodium hexametaphosphate and then sieved through a 63-μ screen. Coarser sediments retained on the screen were dried (60 °C) and weighed. A 40-mL subsample of the filtrate also was dried (60 °C) and used to estimate the percent silt-clay relative to the total sample weight. Approximately 10% of each batch of samples analyzed by the same technician were re-analyzed as a quality control check for the analysis of percent water and percent silt-clay. Measurement differences could not exceed 10%.

Measurements of TOC were obtained from ~ 5 to 10 mg samples of dried sediment that were acidified (with 1M H_3PO_4) to remove carbonates, sonicated, and filtered. Filters containing the sediment were dried and combusted (Salonen 1979) on either a CHN or elemental analyzer to determine TOC concentration (expressed as percent TOC per gram of dried sediment). Portions of the TOC samples, one for each batch of 25 or fewer samples, were run in duplicate as tests of analytical precision. Measurement differences could not exceed 20%. Quality control procedures for TOC also included the analysis of acetanalide standards and certified reference sediments (e.g., BCSS-1 marine sediment from NRC).

2.3.2 Exposure Indicators

2.3.2.1 Dissolved Oxygen

Dissolved oxygen (DO) was measured at each of the base sites with Hydrolab DS3 data loggers as described above in Section 2.3.1. Data from both instantaneous depth profiles and continuous near-bottom records were obtained at each station where possible.

2.3.2.2 Sediment Contaminants

Organic and metal contaminants were measured in subsamples of composited surface sediment (upper 2 cm) from multiple benthic grabs collected at each of the base sites and selected supplemental sites. These subsamples (~ 300 mL for organics and ~ 150 mL for metals) were taken from the same sediment composite used for toxicity testing and the analysis of other physical/chemical characteristics (see Section 2.3.1.2). Stations were represented usually by unreplicated samples, with the exception of duplicates that were run for ~ 10% of the stations as part of the quality control program (see below). All contaminant analyses were performed at Texas A&M University.

A total of 16 inorganic metals, four butyltins, 27 aliphatic hydrocarbons, 44 polynuclear aromatic hydrocarbons (PAHs), 18 polychlorinated biphenyls (PCBs), and 24 pesticides were measured at each of the stations. Table 2-7 summarizes the measurement units, detection limits, analytical methods, and protocol references for each of these analyte groups.

Quality control procedures for the analysis of sediment contaminants consisted of: (1) participation in a series of intercalibration exercises (minimum of two intercalibrations per year for metals and three intercalibrations per year for organics); (2) continuous checks on analytical precision and accuracy from the analysis of Standard Reference Materials (SRMs) with each batch of samples; (3) initial and ongoing instrument calibration checks (ongoing checks performed minimally at the middle and end of each sample batch); (4) analysis of laboratory reagent blanks (one with each sample batch); (5) analysis of laboratory fortified sample matrix spikes and laboratory fortified sample matrix duplicates; (6) analysis of sample duplicates in ~ 10% of the samples (nine field sediment duplicates, five lab duplicates from splits of five of the nine field duplicates); and (7) analysis of internal surrogate and injection standards with each sample. With respect to the analysis of SRMs, if analytical results deviated by more than ± 20% from the certified values for metals, or by more than ± 30% for the organics in the SRM, then a re-analysis of those samples was required. These procedures are consistent with the general quality control requirements of both EMAP-E (Heitmuller and Valente 1993, see

Table 5-4 therein) and the NOAA National Status and Trends Program (Lauenstein and Cantillo 1993).

2.3.2.3 Amphipod Toxicity

The standard 10-day sediment bioassay with the marine amphipod *Ampelisca abdita* (ASTM 1993) has been used in other EMAP surveys, including the previous 1994 effort in the Carolinian Province. This bioassay was used again in 1995 to provide a basis for comparisons among provinces and between years within the Carolinian Province. However, because *Ampelisca abdita* proved to be relatively insensitive to sediment contaminants in prior surveys conducted in both the Carolinian and Louisianian Provinces (Hyland et al. 1996, Macauley et al. 1994), an additional amphipod assay with the congeneric species *Ampelisca verrilli* was included in the 1995 effort. Preliminary testing with *A. verrilli* and a subset of the 1994 sediment samples indicated that this species was more sensitive to sediment contamination than *A. abdita* (Ringwood et al. 1995). Furthermore, *A. verrilli* is a more common member of the infaunal benthos of southeastern estuaries.

TABLE 2-7. Summary of analytical methods for the analyses of contaminants in sediments.

Analyte	Target Detection Limits [a]	Units (dry wgt.)	Method [b]	Reference
Si	10,000	µg/g	FAA	Taylor and Presley 1993
Al	1500	µg/g	FAA	Taylor and Presley 1993
Fe	500	µg/g	INAA	Taylor and Presley 1993
Cr	5.0	µg/g	INAA	Taylor and Presley 1993
Zn	2.0	µg/g	FAA	Taylor and Presley 1993
Mn	1.0	µg/g	FAA	Taylor and Presley 1993
Cu	5.0	µg/g	GFAA	Taylor and Presley 1993
As	1.5	µg/g	INAA	Taylor and Presley 1993
Ni	1.0	µg/g	GFAA	Taylor and Presley 1993
Pb	1.0	µg/g	GFAA	Taylor and Presley 1993
Sb	0.2	µg/g	INAA	Taylor and Presley 1993
Se, Sn	0.1	µg/g	GFAA	Taylor and Presley 1993
Cd	0.05	µg/g	GFAA	Taylor and Presley 1993
Ag	0.01	µg/g	GFAA	Taylor and Presley 1993
Hg	0.01	µg/g	CVAA	Taylor and Presley 1993
Butyltins [c]	1.0	ng Sn/g	GC/FPD	Wade et al. 1990
PAHs [d]	5.0	ng/g	GC/MS-SIM	Wade et al. 1993
Aliphatics [e]	25	ng/g	GC/FID	Wade et al. 1994
Pesticides [f]	0.1	ng/g	GC/ECD	Wade et al. 1993
PCBs [g]	0.1	ng/g	GC/ECD	Wade et al. 1993

[a] Based on sample size of 0.2 g for metals and 15 g for organics.

[b] GC/ECD=Gas Chromatography/Electron Capture Detection; GC/MS-SIM=GC/Mass Spectroscopy - Selective Ion Monitoring Mode; GC/FID=GC/Flame Ionization Detection; FAA=Flame Atomic Absorption; GC/FPD=GC/Flame Photo Detection; INAA=Instrumental Neutron Activation Analysis.

[c] Butyltins: mono-, di-, tri-, tetra-

[d] PAHs: 44 parent compounds & alkylated homologues, Tot. PAHs

[e] Aliphatics: C10–C34 alkanes, Tot. Alk., pristane, phytane

[f] Pesticides: DDD (2,4′& 4, 4′), DDE (2,4′ & 4,4′), DDT(2,4′ & 4,4′), Total DDD/DDE/DDT, aldrin, chlordane (alpha-, gamma-, oxy-), dieldrin, heptachlor, heptachlor epoxide, hexachlorobenzene, BHC (or HCH; alpha-, beta-, gamma-, delta-), mirex, trans- & cis-nonachlor, endrin, endosulfan, toxaphene

[g] PCBs: Congener Nos. 8, 18, 28, 44, 52, 66, 101, 105, 188/108/149, 128, 138, 153, 170, 180, 187/182/159, 195, 206, 209, Tot. PCBs

Bioassays with both amphipod species were used to evaluate potential toxicity of sediments from all base sites and selected supplemental sites (predominately degraded ones). Procedures followed the general guidelines provided in ASTM Protocol E1367-92 (ASTM 1993) and the EMAP-E Laboratory Methods Manual (U.S. EPA 1994). This is an acute toxicity test which measures the effect of sediment exposure on amphipod survival under static conditions. Approximately 3–3.5 L of surface sediments (composite of upper 2 cm from multiple grabs) were collected for each type of assay from each station and stored in 3.7-L polyethylene jars at 4 °C in the dark until testing. Tests were conducted with subsamples of the same sediment on which analyses of contaminants and other sediment characteristics were performed. Wherever possible, sediment samples were tested within 30 days of collection as recommended in the EMAP-E protocol. Sediment holding times ranged from 5 to 33 days for the *A. abdita* tests and from 4 to 48 days for the *A. verrilli* tests.

The *A. abdita* tests were conducted by Science Applications International Corporation (SAIC) in Narragansett, Rhode Island. The *A. verrilli* tests were conducted by the Marine Resources Research Institute of the South Carolina Department of Natural Resources (SCDNR /MRRI) in Charleston, South Carolina. Animals were collected from unpolluted tidal flats in either the Pettaquamscutt River, Rhode Island (*A. abdita*) or the Folly River, South Carolina (*A. verrilli*). Prior to testing, the animals were acclimated at 20 °C for 2–9 days in the case of *A. abdita*, or for 2–4 days in the case of *A. verrilli*. During the acclimation period, the amphipods were fed the diatom *Phaeodactylum tricornutum*. Wherever possible, juvenile amphipods of approximately the same size (usually 3–5 mm in length for *A. abdita*, and 3–10 mm in length for *A. verrilli*) were used to initiate the tests.

The general health of each batch of amphipods was evaluated by a reference toxicity test (i.e., "positive control"). These tests were run in a dilution series with seawater (no sediment phase) and the reference toxicant sodium dodecyl sulfate (SDS). Tests for both species were run under static conditions in dark and followed the basic methods described by ASTM (1993). The exposure period was 96 h for *A. abdita* and 24 h for *A. verrilli*. The shorter exposure period was used for *A. verrilli* to match previous reference toxicant tests conducted with this species by MRRI. LC_{50} values were computed for each batch of test animals for comparison against background toxicity data on these same species and reference toxicant. Animals were not used in definitive tests with field samples unless acceptable reference toxicant results were obtained. A test was considered acceptable if the LC_{50} value was within ± 2 SD of the mean LC_{50} based on the preceding 20 (*A. abdita*) to 22 (*A. verrilli*) reference toxicant tests.

Treatments for the definitive tests with field samples consisted of a single concentration of each sediment sample (100% sediment) and a negative control [i.e., for *A. abdita*, sediment from the Central Long Island Sound (CLIS) reference station established by the U.S. Army Corps of Engineers, New England Division; for *A. verrilli*, sediment from the amphipod collection site]. A negative control was run with each batch of field samples (which ranged from 5 to 17 samples per batch for *A. abdita*, and 8–13 per batch for *A. verrilli*). The tests were conducted under static conditions at a temperature of 20 ± 1 °C and salinity range of 26–33 ‰ for *A. abdita* and 26–35 ‰ (with one outlier at 38 ‰) for *A. verrilli*. Twenty amphipods were randomly distributed to each of five replicates per each treatment including the control. Amphipods were not fed during the tests.

The negative controls provided a basis of comparison for determining statistical differences in survival in the field sediments. In addition, control survival provided a measure of the acceptability of final test results. Test results were considered valid if mean control survival (among the five replicates) was ≥ 85% and

survival in any single control chamber was ≥ 80%. Mean control survival ranged from 91 to 98% for tests with *A. abdita* (after repeating one of the test series) and 89 to 98% for tests with *A. verrilli*.

One-liter glass containers with covers were used as test chambers. Each chamber was filled with 200 mL of sediment and 600–800 mL of filtered seawater. The sediment was press-sieved through a 2.0-mm screen to remove ambient fauna prior to placing it in a chamber. All containers were illuminated constantly throughout the 10-day test to inhibit amphipod emergence from the sediment, thus maximizing exposure to the test sediment. Air was supplied using oil-free aerators and glass pipettes inserted into the test chambers. Water tables with recirculating chiller pumps were used to maintain constant temperatures (20 ± 1 °C). Daily recordings were made of temperature and the number of dead vs. living animals. On days two and eight, two of the five replicate chambers for each treatment were selected randomly and measured for salinity, dissolved oxygen, pH, and total ammonia in the overlying water.

At the conclusion of a test, the sediment from each chamber was sieved through a 0.5-mm screen to remove amphipods. The number of animals dead, alive, or missing was recorded. Sediments with missing *A. abdita* were preserved in formalin containing Rose Bengal stain and re-examined under a dissecting microscope to ensure that no living specimens had been missed. Animals still unaccounted for were considered to have died and decomposed in the sediment. Because of their larger size, *A. verrilli* were much easier to locate with the unaided eye. Thus, if any of these animals were missing after initial examination of the sieved sediment, then they were assumed to have died and decomposed.

Differences between survival of *Ampelisca abdita* in field versus control samples were evaluated by an unpaired heteroscedastic *t*-test run on untransformed percentage data, under the assumptions of normality and unequal variances. For *A. verrilli*, differences between field samples and controls were evaluated by either: (i) an unpaired homoscedastic *t*-test in cases of normal data with equal variances, or (ii) a Mann-Whitney *U*-test in cases of non-normal data or unequal variances. The *A. verrilli* comparisons also were performed on untransformed percentage data. For both bioassays, field samples were considered to be significantly toxic if mean survival in comparison to the corresponding negative control was < 80% and statistically different at $\alpha = 0.05$.

A variety of quality control procedures were incorporated to assure acceptability of amphipod test results and comparability of the data with other studies. As described above, these provisions included the use of standard ASTM and EMAP protocols, positive controls run with a reference toxicant, negative "performance" controls run with reference sediment, and routine monitoring of water quality variables to identify any departures from optimum tolerance ranges. In addition, during the first year of the program, an inter-laboratory comparison of results using the *A. abdita* assay was performed by the two participating testing facilities (SAIC and SCDNR/MRRI). Samples from two of the base sites collected in 1994 were tested by each facility. Results were highly comparable: mean survival in field samples relative to controls was 96% for both samples by one lab, and 98 to 100% by the other lab.

2.3.2.4 Microtox® Toxicity

A third bioassay used to measure potential sediment toxicity at all base sites and selected supplemental sites was the Microtox® solid-phase test with the photoluminescent bacterium *Vibrio fischeri* (formerly *Photobacterium phosphoreum*). This assay provides a sublethal measure of toxicity based on attenuation of light production by the bacterial cells due to exposure to the sediment sample (Bulich 1979, Ross et al. 1991, Microbics 1992 a and b). Microtox® has not been used in other EMAP-E provinces, but

its recent application in other coastal assessment programs suggested that it might be a useful tool to consider for the Carolinian Province. Small sample sizes (a 100-mL subsample of the composited surface sediment from each station) and a short processing time (20-min exposures) provide clear logistical advantages. Results of the Carolinian Province 1993 pilot study (Ringwood et al. 1996) and 1994 monitoring demonstration (Hyland et al. 1996) also suggested that this test is more powerful in its ability to discriminate between degraded and reference sites than the amphipod toxicity test.

Tests were conducted in duplicate following the "large-sample-size" protocol of Microbics Corporation (1992b). Wherever possible, sediment samples were tested within the recommended 10-d holding period. Actual holding times ranged from 1 to 20 d. A 7-g aliquot of each sediment sample was used to make a dilution series ranging from 0.01 to 10% sediment in a 2% saline diluent. A reagent solution containing the bacteria was then added to each sediment suspension. After a 20-min incubation period, a column filter was used to separate the liquid phase and bacterial cells from the sediment. Post-exposure light output in each of the filtrates was measured on a Microtox® Model 500 Analyzer. A log-linear regression model was used to determine an EC_{50} — the sediment concentration that reduced light production by 50% relative to a control (nontoxic reagent blank). EC_{50} values were corrected for percent water content and reported as dry-weight concentrations.

Assays were run with the reference toxicant phenol with each new batch of bacteria. These tests provided measures of the general quality of the bacterial populations, as well as the ability of the laboratory to produce results consistent with the expected phenol toxicity range (i.e., Microtox® EC_{50} values typically between 13–26 mg/L). Use of the standard Microtox® equipment and protocol helped to assure data comparability with results of other Microtox® studies.

2.3.2.5 Mercenaria Toxicity

A fourth sediment bioassay used in the 1995 survey was a 7-d sublethal test of the effects of sediment exposure on growth of juvenile *Mercenaria mercenaria* (referred to hereafter as "seed clams"). The seed-clam bioassay was developed during the Carolinian Pilot Study (Ringwood et al. 1996, Ringwood and Kepler In Press). Field-validation testing on a subset of the 1994 sediment samples indicated that this bioassay was a more sensitive indicator of sediment contamination than the *A. abdita* bioassay (Ringwood et al. 1995). There are other practical advantages. For example, newly metamorphosed clams exhibit very rapid growth, thus effects on growth can be detected within a short time frame. Second, because seed clams can be obtained from cultured populations (available approximately three months after fertilization), experiments can be conducted with animals of similar size, age, and pre-exposure histories. Third, a relatively small sample volume (500 mL) is required, thus minimizing sampling time and storage needs. Lastly, *Mercenaria* feed at the sediment-water interface, where maximum contaminant exposure would be expected. Thus, the bioassay is representative of a realistic exposure scenario.

Seed clams (~ 1 mm in length) were obtained from Atlantic Clam Farms, Folly Beach, S.C. Replicate subsets were dried and weighed to provide initial weight estimates. On the day before initiation of a test, sediment samples were sieved through a 500-µ screen (to remove ambient fauna) and distributed to the test chambers. Approximately 50 mL of sieved sediment were added to each of four replicate 250-mL beakers for each sediment sample. A negative control (same Folly River sediments used as controls in the *Ampelisca verrilli* assays) was run with each batch of field samples. Filtered seawater (1-µ filter), adjusted to 25 ‰ with deionized water, was added to each beaker to bring the total volume up to 200 mL. The sediment suspension was allowed to settle overnight and clams (30–

50 per replicate) were added the next day (which initiated the test).

Tests were conducted for seven days. All tests were conducted at room temperature (23–25 °C) under gentle aeration. Animals were fed three times throughout the test with a phytoplankton mixture consisting of equal volumes of *Isochrysis galbana* and *Chaetocerus gracilis*.

At the end of the 7-d exposure period, clams were sieved from the sediments, placed in clean seawater, and allowed to depurate for ~ 1 h. Clams were re-captured on a sieve and rinsed briefly with distilled water to remove excess salt. Dead clams were removed and not included in subsequent growth estimates (mortality rates generally were < 10%). The remaining live clams were dried overnight (60–70 °C), counted, and weighed on a microbalance. The pre- and post-exposure measurements were then used to determine growth rates, expressed as µg/clam/d. Effects of sediment exposure on growth rates were evaluated using either a *t*-test or Mann-Whitney *U*-test (when assumptions of the parametric test were violated). Samples were considered to be significantly toxic if mean growth rate in comparison to the control was < 80% and statistically different at $\alpha = 0.05$.

Each new batch of seed clams was evaluated for suitability and relative sensitivity with a reference toxicant test ("positive control"). These tests were run under static conditions, at room temperature, in a dilution series with 25 ‰ seawater (no sediment phase) and the reference toxicant cadmium. Treatments within each test consisted of a seawater control and four cadmium concentrations (25, 50, 100, 200 µg/L as $CdCl_2$). Each treatment was represented by 3–4 replicates. The effective Cd concentration that reduced growth by 50% (EC_{50}) relative to the seawater control was estimated by regression analysis.

2.3.2.6 Porewater Ammonia and Sulfide

Concentrations of ammonia and sulfide in porewater were measured from each of the sediment samples collected for the *Ampelisca verrilli* toxicity tests. Prior to initiating a test, a porewater sample was extracted by centrifuging a 50-mL subsample of the sediment. Both chemical parameters were measured spectrophotometrically with a Hach DR/700 colorimeter. Measurement of total ammonia concentrations followed the salicylate-cyanurate procedure in Hach (1994) which was adapted from the method of Bower and Holm-Hansen (1980). Unionized ammonia, the form considered the most toxic to aquatic fauna (U.S. EPA 1989), was calculated based on the total ammonia concentration and the corresponding salinity, pH, and temperature of the sample (Whitfield 1978, Hampton 1977). Measurement of hydrogen sulfide followed the methylene blue procedure in Hach (1994) which was adapted from APHA Standard Method 4500-S^{2-} (APHA 1989). Unionized H_2S, the form considered the most toxic to aquatic fauna (U.S. EPA 1976), was calculated based on the sulfide (S^{2-}) concentration, pH of the sample, and pK′ (ionization constant for H_2S) provided in Standard Method 4500-S^{2-}. Porewater ammonia and sulfide concentrations were used primarily to help interpret sediment toxicity results.

2.3.2.7 Station Classification Based on Exposure Data

A combination of chemical and toxicological criteria were used to group stations into degraded, undegraded, and marginal categories to help in evaluating potential relationships between biological and exposure conditions. Stations were considered to be "degraded" if: (1) there were relatively high concentrations of sediment contaminants (i.e., three or more contaminants in excess of lower, threshold ER-L/TEL sediment bioeffect guidelines, or one or more contaminants in excess of higher ER-M/PEL probable effect guidelines; see Section 3.2.3 for definition of these terms); or (2) there was low dissolved oxygen observed in the water

column (< 0.3 mg/L for any observation, < 2.0 mg/L for 20% or more of observations, or < 5.0 mg/L for all observations over a 24-hr time series); or (3) there was significant toxicity in two or more of the sediment bioassays. "Undegraded" sites had no contamination (as defined above), no evidence of adversely low oxygen levels (as defined above), and no toxicity in any of the assays. "Marginal" sites were those that showed significant toxicity in only one of the sediment bioassays and no accompanying adverse contaminant or DO conditions. Biotic condition indicators are discussed in relation to this station classification scheme in several places throughout the text.

2.3.3 Biotic Condition Indicators

2.3.3.1 Benthic Infaunal Indicators

Four replicate bottom grabs were collected from each station with a 0.04-m^2 Young grab sampler. Care was taken to avoid grabs that were partially filled, slumped or canted to one side, clogged with excessive amounts of shelly substrates, or overfilled to the point that sediment was being pushed through the top of the grab. Contents of the grabs were live-sieved in the field with a 0.5-mm mesh screen. Material retained on the screen was placed in plastic containers, fixed in 10% buffered formalin with rose bengal (to facilitate subsequent sorting), and transferred to the laboratory for further processing. Samples from Virginia and North Carolina sites were processed by the University of North Carolina-Wilmington, samples from South Carolina and Georgia sites were processed by SCDNR/MRRI, and samples from Florida sites were processed by FDEP/FMRI. Further details on infaunal sampling procedures are provided in the Carolinian Province Field Operations Manual (Kokkinakis et al. 1995a).

Once samples were received in the laboratory, they were transferred from formalin to 70% alcohol. Two of the four samples from each station were further processed to characterize the infaunal assemblages and the remaining two samples were archived (for possible future analysis). Samples were processed based on currently accepted practices in benthic ecology (e.g., Holme and McIntyre 1971) and on specific protocols described in the EMAP-E Lab Methods Manual (U.S. EPA 1994). Animals were sorted from sample debris under a dissecting microscope. Sorted specimens were identified to the lowest possible taxon, i.e. the species level wherever possible. As species were identified, and the number of individuals per each species recorded, they were placed back in 70% alcohol and archived permanently by species.

The data were used to compute numbers of species and individuals; the Shannon information function, H′ (Shannon and Weaver 1949); densities of dominant species; and percent abundance of key taxonomic or other functional groups (e.g., % pollution tolerant vs. sensitive species). Base 2 logarithms were used to calculate H′. The following taxonomic groups, though maintained in the species lists, were excluded from the various data analyses: meiofauna (e.g., nematodes, harpacticoid copepods, ostracods, kinorhynchs, turbellarians), pelagic fauna (e.g., cladocerans, calenoid copepods, chaetognaths), terrestrial fauna (e.g., adult stages of flying insects), and obvious epifaunal species (e.g., animals that attach directly to hard substrates, form clusters, or are highly motile).

Several steps were taken to assure data quality and comparability. Each technician responsible for sorting samples needed to demonstrate initial proficiency by removing ≥ 95% of the animals in each of five consecutive samples. Tests of ongoing sorting proficiency were performed by resorting 10% of the samples and checking to see that ≥ 95% of the animals in each sample had been removed by the original sorter. Species identifications were performed by skilled taxonomists using standard taxonomic keys and reference collections. To catch potential misidentifications, a minimum of 10% of the samples was checked by independent qualified taxonomists. Data corrections were incorporated as necessary. Lastly, species lists from the three participating taxonomy laborato-

ries were carefully cross-checked in the process of merging the information into a common province-wide benthic data base. Inconsistencies in coding and nomenclature were corrected as necessary.

2.3.3.2 Benthic Infaunal Index

The health of benthic communities has been characterized traditionally by biological variables such as abundance, biomass, diversity, and relative abundances of key indicator species. These variables have been used in numerous studies to document biological responses to contaminant exposure, organic over-enrichment, hypoxia events, and various other habitat changes. Prior EMAP-E monitoring efforts have demonstrated that combining multiple benthic attributes into a single index can provide an additional powerful tool for distinguishing between environmentally degraded and undegraded areas (Weisberg et al. 1992, Weisberg et al. 1997, Ranasinghe et al. in review, Engle et al. 1994).

EMAP-E efforts to develop a benthic index have followed two basic approaches. One, applied to data from both the Virginian Province (Weisberg et al. 1992) and Louisianian Province (Engle et al. 1994), produces a multivariate index from a combination of stepwise and canonical discriminant analyses. The second approach, applied to Virginian Province data from Chesapeake Bay (Weisberg et al. 1997) and New York/New Jersey Harbor (Ranasinghe et al. In review), is a variation of the Index of Biotic Integrity (IBI) developed originally for freshwater systems (Karr 1981, Karr et al. 1986, Karr 1991, Kerans and Karr 1994). This is a multimetric index of biotic condition that reflects the degree to which component measures of key biological attributes at a site deviate from corresponding optimum values expected under undisturbed conditions (based on the distribution of values at pristine or best available reference sites).

The modified IBI approach of Weisberg et al. (1997) was used to develop a benthic index for southeastern estuaries. Our goal was to develop an index that possessed the following features: (1) suitable for use throughout the region, (2) applicable to a broad range of habitats, (3) easy to understand and interpret, and (4) effective in discriminating between undisturbed and disturbed conditions associated with human influences.

Results of the 1994 survey (Hyland et al. 1996) indicated that several natural abiotic factors (salinity, latitude, silt-clay, and TOC) had strong influences on infaunal variables. In the IBI approach, an attempt is made to account for such variations by defining habitat-specific reference conditions at sites free of anthropogenic stress and then comparing conditions in samples with the expected reference conditions for similar habitat types. The basic steps used to develop the index involved: (1) defining major habitat types based on classification analysis of benthic species composition and evaluation of the physical characteristics of the resulting site groups; (2) selecting a development data set representative of degraded and undegraded sites in each habitat (3) comparing various benthic attributes between reference sites and degraded sites for each of the major habitat types; (4) selecting the benthic attributes that best discriminated between reference and degraded sites for inclusion in the index; (5) establishing scoring criteria (thresholds) for the selected attributes based on the distribution of values at reference sites; (6) constructing a combined index value for any given sample by assigning an individual score for each attribute, based on the scoring criteria, and then averaging the individual scores; and (7) validating the index with an independent data set.

Data from undegraded sites sampled in 1993 and 1994 were first analyzed using classification (cluster) analysis of benthic species composition and evaluation of the physical factors associated with the resulting station clusters to define major habitat types. Several types of cluster analyses were performed. The one that produced the clearest results was a normal (Q-mode) analysis

run on log_{10}-transformed data with flexible sorting as the clustering method and Bray-Curtis similarity as a resemblance measure (see Boesch 1977). Differences in abiotic factors (salinity, latitude, % silt-clay, TOC) among the resulting station clusters were examined by ANOVA and pair-wise multiple comparison tests (Duncan's test and Tukey's HSD) to help delineate the major habitat types. Four site groups resulted: oligohaline–mesohaline stations (≤ 18 ‰) from all latitudes, polyhaline–euhaline stations (> 18 ‰) from northern latitudes (> 34.5° N), polyhaline–euhaline stations from middle latitudes (30–34.5° N) and polyhaline-euhaline stations from southern latitudes (< 30° N).

Seventy-five stations sampled during the 1994 survey were selected for the development data set (Table 2-8). These stations provided data from both degraded and undegraded sites in each of the four habitats. Classification of stations into degraded and undegraded categories was based on the combination of chemical and toxicological criteria (discussed above in Section 2.3.2.7. Marginal sites (minor evidence of stress with toxicity in only one assay and no accompanying adverse contaminant or DO conditions) were not included in the development data set.

Forty different infaunal attributes were tested with the 1994 development data set to determine those that best discriminated between undegraded and degraded sites within each habitat. This initial list of attributes included various measures of diversity, abundance, dominance, and presence of indicator species (e.g., pollution-sensitive vs. pollution-tolerant species, surface vs. subsurface feeders). A subset of six candidate metrics was identified for possible inclusion in the index. Key criteria considered in the selection were whether differences were in the right direction and statistically significant (based on results of Student t-tests, Mann-Whitney *U*-tests, and Komogorov-Smirnov two-sample tests; at $\alpha = 0.1$). These six metrics were: mean number of taxa, mean abundance (all taxa), mean H′ diversity, 100 - % abundance

TABLE 2-8. Test data set for development of the benthic index. All stations were sampled during the summer 1994.

Undegraded Sites		Degraded Sites	
Oligo. – Mesohaline [a], All Latitudes			
CP94038	CP94071	CP94016	CP94067
CP94061	CP94072	CP94017	CP94069
CP94064	CP94084	CP94053	CP94082
CP94065	CP94CF_	CP94054	
CP94068	CP94ES4	CP94062	
CP94070		CP94066	
Poly. – Euhaline [b], Northern Latitudes [c]			
CP94030	CP94044	CP94036	
CP94031	CP94045	CP94047	
CP94032	CP94046	CP94051	
CP94033	CP94049	CP94052	
CP94035	CP94050		
CP94037	CP94055		
CP94039	CP94056		
CP94040	CP94057		
CP94041	CP94058		
CP94042	CP94059		
Poly. – Euhaline [b], Middle Latitudes [d]			
CP94018	CP94076	CP94077	
CP94019	CP94078	CP94DSL	
CP94021	CP94079	CP94NMK	
CP94024	CP94080		
CP94026	CP94081		
CP94027	CP94083		
CP94029	CP94JAC		
CP94073	CP94LTH		
CP94074	CP94MI_		
CP94075			
Poly. – Euhaline [b], Southern Latitudes [e]			
CP94004	CP94008	CP94002	
CP94005	CP94012		
CP94006	CP94013		
CP94007	CP94014		
Total (All Habitats)			
N = 58		N = 17	

[a] Salinity ≤ 18 ‰
[b] Salinity > 18 ‰
[c] Latitude > 34.5° N
[d] Latitude 30.0°–34.5° N
[e] Latitude < 30.0 N

of the two most numerically dominant species, and two different measures of % abundance of pollution-sensitive taxa.

Scoring criteria for each of these metrics were developed based on the distribution of values at undegraded sites: score of 1, if value of metric for sample being evaluated was in the lower 10th percentile of corresponding reference-site values; score of 3, if value of metric for sample was in the lower 10th–50th percentile of reference-site values; or score of 5, if value of metric for sample was in the upper 50th percentile of reference-site values. Scoring criteria were determined separately for each metric and habitat type. A combined index value was then computed for a sample by assigning a score for each component metric (based on the individual scoring criteria for the corresponding habitat type) and then averaging the individual scores. A combined score < 3 suggested the presence of a degraded benthic assemblage (some apparent level of stress to very unhealthy) given that its condition, based on the averaged metrics, deviated from conditions typical of the "best" (upper 50th percentile) reference sites.

Forty different combinations of the six candidate benthic metrics were further evaluated to determine which represented the best combined index. The metric combination that produced the highest percentage of correct classifications (i.e., agreement with predictions of sediment bioeffects based on the chemistry and toxicity data) was then selected to represent the final index. The resulting final index was the average score of four metrics: (1) mean abundance, (2) mean number of taxa, (3) 100 - % abundance of the top two numerical dominants, and (4) % abundance of pollution-sensitive taxa (i.e., percent of total faunal abundance represented by Ampeliscidae + Haustoriidae + Hesionidae + Tellinidae + Lucinidae + Cirratulidae + *Cyathura polita* + *C. burbanki*. Threshold values used to score each of these four component metrics for each of the habitat types are given in Table 2-9. The final combined index correctly classified 93% of the stations province-wide in the development data set and 75% of the stations in the independent validation data set (Table 2-10).

Further discussions of the efficiency of this index and results of its application to the present 1995 survey data are presented in Section 3.3.3.

2.3.3.3 Demersal Species Indicators

Fishes and invertebrates (shrimp, crabs, and squid) were collected at each station with a 4.9-m otter trawl (2.5-cm mesh cod end) towed against the tidal currents. Tow duration was 10 min wherever possible and tow speed was 1–3 kts. Two tows were conducted at each station. Fishes and invertebrates captured in the trawls were carefully removed, sorted and identified to the lowest possible taxon (usually to species), enumerated, measured for length to the nearest mm, and examined for the presence of external pathological disorders. In cases where a species was caught in excessive numbers, a minimum subsample of 30 individuals was measured for length. Specimens were examined for the following types of pathological disorders: lumps due to internal growths, external growths or tumors, ulcers, fin erosion, shell disease in blue crabs, and cotton disease in shrimp. Specimens with pathologies were preserved in the field (Dietrich's solution for fishes and freezing for crustaceans) and transferred to independent specialists for confirmation (fishes: Dr. J. Fournie, EPA-Gulf Breeze, FL; crustaceans: Dr. E. Noga, NC State University, and Dr. Miriam Rodon-Naveira, EPA-RTP).

Several quality control measures were incorporated. To help assure that the biota were identified accurately, all field crews had at least one member on board familiar with the species that were likely to be caught in bottom trawls. In addition, species identifications were validated in the laboratory by examination of voucher specimens collected for each species encountered in the field. The quality of pathology data was checked as well. Subsamples of apparently non-diseased animals (~ 10

TABLE 2-9. Thresholds used to score each benthic index metric for the four habitat types.

Habitat	Metric	Scoring Criteria: 5 [f] Approximating conditions at best reference sites	3 [g] Deviating slightly from conditions at best reference sites	1 [h] Deviating greatly from conditions at best reference sites
Oligo. – Mesohaline [a], All Latitudes	Mean Number of Taxa (species richness)	> 8.50	8.50 – 7.00	< 7.00
	Mean Abundance (all taxa)	> 93.00	93.00 – 53.5	< 53.5
	100 - % Abun. of 2 Most Abundant Taxa	> 25.4545	25.4545 – 9.6234	< 9.6234
	% Abundance of Pollution-sensitive Taxa	> 5.0388	5.0388 – 0.60606	< 0.60606
Poly. – Euhaline [b], Northern Latitudes [c]	Mean Number of Taxa (species richness)	> 17.00	17.00 – 7.50	< 7.50
	Mean Abundance (all taxa)	> 109.75	109.75 – 26.0	< 26.0
	100 - % Abun. of 2 Most Abundant Taxa	> 51.5293	51.5293 – 28.9358	< 28.9358
	% Abundance of Pollution-sensitive Taxa	> 12.8288	12.8288 – 0	–
Poly. – Euhaline, Middle Latitudes [d]	Mean Number of Taxa (species richness)	> 23.00	23.00 – 6.25	< 6.25
	Mean Abundance (all taxa)	> 255.50	255.50 – 18.5	< 18.5
	100 - % Abun. of 2 Most Abundant Taxa	> 52.0416	52.0416 – 17.3624	< 17.3624
	% Abundance of Pollution-sensitive Taxa	> 12.2288	12.2288 – 1.61290	< 1.61290
Poly. – Euhaline, Southern Latitudes [e]	Mean Number of Taxa (species richness)	> 35.00	35.00 – 26.50	< 26.50
	Mean Abundance (all taxa)	> 301.00	301.00 – 112.5	< 112.5
	100 - % Abun. of 2 Most Abundant Taxa	> 61.1886	61.1886 – 52.8889	< 52.8889
	% Abundance of Pollution-sensitive Taxa	> 2.2185	2.2185 – 0.71174	< 0.71174

[a] Salinity ≤ 18 ‰
[b] Salinity > 18 ‰
[c] Latitude > 34.5° N
[d] Latitude 30.0° – 34.5° N
[e] Latitude < 30.0 N
[f] Metric value above 50th percentile of reference data values.
[g] Metric value between the 10th and 50th percentiles of reference data values.
[h] Metric value below 10th percentile of reference data values.

TABLE 2-10. Number and percent of sites correctly classified by the benthic index.

Habitat	1994 Development Data: # of Sites	1994 Development Data: % Correctly Classified	1993/1995 Validation Data: # of Sites	1993/1995 Validation Data: % Correctly Classified
Oligo. – Mesohaline [a], All Latitudes	20	90	46	78
Poly. – Euhaline [b], Northern Latitudes [c]	24	92	13	85
Poly. – Euhaline, Middle Latitudes [d]	22	95	27	74
Poly. – Euhaline, Southern Latitudes [e]	9	100	10	50
Overall (All Habitats)	75	93	96	75

[a] Salinity ≤ 18 ‰
[b] Salinity > 18 ‰
[c] Latitude > 34.5° N
[d] Latitude 30.0° – 34.5° N
[e] Latitude < 30.0 N

individuals of each of 5 target species at 10% of the stations) also were collected and examined by the pathology specialists to evaluate the potential error rate of the field crews with respect to missing abnormalities that may have been present (i.e., false negatives). Database entries for all trawl measurements were checked against the original field-recorded measurements (field sheets) and any inconsistencies were corrected.

2.3.3.4 Uptake of Contaminants by Demersal Species

Organic and metal contaminants were measured in the edible tissues of four commercially and recreationally important species (white shrimp, blue crab, croaker, and spot) collected in demersal trawls at selected degraded and undegraded sites (Table 2-11). Degraded stations were those with ≥ 3 contaminants in excess of ERL/TEL values, or ≥ 1 contaminant in excess of ER-M/PEL values. A minimum of three specimens of each species was combined into a single composite sample for each station. Wherever possible, animals of similar harvestable sizes were used to generate the sample composites. The edible parts used to form the composites consisted of fish fillets, shrimp tails, and the body-cavity meat of crabs.

Wet/dry weight ratio, lipid content, and contaminant concentrations were determined for each of the composited tissue samples. A total of 15 inorganic metals, 4 butyltins, 44 polynuclear aromatic hydrocarbons (PAHs), 18 polychlorinated biphenyls (PCBs), and 24 pesticides were measured in each of the crustacean samples. The same analytes, with the exception of PAHs, were measured in the fish samples (note that fish are known to metabolize PAHs). Table 2-12 summarizes the measurement units, detection limits, analytical methods, and protocol references for each of the analyte groups.

Quality control procedures similar to the ones discussed above for sediment analyses were applied to the analysis of contaminants in

TABLE 2-11. Samples of demersal biota collected for analysis of chemical contaminants in edible tissues. A minimum of 3 specimens of each species was combined into a single composite sample for each station. Level of sediment contamination at each station is indicated.

Demersal Species	Station Number	# Exceedances ERL/TEL, ERM/PEL		Pollution Status
White	CP95166	1,	6	D
Shrimp	CP95169	0,	6	D
	CP95164	3,	3	D
	CP95152	13,	1	D
	CP95172	9,	0	D
	CP95156	5,	0	D
	CP95165	1,	1	D
	CP95SPY (Rep.1)	5,	2 [a]	D
	CP95SPY (Rep.2)	5,	2 [a]	D
	CP95158	0,	0	U
	CP95162	0,	0	U
Blue	CP95165	1,	1	D
Crab	CP95166	1,	6	D
	CP95SPY (Rep.1)	5,	2 [a]	D
	CP95SPY (Rep.2)	5,	2 [a]	D
Croaker	CP95166	1,	6	D
	CP95169	0,	6	D
	CP95172	9,	0	D
	CP95114	3,	1	D
	CP95156	5,	0	D
	CP95SPY(Rep.1)	5,	2 [a]	D
	CP95SPY(Rep.2)	5,	2 [a]	D
	CP95117	2,	0	U
	CP95125	0,	0	U
	CP95115	0,	0	U
Spot	CP95114	3,	1	D
	CP95125	0,	0	U
	CP95115	0,	0	U

[a] Includes Cr at concentration of 20,660 µg/g, which is 56 times higher than the ER-M value of 370 µg/g.

TABLE 2-12. Summary of analytical methods for the analysis of contaminants in biological tissues.

Analyte	Target Detection Limits [a]	Units (dry wgt.)	Method [b]	Reference
Fe, Zn	50	µg/g	INAA	Taylor and Presley 1993
Mn, Cu	5.0	µg/g	FAA	Taylor and Presley 1993
Al	10	µg/g	GFAA	Taylor and Presley 1993
Pb	0.1	µg/g	GFAA	Taylor and Presley 1993
Cr	0.1	µg/g	INAA	Taylor and Presley 1993
As	2.0	µg/g	INAA	Taylor and Presley 1993
Ni	0.5	µg/g	GFAA	Taylor and Presley 1993
Cd	0.2	µg/g	GFAA	Taylor and Presley 1993
Sb	0.2	µg/g	INAA	Taylor and Presley 1993
Se	1.0	µg/g	INAA	Taylor and Presley 1993
Sn	0.05	µg/g	GFAA	Taylor and Presley 1993
Ag	0.01	µg/g	INAA	Taylor and Presley 1993
Hg	0.01	µg/g	CVAA	Taylor and Presley 1993
Butyltins [c]	10	ng Sn/g	GC/FPD	Wade et al. 1990
PAHs [d]	20	ng/g	GC/MS-SIM	Wade et al. 1993, 1994
Pesticides [e]	2.0	ng/g	GC/ECD	Wade et al. 1993, 1994
PCBs [f]	2.0	ng/g	GC/ECD	Wade et al. 1993, 1994

[a] Based on sample size of 0.2 g (dry wgt.) for metals and 10 g (wet wgt.) for organics.
[b] GC/ECD = Gas Chromatography/Electron Capture Detection; GC/MS-SIM = GC/Mass Spectroscopy - Selective Ion Monitoring Mode; FAA = Flame Atomic Absorption; GC/FPD = GC/Flame Photo Detection; INAA = Instrumental Neutron Activation Analysis
[c] Butyltins: mono-, di-, tri-, tetra-
[d] PAHs: 44 parent compounds & alkylated homologues, Tot. PAHs
[e] Pesticides: DDD (2,4′& 4, 4′), DDE (2,4′ & 4,4′), DDT(2,4′ & 4,4′), Total DDD/DDE/DDT, aldrin, chlordane (alpha-, gamma-, oxy-), dieldrin, heptachlor, heptachlor epoxide, hexachlorobenzene, BHC (or HCH; alpha-, beta-, gamma-, delta-), mirex, trans- & cis-nonachlor, endrin, endosulfan, toxaphene
[f] PCBs: Congener Nos. 8, 18, 28, 44, 52, 66, 101, 105, 188/108/149, 128, 138, 153, 170, 180, 187/182/159, 195, 206, 209, Tot. PCBs

tissues. As with the sediments, a Standard Reference Material (SRM) was run with each batch of tissue samples. SRM NIST 1974a (mussel tissue) was used for the analysis of organics. SRM NIST 1566a (oyster tissue), SRM NRCC DOLT2 (dogfish liver tissue), and SRM NRCC DORM2 (dogfish muscle tissue) were used for the analysis of inorganics.

2.3.4 Aesthetic Indicators

Four additional indicators provided measures of environmental quality important from a human aesthetic perspective. These indicators were presence of marine anthropogenic debris (observed either on the sea surface or in bottom trawls), presence of oil (observed either on the sea surface or in bottom sediments), noxious sediment odors (smell of sulfur, oil, or sewage in bottom sediments), and water clarity. A secchi disk was used to measure water clarity.

2.4 QA / QC

As described in the above sections on methods, a variety of quality control measures were incorporated to assure data reliability and comparability. Such provisions included rigorous staff training, the use of standard EMAP and other published protocols, routine instrument calibrations, measures of analytical accuracy and precision (e.g., analysis of standard reference materials, spiked samples, and field and laboratory replicates), measures of the quality of test organisms and overall data acceptability in sediment bioassays (e.g., use of positive and negative controls), range checks on the various types of data, cross-checks between original data sheets (field or lab) and the various computer-entered data sets, and participation in intercalibration exercises. Additional quality assurance elements for this program included an initial program-wide training workshop on all sampling and analysis requirements, program-wide audits of field and laboratory operations, documentation of chain-of-custody, and maintaining open lines of communication and information exchange. A full description of the quality assurance program is provided in Kokkinakis et al. (1995b).

2.5 Data Analysis

The principal approach used to analyze the various indicator data was the application of cumulative distribution functions (CDFs). This same approach has been used by other EMAP-E provinces (Strobel et al. 1994, Summers et al. 1993). The CDFs describe the full distribution of indicator values in relation to their areal extent across the province or a subcomponent of particular interest (e.g., geographic subregion or estuarine class). Approximate 95% confidence intervals for the CDFs also were computed based on estimates of variance.

CDFs and associated variances were estimated using statistical formulas appropriate for the type of estuarine class and corresponding sampling design. The CDF estimate for small estuaries, treated as discrete resources, was based on the following equation from Cochran (1977):

$$\hat{P}_{Sx} = \frac{\sum_{i=1}^{n} A_i \bar{y}_i}{\sum_{i=1}^{n} A_i}$$

where,

$\hat{P}_{Sx}$ = CDF estimate for value x

$\bar{y}_i = \frac{1}{m_i} \sum_{j=1}^{m_i} y_{ij}$

m_i = number of samples at small system i

$y_{ij} = \begin{cases} 1 \text{ if response is less than or equal to } x \\ 0 \text{ otherwise} \end{cases}$

A_i = area of small system i

n = number of small systems sampled.

Because small estuaries sampled in 1994 represented a subset of the total number of small estuaries present in the province, the following modification of the formula given in Cochran

(1977) was used to estimate variance (mean squared error, MSE):

$$MSE(\hat{P}_{Sx}) = \frac{\frac{N^2}{n}(1-f_1)\frac{\sum_{i=1}^{n} A_i^2(\bar{y}_i - \hat{P}_{Sx})^2}{n-1} + \frac{N}{n^*}\sum_{i=1}^{n^*}\frac{A_i^2 S_{2i}^2}{m_i}}{A^2}$$

where,

N = number of small estuaries in the province (194)

$f_1 = \frac{n}{N}$

n^* = number of small estuaries with replicate samples

$S_{2i}^2 = \frac{\sum_{j=1}^{m_i}(y_{ij} - \bar{y}_i)^2}{m_i - 1}$

A = the total area of small estuaries in the province (4907 km^2).

Estimates of CDFs for large tidal rivers, which were treated as extensive continuous resources, were obtained by applying the following Horvitz-Thompson estimator (Cochran 1977) using selection probabilities inversely related to station area:

$$\hat{P}_{Tx} = \frac{1}{A}\sum_{i=1}^{n}\frac{y_i}{\pi_i}$$

where,

$\hat{P}_{Tx}$ = Estimate CDF at value x

$y_i = \begin{cases} 1 \text{ if response is less than or equal to } x \\ 0 \text{ otherwise} \end{cases}$

π_i = inclusion probability for station i (1/area)

A = total area of sampled tidal rivers (1134 km^2)

n = number of stations sampled.

To produce unbiased estimates of variance, joint event probabilities π_{ij} must not be zero. The variance for the CDF estimates was obtained by applying the Yates-Grundy estimate of variance (Cochran 1977) and using approximate joint event probabilities (Stevens et al. 1991), as follows:

$$\hat{\text{var}}(\hat{P}_{Tx}) = \frac{1}{A^2}\sum_{i=1}^{n}\sum_{j>i}^{n}\left(\frac{\pi_i\pi_j - \pi_{ij}}{\pi_{ij}}\right)\left(\frac{y_i}{\pi_i} - \frac{y_j}{\pi_j}\right)^2$$

where,

π_{ij} = probability that sites i and j are selected for sampling

$\pi_{ij} = \frac{2(n-1)\pi_i\pi_j}{2n - \pi_i - \pi_j}$.

Formulas used to estimate CDFs and corresponding variances for large estuaries were the same as those presented above for large tidal rivers. Areas for all base stations in large estuaries were 280 km^2 (the size of hexagonal grid cell). The total sampled area for large estuaries in 1995 was 4480 km^2 (i.e., 16 hexagons each with an area of 280 km^2). Actual total area of large estuaries (not the area of hexagons sampled) is 5581.1 km^2.

Estimates of the CDFs across strata were computed as weighted averages of the relevant station class CDFs, as follows:

$$\hat{P}_x = W_S\hat{P}_{Sx} + W_T\hat{P}_{Tx} + W_L\hat{P}_{Lx}$$

where,

W_S = relative area of small estuaries

W_T = relative area of large tidal rivers

W_L = relative area of large estuaries.

The above variance estimates were used to calculate approximate 95% confidence intervals based on the formula:

$$\hat{P}_x \pm 1.96\sqrt{MSE(\hat{P}_x)}$$

In order to produce these confidence intervals it was assumed that the CDF estimates were distributed normally.

One way of presenting the CDF data was to produce plots with indicator values on the x-axis and the cumulative percentage of estuarine area on the y-axis. A CDF plot provides a direct means of assessing the range in indicator values across the province and portions of estuaries characterized by the individual values. In addition, the proportion of estuarine resources with indicator values above or below specific environmental guidelines (breakpoint values) can be determined directly from these plots. This can be a very useful management tool. For example, a CDF for dissolved oxygen (DO) could be used to determine the percent of estuarine bottom waters within the province that had DO concentrations below the general water quality standard of 5 mg/L adopted by many states.

Information from the CDFs also was presented as bar graphs to show percentages of estuaries with indicator values above or below specific guideline values. Wherever possible, published guidelines were used for this purpose. For example, sediment quality guidelines for chemical contaminants were based on the Effects Range Low (ER-L) and Effects Range Median (ER-M) values of Long et al. (1995, Long and Morgan 1990) or the comparable Threshold Effects Level (TEL) and Probable Effect Level (PEL) values of MacDonald (1994, MacDonald et al. 1996). Conditions were evaluated in relation to other more subjective criteria for some indicator variables (e.g., water clarity and most biotic condition indicators).

Correlation analysis also was conducted to examine the strength and direction of association between biotic condition indicators and various measures of exposure and habitat conditions. Data transformations were made to establish conditions of normality wherever possible. Pearson's product-moment correlation coefficient, r, and Spearman's correlation coefficient, r_s, were used for the analysis of normal and non-normal data, respectively, based on procedures provided in SAS (1989).

2.6 Unsamplable Area

One small estuary (Rattan Bay, NC, containing Station 137) could not be sampled because it was in a restricted military testing zone. This estuary represented 0.2% of the total area of the province. Another site in a small estuary (Station 144, White Oak River, NC) could not be sampled for sediment-related variables due to extensive oyster reefs in the area. This site represented 0.6% of the total area of the province. Dense algae and other bottom obstructions prevented successful trawling at Station 178 in Newfound Harbor, FL and Station 185 in Indian River, FL. These two sites represented 0.5% of the total area of the province. Remaining stations were samplable with respect to other core environmental indicators. However, due to instrument failures and other logistical problems, time-series records of dissolved oxygen were not obtained at three stations (114, 119, and 133) and secchi measurements were not taken at two stations (123 and 150).

3. INDICATOR RESULTS

3.1 Habitat Indicators

3.1.1 Water Depth and Tidal Range

Figure 3.1-1 shows the distribution of bottom depth in relation to the cumulative percent area of Carolinian Province estuaries. Because of the large tidal ranges that occur at many of these sites (discussed below), all depths were standardized to mean lower low water (MLLW) based on tidal prediction data from the nearest NOAA harmonic stations (Nautical Software 1995). MLLW-corrected depths ranged from 0 to 12.7 m. Most of these estuaries had fairly shallow depths: 89% had depths < 6.4 m (lower half of depth range). About 15% of the area of the province was represented by depths < 1 m, though all of these sites had at least 0.5 m of water at the time of sampling. Table 3.1-1 shows that the shallowest sites usually occurred in large tidal rivers (mean depth of 2.5 m and range of < 0.1–6.5 m) while the deepest sites were in small estuaries (mean of 3.3 m and range of < 0.1–12.7 m).

The maximum daily tidal range (max. – min. water depths recorded over at least a 12-h. observation period) at a station varied from < 0.1 to 3.8 m across the province (Fig. 3.1-2). At most stations these fluctuations were < 1 m over a minimum 12-h period. However, about 8% of the province was characterized by relatively large tides in excess of 2 m. These fluctuations were the most pronounced in the SC/GA portion of the province, where 49% of the area of these

TABLE 3.1-1. Mean, median, and range (min. – max.) by estuarine class for observations of depth, dissolved oxygen, salinity, temperature, and pH of bottom waters.[a]

		Estuarine Class			
Parameter	Statistic	All	Large	Small	Tidal
Depth [b] (m)	mean	3.2	3.2	3.3	2.6
	median	2.2	3.0	2.0	2.0
	range	(0.0-12.7)	(0.0- 6.3)	(0.0-12.7)	(0.6- 6.5)
Dissolved Oxygen (mg/L)	mean	5.8	6.7	5.8	4.9
	median	5.9	6.6	5.8	5.4
	range	(0.3-10.2)	(4.8- 8.3)	(0.3-10.2)	(1.1- 7.5)
Salinity (‰)	mean	19.2	18.6	19.1	19.8
	median	20.4	21.6	20.4	18.6
	range	(0.1-36.8)	(0.2-27.8)	(0.1-36.8)	(13.8-30.2)
Temperature (°C)	mean	28.5	27.8	28.4	29.5
	median	28.7	28.1	28.5	30.1
	range	(23.6-32.7)	(24.6-29.9)	(23.6-32.3)	(26.4-32.7)
pH	mean	7.8	8.0	7.7	7.8
	median	7.8	8.0	7.7	7.8
	range	(6.4- 9.1)	(7.5- 8.3)	(6.4- 9.1)	(7.2- 8.1)

[a] Based on instantaneous profile data at maximum recorded depth.
[b] Bottom depths based on instantaneous profile depths corrected to Mean Lower Low Water.

estuaries had tides > 2 m (Fig. 3.1-3). There were no SC/GA estuaries with tides < 1 m. Tidal ranges in large estuaries and large tidal rivers usually were under 1 m and never exceeded 2 m (Fig. 3.1-3). Such a pattern is consistent with the fact that both of these estuarine classes are represented entirely by estuaries outside SC/GA.

3.1.2 Salinity

Bottom salinities ranged from 0.1 to 36.8 ‰ across the province (Fig. 3.1-4, Table 3.1-1). Based on the Venice salinity classification system (Carriker 1967), 17% of these estuarine waters were oligohaline (< 5 ‰), 23% were mesohaline (5–18 ‰), 55% were polyhaline (> 18–30 ‰), and 5% were euhaline ("marine," > 30 ‰) (Fig. 3.1-5). Large tidal rivers consisted mostly of mesohaline and polyhaline waters (no oligohaline), large estuaries consisted mostly of polyhaline waters (no euhaline), and small estuaries were represented by a mix of all four salinity classes (Fig. 3.1-5). Polyhaline salinites dominated all three subregions (Fig. 3.1-5).

3.1.3 Water Temperature

Temperature ranged from 23.6 to 32.7 °C in bottom waters across the province (Fig. 3.1-6, Table 3.1-1). A majority of the province (62%) was characterized by temperatures within a narrow range of 27–30 °C. Temperatures (mean, median, and range) were slightly higher in large tidal rivers than in the other two, generally deeper, estuarine classes (Table 3.1-1). These temperatures are representative of the sampling period from July 5 to September 14, 1995.

3.1.4 pH

The pH of bottom waters ranged from 6.4 to 9.1 in estuaries throughout the province (Fig. 3.1-7, Table 3.1-1). Most of the province (93%) was characterized by pH within a narrow range of 7.3–8.3. Mean and median pH values showed little variation in relation to estuarine class (Table 3-1).

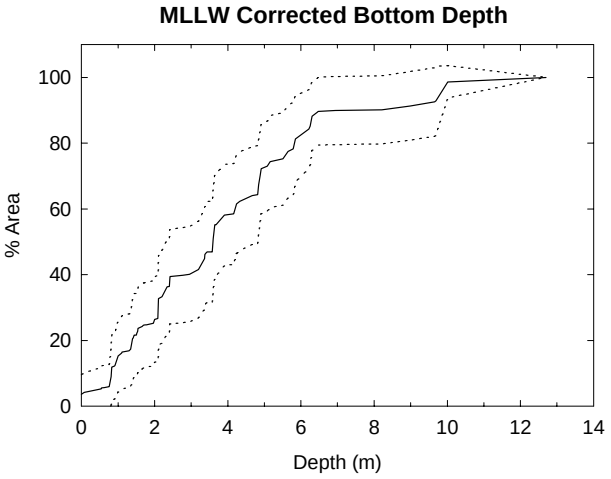

FIGURE 3.1-1. Percent area (and 95% C.I.) of CP estuaries vs. bottom depths converted to mean lower low water. Data are from instantaneous water column profiles.

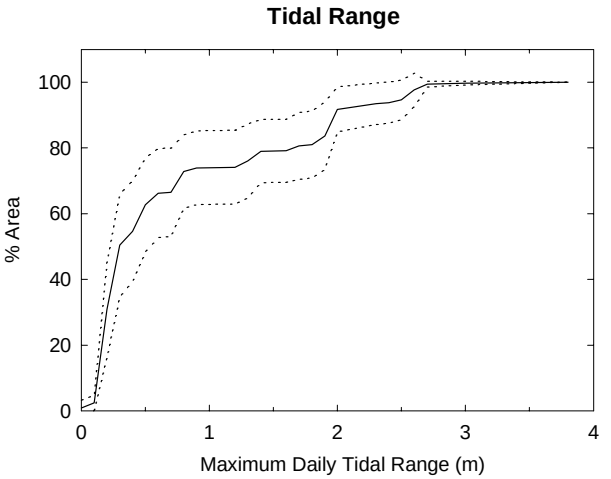

FIGURE 3.1-2. Percent area (and 95% C.I.) of CP estuaries vs. maximum daily tidal range (max.-min. water depths recorded over min. of 12-hr period at a station).

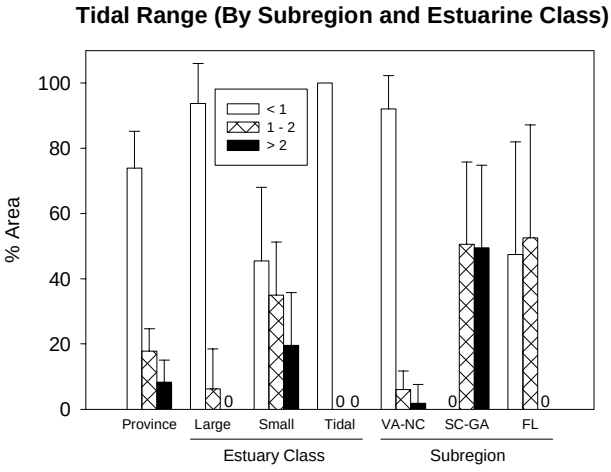

FIGURE 3.1-3. Comparison by subregion, and estuarine class, of CP estuaries with small (< 1 m), medium (1–2 m), or large (> 2 m) maximum daily tidal ranges.

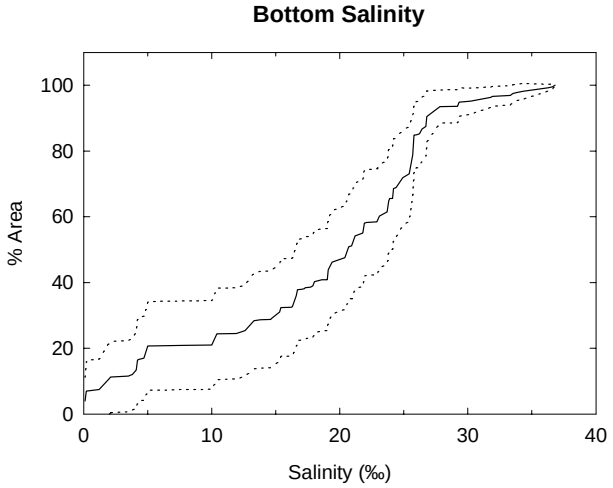

FIGURE 3.1-4. Percent area (and 95% C.I.) of CP estuaries vs. salinity of bottom waters. Data from instantaneous water column profiles.

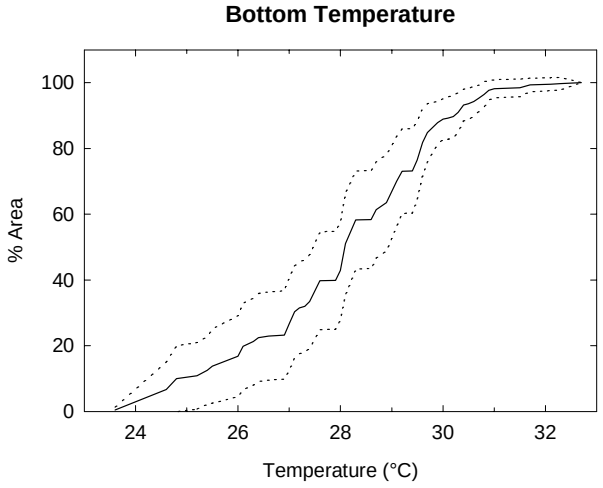

FIGURE 3.1-6. Percent area (and 95% C.I.) of CP estuaries vs. temperature of bottom waters. Data from instantaneous water column profiles.

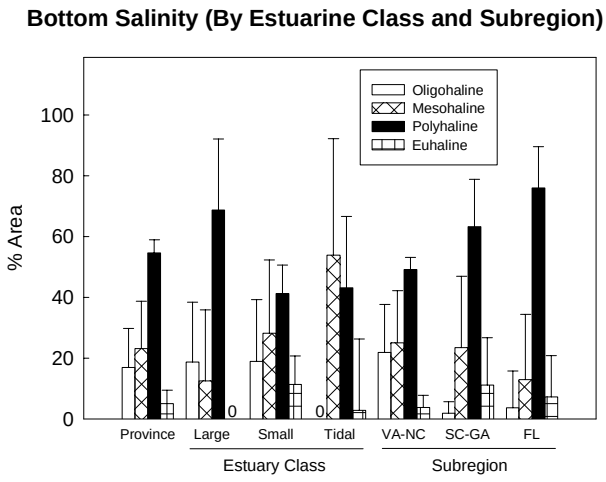

FIGURE 3.1-5. Comparison by estuarine class, and subregion, of CP estuaries with oligohaline (<5 ‰), mesohaline (5–18 ‰), polyhaline (>18–30 ‰), or euhaline (>30 ‰) salinity ranges in bottom waters. Data from instantaneous water column profiles.

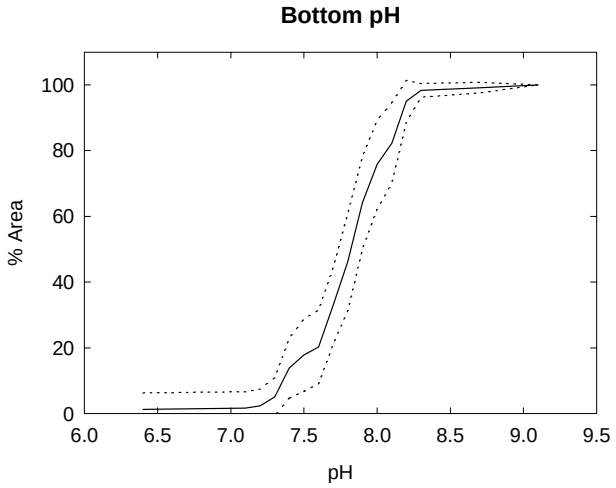

FIGURE 3.1-7. Percent area (and 95% C.I.) of CP estuaries vs. pH of bottom waters. Data from instantaneous water column profiles.

3.1.5 Percent Silt-Clay and TOC

Sediment characteristics such as grain size and organic content can have significant effects on the distribution of benthic species and on the concentrations and bioavailability of sediment associated contaminants. Higher percentages of sand, for example, may provide a greater number of microhabitats for interstitial species to exist and could increase sediment permeability allowing greater exchange of oxygen and nutrients at depth in the sediment (Hyland et al. 1991, Weston 1988). Grain size and organic content of sediments also are known to be strongly correlated with one another. Finer substrates tend to have a proportionally greater organic content than coarser sediments due to a higher surface-to-volume ratio of the sediment particles. There are logical functional links between benthic organisms and the presence of sediment organic matter as potential food sources. However, the higher surface-to-volume ratio of muds may also provide a greater surface area for sorption of chemical contaminants.

The percent silt-clay content of sediments ranged from 0.3 to 99.6% (Fig. 3.1-8, Appendix B). About 54% of the province was comprised of sands (< 20% silt-clay), about 19% was comprised of intermediate muddy sands (20–80% silt-clay), and about 27% was comprised of muds (> 80% silt-clay) (Fig. 3.1-9). Large estuaries were dominated by sands, while large tidal rivers were dominated by muds (Fig. 3.1-9). Small estuaries were represented by all three sediment categories in nearly equal proportions. By subregion, muddy substrates dominated FL sites and were absent at SC/GA sites. Sandy substrates dominated sites in VA/NC and SC/GA.

Percent TOC ranged from 0.04% to 14.8% (Fig. 3.1-10, Appendix B). Low to normal TOC levels (< 1%, *sensu* Summers et al. 1993) occurred in 57% of the province sediments. Higher levels (> 2%), suggestive of organic enrichment either from natural or anthropogenic inputs, occurred in 30% of the province. Such organically enriched substrates dominated estuaries within the large tidal river class (Fig. 3.1-11). Most large estuaries had low amounts of TOC, while small estuaries were represented by sediments with low and high TOC levels in nearly equal proportions. TOC > 2% was not found in any of the SC/GA estuaries.

Relationships between the silt-clay and TOC content of sediments and various biological, toxicological, and chemical variables are discussed below.

3.1.6 Density Stratification

Density stratification of the water column was measured as $\Delta\sigma_t$, the σ_t difference between surface and bottom waters, where σ_t is the density of a parcel of water with a given salinity and temperature relative to atmospheric pressure. Sigma-t is a commonly used measure of seawater density and can be computed from standard σ_t tables based on the observed salinity and temperature of the sample (e.g., Knauss 1978).

Stratification of the water column is an important factor to consider because, if large enough, it can restrict the normal mixing of bottom and oxygen-rich surface waters, allowing the bottom layer to become hypoxic or anoxic. Stratification also may create conditions favorable for phytoplankton growth in the surface layer (e.g., higher concentrations of nutrients) which could lead to subsequent increases in detrital loading and biological oxygen demand in the bottom layer.

The CDF for $\Delta\sigma_t$ (Fig. 3.1-12) included values ranging from - 0.16 to 14.75. The majority of these estuarine waters (77%) had $|\Delta\sigma_t|$ values < 1 unit (Fig. 3.1-13), suggesting relatively unstratified, well-mixed conditions. Nineteen percent showed high degrees of stratification (defined here as $|\Delta\sigma_t| > 2$). These more stratified waters were the least pronounced in large estuaries of NC. Similar percentages of stratified estuarine waters were observed both in the Virginia Province (13% for 1990 – 1993,

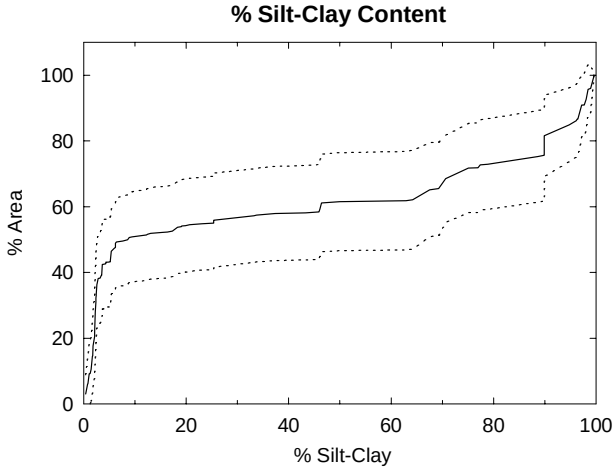

FIGURE 3.1-8. Percent area (and 95% C.I.) of CP estuaries vs. percent silt-clay content of sediments.

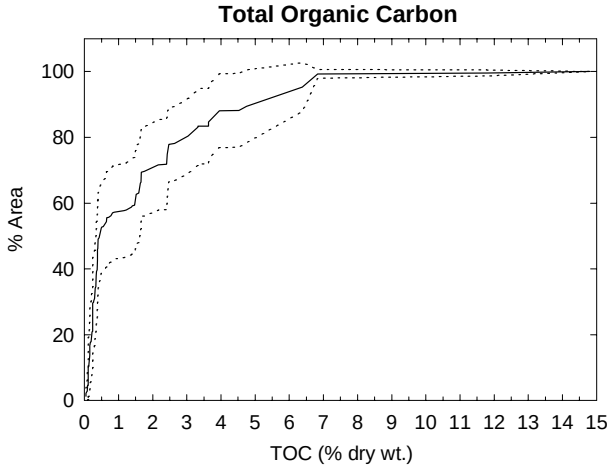

FIGURE 3.1-10. Percent area (and 95% C.I.) of CP estuaries vs. mean total organic carbon (TOC) in sediments.

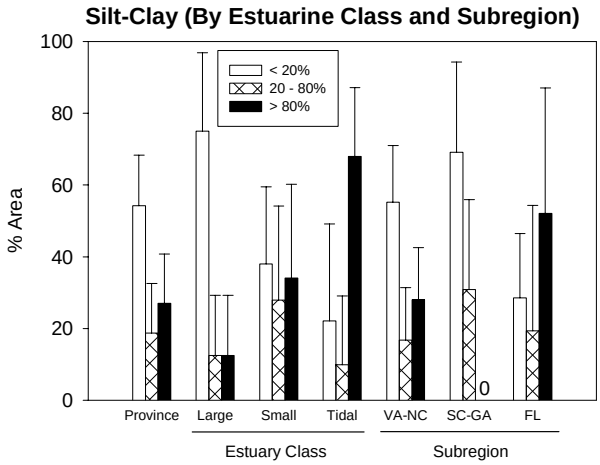

FIGURE 3.1-9. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low (<20%), moderate (20–80%), or high (>80%) silt-clay content of sediments.

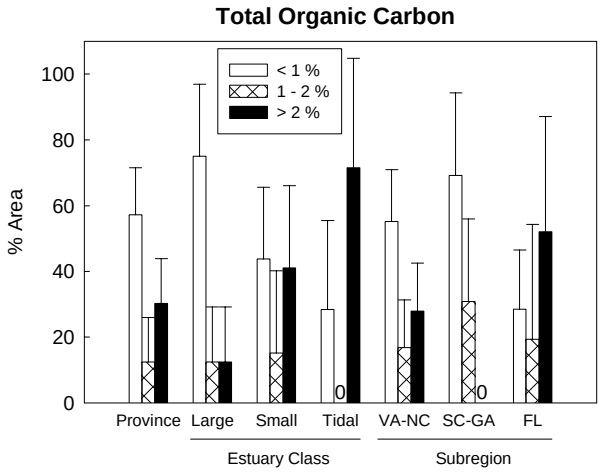

FIGURE 3.1-11. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low to normal (<1%), moderate (1–2%), or high (>2%) percentages of total organic carbon (TOC) in sediments.

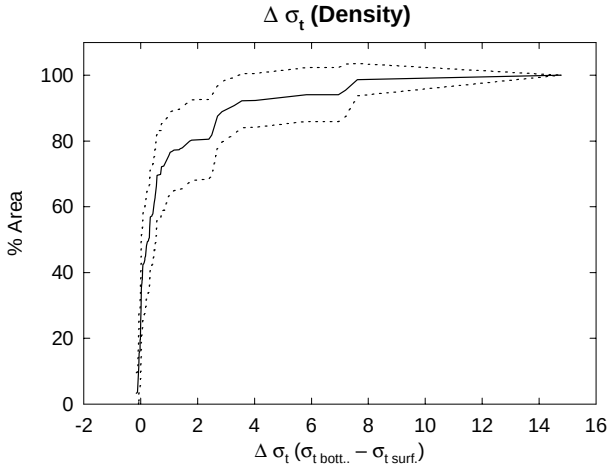

FIGURE 3.1-12. Percent area (and 95% C.I.) of CP estuaries vs. $\Delta\sigma_t$ (sigma-t density difference between bottom and surface waters).

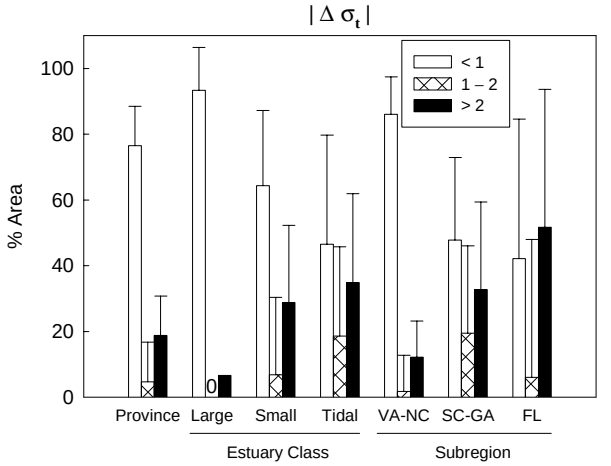

FIGURE 3.1-13. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low (<1), moderate (1–2), or high (>2) degrees of stratification ($|\Delta\sigma_t|$).

Strobel et al. 1995) and Louisianian Province (19% in 1993, Macauley et al. 1995).

Density patterns in relation to dissolved oxygen concentrations are discussed below in Section 3.2.1.

3.2 Exposure Indicators

3.2.1 Dissolved Oxygen (Instantaneous)

Dissolved oxygen (DO) is treated here as an exposure indicator because of the potential adverse biological consequences of low-oxygen conditions. Anoxic and severely hypoxic conditions can cause significant mortality in aquatic populations even over brief exposure periods. High benthic mortalities following periods of anoxia have been noted in the New York Bight (Falkowski et al. 1980, Swanson and Sindermann 1979) and Chesapeake Bay (Seliger et al. 1985). DO concentrations less than 0.21 mg/L have been shown to be lethal to a variety of benthic invertebrates in short-term laboratory exposures (Theede 1973). Extended exposure to less severe hypoxic conditions also can lead to longer-term chronic effects on survival. Hyland et al. (1991) found reduced numbers of benthic species and abundances off the coast of southern California at sites where DO concentrations were below ~ 2 mg/L. Rhoads et al. (1971) also noted that the diversity of benthic invertebrates in several oxygen-deficient marine basins drops markedly as oxygen falls below 1.43 mg/L. Many states have set water quality standards for DO at 5.0 mg/L to protect the more sensitive species and life stages.

DO concentrations in the Carolinian Province, based on instantaneous daytime measurements, ranged from 4.4 to 10.3 mg/L in surface waters (Fig. 3.2-1A) and from 0.3 to 10.2 mg/L in bottom waters (Fig. 3.2-1B, Table 3.1-1). Bottom DO concentrations were below the general water quality standard of 5 mg/L in 20% of the province, including sites in all estuarine classes and subregions (Fig. 3.2-2). Such conditions were the most pronounced in large tidal

rivers. DO concentrations < 2 mg/L (a more probable bioeffect range) were rare, found only in 3% of the province. Bottom DO concentrations in this lower range, based on instantaneous daytime records, were observed only in the Pamlico River and small estuaries of North Carolina. Due to the conditions observed in the Pamlico River, 32% of the large tidal river estuarine class exhibited low DO concentrations < 2 mg/L.

In most places, DO concentrations in surface and bottom waters were similar, reflecting the absence of significant water-column stratification at the time of sampling. As was discussed above (Section 3.1.6), highly stratified waters appeared in a moderately small percentage (19%) of these estuaries. Results of regression analysis did not reveal any strong variations in bottom DO concentrations, or surface-to-bottom differences in DO, as a function of density stratification (r^2 = 0.20 for $\Delta\sigma_t$ vs. bottom DO, and 0.17 for $\Delta\sigma_t$ vs. Δ_{DO}). Small surface-to-bottom differences in DO of < 1 mg/L were observed in 73% of the province (Fig. 3.2-3). Larger differences in excess of 1 mg/L were the most pronounced in large tidal rivers (Fig. 3.2-4). Thirty-two percent of the large tidal rivers exhibited major surface-to-bottom differences in DO > 5 mg/L. Such differences were limited to the VA/NC subregion.

A summary of the DO data by station, both from instantaneous and continuous records, is presented in Appendix A along with other water quality data.

3.2.2 Dissolved Oxygen (Continuous)

The continuous measurements provided a more complete record of DO conditions at a station including potential diurnal and tidal variations. Minimum near-bottom DO concentrations based on these records ranged from 0 to 10.6 mg/L across the province (Fig. 3.2-5), which was very close to the range of daytime instantaneous measurements (0.3–10.2 mg/L, Fig. 3.2-1B). Only three stations (CP95121,

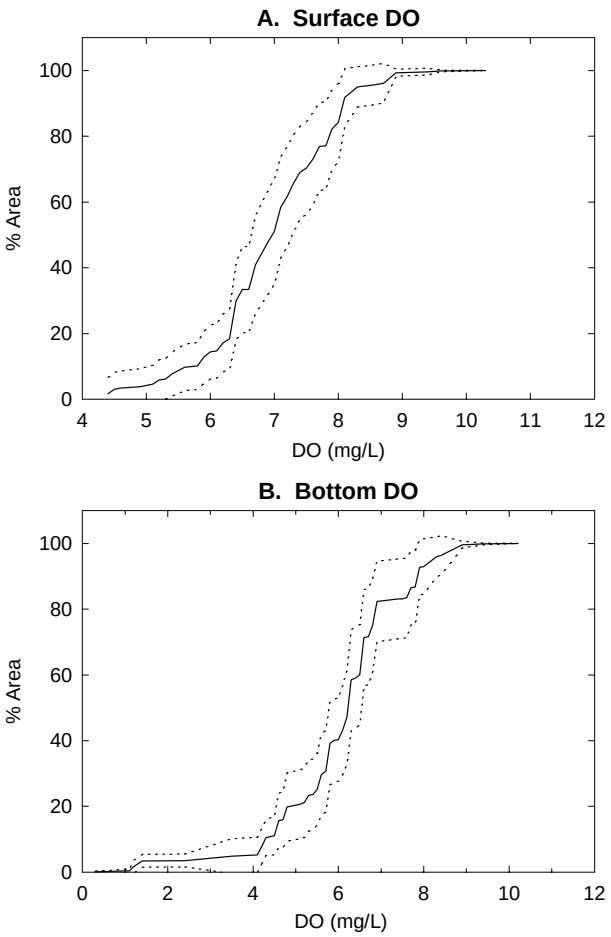

FIGURE 3.2-1. Percent area (and 95% C.I.) of CP estuaries vs. dissolved oxygen concentration in surface waters (A) and bottom waters (B) based on instantaneous water column profiles.

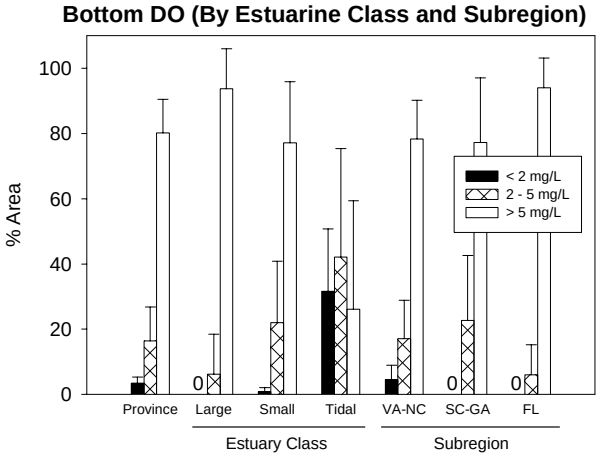

FIGURE 3.2-2. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low (<2 mg/L), moderate (2–5 mg/L), or high (>5 mg/L) DO in bottom waters. Data are from instantaneous water column profiles.

CP95122, CP95167) had minimum DO concentrations, based on the continuous records, that were below the range of instantaneous measurements. Estimates of the percentage of estuarine waters with bottom DO concentrations below the lower bioeffect criterion of 2 mg/L also were about the same for the two measurement techniques: 4% had DO < 2 mg/L based on continuous records (Fig. 3.2-5) and 3% had DO concentrations < 2 mg/L based on instantaneous records (Fig. 3.2-1B). The continuous records, however, did detect a higher percentage of stations with marginal DO conditions: 42% had DO < 5 mg/L based on continuous records and 20% had DO < 5 mg/L based on instantaneous records. Low-oxygen conditions were again the most pronounced in large tidal rivers (Fig. 3.2-6).

Sites were classified as degraded with respect to DO based on a combination of the following three criteria: DO < 0.3 mg/L at any time (to represent short-term exposure to severe hypoxic conditions), DO < 2.0 mg/L for more than 20% of the measurement period, or DO < 5.0 mg/L throughout the measurement period (to represent extended exposure to higher chronic effect levels). Only four sites (Station 124 and replicate Stations 121 and 122 in Pamlico River, NC; and Station 167 in Hampton River, GA) were classified as degraded based on these multiple criteria. These four sites represented only 3% of the total province area (Table 3.2-1). A similar small percentage of estuarine waters (5%) was classified as degraded based on these same criteria in 1994 (Hyland et al. 1996).

A wide range of DO patterns occurred in these estuaries. In some places, DO followed cyclical patterns consisting of both diurnal and tidal components. An example is provided by Station 154, in Parrot Point, SC, where the highest DO concentrations occurred at late afternoon to early evening during high tide and the lowest concentrations occurred during early morning low tides (Fig. 3.2-7A). Station 101 in Back Bay, VA, showed a simpler DO pattern consisting of large day-night variations without any significant tidal influences (Fig. 3.2-7B). In contrast, Station 165 in North Newport River, GA was characterized by a DO pattern that was primarily tidal driven (Fig. 3.2-7C). The contribution of the tidal component to variations in DO was the most pronounced in the SC/GA portion of the province, which is consistent with the greater tidal ranges observed in these estuaries relative to those in NC and FL (Section 3.1.1).

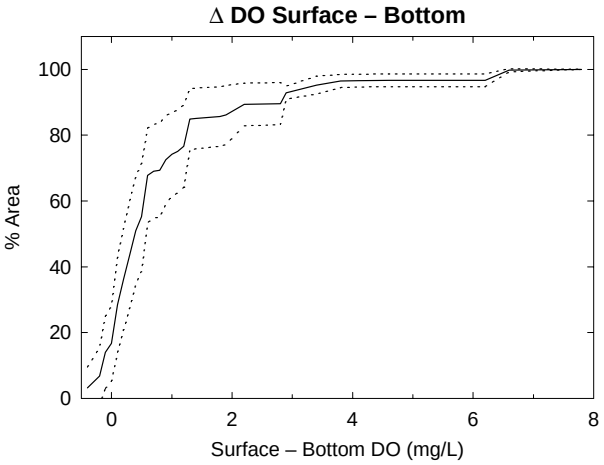

FIGURE 3.2-3. Percent area (and 95% C.I.) of CP estuaries vs. differences in DO concentrations between surface and bottom waters. Data from instantaneous water column profiles.

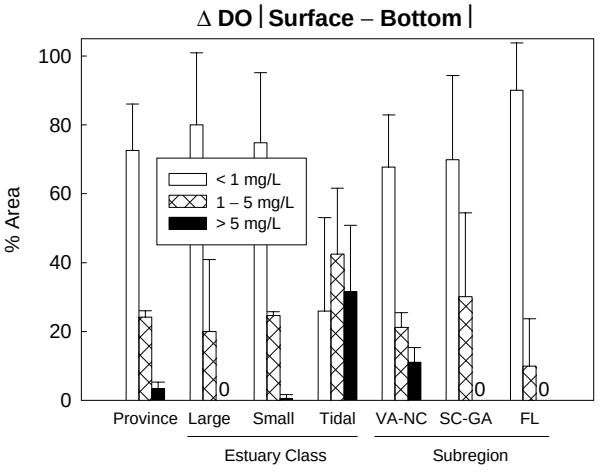

FIGURE 3.2-4. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low (<1 mg/L), moderate (1–5 mg/L), or high (>5 mg/l) differences in DO concentrations between surface and bottom waters ($|DO_{sur.}-DO_{bot.}|$). Data are from instantaneous water column profiles.

TABLE 3.2-1. Percent area (and 95% C.I.) of CP estuaries with significantly low DO concentrations: <0.3 mg/L at any time, or <2.0 mg/L for more than 20% of the measurement period, or <5.0 mg/L at all times throughout the measurement period. Data are from continuous near-bottom observations.

Estuary Class	# of Stations	% Area ± 95% C.I.
Province	4 [a]	3 ± 2
Large	0	0
Small	1	1 ± 2
Tidal Rivers	3 [a]	32 ± 14

[a] Station CP95121 and its replicate site CP95122 in the Pamlico River are both included in the number of stations reported.

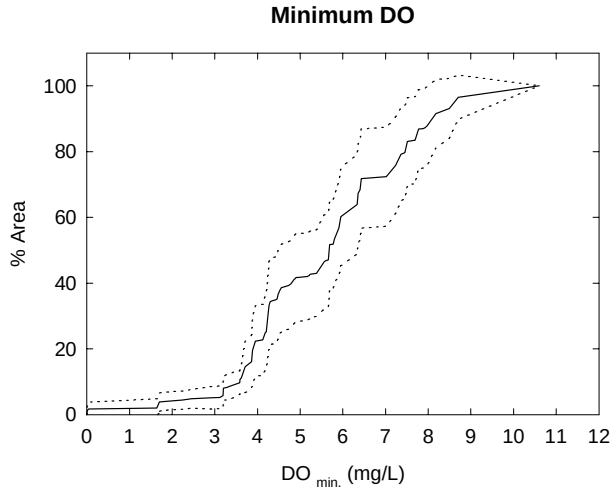

FIGURE 3.2-5. Percent area (and 95% C.I.) of CP estuaries vs. minimum near-bottom DO concentrations observed during continuous water-quality sampling.

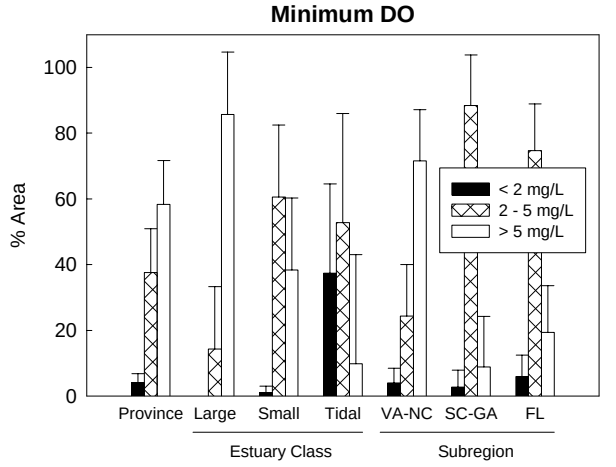

FIGURE 3.2-6. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low (<2 mg/L), moderate (2–5 mg/L), or high (>5 mg/L) minimum DO concentrations in bottom waters. Data are from continuous near-bottom data.

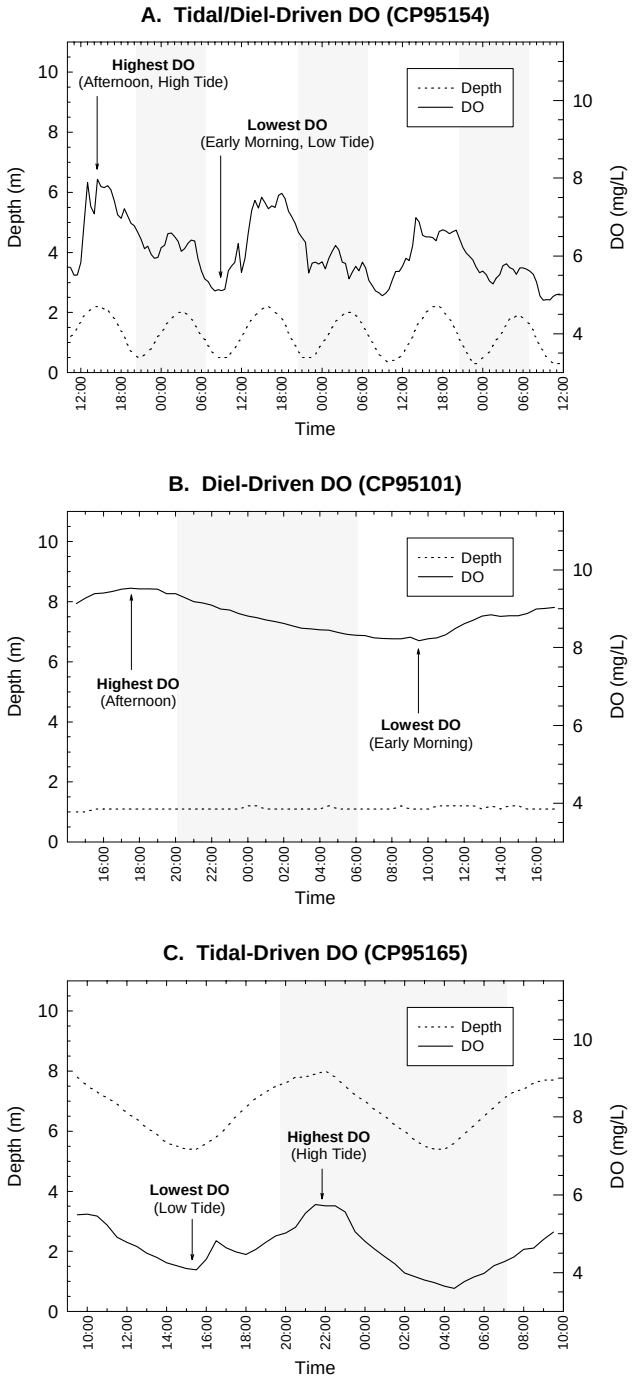

FIGURE 3.2-7. Variations in DO patterns in relation to (A) combined tidal/diel, (B) diel, and (C) tidal influences over time. Time from sunset to sunrise is shaded. Data are from continuous, near-bottom datasonde records.

3.2.3 Sediment Contaminants

Concentrations of selected sediment hydrocarbons, PCBs and pesticides, and metals are listed by station in Appendices C, D, and E, respectively. Contaminants that were present in excess of concentrations previously associated with adverse effects on marine biota have been highlighted. In most cases, the numerical values used for these comparisons were the Effects Range-Low (ER-L) and Effects Range-Median (ER-M) guidelines of Long et al. (1995, Long and Morgan 1990) or the comparable Threshold Effects Level (TEL) and Probable Effects Level (PEL) guidelines of MacDonald (1994, MacDonald et al. 1996). ER-M and PEL values both represent mid-range concentrations above which adverse effects on a wide variety of benthic organisms are likely to occur. ER-L and TEL values represent lower threshold levels below which bioeffects are rarely expected. Guideline values for each contaminant are included at the end of the appendices.

A summary of the number of base stations, and corresponding percent area of the province, that had contaminants in excess of the ER-L/TEL or ER-M/PEL Sediment Quality Guidelines (SQGs) is presented in Table 3.2-2. The ranges in concentrations observed among the various sites, along with the median and mean concentrations, are included for each of the contaminants. Comparisons were based on ER-L and ER-M values for the following chemicals: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[a]pyrene, dibenzo[a,h]anthracene, 2-methylnapthalene, total PAHs, total PCBs, 4,4′–DDE (p,p′–DDE), total DDT, silver, arsenic, cadmium, chromium, copper, nickel, lead, zinc, mercury, and antimony. TEL and PEL values were used for dieldrin, total chlordane, 4,4′–DDD (p,p′–DDD), 4,4′–DDT (p,p′–DDT), and lindane. SQGs for endrin, though available (Long and Morgan 1990), were not used in these comparisons because the ER-L value (0.02 ng/g) is below the method detection limits measured in this study (mean of 0.18 ng/g). Concentrations of endrin were below detection limits in most samples and below the ER-M value in all samples (Appendix D).

Over half of the province (54%) showed low levels of sediment contamination with all of the measured contaminants falling below corresponding threshold ER-L or TEL values (Fig. 3.2-8). Still, a sizable portion (30%, represented by 25 sites) showed high sediment contamination defined by the presence of three or more contaminants in excess of the lower ER-L/TEL values, or one or more contaminants in excess of the higher ER-M/PEL values. Sites with such exceedances represented a much smaller portion of the province (12%) in 1994 (Hyland et al. 1996). The association between sediment contamination and sampling year was statistically significant based on the Pearson chi-square test of independence (P = 0.005), suggesting that the percentage of estuaries with high sediment contamination was significantly higher in 1995 than in 1994. A discussion of this difference is included in Section 3.6 below.

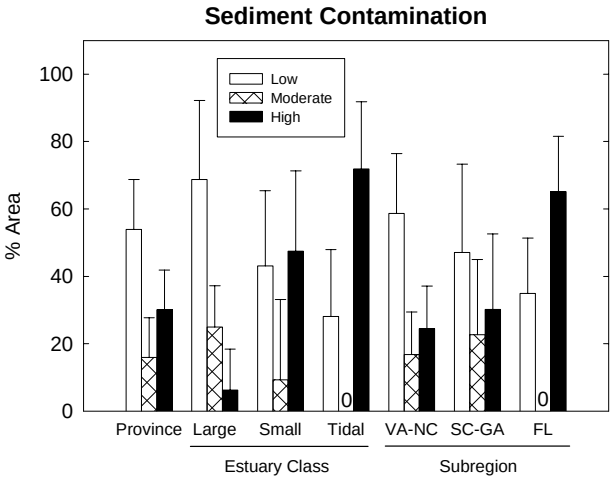

FIGURE 3.2.8. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low (no ER-L or TEL exceedances), moderate (1–2 ER-L or TEL exceedances), or high (≥3 ER-L or TEL exceedances, or ≥ 1 ER-M or PEL exceedances) levels of sediment contamination.

TABLE 3.2-2. Summary of contaminant concentrations in sediments at EMAP sites in the Carolinian Province in 1995. Number and % area (± 95% C.I.s) of stations with contaminant concentrations in excess of corresponding sediment quality guideline values also are given. [Actual bioeffect guideline values are included at the end of Appendices C, D, and E for hydrocarbons, PCBs and pesticides, and metals, respectively.] N.D. = Not detectable.

Contaminant	Median Conc.	Mean Conc.	Range (Min – Max)	ER–L / TEL exceedances No. Sites[e]	ER–L / TEL exceedances % Area	ER–M / PEL exceedances No. Sites	ER–M / PEL exceedances % Area
Metals (µg/g)							
Antimony	N.D.	0.15	N.D. – 0.90	0	0	0	0
Arsenic	2.98	4.65	N.D. – 22.29	18	32 ± 15	0	0
Cadmium	0.05	0.12	N.D. – 1.30	1	1 ± 2	0	0
Chromium	25.66	35.76	0.79 – 98.07	7	14 ± 11	0	0
Copper	2.54	6.80	0.52 – 35.41	1	3 ± 6	0	0
Lead	8.87	14.19	0.90 – 45.62	0	0	0	0
Mercury	0.02	0.04	N.D. – 0.19	2	1 ± 2	0	0
Nickel	3.75	8.10	0.50 – 40.30	12	23 ± 12	0	0
Silver	0.02	0.05	N.D. – 0.51	0	0	0	0
Zinc	25.74	42.95	5.83 – 156.73	1	4 ± 7	0	0
PAHs (ng/g)							
Acenaphthene	0.30	1.44	N.D. – 53.20	1	< 1 ± < 1	0	0
Acenaphthylene	0.35	3.33	N.D. – 56.30	1	< 1 ± < 1	0	0
Anthracene	0.50	5.19	N.D. – 142.40	1	< 1 ± < 1	0	0
Benzo[a]anthracene	1.30	19.68	N.D. – 333.20	2	< 1 ± < 1	0	0
Benzo[a]pyrene	1.75	27.33	N.D. – 685.90	1	< 1 ± < 1	0	0
Chrysene	1.85	26.92	N.D. – 620.50	1	< 1 ± < 1	0	0
Dibenz[a,h]anthracene	0.30	3.86	N.D. – 71.40	1	< 1 ± < 1	0	0
Fluoranthene	3.00	38.27	0.10 – 701.60	1	< 1 ± < 1	0	0
Fluorene	0.50	2.24	0.10 – 45.60	1	< 1 ± < 1	0	0
2–Methylnaphthalene	0.75	1.74	0.10 – 12.00	0	0	0	0
Naphthalene	2.90	5.92	1.10 – 39.90	0	0	0	0
Phenanthrene	1.15	8.13	0.20 – 114.60	0	0	0	0
Pyrene	3.45	80.37	0.30 – 3855.40	1	< 1 ± < 1	1	< 1 ± < 1
Total PAHs [a]	50.70	534.18	9.10 – 12307.90	2	4 ± 7	0	0
PCBs (ng/g)							
Total PCBs	4.15	8.27	2.22 – 80.88	5	11 ± 11	0	0
Pesticides (ng/g)							
Chlordane [b]	0.12	0.26	N.D. – 3.12	1	< 1 ± < 1	0	0
4,4'–DDD (p,p'–DDD)	0.03	3.30	N.D. – 150.91	13	11 ± 8	5	6 ± 8
4,4'–DDE (p,p'–DDE)	0.07	1.62	N.D. – 34.16	10	6 ± 4	2	1 ± 2
4,4'–DDT (p,p'–DDT)	N.D.	1.64	N.D. – 35.01	10	8 ± 8	6	3 ± 3
Dieldrin	N.D.	1.38	N.D. – 38.53	11	9 ± 8	5	3 ± 3
Lindane [c]	N.D.	1.20	N.D. – 30.52	15	12 ± 9	10	4 ± 4
Total DDT [d]	0.34	8.06	N.D. – 213.17	22	27 ± 12	4	2 ± 2

[a] without Perylene
[b] alpha–, gamma–, and oxychlordane
[c] gamma BHC (or HCH)
[d] all six DDD, DDE, and DDT congeners
[e] Note that ER-M/PEL exceedances are included in counts of ER-L/TEL exceedances.

As reported above, 25 of the 86 base stations with samplable substrates were classified as being contaminated based on the number of SQGs that were exceeded. The criteria used here for defining "high" sediment contamination (≥ 3 contaminants in excess of ER-L/TEL values or ≥ 1 contaminant in excess of ER-M/PEL values) seem reasonable given that these 25 stations represented over half (57%) of the sites in 1995 that showed evidence of a degraded benthos (low infaunal species richness, H′ diversity, abundance, or benthic index score, as defined in Sections 3.3.1–3.3.3 below).

Also, we now are in the process of examining the incidence of degraded benthic conditions in relation to ranges in mean SQG quotients (i.e., the mean of the ratios of individual contaminant concentrations in a sample relative to their respective ER-M or PEL values, *sensu* Long et al. 1998a). Preliminary results, based on data from over 200 sites sampled during the summers of 1994–96, have shown that 50% of the samples with a degraded benthos have a mean ER-M quotient of 0.052 (based on a best-fit curve applied to the data; the value changes slightly to 0.057 if raw data are used). The range is 0.0049–0.4381. No sample with a degraded benthos has a corresponding ER-M quotient > 1.0, the beginning of the range for "highly toxic samples" based on the broader national database discussed in Long et al. (1998a). Thus, for the EMAP-Carolinian samples, ER-M quotients ranging from about 0.05 to 0.5 appear to be indicative of "high" sediment contamination associated with a relatively high incidence of benthic impacts. Nearly the same list of samples (different by only about 5% of total samples) is produced when the above criteria for number of exceeded SQGs are used as the evaluation basis. These and related results are the subject of a separate publication currently in preparation. In the present report, further references to sediment contamination are based on the number of exceeded SQGs.

About 72% of the area of large tidal rivers was estimated as having high sediment contamination, based on the number of SQGs exceeded (Fig. 3.2.8). This relatively large proportion was due primarily to contributions of the Neuse River (Stations 136 and 139) and Pamlico River (Stations 121, 122, and 124). These two rivers accounted for 95% of the sediment contamination in the large tidal river class. In contrast, a very small proportion of large estuaries (6%) had high sediment contamination. High sediment contamination was found in about 48% of small estuaries, including sites in all three subregions. Most Florida estuaries (65% of area) had high sediment contamination (Fig. 3.2.8). In contrast, most estuaries in the VA/NC and SC/GA subregions (75% and 70%, respectively) had low to moderate levels of sediment contamination. As noted above, high sediment contamination was estimated to have occurred in about 30% of the total province area, or about 3,487 km^2. Of this total, about 60% was attributable to VA/NC estuaries, about 26% to FL estuaries, and about 14% to SC/GA estuaries (breakdown not shown in figures).

Dominant contaminants in the Carolinian Province in 1995 were arsenic, chromium, nickel, pyrene, total PCBs, DDT and derivatives, lindane, and dieldrin (Table 3.2-2). These contaminants were found either at concentrations in excess of ER-M/PEL values in at least one estuary (i.e., pyrene, DDT and derivatives, dieldrin, and lindane) or at concentrations in excess of the lower ER-L/TEL values in three or more estuaries (remaining ones). The most pronounced contaminant group was pesticides — especially lindane, DDT and derivatives, and dieldrin. Lindane, for example, was found at 10 stations in excess of the PEL value of 0.99 ng/g and at five additional stations in excess of the lower TEL value of 0.32 ng/g. Also, total DDT was found at four stations in excess of the ER-M value of 46.1 ng/g and at 18 additional stations in excess of the ER-L value of 1.58 ng/g. PCBs, dieldrin, DDT and derivatives, arsenic, chromium, and nickel also were dominant contaminants during the previous year of sampling (Hyland et al. 1996). However, in 1994, PCBs

rather than pesticides appeared to be the most pronounced contaminant group.

SQGs for total DDT (as well as a few other chemicals) have been shown to be relatively unreliable indicators of the concentration ranges probably, possibly, or not likely of being associated with adverse biological effects (Long et al. 1995, MacDonald et al. 1996). In fact, Fulton et al. (1997) found that ER-M and PEL values for total DDT (0.0461 and 0.0517 µg/g, respectively) are at least 100 times below LC_{50} values for copepods (> 10 µg/g), grass shrimp (4.5 µg/g), clams (5.8 µg/g), and amphipods (8.2–8.3 µg/g) in 10-d sediment exposures. Similarly, the lowest effect concentration in Microtox® assays in this latter study was > 10 µg/g. Thus, it is quite possible that samples with DDT levels within the ER-L to ER-M range, or slightly above it, would not be toxic to a variety of ambient biota. This point should be considered when evaluating toxicity in the present samples. However, note that present conclusions regarding province-wide sediment contamination would not change drastically even if DDT exceedances (relative to ER-L and ER-M values) were not considered at all. For example, there were 25 base stations classified as "highly contaminated," based on our criteria of ≥ 3 contaminants in excess of ER-L/TEL values or ≥ 1 contaminant in excess of ER-M/PEL values. Only four of these sites (Stations CP95136, CP95140, CP95171, and CP95174) would drop from the list if DDT exceedances were not included in the counts.

The range for arsenic was 0–20.5 µg/g in 1994 and 0–22.3 µg/g in 1995. This range included moderately high concentrations, above the ER-L value of 8.2 µg/g but below the ER-M value of 70 µg/g, at 13 of 82 stations in 1994 and at 18 of 86 stations in 1995. Windom et al. (1989) reported that southeastern estuarine and coastal sediments are enriched with arsenic relative to concentrations expected from average continental crustal rocks and soils and that these higher concentrations may be related to phosphate deposits that occur commonly throughout the region. Though present possibly as a result of such natural geologic processes, arsenic concentrations near the ER-L value have been shown to be toxic in laboratory bioassays. For example, Wirth et al. (1996) reported EC_{50} values of 7.2–12.17 µg/g for the commercially important oyster *Crassostrea virginica*.

Concentration ranges for all chemical analytes measured in this study are given in Appendix F. Comprehensive bioeffect guidelines, such as ER-L/TEL and ER-M/PEL values, do not exist for all of these analytes. The above estimates of uncontaminated vs. contaminated sediments do not account for such substances, even though they may have been present at concentrations well above detection limits at many of the sites. The "total alkane" parameter is an example. Sediment quality guidelines have not been established for total alkanes. Macauley et al. (1994) used a criterion of > 7000 ng/g to flag concentrations within a potential toxicity range for estuaries of the Louisianian Province. Nine stations in the Carolinian Province in 1995, representing 17% of the province, had concentrations of alkanes > 7000 ng/g (Fig. 3.2-9). Eight of these stations were in North Carolina, mostly in small estuaries and large tidal rivers. This result suggests that alkanes are present in some places at concentrations that could be causing or contributing to adverse biological effects. However, because the sediment bioeffect range for total alkanes is not clearly defined as yet, these data were not included in the above CDF estimates of contaminated vs. uncontaminated estuaries.

Another example of a contaminant with an uncertain bioeffect range in sediments is tributyltin (TBT), a compound found in antifouling paints. Though known to be highly toxic in the water column (Carr et al. 1987, U.S. EPA 1988), there are limited data on its toxicity in sediments. The EMAP-E program in the Louisianian Province used a criterion of > 5 ppb (expressed as ng Sn/g dry wt. sediment) to flag concentrations in a potential toxicity range (Macauley et al. 1994). Hyland et al. (1996)

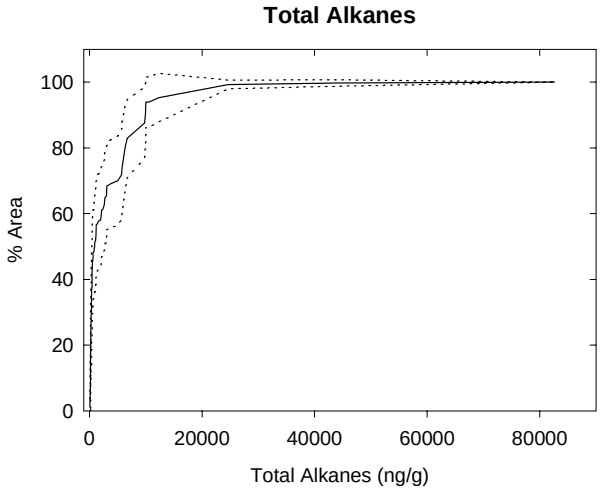

FIGURE 3.2-9. Percent area (and 95% C.I.) of CP estuaries vs. total alkanes concentrations in sediments.

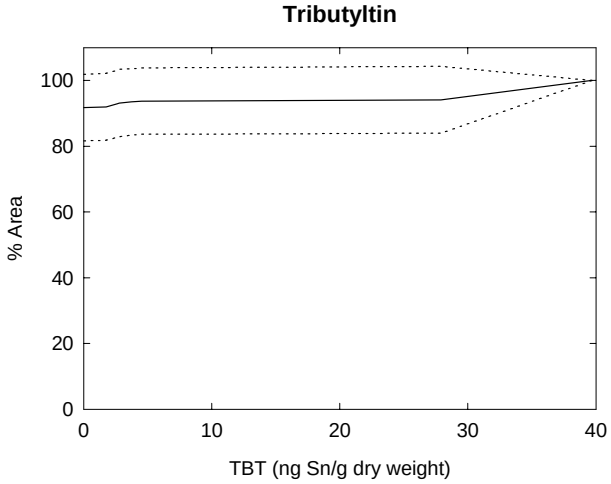

FIGURE 3.2-10. Percent area (and 95% C.I.) of CP estuaries vs. total alkanes concentrations in sediments.

reported that 23% of the estuarine area of the Carolinian Province in 1994 (represented by 16 stations) had TBT concentrations above this level, suggesting that TBT also may be a potential problem in these estuaries.

The extent of TBT contamination detected during the present 1995 sampling effort, however, was lower than in the previous year. In 1995, only 6% of the area of the province (represented by two stations) had TBT concentrations > 5 ppb (Fig. 3.2-10). Concentrations below detection limits were found in 92% of the province in 1995 compared to only 40% in 1994. Concentrations ranged up to 289 ng/g in 1994 and to only 39.7 ng/g in 1995. The two stations in 1995 where TBT was > 5 ppb were both in small estuaries in Florida (Station 171 in St. Johns River and Station 172 in Doctors Lake). The combined 1994-95 data indicate a greater association of TBT contamination with Florida estuaries than with other subregions.

Additional evidence of sediment contamination was observed in this study at some nonrandom stations near potential contaminant sources. For example, significant chromium contamination was found in sediments at Shipyard Creek, a supplemental site in Charleston Harbor, SC. The chromium concentration at this site in 1995 (CP95SPY) was 20,660 µg/g (Appendix E), which exceeds the ER-M bioeffect value for chromium (Long et al. 1995) by a factor of 56 and is much greater than concentrations considered to be "high" in national and worldwide chromium databases (Cantillo and O'Connor 1992). This result is consistent with the high level of chromium contamination recorded at this same site in 1994 (1,911 µg/g, Hyland et al. 1996). The data from this and other supplemental sites were not included in the above CDF estimates of contaminated vs. uncontaminated estuaries.

3.2.4 Sediment Toxicity

Only one of the 86 samplable base stations — Station 178 in Newfound Harbor, FL —

showed significant toxicity based on the *Ampelisca abdita* assay (Appendix G). A sample was regarded as being toxic if percent survival in the test sediment was statistically different from the corresponding control survival (tested at α = 0.05) and ≤ 80% of control survival. The toxicity observed at Station 178 represented < 1% of the area of the province (Fig. 3.2-11A), which is similar to the low percentage of toxic sediment (2%) detected by this assay in 1994 (Hyland et al. 1996). The *A. abdita* assay also showed a low incidence of toxicity in samples from the EMAP Louisiana Province (e.g., only 1% of the total province area in 1993, Macauley et al. 1995) and from selected estuaries of South Carolina and Georgia (< 0.3% of overall survey area, Long et al. 1998b).

The *A. abdita* assay did not appear to be a very sensitive indicator of degraded sediment conditions. Because of the low incidence of toxicity, there were no significant correlations between amphipod survival and any of the sediment contaminants (Table 3.2-3). As shown in Appendix G, several stations where there was no evidence of *A. abdita* toxicity had high sediment contamination, defined as in Fig. 3.2.8. The single toxicity occurrence at Station 178 was accompanied by a high concentration of the pesticide Lindane in excess of the ERM value (Appendices D and G). However, a high unionized ammonia nitrogen (UAN) concentration of 2,628 µg/L in sediment porewater is likely to have contributed to the toxicity of this sample (Appendices B and G). The U.S. EPA (1989) established water quality criteria (WQC) for unionized ammonia in marine systems based on a chronic value of 35 µg/L and an acute value of 233 µg/L. Kohn et al. (1994) reported a Lowest Observable Effect Concentration (LOEC) of 446 µg UAN/L for *Ampelisca abdita* and an EC_{50} of 800 µg/L.

The new assay conducted with *Ampelisca verrilli* showed a slightly higher incidence of toxicity than the *A. abdita* assay (Fig. 3.2-11A). However, use of this alternative amphipod species still resulted in only three base stations

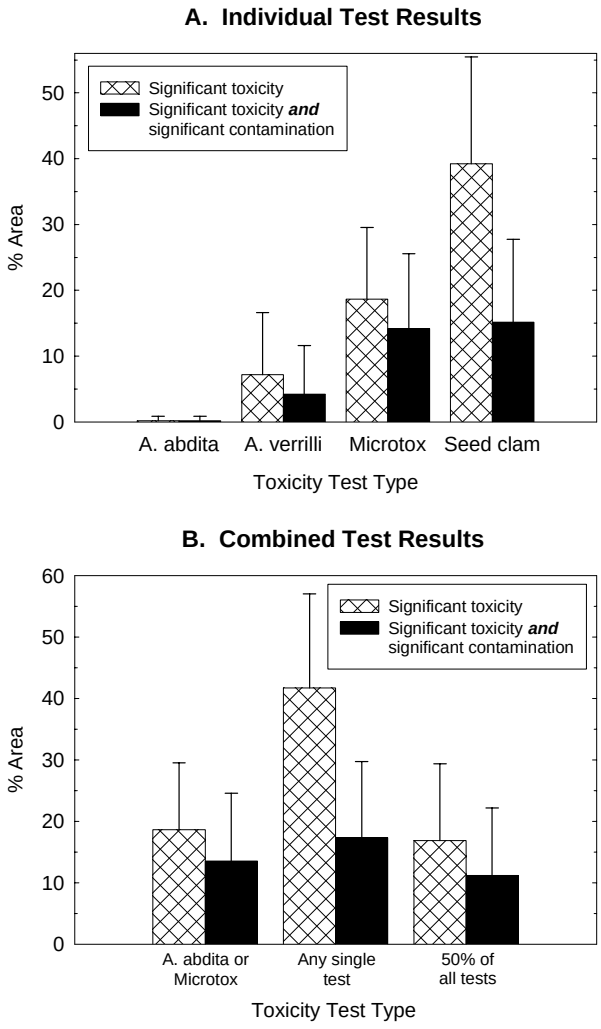

FIGURE 3.2-11. Percent area (and 95% C.I.) of CP estuaries that showed evidence of sediment toxicity accompanied by high sediment contamination, based on results of individual assays (A) and combined assays (B). Significant *A. abdita* and *A. verrilli* toxicity = mortality relative to control ≥ 20% and sig. at α=0.05. Sig. Microtox® toxicity = EC_{50} ≤ 0.2% if silt-clay ≥ 20%, or EC_{50} ≤ 0.5% if silt-clay < 20%. Sig. contamination is defined as ≥ 3 ER-L or TEL exceedances, or ≥ 1 ER-M or PEL exceedance.

TABLE 3.2-3. Results of Spearman rank-order correlations (r_s) between toxicity testing indicators vs. habitat and exposure measures . S = significant correlation at Dunn-Sidák adjusted significance level of $\alpha' = 0.0032$ (to control for experiment-wise error rate), based on unadjusted $\alpha = 0.05$ and k = 16 comparisons; NS = not significant.

	Microtox EC_{50} (% sediment dilution)			*Ampelisca abdita* Survival (% relative to control)			*Ampelisca verrilli* Survival (% relative to control)			Seed clam Survival (% relative to control)		
Measure	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result
Porewater Ammonia	0.26	0.0193	NS	0.01	0.9068	NS	0.10	0.3880	NS	-0.07	0.5563	NS
Porewater Sulfide	-0.22	0.0471	NS	0.09	0.4190	NS	-0.32	0.0045	NS	-0.41	0.0002	S
% Silt-Clay Content	-0.80	0.0001	S	0.15	0.1560	NS	-0.16	0.1377	NS	-0.12	0.2661	NS
Total Organic Carbon	-0.66	0.0001	S	0.06	0.5609	NS	-0.10	0.3600	NS	-0.16	0.1394	NS
Arsenic	-0.57	0.0001	S	0.10	0.3437	NS	-0.14	0.2055	NS	0.22	0.0462	NS
Chromium	-0.62	0.0001	S	0.08	0.4428	NS	-0.19	0.0776	NS	0.04	0.7009	NS
Nickel	-0.64	0.0001	S	0.08	0.4863	NS	-0.12	0.2576	NS	-0.06	0.5643	NS
Total Alkanes	-0.52	0.0001	S	0.12	0.2758	NS	-0.14	0.2089	NS	-0.22	0.0457	NS
4,4'-DDD	-0.42	0.0001	S	0.09	0.4284	NS	-0.10	0.3433	NS	-0.10	0.3562	NS
4,4'-DDE	-0.32	0.0023	S	0.09	0.4093	NS	-0.03	0.7752	NS	0.08	0.4907	NS
4,4'-DDT	-0.37	0.0005	S	0.07	0.4947	NS	-0.14	0.1865	NS	-0.06	0.5964	NS
Total DDT	-0.52	0.0001	S	0.09	0.4292	NS	-0.15	0.1598	NS	-0.11	0.2999	NS
Dieldrin	-0.09	0.3990	NS	0.03	0.7532	NS	-0.13	0.2490	NS	-0.06	0.5688	NS
Lindane	-0.12	0.2761	NS	0.04	0.7311	NS	-0.21	0.0547	NS	0.15	0.1721	NS
Pyrene	-0.68	0.0001	S	0.02	0.8257	NS	-0.21	0.0579	NS	-0.22	0.0492	NS
Total PCBs	-0.56	0.0001	S	0.14	0.1943	NS	-0.25	0.0217	NS	-0.14	0.2065	NS

(103, 108, and 178) being coded as toxic (Appendix G). These sites represented 7% of the province area. Two of the sites (Stations 103 and 178), which represented 4% of the province area, were accompanied by significant sediment contamination (Fig. 3.2-11A, Appendix G). However, as noted for *A. abdita*, the very high UAN concentration at Station 178 is likely to have contributed to the *A. verrilli* mortality in this sample.

In general, the two amphipod assays showed comparable results with respect to percent survival in various test sediments. Though the *A. verrilli* assay showed slightly greater sensitivity than the *A. abdita* assay, both were less sensitive to chemically contaminated sediments than the other two companion assays (Fig. 3.2-11A). Neither amphipod assay showed significant province-wide correlations with key sediment contaminants (Table 3.2-3).

Twenty base stations, representing 19% of the area of the province, showed significant Microtox® toxicity (Fig. 3.2-11A, Appendix G). Results were expressed as EC_{50} values — the sediment concentration causing a 50% reduction in light production by photoluminescent bacteria, *Vibrio fischeri*, relative to controls (nontoxic reagent blank). The reporting unit for these values is the percent dilution of the original sediment sample in a 2% saline solution. Because of the strong inverse relationship between Microtox® EC_{50} values and percent silt-clay content (Table 3.2-3), evaluation criteria were established for two separate silt-clay classes. Samples with ≥ 20% silt-clays (muddy sands to muds) were classified as being toxic if EC_{50} values were ≤ 0.2% sediment; samples with < 20% silt-clays (sands) were classified as being toxic if EC_{50} values were ≤ 0.5% sediment (*sensu* Ringwood et al. 1995). Lower EC_{50} values in muddier sediments are believed to be caused by physical adsorption of the bacteria to the sediment particles. Ringwood et al. (1995, 1997) demonstrated this effect by conducting Microtox® assays in artificial sediment mixtures of pure sand and kaolin clay and evaluating the EC_{50} values as a function of the finer-particle content.

Microtox® EC_{50} values showed strong negative correlations with several contaminants: arsenic, chromium, nickel, total alkanes, DDT and derivatives, pyrene, and total PCBs (Table 3.2-3). However, only eight of the 20 base stations that had toxic sediments based on the Microtox® assay also were coded as having high sediment contamination (Appendix G). These sites represented 14% of the province area (Fig. 3.2-11A). High toxicity in the remaining 12 samples with low contamination is difficult to explain, though a possible source (as discussed below) could be unmeasured contaminants.

Twenty-seven base stations, representing 39% of the province area, showed significant sediment toxicity based on the seed-clam assay (Fig. 3.2-11A, Appendix G). Ten of these stations, representing 15% of the province area, also had high sediment contamination. High toxicity in the remaining 17 samples with low contamination may be attributable in some cases to high UAN levels. Province-wide UAN concentrations showed no significant correlations with seed-clam growth rates (Table 3.2-3). However, seven of these 17 samples contained UAN at levels above the EPA acute WQC value of 233 µg/L (Appendix G).

There are numerous other chemical substances that were not measured in this study but are known to be highly toxic to aquatic life. Examples are dioxins, furans, and a variety of nonpersistent pesticides such as organophosphate insecticides (e.g., azinophosmethyl, chlorpyrifos, disulfoton, malathion, phorate), chlorophenyl fungicides (e.g., chlorothalonil, quintozene), dinitroanaline herbicides (e.g., trifluralin), and pyrethroids (e.g., fenvalerate, tralomethrin), among others. The discharge of some nonpersistent pesticides due to agriculture and mosquito control activities has been implicated as a major cause of fish kills in South Carolina coastal waters (Scott et al. 1992, Trim and Marcus 1990). Such unmeasured contaminants

could have contributed to toxicity in the above assays and may account for some of the cases where toxicity co-occurred with low concentrations of targeted analytes.

Also, there is a large suite of chemicals that were measured in this study but not included in the sediment contamination coding process because they lacked ER-L/ER-M or TEL/PEL SQGs (Appendix F). Some of these chemicals could have contributed to toxicity as well. For example, alkanes > 7000 ng/g co-occurred with toxicity at six stations (101, 103, 109, 120, 139, and 172) and TBT > 5 ng/g co-occurred with toxicity at two stations (171 and 172). However, two lines of evidence suggest that such chemicals were not the major causes of toxicity in Carolinian Province samples. First, generally the presence of these chemicals did not help to explain toxicity in samples otherwise coded as having low contamination. Of the above seven stations with relatively high levels of alkanes or TBT, only one (CP95101) did not have simultaneously high concentrations of other targeted analytes in excess of the ER-L/ER-M or TEL/PEL guidelines.

Secondly, several of these chemicals showed no apparent connection between the incidence of toxicity and concentrations in excess of other reported bioeffect levels. For example, Zarba (1989) reported sediment bioeffect thresholds (based on the sediment-water equilibrium partitioning approach or other toxicological endpoints) of 21 ng/g, 20 ng/g, and 20 ng/g for aldrin, heptachlor, and toxaphene, respectively. Concentrations in excess of these levels for the same three chemicals never co-occurred with toxicity at any of the base stations in the present study. Also, Long and Morgan (1990) produced an ER-M value of 45 ng/g for endrin, and McLeese and Metcalfe (1990) reported an LC_{50} for the shrimp *Crangon septemspinosa* at a similar endrin concentration of 47 ng/g. Sediment-associated concentrations of endrin in the present study did not range above 37 ng/g. A similar finding applied to endosulfan. McLeese et al. (1982) reported a 12-day LC_{50} of 340 ng/g for the sandworm *Nereis virens*. Chandler and Scott (1991) reported mortality to copepods at 200 ng/g and effects on colonization of polychaetes at 50 ng/g. Sediment-associated concentrations of endosulfan in the present study did not range above 20.4 ng/g.

Hydrogen sulfide concentrations in sediment porewater (expressed as unionized H_2S) ranged from < 1 to 18 µg/L (Appendix G). These levels are well below bioeffect ranges summarized in a recent literature review by Sims and Moore (1995). Effects on survival and various sublethal parameters in 12 species of marine invertebrates (including a clam and two species of amphipods) were reported by these authors at concentrations of 48 to > 50,098 µg/L. Effects on survival of two species of marine fishes also were reported at 17,892–23,856 µg/L. Thus, sulfide is not implicated as a major contributor to the toxicity of Carolinian Province samples.

The seed-clam test appeared to be the most sensitive of the four assays to contaminant-associated sediment toxicity. This assay resulted in the highest percentage of samples in which toxicity was detected where sediment contamination was high, as defined above ("correct positives"), and the lowest percentage of samples in which toxicity was not detected where contamination was high ("false negatives") (Table 3.2-4). However, the seed-clam assay also produced the highest percentage of samples with significant toxicity and low contamination ("false positives"), thus suggesting over-sensitivity or possibly responses to unmeasured toxicants. In comparison, the Microtox® assay was slightly less sensitive in detecting toxicity in contaminated sediments, but more reliable at demonstrating the lack of toxicity where contamination was low ("correct negatives"). In comparison to either of the amphipod assays, both the seed-clam and Microtox® assays showed greater concordance with predictions of toxicity based on sediment chemistry. Note, however, that conclusions about the relative sensitivities of these assays could change if different assessment criteria

(e.g., lists of chemicals and evaluation guidelines) were used.

Fig. 3.2-11B shows estimates of the % area of estuaries with toxic sediments based on three methods of combining the different assay results. Estimates based on toxicity in either the *A. abdita* or Microtox® assay are included as a basis for comparing 1995 data with those from the previous year, when these two assays were the only ones performed province-wide (Hyland et al. 1996). As expected, the estimate of percent toxic sediments is the highest (42% of the province area) when the evaluation criterion is toxicity in any one of the four tests performed. Though this latter method results in the highest percentage of correct positives, i.e. detecting toxicity where expected based on chemistry, it also has the highest false-positive rate (Table 3.2-4). A reasonable balance between maximizing correct positives and negatives, and minimizing false positives and negatives, can be accomplished by using a 50% criterion — i.e., judging a sample toxic if 50% or more of the assays performed on the sample were positive. Such an approach should help to compensate for the under- or over-sensitivity of any single assay. Also, this approach allows inter-year comparisons in cases where different numbers and types of assays are used.

High sediment contamination accompanied by significant toxicity in 50% or more of the assays occurred at only five stations, representing about 11% of the total province area (Fig. 3.2-11B). These results agree well with observations of Long et al. (1998b) who found that most samples from a survey of selected estuaries in South Carolina and Georgia were less contaminated and toxic than those analyzed by NOAA from other US estuaries nationwide.

TABLE 3.2-4. Summary of the association between sediment contamination and toxicity in various bioassays (data are from base stations only).

	Ampelisca abdita [a]	*Ampelisca verrilli* [b]	Microtox [c]	Seed Clam [d]	50% of All Tests Rule [e]	Any Test Rule [f]	*A.abdita* or Microtox [g]
Correct Positives [h]	4%	8%	32%	42%	20%	52%	32%
False Positives [i]	0%	2%	20%	28%	8%	41%	20%
Correct Negatives [j]	100%	98%	80%	72%	92%	59%	80%
False Negatives [k]	96%	92%	68%	58%	80%	48%	68%

[a] Sig. *A. abdita* tox. = mortality relative to control ≥ 20% and sig. at $\alpha = 0.05$.
[b] Sig. *A. verrilli* tox. = mortality relative to control ≥ 20% and sig. at $\alpha = 0.05$.
[c] Sig. Microtox tox. = EC 50 ≤ 0.2% if silt-clay content of sediment ≥ 20%, or EC50 ≤ 0.5 if silt-clay < 20%.
[d] Sig. Seed Clam tox. = mortality relative to control ≥ 20 % and sig. at $\alpha = 0.05$.
[e] "High" tox. based on sig. tox. hits in ≥ 50% of assays performed (*i.e.*, 2 or more of the 4 used in 1995).
[f] "High" tox., based on sig. tox. hits in any of the assays performed.
[g] "High" tox., based on sig. tox. hits in either the *A. abdita* **or** Microtox toxicity tests.
[h] (Number of sites with both tox. and contamination)/(Number of contaminated sites).
[i] (Number of sites with tox. but no contamination)/(Number of uncontaminated sites).
[j] (Number of sites with no tox. or contamination)/(Number of uncontaminated sites).
[k] (Number of sites with no tox. but with contamination)/(Number of contaminated sites).
[l] Contamination defined as ≥ 3 ER-L or TEL exceedances, or ≥ 1 ER-M or PEL exceedance.

3.3 Biotic Condition Indicators

3.3.1 Infaunal Species Richness and Diversity

One of the most common attributes used to describe faunal communities is diversity — the numbers and relative proportions of species present. Diversity measures have been used for many years as tools for assessing ecological impacts of water pollution (Wilhm and Dorris 1968, Boesch 1977). Such an application has been very popular in investigations of benthic communities. Reductions in benthic species diversity have been documented for a variety of pollution incidents, including oil spills (Sanders et al. 1980), sewage inputs (Anger 1975), discharges of paper-mill wastes (Pearson and Rosenberg 1978), and numerous other examples. Although patterns in benthic species diversity are influenced by a variety of natural environmental factors (e.g., latitudinal gradients, salinity, sediment particle size and organic content, food availability, biological interactions), certain characteristics of these biota render them very appropriate for use in pollution studies. For example, benthic fauna live in close association with bottom substrates where chemical contaminants and organic pollutants tend to accumulate, and where low-oxygen conditions are typically the most severe. Moreover, because most benthic organisms have limited mobility, it can be very difficult for them to avoid exposure to pollutants and other adverse conditions in their immediate surroundings.

One of the simplest measures of diversity is species richness, expressed in this study as the number of species present in a sample. Values of the mean number of species per grab (0.04 m^2) ranged from 0 to 42 (Fig. 3.3-1, Appendix H). The CDF included "low" numbers (defined here as ≤ 3 species per grab) in 19 ± 12% of the province. A comparable percentage (9 ± 6%) was estimated for 1994 (Hyland et al 1996).

Species richness showed highly significant correlations ($P \leq 0.0030$, Dunn-Sidák adjusted significance level) with latitude, bottom salinity, and silt-clay and TOC content of sediment (Table 3.3-1). Because of the potential influence of these natural factors on species richness, caution must be used in attempting to attribute low-species numbers solely to anthropogenic stress. However, Fig. 3.3-2 shows that stations with ≤ 3 species per grab were always at sites that were classified as degraded based on the various exposure variables (i.e., high sediment contamination, low DO, and/or significant sediment toxicity). Mean differences in numbers of species among degraded, undegraded, and marginal station categories were highly significant ($P = 0.0059$) based on the χ^2 approximation to the Kruskal-Wallis test (Table 3.3-2).

Low species richness was the most pronounced in large tidal rivers, where 55% of these estuarine habitats had ≤ 3 species per grab (Fig. 3.3-3). As noted above, sediment contamination also was the most pronounced in this estuarine class. Low species richness was more prevalent in Florida estuaries (52% of area) than in the other two subregions (16% and 6% for VA-NC and SC-GA, respectively).

Another measure of diversity used in this study was the Shannon information function, H′ (Shannon and Weaver 1949). This index provides a combined measure of both species richness and the distribution of abundance among species. H′ (derived using base-2 logarithms) ranged from 0 to 4.4 (Fig. 3.3-4, Appendix H). The CDF included "low" numbers (defined here as ≤ 1) in 15 ± 9% of the province. Similarly, in 1994, stations with infaunal H′ values below this criterion represented 12 ± 7% of the province (Hyland et al 1996).

As with species richness, H′ showed highly significant correlations ($P \leq 0.0030$) with bottom salinity and the silt-clay and TOC content of sediment (Table 3.3-1). There also was a marginally significant correlation with latitude ($P = 0.0039$). Thus, the potential influence of these and possibly other unmeasured natural factors must be considered when attempting to

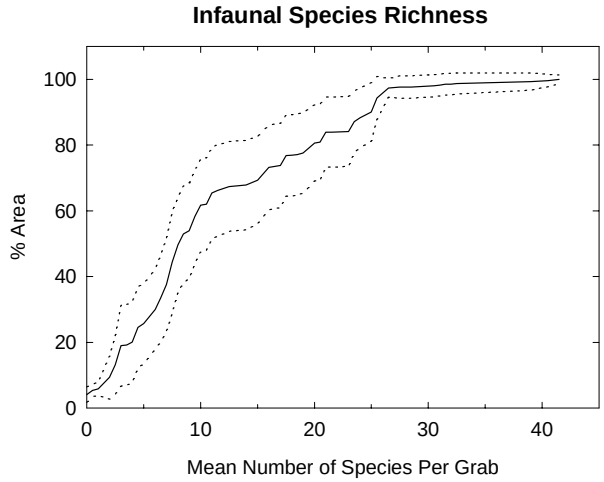

FIGURE 3.3-1. Percent area (and 95% C.I.) of CP estuaries vs. mean number of infaunal species per grab (0.04 m^2).

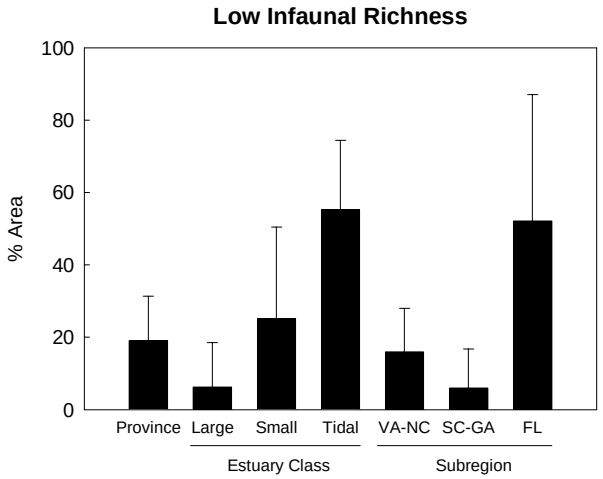

FIGURE 3.3-3. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low infaunal richness (mean number of species per grab ≤ 3).

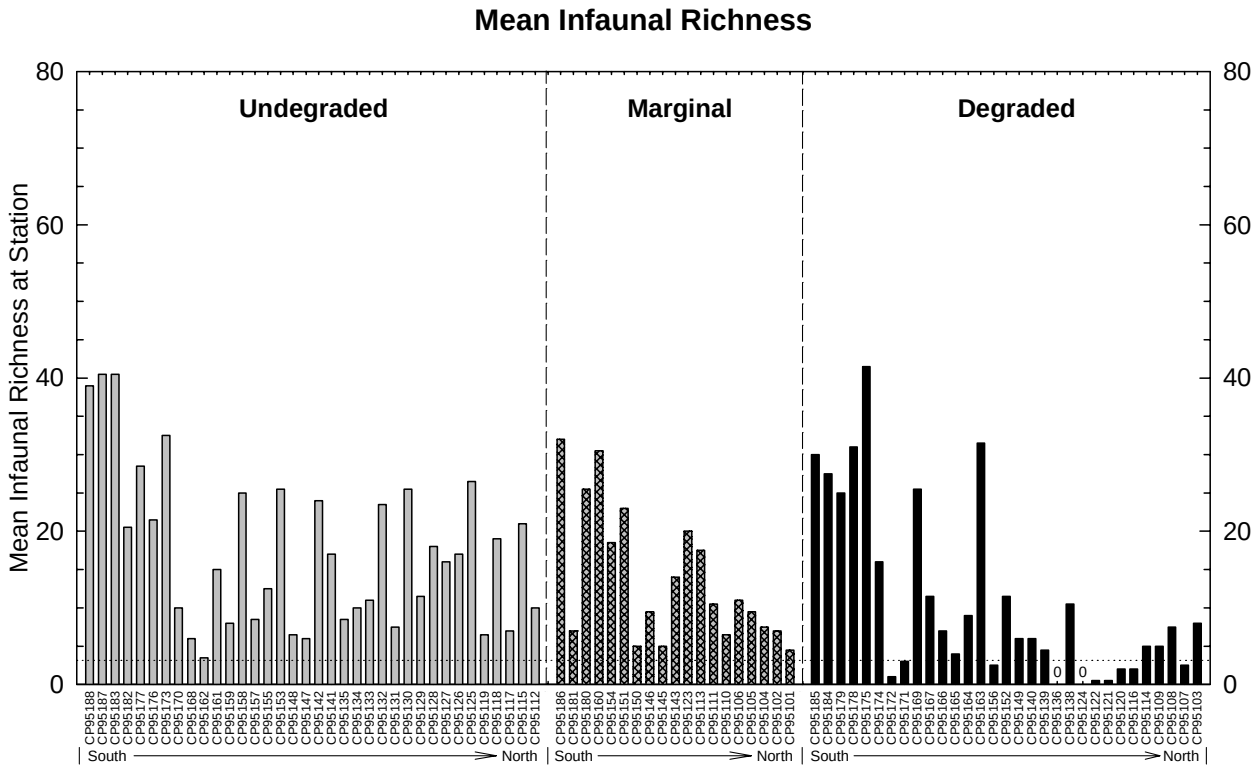

FIGURE 3.3-2. Mean infaunal richness by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see Section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values below the dotted reference line (i.e., ≤ 3) indicate possibly degraded benthos based on mean infaunal richness values.

TABLE 3.3-1. Results of Spearman rank-order correlations (r_s) between a select group of infaunal species biotic condition indicators vs. habitat and exposure measures . S = significant correlation at Dunn-Sidák adjusted significance level of $\alpha' = 0.0030$ (to control for experiment-wise error rate), based on unadjusted $\alpha = 0.05$ and k = 17 comparisons; NS = not significant.

	Mean Abundance per Station			Mean Richness Per Station			Mean H′ Diversity Per Station			Benthic Index Score For Station		
Measure	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result
Bottom Salinity	0.17	0.1199	NS	0.47	0.0001	S	0.52	0.0001	S	0.21	0.0550	NS
Bottom D.O.	0.20	0.0584	NS	0.08	0.4646	NS	0.11	0.3034	NS	0.26	0.0138	NS
Station Latitude	-0.24	0.0248	NS	-0.45	0.0001	S	-0.31	0.0039	NS	-0.06	0.6044	NS
% Silt-Clay Content	-0.33	0.0016	S	-0.40	0.0001	S	-0.34	0.0013	S	-0.57	0.0001	S
Total Organic Carbon	-0.38	0.0003	S	-0.49	0.0001	S	-0.40	0.0001	S	-0.50	0.0001	S
Arsenic	-0.53	0.0001	S	-0.51	0.0001	S	-0.33	0.0016	S	-0.59	0.0001	S
Chromium	-0.50	0.0001	S	-0.50	0.0001	S	-0.38	0.0003	S	-0.58	0.0001	S
Nickel	-0.46	0.0001	S	-0.50	0.0001	S	-0.36	0.0006	S	-0.54	0.0001	S
Total Alkanes	-0.43	0.0001	S	-0.57	0.0001	S	-0.45	0.0001	S	-0.57	0.0001	S
4,4'-DDD	-0.42	0.0001	S	-0.46	0.0001	S	-0.36	0.0008	S	-0.57	0.0001	S
4,4'-DDE	-0.35	0.0010	S	-0.34	0.0014	S	-0.26	0.0143	NS	-0.45	0.0001	S
4,4'-DDT	-0.32	0.0027	S	-0.30	0.0053	NS	-0.16	0.1391	NS	-0.39	0.0016	S
Total DDT	-0.41	0.0001	S	-0.40	0.0001	S	-0.31	0.0039	NS	-0.55	0.0001	S
Dieldrin	-0.22	0.0419	NS	-0.21	0.0545	NS	-0.12	0.2643	NS	-0.28	0.0087	NS
Lindane	-0.23	0.0342	NS	-0.13	0.2363	NS	-0.02	0.8837	NS	-0.23	0.0308	NS
Pyrene	-0.38	0.0003	S	-0.38	0.0003	S	-0.28	0.0083	NS	-0.48	0.0001	S
Total PCBs	-0.37	0.0005	S	-0.27	0.0121	NS	-0.20	0.0684	NS	-0.49	0.0001	S

TABLE 3.3-2. Comparison of infaunal species richness, diversity, total faunal abundance, and abundances of dominant taxa at undegraded, marginal, and degraded sites in the Carolinian Province. Means and results of Kruskal-Wallis tests [a] for differences among site categories are reported. Results of Dunn's multiple comparison test for unequal sample sizes (Hollander and Wolfe 1973) are also reported. Means connected by bars are not significantly different at $\alpha = 0.05$. $N_{undegraded} = 36$, $N_{marginal} = 19$, $N_{degraded} = 31$.

Taxa	Undegraded Stations	Marginal Stations	Degraded Stations	Kruskal-Wallis [a] χ^2	Kruskal-Wallis [a] $P > \chi^2$	Dunn's
Halmyrapseudes bahamensis	0.00	0.03	47.18	5.11	0.0776	U M D
Streblospio benedicti	14.43	1.40	8.48	2.68	0.2624	U M D
Mulinia lateralis	3.65	31.58	0.85	6.76	0.0340	U M D
Mediomastus spp.	8.76	6.68	7.95	1.89	0.3881	U M D
Unidentified Oligochaete	8.54	7.37	6.81	4.21	0.1220	U M D
Overall Assemblage	**Undegraded Stations**	**Marginal Stations**	**Degraded Stations**	**Kruskal-Wallis [a] χ^2**	**Kruskal-Wallis [a] $P > \chi^2$**	**Dunn's**
Mean Richness	17.47	13.90	10.89	10.28	0.0059	U M D
Mean Abundance	131.71	121.24	144.82	5.82	0.0545	U M D
Mean Diversity	2.82	2.64	1.71	14.58	0.0007	U M D

[a] The procedure uses the χ^2 approximation to the Kruskal-Wallis test.

associate low-diversity values with anthropogenic stress. However, Fig. 3.3-5 shows that all but one of the base stations having H′ values ≤ 1 corresponded with sites also classified as degraded based on the various exposure indicators. Mean differences in H′ among degraded, undegraded, and marginal station categories were highly significant (P = 0.0007) based on the χ^2 approximation to the Kruskal-Wallis test (Table 3.3-2).

Consistent with species richness patterns, low H′ was the most pronounced in large tidal rivers, where 68% of this estuarine class had H′ ≤1 (Fig. 3.3-6). Low H′ appeared in similarly small proportions in the remaining two estuarine classes (i.e., 6% and 12% for large and small estuaries, respectively). Low H′ showed no major differences by subregion.

Species richness and/or H′ diversity showed highly significant negative correlations ($P \leq$ 0.0030) with arsenic, chromium, nickel, total alkanes, total DDT, 4,4′-DDD, 4,4′-DDE, and pyrene (Table 3.3-1). There also were marginally significant negative correlations between species richness and 4,4′-DDT (P = 0.0053) and total PCBs (P = 0.0121). Neither of these infaunal diversity measures were significantly correlated with dissolved oxygen.

3.3.2 Infaunal Abundance and Taxonomic Composition

Total faunal abundance is another attribute commonly used to characterize benthic communities. Abundance (mean number of individuals per grab) ranged from 0 to 1,570 (Fig. 3.3-7, Appendix H). The CDF included "low" values (defined here as ≤ 25) in 32 ± 14% of the province. A similar proportion of the province (22 ± 11%) had infaunal abundances below this criterion in 1994 (Hyland et al 1996).

As with diversity, abundance showed highly significant correlations ($P \leq$ 0.0016) with the silt-clay and TOC content of sediment (Table 3.3-1). Thus, the potential influence of these and possibly other unmeasured natural factors must be considered when attempting to associate low-abundance values with anthropogenic stress. In the prior 1994 study, it was found that stations with infaunal abundance ≤ 25 per grab usually were sites classified as degraded based on the various exposure indicators (13 of 16 stations with abundance below this criterion were degraded sites). Fig. 3.3-8 shows that, in 1995, the majority of stations with infaunal abundance ≤ 25 per grab also corresponded to degraded sites (there was low abundance at 12 degraded sites, seven undegraded sites, and two marginal sites). However, the seven undegraded sites with low abundance represent a higher incidence of misclassifications than in the previous year. Such variability demonstrates the importance in using combined biological and exposure criteria as a basis for evaluating overall condition at a site (e.g., co-occurrence of reduced abundances and adverse exposure conditions).

Low infaunal abundance was the most pronounced in large tidal rivers, though differences in the percentage of affected area among the three estuarine classes were fairly small (Fig. 3.3-9). Similarly, there were no major differences among the three subregions.

Infaunal abundance was significantly correlated with arsenic, chromium, nickel, total alkanes, total DDT and component derivatives, pyrene, and total PCBs (Table 3.3-1). Most of these same analytes, except 4,4′-DDT and total PCBs, also were significantly correlated with one or both of the biodiversity measures. As with the diversity measures, infaunal abundance was not significantly correlated with dissolved oxygen.

A total of 23,055 infaunal organisms, representing 388 taxa (most identified to the species level), were encountered among the 171 grabs (0.04 m^2 each) collected at base stations throughout the province. Annelids (polychaetes and tubificid oligochaetes) represented the majority of these taxa province-wide, based on both abundance (44%) and species numbers (40%)

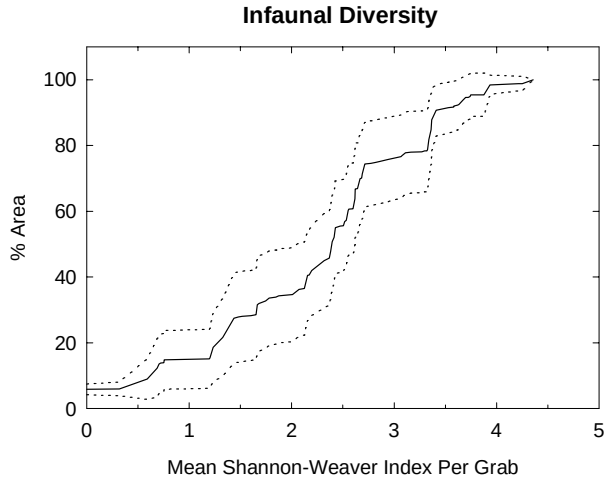

FIGURE 3.3-4. Percent area (and 95% C.I.) of CP estuaries vs. mean Shannon-Weaver Index (H′) per grab.

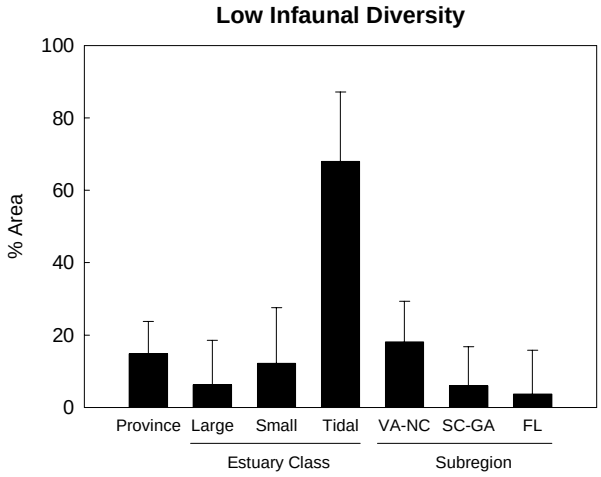

FIGURE 3.3-6. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low infaunal species diversity (mean H′ per grab ≤ 1).

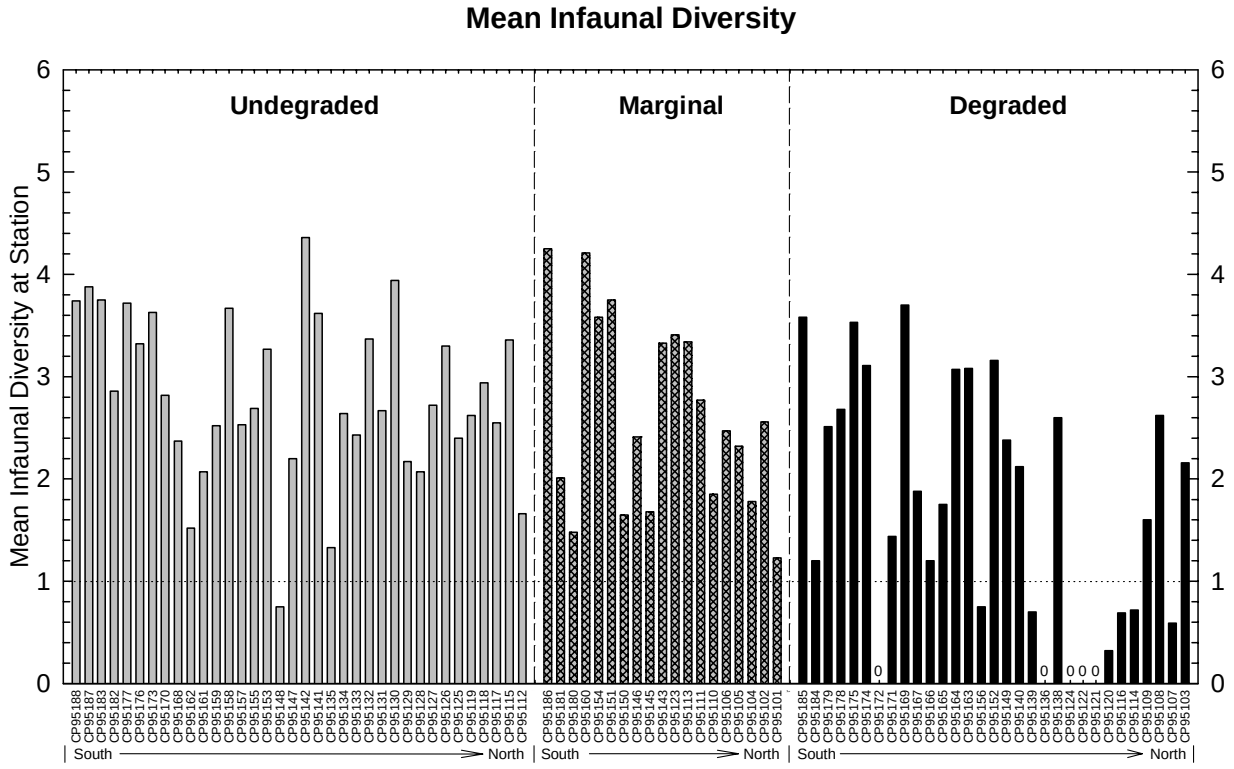

FIGURE 3.3-5. Mean infaunal diversity by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values below the dotted reference line (i.e., ≤ 1) indicate possibly degraded benthos based on mean infaunal diversity values.

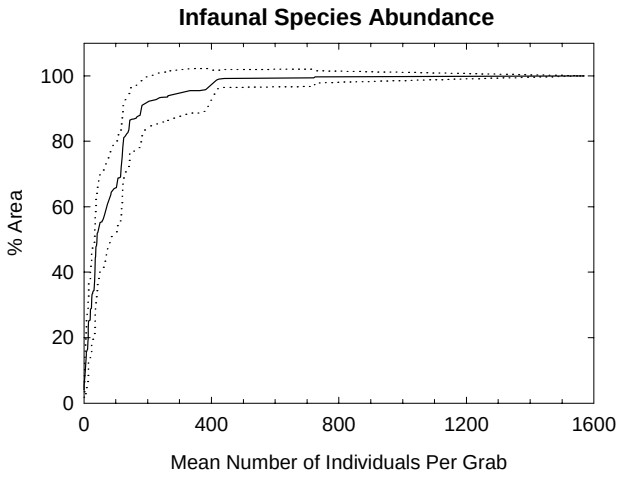

FIGURE 3.3-7. Percent area (and 95% C.I.) of CP estuaries vs. mean infaunal species abundance per grab.

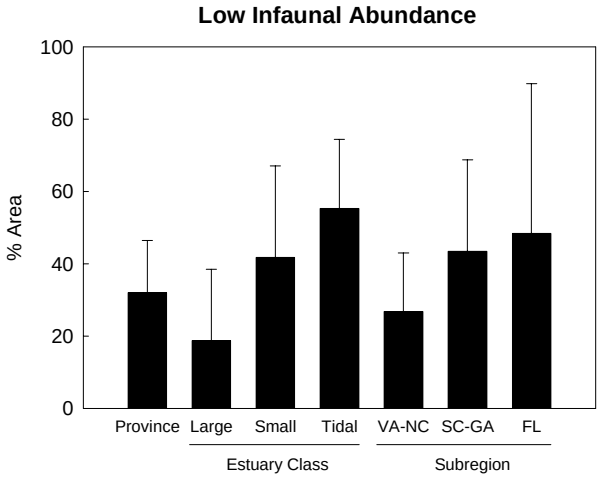

FIGURE 3.3-9. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low infaunal abundance (mean abundance per grab ≤ 25).

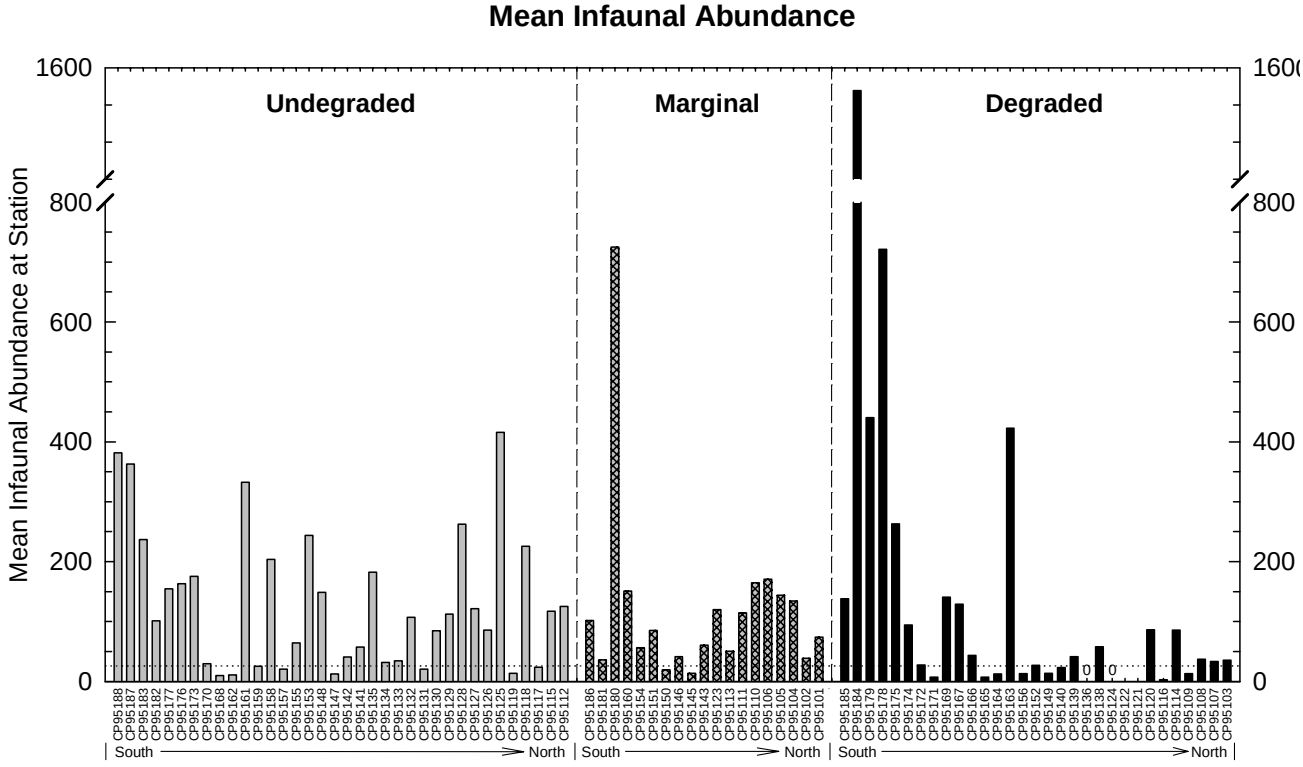

FIGURE 3.3-8. Mean infaunal abundance by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values below the dotted reference line (i.e., ≤ 25) indicate possibly degraded benthos based on mean infaunal abundance values.

TABLE 3.3-3. Relative percent composition of major taxonomic groups by estuarine class.

Estuarine	Percent Abundance				Percent Species			
Class	Annelida	Arthropoda	Mollusca	Other	Annelida	Arthropoda	Mollusca	Other
All	43.9	27.4	18.9	9.9	39.9	32.0	19.3	8.8
Large	34.3	19.2	25.7	20.8	47.0	24.3	18.3	10.4
Small	56.3	23.2	13.8	6.7	40.7	33.1	19.7	6.6
Tidal	31.2	36.0	22.9	9.9	46.4	23.5	19.0	11.1

(Table 3.3-3). Arthropods (mostly peracarid crustaceans and chironomid insect larvae) were the next most abundant group (representing 27% of the taxa) followed by molluscs (19%). Similarly, arthropods represented the second highest percentage of species (32%), followed by molluscs (19%). The relative proportions of these broad taxonomic groups were fairly consistent across the three estuarine classes with a few possible exceptions. In large estuaries, the contribution of molluscs increased with respect to abundance. Also, in large tidal rivers, arthropods (rather than annelids) represented the most dominant group based on abundance.

Table 3.3-4 summarizes the five most abundant taxa (i.e. "dominants") by estuarine class and subregion. Province-wide dominants (in decreasing order of abundance) were the tanaid *Halmyrapseudes bahamensis*, the polychaete *Mediomastus* spp., the polychaete *Streblospio benedicti*, unidentified oligochaetes, and the bivalve *Mulinia lateralis*. All of these taxa, except the tanaid also appeared as dominants in the 1994 survey (Hyland et al. 1996). Within a year, dominance patterns showed distinct shifts among the various estuarine classes and subregions. For example, in 1995 only one of the above taxa (*Mediomastus*) was dominant in all categories.

None of the five province-wide dominants exhibited significant differences in mean abundances among degraded, undegraded, and marginal site categories (Table 3.3-2).

3.3.3 Benthic Infaunal Index

A multimetric index of biotic integrity was developed for infaunal macroinvertebrate assemblages sampled in the Carolinian Province. The process used to develop this index was described in Section 2.3.3.2. This index — consisting of measures of abundance, number of species, dominance, and relative abundance of pollution-sensitive taxa — produced a high percentage of correct station classifications (i.e., agreement with predictions of sediment bioeffects based on chemistry and toxicity data) in comparison to other metric combinations that were tested. As was shown in Table 2-10, the index correctly classified stations province-wide 93% of the time in the 1994 development data set and 75% of the time in the independent 1993/1995 validation data set.

Figure 3.3-10 further illustrates that stations with index values below 3 (suggestive of some apparent stress to highly degraded conditions) usually coincided with sites considered to be degraded based on a combination of chemistry and toxicity data, and that stations with scores of 3 or higher usually coincided with undegraded sites. Agreement is the highest at the two ends of the scale. Thus, the evaluation of sediment quality based on the benthic index appears to agree reasonably well with predictions of sediment bioeffects based on the combined exposure data. Additional comparisons revealed that the benthic index detected a higher percentage of samples where bioeffects were expected (based

Table 3.3-4. Abundances of dominant infaunal species (listed in decreasing order of abundance) and all infauna by estuarine class (A), and subregion (B). Mean abundance per grab (0.04 m^2), averaged over all stations, and range of mean abundance per grab over all stations are given.

A.

Province		Large		Small		Tidal	
Taxa	Abundance	Taxa	Abundance	Taxa	Abundance	Taxa	Abundance
Halmyrapseudes bahamensis Tanaid	17.0 (0 – 1146)	*Phoronis* spp. Phoronid	18.0 (2 – 246)	Unidentified Oligochaete	13.7 (0 – 214)	*Halmyrapseudes bahamensis* Tanaid	67.5 (0 – 1146)
Mediomastus spp. Polychaete	9.6 (0 – 122)	*Parvilucina multilineata* Bivalve	9.4 (0 – 42)	*Streblospio benedicti* Polychaete	12.5 (0 – 159)	*Mulinia lateralis* Bivalve	40.2 (0 – 580)
Streblospio benedicti Polychaete	9.4 (0 – 159)	*Acanthohaustorius millsi* Amphipod	8.3 (0 – 125)	*Mediomastus* spp. Polychaete	9.0 (0 – 82)	*Laonome* sp1 Polychaete	24.6 (0 – 347)
Unidentified Oligochaete	8.9 (0 – 214)	*Mediomastus* spp. Polychaete	7.8 (0 – 31)	*Cerapus benthophilus* Amphipod	6.3 (0 – 255)	*Mediomastus* spp. Polychaete	13.6 (0 – 122)
Mulinia lateralis Bivalve	8.8 (0 – 580)	*Polydora cornuta* Polychaete	4.8 (0 – 58)	*Halmyrapseudes bahamensis* Tanaid	6.0 (0 – 230)	*Phoronis* spp. Phoronid	12.8 (0 – 125)
All Fauna (388 spp. from 171 grabs)	134.1 (0 – 1570)	All Fauna (115 spp. from 32 grabs)	101.9 (14 – 416)	All Fauna (290 spp. from 105 grabs)	106.2 (3 – 721)	All Fauna (153 spp. from 34 grabs)	251.6 (0 – 1570)

B.

VA – NC		SC – GA		FL	
Taxa	Abundance	Taxa	Abundance	Taxa	Abundance
Mediomastus spp. Polychaete	10.4 (0 – 82)	Unidentified Oligochaete	21.7 (0 – 214)	*Halmyrapseudes bahamensis* Tanaid	77.0 (0 – 1146)
Phoronis spp. Phoronid	7.3 (0 – 246)	*Streblospio benedicti* Polychaete	16.2 (0 – 159)	*Mulinia lateralis* Bivalve	37.0 (0 – 580)
Streblospio benedicti Polychaete	6.6 (0 – 148)	*Scoloplos rubra* Polychaete	6.1 (0 – 66)	*Laonome* sp1 Polychaete	22.0 (0 – 347)
Unidentified Oligochaete	5.4 (0 – 80)	*Mediomastus* spp. Oligochaete	3.5 (0 – 18)	*Cerapus benthophilus* Amphipod	21.2 (0 – 255)
Marenzellaria viridis Polychaete	4.4 (0 – 57)	*Parapionosyllis longicirrata* Polychaete	3.3 (0 – 57)	*Mediomastus* spp. Oligochaete	14.4 (0 – 122)
All Fauna (167 spp. from 92 grabs)	82.0 (0 – 416)	All Fauna (165 spp. from 41 grabs)	96.8 (8 – 422)	All Fauna (189 spp. from 38 grabs)	301.6 (7 – 1570)

on sediment quality guideline exceedances) than did any of the four individual sediment bioassays (Fig. 3.3-11A) or individual infaunal attributes (Fig. 3.3-11B).

Benthic index values for base stations sampled in 1995 covered the full scale from 1 to 5 (Appendix H). Values ≤ 1.5 (clearest evidence of a degraded benthos) occurred at 14 of the 86 base sites, which represented 21% of the province area (Fig. 3.3-12). Transitional values of 2 to 2.5 (suggestive of some possible stress) occurred at an additional 14 sites, representing another 15% of the province. Values ≥ 3 (suggestive of an undegraded benthos) occurred at the remaining 58 base sites, representing 64% of the area of the province.

By estuarine class, the estimated percentage of area with degraded benthic assemblages was the highest for large tidal rivers and the lowest for large estuaries (Fig. 3.3-13). By subregion, this percentage was the highest in Florida estuaries and the lowest in SC/GA estuaries.

3.3.4 Demersal Species Richness and Diversity

A total of 91 demersal species was sampled from 169 trawls conducted in the Carolinian Province. The mean number of species per trawl at a station ranged from 0 to 19 (Fig. 3.3-14, Appendix H). Most stations had about 3–10 species per trawl. Only 7% of the province area, represented by six stations, exhibited very low numbers of species (defined here as ≤ 2 species/trawl). Four of these stations were from sites classified as degraded based on various exposure indicators (Fig. 3.3-15). Low species richness was the most pronounced in large tidal rivers (Fig. 3.3-16). Four of the six stations with ≤ 2 species/trawl (CP95184, CP95124, CP95124, and CP95121) were from this estuarine class. All but one (CP95184 in Indian River Lagoon, Florida) were from North Carolina.

Mean H′ diversity per trawl ranged from 0 to 3.2 (Fig. 3.3-17, Appendix H). Most stations had values between 1.0 and 2.5. About 11% of the province area, represented by seven stations, exhibited low diversity (defined here as H′ ≤ 0.5). Five of these seven stations were from degraded sites, based on the various exposure indicators, and only one was from an undegraded site (Fig. 3.3-18). Mean H′ at degraded sites was significantly lower (at $\alpha = 0.05$) than at undegraded sites (Table 3.3-5), suggesting that this parameter may be a fairly good indicator of pollution-induced impacts on these biota. However, the potential influence of other natural controlling factors — such as salinity, depth, substrate, latitude — also must be considered when attempting to associate low-diversity values with anthropogenic stress.

TABLE 3.3-5. Comparison of demersal species richness, diversity, and abundance at undegraded, marginal, and degraded sites in the Carolinian Province. Means and results of Kruskal-Wallis tests [a] for differences among site categories are reported. Results of Dunn's multiple comparison test for unequal sample sizes (Hollander and Wolfe 1973) are also reported. Means connected by bars are not significantly different at $\alpha = 0.05$. $N_{undegraded} = 36$, $N_{marginal} = 19$, $N_{degraded} = 31$.

Taxa	Undegraded Stations	Marginal Stations	Degraded Stations	Kruskal-Wallis [a] χ^2	Kruskal-Wallis [a] $P > \chi^2$	Dunn's
Mean Richness	7.61	6.71	6.22	2.01	0.3654	U M D
Mean Abundance	78.93	78.37	100.88	0.24	0.8848	U M D
Mean Diversity	1.84	1.79	1.32	9.20	0.0101	U M D

[a] The procedure uses the χ^2 approximation to the Kruskal-Wallis test.

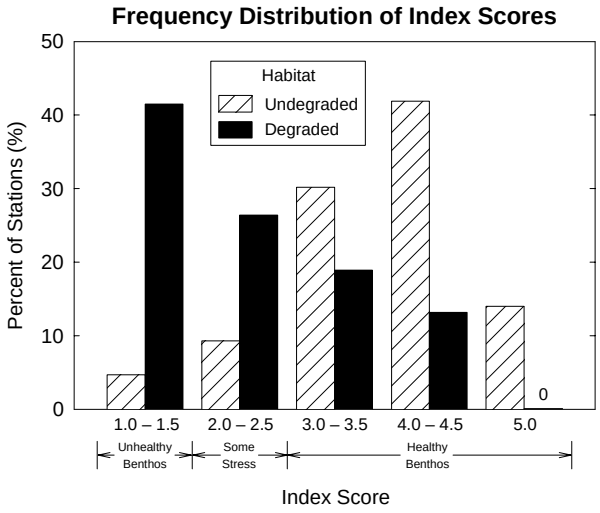

FIGURE 3.3-10. Frequency distribution of index scores for undegraded vs. degraded stations in 1993/1995 "development" data set.

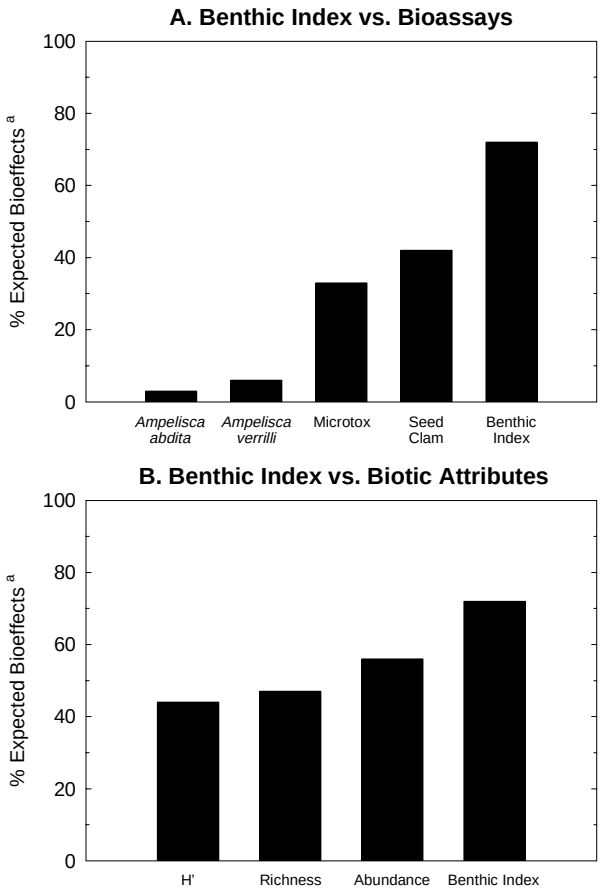

FIGURE 3.3-11. Comparison of the percent of expected bioeffects detected with the benthic index vs. (A) four sediment bioassays, and (B) three individual infaunal attributes. [a] Percent expected bioeffects = # stations (1995 core & supplemental) where an effect was detected / # stations with ≥ 1 ER-M/PEL or ≥ 3 ER-L/TEL exceedance

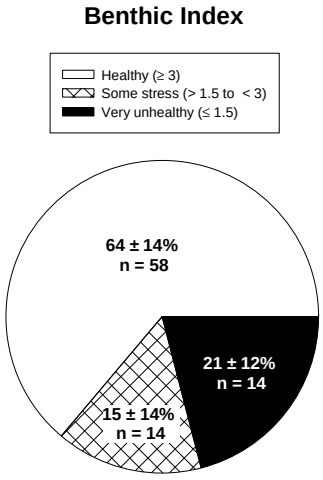

FIGURE 3.3-12. Percent area (and 95% C.I.) of CP estuaries with high (≥ 3), intermediate (> 1.5 to < 3), and low (≤ 1.5) benthic index values.

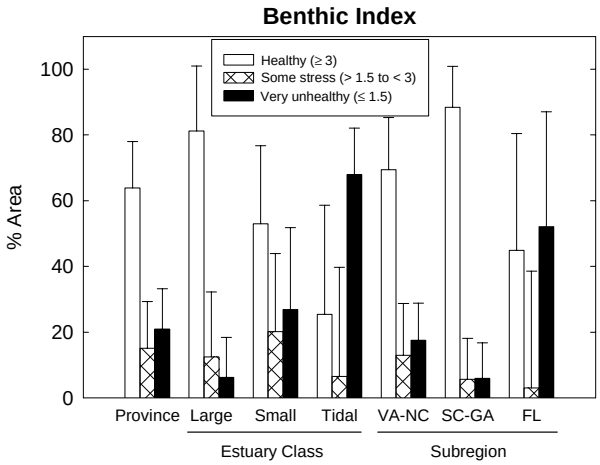

FIGURE 3.3-13. Comparison of benthic index values by estuarine class and subregion.

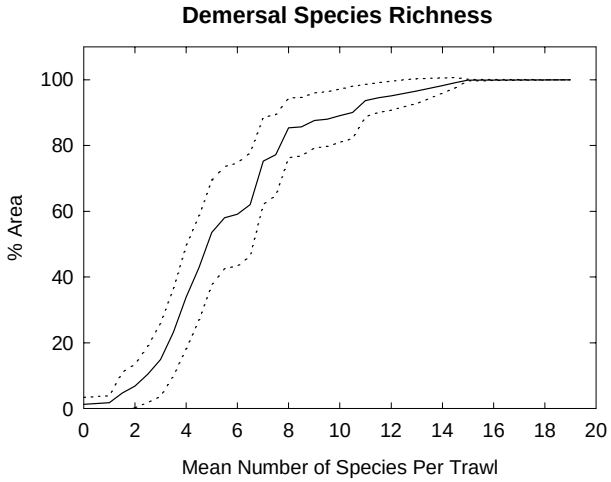

FIGURE 3.3-14. Percent area (and 95% C.I.) of CP estuaries vs. mean number of demersal species per trawl.

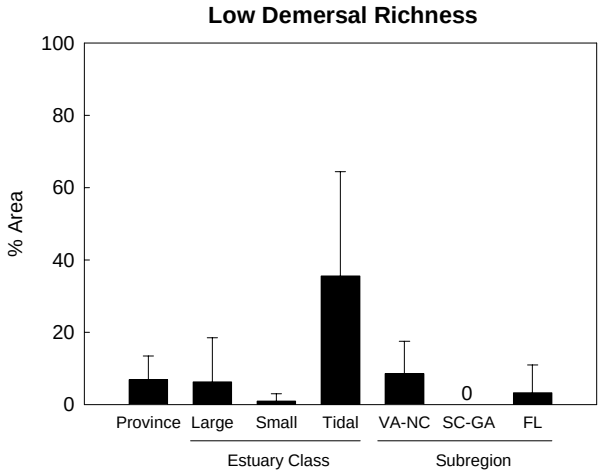

FIGURE 3.3-16. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low demersal species richness (mean number of species per trawl ≤ 2).

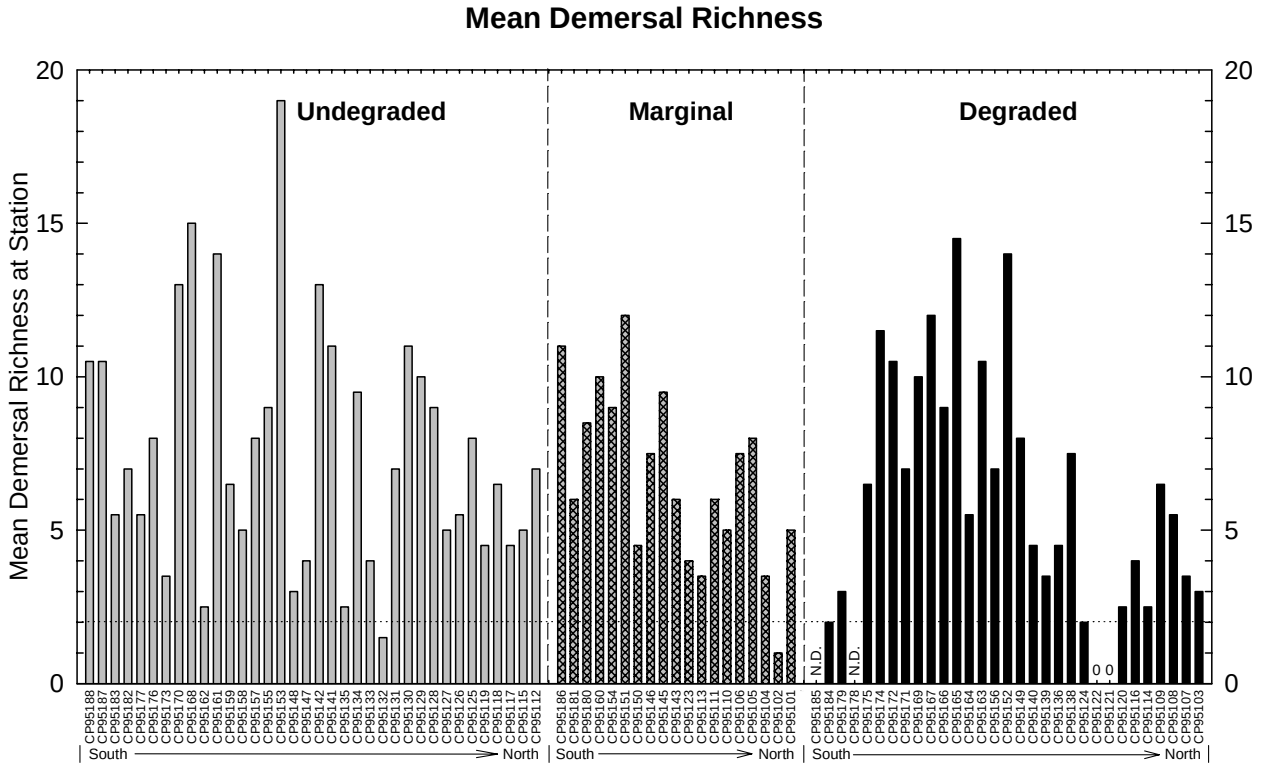

FIGURE 3.3-15. Mean demersal richness by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see Section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values below the dotted reference line (i.e., ≤ 2) indicate possibly degraded conditions based on mean demersal richness values. N.D. = no data.

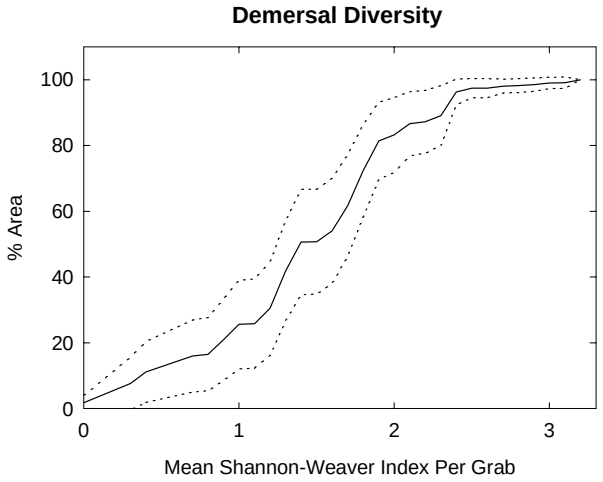

FIGURE 3.3-17. Percent area (and 95% C.I.) of CP estuaries vs. mean Shannon-Weaver (H′) diversity per trawl.

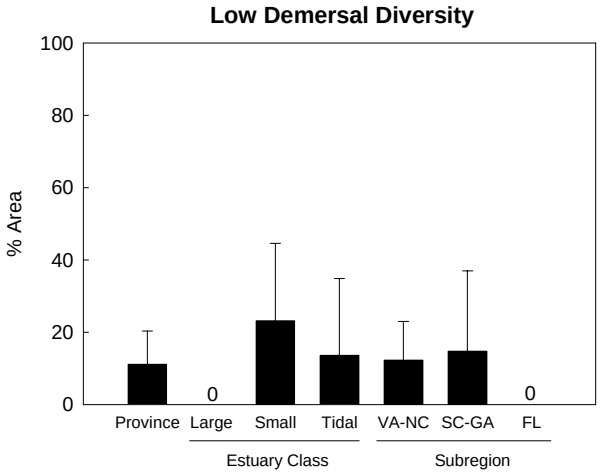

FIGURE 3.3-19. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low demersal species diversity (mean H′ diversity per trawl ≤ 0.5).

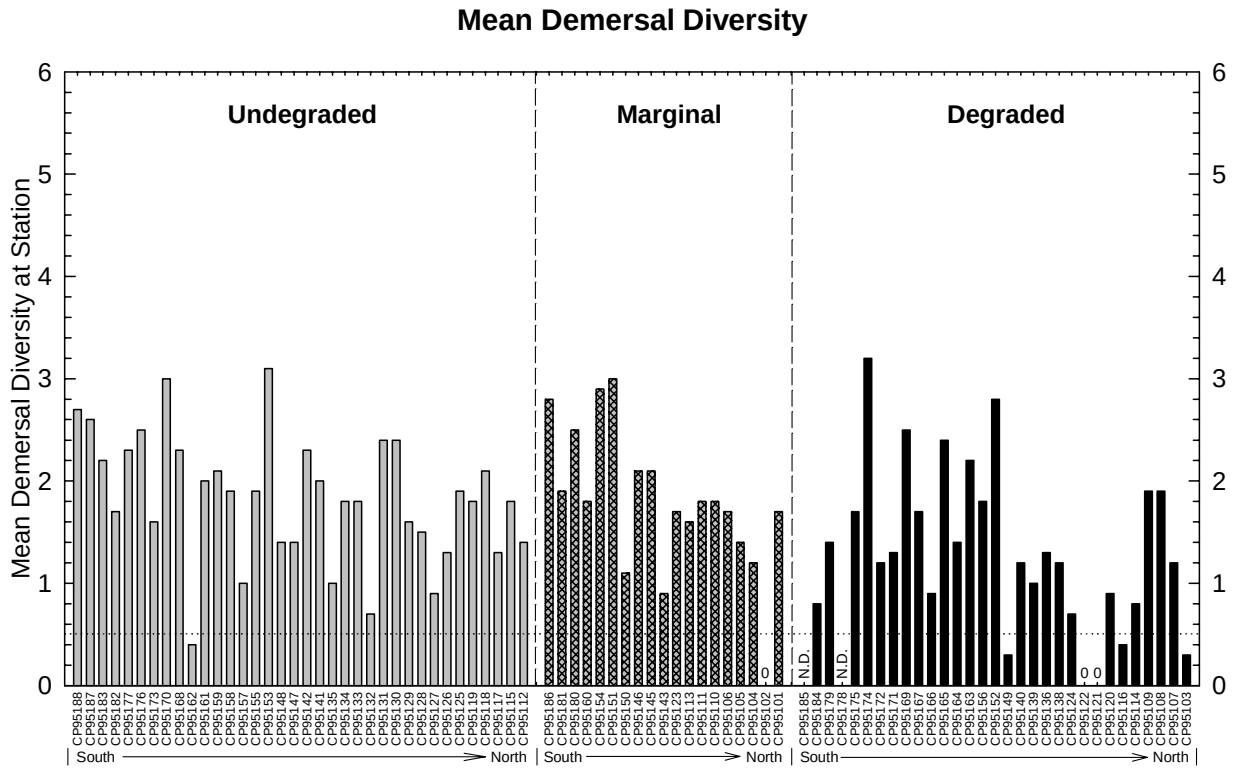

FIGURE 3.3-18. Mean demersal diversity by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see Section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values below the dotted reference line (i.e., ≤ 0.5) indicate possibly degraded conditions based on mean demersal diversity values. N.D. = no data.

The percent area represented by stations with $H' \leq 0.5$ was about the same for small estuaries and large tidal rivers (Fig. 3.3-19). H′ below this criterion was not observed at all in the large estuarine class or the Florida subregion. Similar to species richness, all but two of the stations with low H′ (CP95162 and CP95149) were in North Carolina.

Both measures of diversity showed significant correlations with salinity and latitude (Table 3.3-6). The positive associations with salinity and negative associations with latitude are common spatial patterns observed in studies of demersal biota (e.g., Weinstein 1979 and Briggs 1974, respectively). H′ showed significant negative correlations with TOC and total alkanes. Neither measure of diversity showed a significant correlation with bottom dissolved-oxygen concentration (at $\alpha = 0.05$).

3.3.5 Demersal Abundance and Taxonomic Composition

A total of 14,586 demersal organisms was sampled from 169 trawls conducted in the Carolinian Province. The mean number of demersal individuals per trawl at a station ranged from 0 to 636.5 (Fig. 3.3-20, Appendix H). Over half of the province area (57%) was represented by stations with at least 50 animals per trawl. Most stations, representing about 73% of the area, had between 10 and 150 animals per trawl. Only 9% of the area, represented by eight stations, displayed low abundances (defined here as ≤ 5 individuals/trawl). These stations were distributed equally among degraded sites and other sites classified as either undegraded, or marginal, based on exposure indicators (Fig. 3.3-21). Consequently, there was no significant difference in abundance (at $\alpha = 0.05$) between degraded and undegraded site categories (Table 3.3-5). Abundances ≤ 5 individuals/trawl appeared in similarly low proportions among the three estuarine size-classes and were not observed at all in the SC-GA subregion (Fig. 3.3-22).

There were no significant province-wide correlations between abundance and measures of bottom salinity, bottom dissolved-oxygen concentrations, TOC or silt-clay content of sediment, or station latitude (Table 3.3-6). There also were no significant negative correlations between abundance and the major sediment contaminants.

The five most numerically dominant species province-wide (listed in decreasing order of abundance) were white shrimp (*Penaeus setiferus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), pinfish (*Lagodon rhomboides*), and brown shrimp (*Penaeus aztecus*) (Table 3.3-7). A similar province-wide list was observed during the previous year of sampling — all of these species except white shrimp were among the top-five dominants in both years. There were distinct differences in dominance structure among the various estuarine classes and subregions. Atlantic croaker and spot were the only dominants in all three estuarine classes. Atlantic croaker was the only dominant in all three subregions.

Four of the five dominants (Atlantic croaker, spot, brown shrimp, and white shrimp) are harvested commercially and/or recreationally. Other dominants associated with individual estuarine classes and subregions (e.g., blue crab and weakfish) are also of commercial or recreational fishing value.

As a final note on demersal species distributions, it must be understood that the above results represent the view that one gets from using this particular type of gear and sampling protocol. Some important game species that occur in the region (e.g., the red drum *Sciaenops ocellatus* and tarpon *Megalops atlanticus*) were never caught in the EMAP trawls. There also is evidence that the trawl may have underestimated the abundances of smaller sizes of some species (Wheeler et al. 1996). Estimates of species diversity and abundances could be much different if other types of gear and sampling protocols

TABLE 3.3-6. Results of Spearman rank-order correlations (r_s) between demersal species biotic condition indicators vs. habitat measures and exposure measures. S = significant correlation at Dunn-Sidák adjusted significance level of $\alpha' = 0.0030$ (to control for experiment-wise error rate), based on unadjusted a = 0.05 and k = 17 comparisons; NS = not significant.

	Mean Richness per Trawl			Mean Abundance Per Trawl			Mean Diversity Per Trawl			Mean Number of Pathologies Per Trawl		
Habitat Measure	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result	r_s	$P > \|r_s\|$	Result
Bottom Salinity	0.33	0.0021	S	-0.16	0.1340	NS	0.41	0.0001	S	-0.18	0.1058	NS
Bottom D.O.	-0.04	0.6956	NS	0.02	0.8442	NS	0.07	0.5486	NS	0.03	0.7642	NS
Station Latitude	-0.42	0.0001	S	0.05	0.6248	NS	-0.40	0.0001	S	-0.08	0.4863	NS
% Silt-Clay Content	-0.18	0.1006	NS	-0.02	0.9878	NS	-0.24	0.0264	NS	0.06	0.5637	NS
Total Organic Carbon	-0.24	0.0280	NS	0.08	0.4656	NS	-0.35	0.0010	S	0.02	0.8290	NS
Arsenic	-0.11	0.2983	NS	0.02	0.8532	NS	-0.22	0.0396	NS	-0.05	0.6805	NS
Chromium	-0.15	0.1689	NS	0.10	0.3885	NS	-0.30	0.0055	NS	-0.05	0.6642	NS
Nickel	-0.20	0.0653	NS	0.08	0.4779	NS	-0.31	0.0042	NS	0.05	0.6519	NS
Total Alkanes	-0.26	0.0187	NS	0.12	0.2764	NS	-0.38	0.0003	S	-0.05	0.6829	NS
4,4′-DDD	-0.09	0.4321	NS	0.11	0.3380	NS	-0.23	0.0340	NS	-0.04	0.7209	NS
4,4′-DDE	0.11	0.3387	NS	0.19	0.0832	NS	-0.12	0.2692	NS	-0.08	0.4492	NS
4,4′-DDT	-0.02	0.8533	NS	0.07	0.5142	NS	-0.17	0.1277	NS	-0.03	0.7802	NS
Total DDT	-0.003	0.9765	NS	0.16	0.1558	NS	-0.19	0.0825	NS	-0.03	0.8148	NS
Dieldrin	0.07	0.5230	NS	0.16	0.1531	NS	-0.10	0.3753	NS	0.02	0.8647	NS
Lindane	0.37	0.0006	S	0.38	0.0003	S	0.07	0.5510	NS	-0.06	0.5876	NS
Pyrene	-0.09	0.4057	NS	0.02	0.8282	NS	-0.14	0.1960	NS	-0.16	0.8886	NS
Total PCBs	0.06	0.6016	NS	0.11	0.3371	NS	-0.10	0.3511	NS	0.09	0.3951	NS

TABLE 3.3-7. Abundances of dominant demersal species (listed in decreasing order of abundance) and all demersal biota by estuarine class (A), and subregion (B). Mean abundance per trawl (averaged over all stations) and range of mean abundance per grab over all stations are given.

A.

Province		Large		Small		Tidal	
Species	Abundance	Species	Abundance	Species	Abundance	Species	Abundance
White Shrimp *Penaeus setiferus*	23.5 (0 – 615)	Atlantic Croaker *Micropogonias undulatus*	27.5 (0 – 117)	White Shrimp *Penaeus setiferus*	37.7 (0 – 615)	Neon Goby *Gobiosoma robustum*	6.4 (0 – 42)
Atlantic Croaker *Micropogonias undulatus*	21.0 (0 – 202)	Spot *Leiostomus xanthurus*	20.8 (0 – 98)	Atlantic Croaker *Micropogonias undulatus*	23.5 (0 – 202)	Atlantic Croaker *Micropogonias undulatus*	6.3 (0 – 59)
Spot *Leiostomus xanthurus*	12.0 (0 – 110)	Blue Crab *Callinectes sapidus*	2.1 (0 – 11)	Spot *Leiostomus xanthurus*	11.8 (0 – 110)	Spot *Leiostomus xanthurus*	4.3 (0 – 30)
Pinfish *Lagodon rhomboides*	4.5 (0 – 90)	Weakfish *Cynoscion regalis*	1.5 (0 – 9)	Pinfish *Lagodon rhomboides*	6.6 (0 – 90)	Silver Perch *Bairdiella chrysoura*	3.0 (0 – 19)
Brown Shrimp *Penaeus aztecus*	3.2 (0 – 83)	Pigfish *Orthopristis chrysoptera*	1.1 (0 – 9)	Star Drum *Stellifer lanceolatus*	5.0 (0 – 78)	Hardhead Catfish *Arius felis*	2.1 (0 – 20)
All Fauna (91 spp. from 169 trawls)	86.0 (0 – 637)	All Fauna (30 spp. from 32 trawls)	58.6 (3 – 232)	All Fauna (73 spp. from 105 trawls)	110.2 (1 – 637)	All Fauna (43 spp. from 32 trawls)	32.9 (0 – 72)

B.

VA – NC		SC – GA		FL	
Species	Abundance	Species	Abundance	Species	Abundance
Atlantic Croaker *Micropogonias undulatus*	33.5 (0 – 202)	White Shrimp *Penaeus setiferus*	74.8 (1 – 615)	White Shrimp *Penaeus setiferus*	23.3 (0 – 343)
Spot *Leiostomus xanthurus*	20.1 (0 – 110)	Star Drum *Stellifer lanceolatus*	12.7 (0 – 78)	Atlantic Croaker *Micropogonias undulatus*	7.0 (0 – 86)
Pinfish *Lagodon rhomboides*	7.4 (0 – 90)	Lesser Blue Crab *Callinectes similis*	5.0 (0 – 68)	Neon Goby *Gobiosoma robustum*	6.1 (0 – 42)
Blue Crab *Callinectes sapidus*	4.5 (0 – 33)	Hogchoker *Trinectes maculatus*	5.0 (0 – 35)	Silver Perch *Bairdiella chrysoura*	2.9 (0 – 19)
Brown Shrimp *Penaeus aztecus*	4.4 (0 – 83)	Atlantic Croaker *Micropogonias undulatus*	4.3 (0 – 32)	Hardhead Catfish *Arius felis*	2.7 (0 – 20)
All Fauna (49 spp. from 94 trawls)	77.8 (0 – 317)	All Fauna (53 spp. from 41 trawls)	124.6 (19 – 637)	All Fauna (53 spp. from 34 trawls)	60.4 (2 – 416)

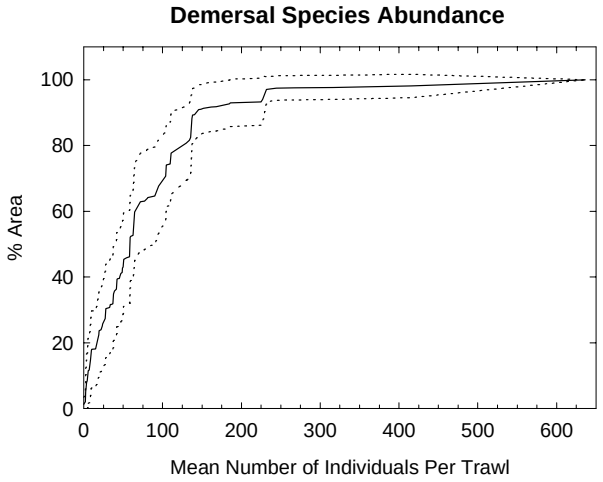

FIGURE 3.3-20. Percent area (and 95% C.I.) of CP estuaries vs. mean demersal species abundance per trawl (total abundance).

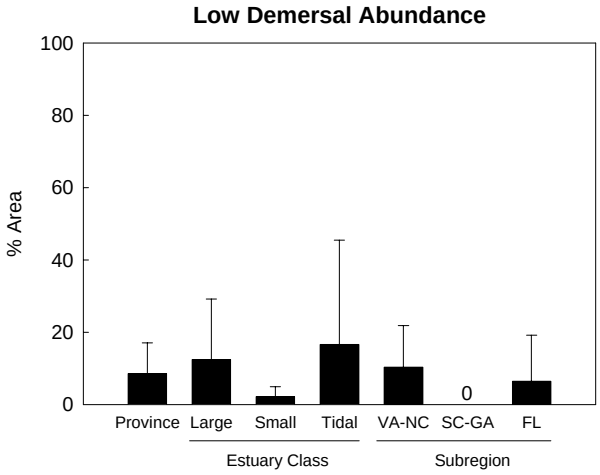

FIGURE 3.3-22. Comparison by estuarine class, and subregion, of the percent area (and 95% C.I.) of CP estuaries with low demersal abundance (mean abundance per trawl ≤ 5).

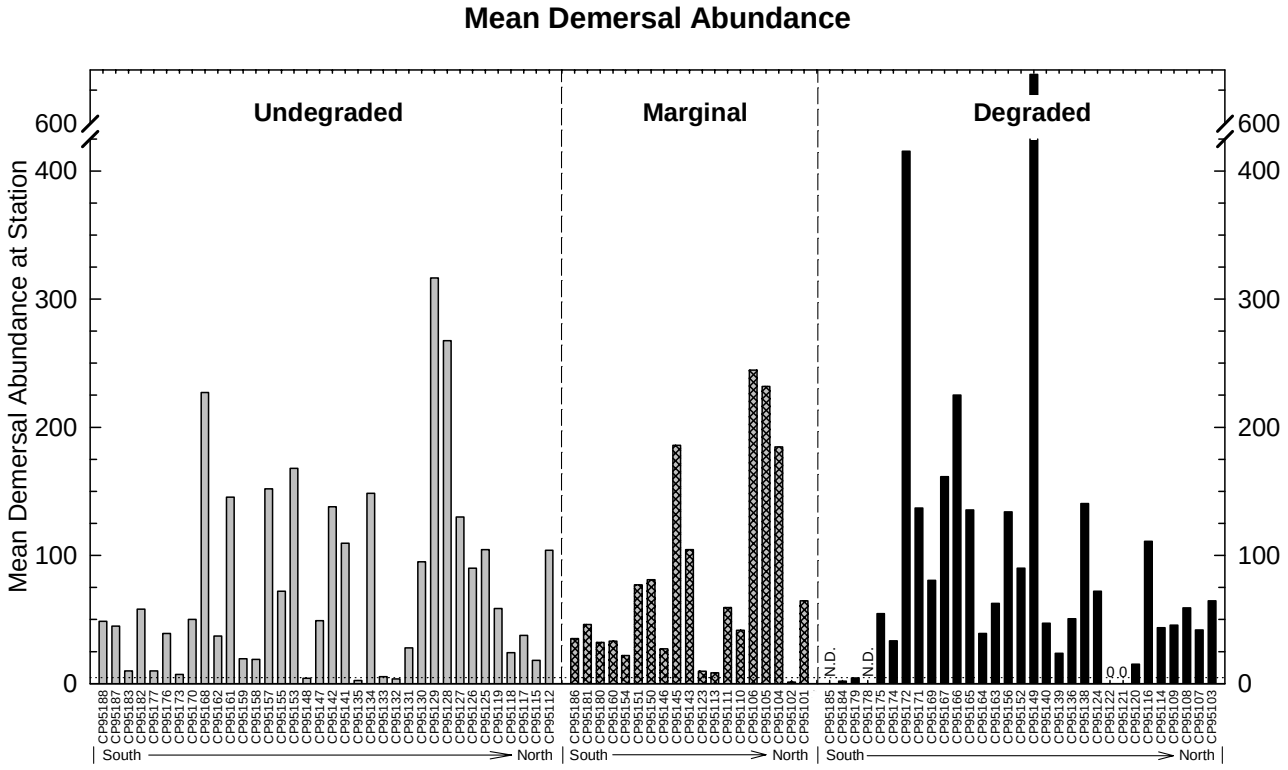

FIGURE 3.3-21. Mean demersal abundance by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see Section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values below the dotted reference line (i.e., ≤ 5) indicate possibly degraded conditions based on mean demersal abundance values. N.D. = no data.

were used. The EMAP methods, however, were selected to provide a consistent basis for comparisons across the region and with other provinces.

3.3.6 Pathological Disorders in Demersal Biota

A total of 14,586 demersal fishes, crabs, and shrimp were caught in otter trawls and examined externally for obvious signs of pathological disorders (lumps due to internal growths, external growths, ulcers, and fin rot). Only 11 pathologies, representing 0.08% of the sample population, were noted (Table 3.3-8). They were recorded from six stations representing 6% of the area of the province. Only one of these stations (CP95103 in the Chowan River, NC), had a high mean number of pathologies per trawl, defined here as > 1 (Fig. 3.3-23). This small-estuary site represented 4% of the province area (Fig. 3.3-24). Three of the six stations where pathologies were noted (CP95103, CP95165, CP95167) were in areas that showed additional signs of environmental degradation based on various exposure indicators (Fig. 3.3-23). Two other stations where pathologies were noted (CP95106 and CP95180) were at sites with possible indications of stress (low contamination accompanied by a single toxicity hit). There were no significant correlations (tested at $\alpha = 0.05$) between mean number of pathologies per trawl and bottom salinity, bottom DO, or station latitude (Table 3.3-6).

Pathological disorders in fishes were observed at seven stations representing 5% of the area of the province (Table 3.3-8). The affected specimens (seven) represented 0.08% of the sampled fish population. By species (Table 3.3-9), the highest percentage of pathologies was noted in white perch (3.4% of the sample population of white perch). Pathologies also were observed in Atlantic croaker (0.03%) and Atlantic spadefish (1.4%). Among the seven pathologies found in fishes, there were three cases of fin rot, two cases of external growths, and two cases of ulcers.

Shrimp "cotton disease" was noted at three stations representing 2% of the area of the province (Table 3.3-8). The diseased specimens represented 0.07% of the sampled shrimp population and included both white shrimp (*Penaeus setiferus*) and brown shrimp (*Penaeus aztecus*) (Table 3.3-9). Two of the three stations where this condition was recorded (CP95165 and CP95167) were from degraded sites based on exposure indicators (Fig. 3.3-23). The cause of cotton disease (also called milk disease) is believed to be microsporidian parasites (Johnson 1989). High occurrences of cotton disease could have a negative effect on commercial fisheries due to a decline in the marketability of the diseased shrimp. Also, an absence of eggs has been noted in female shrimp infected with cotton disease (Johnson 1989). Thus, the disease could lead to long-term reductions in shrimp populations.

Only one station (CP95165), a degraded site in North Newport River, GA, showed an incidence of shell disease in the blue crab *Callinectes sapidus* (Tables 3.3-8 and 3.3-9). A single diseased crab was found at this station, which represented 1% of the area of the province. Crab shell disease can occur as rust-like spots on the carapace and appendages, large ulcers, or losses of portions of the body. Though the etiology is uncertain, a number of pathogens (fungi and chitinoclastic bacteria of the genera *Vibrio* and *Pseudomonas*) have been reported from lesions (Johnson 1989). Increased incidences of shell disease have been reported from polluted environments (Young and Pearce 1975) and there is some evidence of effects on immunological function in crabs from such areas (Noga et al. 1990). During the 1993 Carolinian Province pilot study (Ringwood et al. 1995), 11 diseased crabs (from a total sample of 270 crabs) were found at four of the 24 stations sampled. All four of these stations were in polluted areas.

TABLE 3.3-8. Summary of the occurrences of pathologies in demersal biota of the Carolinian Province.

Pathology Type	Number of Pathologies	Number of Biota Examined	% of Biota Examined	Number of Stations	% Area ± 95 % C.I.
Fish Pathologies	7	9,186	0.08	3	5 ± 7
Shrimp Cotton Disease	3	4,558	0.07	3	2 ± 3
Crab Shell Disease	1	747	0.13	1	1 ± 2
Other	0	95	0.00	0	0 ± 0
All Pathologies	11	14,586	0.08	6	6 ± 8

TABLE 3.3-9. Breakdown by species of the occurrences of pathologies in demersal biota.

Taxon	Number of Pathologies	Number Examined	% of Taxon Examined	% of All Biota Examined [a]	Pathology Type [b]	States and Stations Where Observed
Fishes						
Atlantic Croaker (*Micropogonias undulatus*)	1	3564	0.03	0.01	1 GR	NC (106)
White Perch (*Morone americana*)	5	146	3.40	0.03	3 FR, 2 UL	NC (103)
Atlantic Spadefish (*Chaetodipterus faber*)	1	74	1.40	0.01	1 GR	FL (180)
Crustaceans						
Blue Crab (*Callinectes sapidus*)	1	483	0.20	0.01	1 SD	SC (165)
White Shrimp (*Penaeus setiferus*)	2	3990	0.10	0.01	2 CD	SC (165, 167)
Brown Shrimp (*Penaeus aztecus*)	1	543	0.20	0.18	1 CD	FL (188)

[a] Total number of trawl biota examined = 14,586
[b] FR = fin rot, UL = ulcer, GR = growth, LU = lumps, CD = cotton disease, SD = shell disease

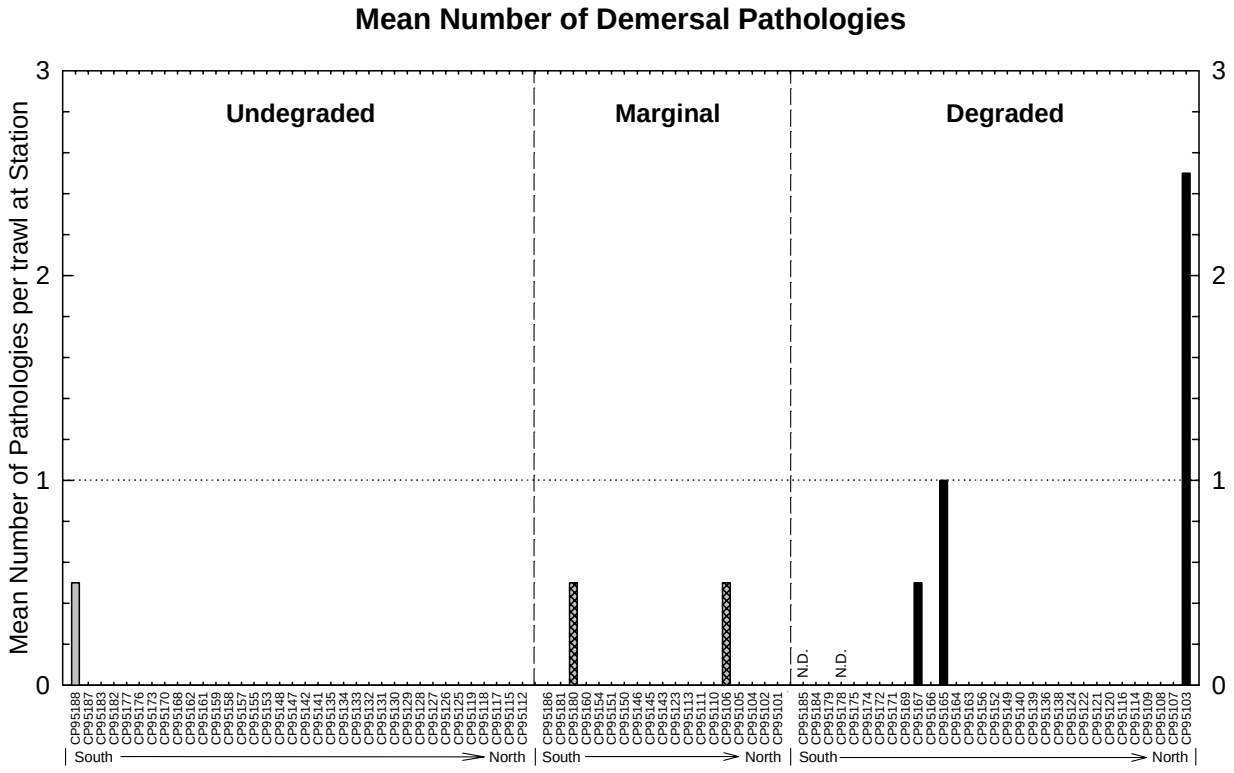

FIGURE 3.3-23. Mean number of demersal pathologies by station, with stations grouped into undegraded, marginal, and degraded categories based on contaminant levels, DO conditions, and toxicity testing results (see Section 2.3.2.7 for grouping criteria). Stations are sorted by latitude within groups. Values above the dotted reference line (i.e., > 1) indicate degraded conditions based on mean number of demersal pathologies. N.D. = no data.

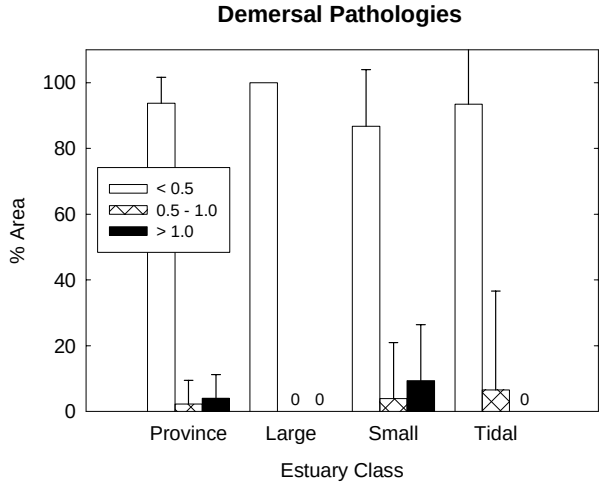

FIGURE 3.3-24. Percent area (and 95% C.I) of CP estuaries with low (<0.5), moderate (0.5–1.0), and high (>1.0) mean numbers of demersal pathologies per trawl.

3.3.7 Contaminants in Demersal Biota

Samples of spot, croaker, blue crab, and penaeid shrimp were analyzed for presence of contaminants in edible tissues (fish filets, shrimp tails, crab body-cavity meat). The samples were obtained from a subset of 13 base stations and one supplemental site in Shipyard Creek, S.C. (Table 2-11). All measured analytes in these samples were below corresponding FDA tissue guidelines — i.e., "Action Levels" for PCBs, pesticides, and mercury and "Levels of Concern" in shellfish for five additional metals (arsenic, cadmium, chromium, lead, and nickel) (Table 3.3-10, Appendices I–K). Concentrations below these guidelines were observed in spite of the fact that most of the samples were from stations where high levels of sediment contamination had been found (Table 2-11). For example, even stations with up to 13 ER-L exceedances (Station CP95152), or up to six ER-M exceedances (Stations CP95166 and CP95169), showed no evidence of tissue contamination above FDA guidelines. Also, though total arsenic was observed in sediments at moderate concentrations (between the ER-L and ER-M sediment bioeffect guidelines) at 18 stations throughout the province (see Section 3.2.3), its range in tissues (undetectable to 37 μg/g dry wt.) fell well below the FDA Level of Concern value of ~ 215 μg/g dry wt. (based on a reported wet-wt. value of 43 μg/g, set for humans in the 2–5 yr. age group, consuming crustaceans at the 90th percentile consumption rate).

Tissue contaminant data from this study did not produce any major evidence that would suggest a human-health problem from consumption of seafood. This conclusion is consistent with results of Mathews (1994) who found that contaminants in recreationally important estuarine finfish (red drum, seatrout, flounder) from South Carolina were generally low compared to human health guidelines. However, it must be understood that the analyses in the present study were limited to a very small subset of stations. The lack of a tissue contamination signal from these data does not mean necessarily that such problems do not exist, especially in local contaminant hot spots. In fact, the few samples of blue crabs that were analyzed from the chromium hot spot in Shipyard Creek, S.C. (see Section 3.2.3) appeared to have accumulated higher concentrations of this contaminant (3.7–12.9 μg/g dry wt.) in comparison to crabs from other sites in the region (undetectable – 0.34 μg/g dry wt), although the highest concentration in crabs from Shipyard Creek was still below the lowest FDA Level of Concern for chromium (~ 55 μg/g dry wt., based on a reported wet-wt. value of 11 μg/g). Potential chromium contamination in animals from this site is being examined in greater detail, with a larger sample population, as part of a subsequent (1997) monitoring effort.

3.4 Aesthetic Indicators

The presence of anthropogenic debris ("trash") in surface and bottom waters provides an obvious sign of human impacts. Floating debris was observed in about 7% of the province and bottom debris was observed in about 22% (Fig. 3.4-1). In comparison, surface and bottom debris were found in smaller proportions of these estuaries during the previous summer 1994 — < 1% and 10%, respectively (Hyland et al. 1996). Strobel et al. (1995) reported bottom debris in a comparable proportion of Virginian Province estuaries — 20% for an overall 1990 to 1993 index period. Two other indicators of human activity were the presence of oil and noxious sediment odor (i.e., smell of sewage, oil, or H_2S). Oil was observed only in 6% of the bottom sediments of the province and in none of the surface waters (Fig. 3.4-2). Noxious odors were detectable in 18% of the province sediments (Fig. 3.4-3). Bottom debris, oily sediments, and noxious sediment odors were the least pronounced in large estuaries and the most pronounced in large tidal rivers and small estuaries. Such a pattern is logical given the higher intensity of industry, human settlement, and recreational activities in inland areas associated with these latter two estuarine classes.

TABLE 3.3-10. Summary of contaminant concentration ranges observed in edible tissues of finfish and shellfish from selected contaminated and uncontaminated stations (based on sediment chemistry). All concentrations are reported on a dry-weight basis. FDA guideline values have been converted to dry weight by multiplying published wet-weight values by a factor of 5.

		Spot (N=3)	Croaker (N=10)	Blue Crab (N=4)	W. Shrimp (N=11)
Analyte	FDA Guideline	Min. – Max.	Min. – Max.	Min. – Max.	Min. – Max.
Metals (µg/g dry wt.)					
Aluminum	–	7.40 – 23.00	4.50 – 43.00	39.00 – 45.00	38.00 – 531.00
Antimony	–	N.D. – 0.01	N.D. – 0.01	N.D. – 0.03	N.D. – 0.07
Arsenic	215.0 [a]	2.70 – 4.60	N.D. – 24.20	8.00 – 22.80	N.D. – 37.00
Cadmium	15.0 [a]	0.02 – 0.26	N.D. – 0.50	0.06 – 0.85	0.02 – 1.45
Chromium	55.0 [a]	N.D. – 0.48	N.D. – 2.60	N.D. – 12.90	N.D. – 1.40
Copper	–	1.30 – 2.30	0.90 – 1.90	56.00 – 89.00	15.80 – 33.00
Iron	–	26.00 – 42.00	21.00 – 46.00	47.00 – 67.00	39.00 – 327.00
Lead	3.0 [a]	0.08 – 0.24	0.03 – 0.36	0.16 – 0.38	0.11 – 0.36
Manganese	–	N.D. – 1.40	N.D. – 4.20	10.00 – 17.00	N.D. – 10.00
Mercury	5.0 [b]	0.08 – 0.10	0.03 – 0.28	0.18 – 0.31	0.03 – 0.11
Nickel	350.0 [a]	0.12 – 0.60	N.D. – 0.41	0.05 – 0.20	0.08 – 0.50
Selenium	–	0.92 – 2.90	1.20 – 4.10	1.90 – 2.10	0.96 – 2.60
Silver	–	N.D. – N.D.	N.D. – N.D.	0.16 – 0.85	N.D. – 0.43
Tin	–	0.09 – 0.18	N.D. – 0.57	N.D. – 0.27	N.D. – 0.26
Zinc	–	22.00 – 28.00	18.00 – 36.00	57.00 – 174.00	53.00 – 63.00
Butyltins (ng Sn/g dry wt.)					
Dibutyltin	–	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.
Monobutyltin	–	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.
Tetrabutyltin	–	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.
Tributyltin (TBT)	–	N.D. – N.D.	N.D. – 7.16	N.D. – 8.87	N.D. – 46.85

[a] FDA Level of Concern for contaminant in shellfish. Value is lowest of multiple values reported by FDA for humans of various ages consuming either crustaceans or molluscs at the 90th percentile consumption rate. Values (converted from wet to dry weight) are from: FDA 1993a–As, FDA 1993b–Cd, FDA 1993c–Cr, FDA 1993d–Pb, FDA 1993e–Ni.

[b] FDA Action Level for poisonous or deleterious substances in human food and animal feed (level for edible portion of fish is given). FDA 1994.

TABLE 3.3-10 (Continued).

Analyte	FDA Guideline	Spot (N=3) Min. – Max.	Croaker (N=10) Min. – Max.	Blue Crab (N=4) Min. – Max.	W. Shrimp (N=11) Min. – Max.
PAHs (ng/g dry wt.)					
Acenaphthene	–	–	–	2.10 – 34.80	2.10 – 25.40
Acenaphthylene	–	–	–	1.70 – 10.00	0.70 – 4.00
Anthracene	–	–	–	2.10 – 6.50	0.20 – 30.40
Benzo[a]anthracene	–	–	–	1.10 – 14.90	0.60 – 16.40
Benzo[a]pyrene	–	–	–	0.20 – 2.80	0.30 – 6.70
Benzo[e]pyrene	–	–	–	0.50 – 2.40	0.40 – 4.60
Benzo[b]fluoranthene	–	–	–	0.30 – 3.90	0.40 – 9.70
Benzo[k]fluoranthene	–	–	–	0.70 – 2.30	0.20 – 3.10
Benzo[ghi]perylene	–	–	–	0.50 – 1.00	0.10 – 2.70
Biphenyl	–	–	–	4.70 – 10.20	1.60 – 14.00
Chrysene	–	–	–	0.90 – 3.50	0.70 – 20.40
Dibenz[a,h]anthracene	–	–	–	0.70 – 1.30	0.20 – 0.90
Dibenzothiophene	–	–	–	2.80 – 8.00	0.90 – 8.00
2,6-Dimethylnaphthalene	–	–	–	6.50 – 8.90	1.80 – 10.00
Fluoranthene	–	–	–	1.10 – 45.80	1.00 – 168.80
Fluorene	–	–	–	4.30 – 11.40	2.40 – 22.20
Indeno[1,2,3-cd]pyrene	–	–	–	0.40 – 1.20	0.20 – 1.70
1-Methylnaphthalene	–	–	–	4.80 – 14.00	2.20 – 13.90
2-Methylnaphthalene	–	–	–	4.40 – 17.50	2.70 – 13.00
1-Methylphenanthrene	–	–	–	1.50 – 7.00	0.80 – 12.20
Naphthalene	–	–	–	41.80 – 53.20	8.90 – 48.40
Perylene	–	–	–	1.20 – 2.50	0.40 – 3.50
Phenanthrene	–	–	–	2.90 – 19.50	2.10 – 77.70
Pyrene	–	–	–	2.20 – 41.80	3.10 – 178.70
1,6,7-Trimethylnaphthalene	–	–	–	2.80 – 7.90	1.40 – 7.20
Total PAHs (without Perylene)	–	–	–	90.90 – 401.40	71.60 – 802.20

TABLE 3.3-10 (Continued).

Analyte	FDA Guideline	Spot (N=3) Min. – Max.	Croaker (N=10) Min. – Max.	Blue Crab (N=4) Min. – Max.	W. Shrimp (N=11) Min. – Max.
PCBs (ng/g dry wt.)					
Total PCBs	10000.0 [c]	51.37 – 141.60	48.70 –343.40	21.25 – 386.88	19.41 – 125.46
Pesticides (ng/g dry wt.)					
Aldrin	1500.0 [b]	N.D. – 0.17	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.
Alpha Chlordane	–	0.84 – 1.40	N.D. – 5.81	N.D. – N.D.	N.D. – 0.51
Gamma Chlordane	–	N.D. – 1.10	N.D. – 3.19	N.D. – 0.47	N.D. – N.D.
Oxychlordane	–	0.85 – 1.11	N.D. – 1.85	N.D. – 6.63	N.D. – 0.65
Chlordane [d]	1500.0 [b]	6.25 – 6.89	0.39 – 22.83	N.D. – 11.24	N.D. – 3.05
DDD [e]	25000.0 [b]	4.33 – 9.57	0.39 – 35.59	N.D. – 11.16	N.D. – 1.52
DDE [e]	25000.0 [b]	14.45 – 43.37	1.86 – 79.37	1.94 – 20.40	0.82 – 3.91
DDT [e]	25000.0 [b]	1.29 – 3.73	N.D. – 8.08	N.D. – N.D.	N.D. – 0.14
Total DDTs [f]	25000.0 [b]	21.25 – 56.67	3.56 –123.03	1.94 – 31.56	1.08 – 5.57
Dieldrin	1500.0 [b]	2.58 – 10.21	N.D. – 6.61	N.D. – 4.12	N.D. – 1.24
Endosulfan II (Beta-Endosulfan)	–	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.
Endrin	1500.0 [b]	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.	N.D. – 2.85
Alpha BHC (Alpha HCH)	–	N.D. – 0.60	N.D. – 0.70	N.D. – N.D.	N.D. – N.D.
Beta BHC (Beta HCH)	–	1.24 – 1.47	N.D. – 1.75	N.D. – 1.60	N.D. – 0.31
Delta BHC (Delta HCH)	–	N.D. – N.D.	N.D. – 0.46	N.D. – 2.67	N.D. – 0.52
Gamma BHC (Gamma HCH or Lindane)	–	0.49 – 1.55	N.D. – 0.84	N.D. – 0.35	N.D. – 0.08
Total BHC (Total HCH)	–	2.07 – 2.86	N.D. – 3.20	N.D. – 4.62	N.D. – 0.83
Hexachlorobenzene (HCB)	–	0.59 – 1.31	0.37 – 2.24	0.40 – 0.54	N.D. – 0.36
Heptachlor	1500.0 [b]	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.	N.D. – N.D.

[b] FDA Action Level for poisonous or deleterious substances in human food and animal feed (level for edible portion of fish is given). FDA 1994.

[c] FDA tolerance for unavoidable residues of PCBs in fish and shellfish. FDA 1984.

[d] Chlordane = cis-chlordane + trans-chlordane + cis-nonachlor + trans-nonachlor + oxychlordane + alpha-chlordene + beta-chlordene + gamma-chlordene + chlordene. Classification used by FDA 1994. Note, however, that only cis-nonachlor (=alpha-chlordane), trans-nonachlor, oxychlordane, and cis-chlordane were measured in this study and included in the summary values.

[e] DDD = 2,4′-DDD + 4,4′-DDD; DDE = 2,4′-DDE + 4,4′-DDE; DDT = 2,4′-DDT + 4,4′-DDT. Classification used by FDA 1994.

[f] Total DDTs = 2,4′-DDD + 4,4′-DDD + 2,4′-DDE + 4,4′-DDE + 2,4′-DDT + 4,4′-DDT.

TABLE 3.3-10 (Continued).

Analyte	FDA Guideline	Spot (N=3) Min. – Max.	Croaker (N=10) Min. – Max.	Blue Crab (N=4) Min. – Max.	W. Shrimp (N=11) Min. – Max.
Pesticides (ng/g dry wt.) [Continued]					
Heptachlor epoxide	1500.0 [b]	0.35 – 0.91	N.D. – 0.93	N.D. – 2.60	N.D. – N.D.
Heptachlor + Heptachlor Epoxide	1500.0 [b]	0.35 – 0.91	N.D. – 0.93	N.D. – 2.60	N.D. – N.D.
Mirex	500.0 [b]	0.20 – 0.57	N.D. – 4.35	0.61 – 3.13	N.D. – 2.66
cis-Nonachlor	–	1.59 – 1.99	0.20 – 5.43	N.D. – 1.26	N.D. – 0.53
trans-Nonachlor	–	2.15 – 3.45	0.19 – 9.90	N.D. – 3.35	N.D. – 1.60
Toxaphene	25000.0 [b]	–	–	–	–
Percent Lipid	–	2.64 – 5.47	0.04 – 5.82	0.17 – 0.34	0.13 – 0.42

[b] FDA Action Level for poisonous or deleterious substances in human food and animal feed (level for edible portion of fish is given). FDA 1994.

Secchi-disk readings were taken at each station as a measure of water clarity. Secchi depths ranged from 0.3 to 2.3 m (Fig. 3.4-4). A secchi depth < 0.5 m was used as a criterion to characterize low water clarity (*sensu* Summers et al. 1993). Twelve percent of the province area had low water clarity (poor visibility) based on this criterion. For comparison, this percentage of affected area is larger than the 1% reported for these estuaries during the previous summer 1994 (Hyland et al. 1996) but smaller than the 24% reported for estuaries of the Lousianian Province (summer 1991, Summers et al. 1993). In 1995, 59% of the Carolinian Province area had intermediate water clarity (secchi depths of 0.5–1.0 m) and 29% had relatively high water clarity (secchi depths > 1.0 m). Poor to intermediate water clarity was the most notable in large tidal rivers (Fig. 3.4-5).

Turbid waters are often interpreted as a sign of poor environmental quality caused by factors such as nutrient over-enrichment. However, it must be understood that turbid waters also are a natural characteristic of estuaries due to factors such as high primary productivity, large tidal ranges, and high detrital and sediment loadings. Thus, the secchi-disk data must be interpreted with caution.

3.5 Linkages Between Biological Impacts and Anthropogenic Factors

Degraded condition of infaunal assemblages was more closely coupled with sediment contamination than with any of the other indicators of exposure or aesthetic quality (Table 3.5-1). High sediment contamination occurred at 11 of 12 sites with low infaunal diversity, 10 of 10 sites with low infaunal species richness, 11 of 21 sites with low infaunal abundance, and 10 of 14 sites with low benthic index values. Of the remaining exposure indicators, sediment toxicity based on the *Mercenaria* ("seed clam") assay showed the next closest concordance with degraded infaunal conditions. The two amphipod assays showed the least concordance. Noxious sediment odor was the aesthetic indicator most coupled with evidence of a degraded benthos.

Low DO did not appear to be the primary cause of adverse conditions in these benthic assemblages. Overall, there were 17 stations that exhibited evidence of a degraded benthos accompanied by one or more measures of adverse exposure conditions (Table 3.5-2). Degraded infaunal conditions were accompanied by high sediment contamination at all but one of these stations, and by low DO at only three of the stations. There were no stations where degraded benthic conditions co-occurred with low DO alone since all three stations with low DO and degraded infauna also had high sediment contamination. However, low DO could have contributed to the observed benthic impacts at these few sites.

Other adverse sediment conditions related to organic over-enrichment may also have contributed to observed infaunal bioeffects. Of the 17 degraded infaunal sites listed in Table 3.5-2, all but two (CP95164 and CP95165) had TOC concentrations above 2% (Appendix B). Only three of the total 18 base stations with TOC > 2% (CP95103, CP95117, and CP95181, Appendix B) did not show some concomitant evidence of a degraded benthos. As presented in Section 3.1.5, high levels of TOC above this criterion may be suggestive of organic over-enrichment, either from natural or anthropogenic inputs. Organically enriched substrates are essential to the energetics of benthic communities (Darnell 1967, Tenore 1977). However, harmful conditions may also arise as toxic metabolic byproducts (e.g., unionized ammonia and hydrogen sulfide) accumulate to excessive levels from decomposition of the excess organic material.

Evidence of degraded biotic conditions was observed less frequently in demersal assemblages than in infauna. As summarized in Table 3.5-1, there were only seven base stations with low H′, six with low numbers of species, eight

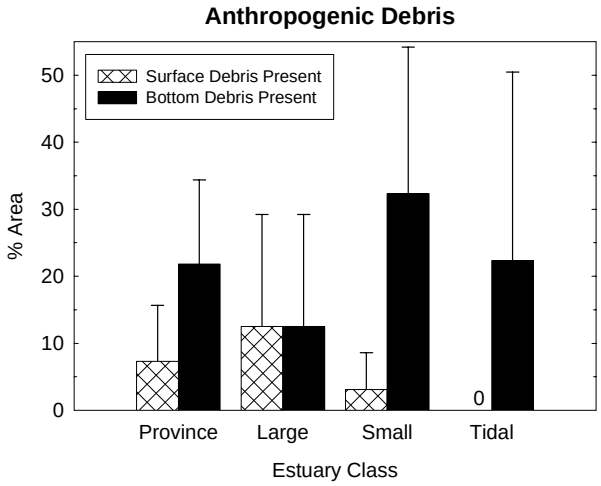

FIGURE 3.4-1. Percent area (and 95% C.I.) of CP estuaries with anthropogenic debris present in surface waters or on the bottom.

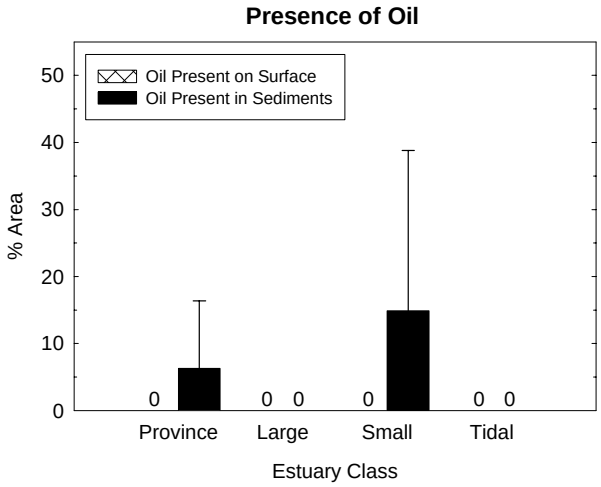

FIGURE 3.4-2. Percent area (and 95% C.I.) of CP estuaries with oil detected (by smell or sight) in surface waters or in bottom sediments.

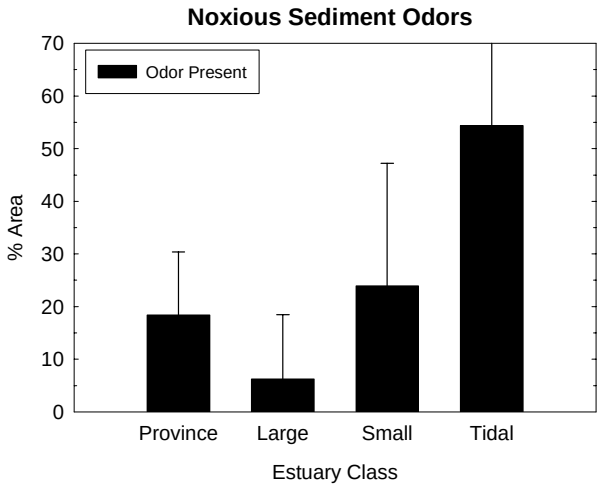

FIGURE 3.4-3. Percent area (and 95% C.I.) of CP estuaries with noxious sediment odors (sulfur, oily, or sewage).

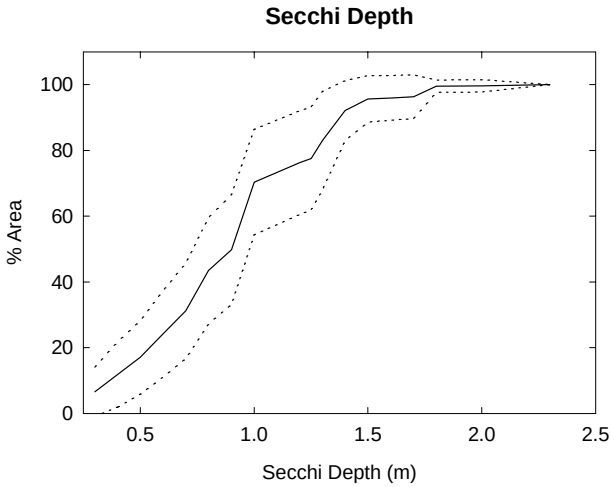

FIGURE 3.4-4. Percent area (and 95% C.I.) of CP estuaries vs. secchi depths (m). Calculations based on stations with bottom depths > 0.5 m (N = 77).

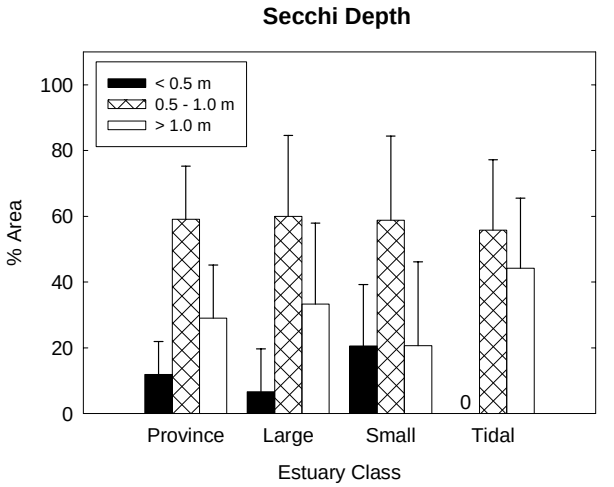

FIGURE 3.4-5. Percent area (and 95% C.I.) of CP estuaries with low (< 0.5 m), moderate (0.5–1.0 m), or high (> 1.0) secchi depths. Calculations based on stations with bottom depths > 0.5 m (N = 77).

TABLE 3.5-1. Summary of the overall condition of Carolinian Province estuaries in 1995 based on various combinations of exposure, aesthetic and biotic condition indicators. Percent area (and number of stations) are given.

A.

		Exposure Indicators						Aesthetic Indicators			
Biotic Condition Indicators		Low DO [a] (3%, N=4)	Sig. Sediment Contamination [b] (30%, N=25)	Sig. A.abdita Toxicity [c] (< 1%, N=1)	Sig. A. verrilli Toxicity [c] (7%, N=3)	Sig. Microtox Toxicity [d] (19%, N=20)	Sig. M. mercenaria Toxicity [e] (39%, N=27)	Low Water Clarity [f] (12%, N=9)	Noxious Sediment Odor (18%, N=25)	Oily Sediments (6%, N=2)	Trash Present (25%, N=27)
Low Infaunal Diversity [g]	(15%, N=12)	3 (3)	15 (11)	0 (0)	0 (0)	2 (2)	6 (6)	1 (1)	4 (4)	0 (0)	2 (4)
Low Infaunal Richness [h]	(19%, N=10)	3 (3)	19 (10)	0 (0)	0 (0)	7 (2)	12 (6)	1 (1)	9 (5)	6 (1)	< 1 (2)
Low Infaunal Abundance [i]	(32%, N=21)	3 (3)	18 (11)	0 (0)	0 (0)	9 (5)	10 (6)	2 (3)	12 (5)	6 (1)	5 (4)
Low Benthic Index Score [j]	(21%, N=14)	3 (3)	17 (10)	0 (0)	0 (0)	8 (4)	15 (8)	4 (3)	9 (5)	6 (1)	2 (4)
Low Demersal Diversity [k]	(11%, N=7)	1 (2)	9 (4)	0 (0)	4 (1)	6 (3)	7 (3)	< 1 (1)	2 (3)	< 1 (1)	4 (2)
Low Demersal Richness [l]	(7%, N=6)	3 (3)	3 (3)	0 (0)	0 (0)	1 (2)	2 (2)	0 (0)	4 (4)	< 1 (1)	0 (0)
Low Demersal Abundance [m]	(9%, N=8)	1 (2)	1 (2)	0 (0)	0 (0)	1 (3)	2 (3)	0 (0)	2 (3)	< 1 (1)	< 1 (1)
High Demersal Pathologies [n]	(4%, N=1)	0 (0)	4 (1)	0 (0)	4 (1)	4 (1)	4 (1)	0 (0)	0 (0)	0 (0)	4 (1)

B.

Degraded conditions based on any of above biotic, exposure, or aesthetic indicators	82 (76)
Degraded biological conditions [o], accompanied by significant pollution exposure [p]	29 (20)

[a] Low near-bottom DO (one or more observations < 0.3 mg/L, or ≥ 20 % of the observations < 2.0 mg/L, or all observations < 5.0 mg/L).

[b] ≥ 3 ER-L or TEL contaminant exceedances, or ≥ 1 ER-M or PEL exceedance.

[c] Significant *Ampelisca* sp. toxicity (Percent survival difference relative to control > 20 %, and significant at $\alpha = 0.05$).

[d] Significant Microtox® toxicity (Water corrected $EC_{50} \leq 0.2$ % if silt-clay content of sediment ≥ 20 %, or $EC_{50} \leq 0.5$ % if silt-clay content < 20 %).

[e] Significant *Mercenaria mercenaria* toxicity (Percent mortality relative to control ≥ 20%, and significant at $\alpha = 0.05$).

[f] Secchi depth < 0.5 m (of only those observations with depths > 0.5 m)

[g] Mean infaunal diversity per grab ≤ 1.

[h] Mean infaunal richness per grab ≤ 3.

[i] Mean infaunal abundance per grab ≤ 25.

[j] Benthic index score ≤ 1.5.

[k] Mean demersal diversity per grab ≤ 0.5.

[l] Mean demersal richness per trawl ≤ 2.

[m] Mean demersal abundance per trawl ≤ 5.

[n] Mean number of demersal pathologies per trawl > 1.

[o] Based on any of the biotic indicators ([g–n])

[p] Defined as either low DO ([a]), or high sediment contamination ([b]), or sig. toxicity in ≥ 50% of assays at a station ([c–e]).

TABLE 3.5-2. Stations sampled in the Carolinian Province in 1995 that exhibited evidence of degraded biological conditions accompanied by significant pollution exposure.

			Adverse Condition	
Station	Estuary Type	Location	Exposure [a]	Biotic [b]
CP95103	Small Estuary	Chowan River, NC	CON, MTX, AV, MER	DEM
CP95107	Large Estuary	Albemarle Sound, NC	CON, MER	INF
CP95109	Small Estuary	Little Alligator River, NC	CON, MTX, MER	INF
CP95114	Small Estuary	Pungo Creek, NC	CON, MER	INF
CP95116	Small Estuary	Pongo River, NC	CON	INF, DEM
CP95120	Small Estuary	Durham Creek, NC	CON, MER	INF
CP95121	Large Tidal River	Pamlico River, NC	CON, DO	INF, DEM
CP95122	Large Tidal River (Rep.)	Pamlico River, NC	CON, DO, MER	INF, DEM
CP95124	Large Tidal River	Pamlico River, NC	CON, DO	INF, DEM
CP95136	Large Tidal River	Neuse River, NC	CON	INF
CP95139	Large Tidal River	Neuse River, NC	CON, MTX	INF
CP95140	Small Estuary	Adams Creek, NC	CON	INF
CP95149	Small Estuary	Winyah Bay, SC	MTX, MER	INF, DEM
CP95156	Small Estuary	South Edisto River, SC	CON, MTX, MER	INF
CP95164	Small Estuary	Ogeechee River, GA	CON	INF
CP95165	Small Estuary	North Newport River, GA	CON	INF
CP95171	Small Estuary	Saint Johns River, FL	CON, MTX, MER	INF
CP95172	Small Estuary	Doctors Lake, FL	CON, MER	INF
CP95179	Small Estuary	Newfound Harbor, FL	MTX, MER	DEM
CP95184	Large Tidal River	Indian River Lagoon, FL	MTX, MER	DEM

[a] Significant pollution exposure defined as either significant sediment contamination, low DO, or significant toxicity in ≥ 50% of assays at a station:
CON = High sediment contamination.
DO = Low dissolved oxygen.
MTX = Sig. sediment toxicity based on Microtox® assay.
AV = Sig. sediment toxicity based on *Ampelisca abdita* survival assay.
MER = Sig. sediment toxicity based on *Mercenaria mercenaria* growth assay.

[b] Significantly degraded biological conditions defined as either of the following:
DEM = Low values of demersal species richness, abundance or diversity, or high occurrence of pathologies.
INF = Low values of infaunal species richness, abundance or diversity, or low benthic index score.

with low abundance, and one with a high number of pathological disorders. Of the 85 base stations where trawls were obtained, only eight exhibited one or more of these conditions along with some measure of adverse exposure condition (Table 3.5-2). Five of these eight stations had either high sediment contamination (two) or a combination of high sediment contamination and low DO (three). As for infauna, it is interesting to note that the only three sites with low DO also had degraded demersal assemblages. At two of these stations (CP95121 and CP95122 in the Pamlico River), trawls were completely void of life and numerous dead fish (including commercial species such as red drum, *Sciaenops ocellatus*) were observed floating on the surface of the water (Wheeler et al. 1996).

About 82% of the province area, represented by 76 of the 87 samplable base stations, showed some indication of environmental disturbance based on any one of the multiple indicators of biotic, exposure, or aesthetic conditions that were measured in this study (Table 3.5-1, Part B). However, co-occurrences of adverse biological conditions, either in infauna or demersal biota, and evidence of adverse exposure conditions (i.e., significant sediment toxicity, high sediment contamination in excess of bioeffect guidelines, or low DO in bottom waters) were observed in a much smaller proportion of the province — 29% (represented by 20 stations). These 20 stations are listed in Table 3.5-2. Over half of these sites (12) were in North Carolina, as were most degraded sites during the previous year of sampling (Hyland et al. 1996). As noted above, the majority of these sites were characterized by degraded infaunal assemblages accompanied by high sediment contamination and/or significant sediment toxicity based on *Mercenaria* ("seed clam") and Microtox® assays.

Data on sediment contamination, sediment toxicity, and macroinfaunal composition were examined to evaluate conditions of Carolinian Province estuaries from the perspective of sediment quality. Combining measures of sediment chemistry, toxicity, and in-situ benthic condition has been shown to be very effective as a weight-of-evidence approach to assessing contaminant-induced degradation of the benthos (Chapman 1990, Chapman et al. 1991). Table 3.5-3 summarizes results of this analysis, based on data from both 1994 and 1995, and on three different methods of evaluating the multiple sediment toxicity results. A sizable portion of the province in both years — 36% in 1994 and 51% in 1995 — showed some evidence of either degraded benthic assemblages, contaminated sediment in excess of bioeffect guidelines, or high sediment toxicity (based on significant toxicity in ≥ 50% of assays at a station). However, co-occurrences of a degraded benthos and adverse exposure conditions (sediment contamination and/or toxicity) were much less extensive. Such conditions were found at 16 of 82 stations with samplable substrates in 1994 (representing 17% of the province) and 17 of 86 stations in 1995 (representing 25% of the province).

Only four sites in 1994 (representing 5% of the province area) and three sites in 1995 (representing 7%) had degraded infauna accompanied by both sediment contamination and toxicity (based on significant hits in ≥ 50% of assays at a station). These data suggest that strong contaminant-induced effects on the benthos are probably limited to a fairly small percentage of estuarine area province-wide. Note that a similar conclusion would be reached if the two alternative criteria for evaluating sediment toxicity were used. For example, the 1995 estimate for percent area of estuaries with a degraded benthos, sediment contamination, and sediment toxicity would shift only from 7 to 8% (due to the addition of one station) if the determination of toxicity were based on a significant response in either the *Ampelisca abdita* or Microtox® assays (the two bioassays performed province-wide in both years). This estimate would shift only to 13% (due to the addition of six more stations) even if the determination of toxicity were based on a significant response in any one of the four assays performed on 1995 samples.

TABLE 3.5-3. Comparisons of the % area of Carolinian Province estuaries exhibiting designated combinations of sediment toxicity, contamination, and in-situ benthic conditions, based on three different criteria for evaluating sediment toxicity. Percent area ± 95% C.I. are given. Numbers of stations also are given in parentheses.

	1994			1995		
Ecological Condition:	*A. abdita* Tox. or Microtox	≥50% of Tox. Tests[a]	Any Tox. Test Hit[a]	*A. abdita* Tox. or Microtox	≥50% of Tox. Tests[b]	Any Tox. Test Hit[b]
Undegraded Benthos without sediment contamination or toxicity	64 ± 13 (49)	64 ± 13 (49)	64 ± 13 (49)	49 ± 14 (39)	49 ± 14 (45)	34 ± 14 (28)
Some stress, but no connection between adverse biotic and exposure conditions [c]	18 ± 9 (17)	18 ± 9 (17)	18 ± 9 (17)	26 ± 12 (29)	27 ± 12 (24)	38 ± 12 (38)
Degraded Benthos with sediment contamination or toxicity (but not both)	12 ± 5 (12)	12 ± 5 (12)	12 ± 5 (12)	17 ± 10 (14)	18 ± 10 (14)	15 ± 12 (11)
Degraded Benthos with sediment contamination and toxicity	5 ± 5 (4)	5 ± 5 (4)	5 ± 5 (4)	8 ± 10 (4)	7 ± 10 (3)	13 ± 12 (9)

[a] Total of two toxicity tests were performed.
[b] Total of four toxicity tests were performed.
[c] Degraded benthos, without contamination or toxicity; or, healthy benthos, with contamination and/or toxicity.

It must be understood that the above estimates of degraded estuarine area were derived from the broad-scale probabilistic sampling framework of EMAP-Estuaries. This design was not intended to support detailed characterizations of pollutant distributions and sources within individual estuarine systems. In fact, only one station was sampled in many of these estuaries. Thus, some estuaries classified as undegraded may include additional degraded portions outside the immediate vicinity of randomly selected sites. Such localized impacts were detected in this study at some nonrandom supplemental sites near suspected contaminant sources (Ringwood et al. 1995, 1996).

3.6 Between-Year Comparisons in Ecological Conditions

There were three indicators that showed fairly substantial differences between the 1994-95 surveys. They were: % area with euhaline bottom salinities (> 30 ‰), % area with alkane concentrations in sediments > 7000 ng/g, and % area of degraded estuaries based on any biotic, exposure, or aesthetic indicator (Table 3.6-1). Ninety-five percent confidence intervals for the two years do not overlap for these three indicators. It is difficult to determine exactly what these differences mean ecologically. Because a new set of random sites was sampled each year, such differences could be due simply to the non-homogeneous nature of the environment. Also, the data represent only two sampling periods and thus are insufficient to define temporal trends. Yet, some possible interpretations of these differences and other related points may be made from the combined survey data.

The lower percentage of euhaline water in 1995 (Table 3.6-1) is suggestive of larger freshwater inputs in comparison to the previous year. The summer of 1995, in fact, was a period of intense storm activity along the southeastern coast. According to a report by the NOAA National Climatic Data Center and National Hurricane Center (NCDC and NHC 1996), the 1995 Atlantic hurricane season was the busiest one (yielding the highest number of named storms) since 1933 and second busiest since 1871. An analysis of NCDC monthly precipitation data also indicated that total combined rainfall for June–August in eastern portions of Florida, Georgia, South Carolina, and North Carolina was significantly higher in 1995 versus 1994 (mean of 23.30 inches for 73 sites in 1995, and mean of 17.87 inches for 67 sites in 1994; $p < 0.001$).

Though speculative, the potential increases in storm-water runoff may also have contributed to increases in non-point source contaminant inputs from land, or in the redistribution of existing contaminants over broader areas within the estuaries. Total alkanes > 7000 ng/g, for example, were found in 17 ± 12% of the province in 1995 and in only 1 ± 1% in 1994. Moreover, the % area of estuaries with high overall sediment contamination (≥ 3 ER-L/TEL or ≥ 1 ER-M/PEL exceedances) was much greater in 1995 (30 ± 12%) than in 1994 (12 ± 8%). The 95% confidence intervals for this latter indicator overlapped slightly between years (Table 3.6-1). However, as discussed in Section 3.2.3, the association between sediment contamination and sampling year was statistically significant based on the Pearson chi-square test of independence ($P = 0.005$), suggesting that the percentage of estuaries with high sediment contamination was significantly higher in 1995 than in 1994. Greater contamination in 1995 by pesticides (namely dieldrin, lindane, and DDT and derivatives) accounted for most of the difference.

Combined evidence of environmental degradation based on any one of the multiple biotic, exposure, or aesthetic indicators measured in this study was found over a greater proportion of the province in 1995 than in 1994. Ninety-five percent confidence intervals for this combined set of conditions (82 ± 12% in 1995, 49 ± 14% in 1994, Table 3.6-1) were non-overlapping

TABLE 3.6-1. Between year comparison of the percent estuarine area (and 95 % C.I.) exhibiting designated levels of selected indicators. Bolded intervals are non-overlapping between years.

Indicators and Characteristics	1994 (N = 84)	1995 (N = 88)
Habitat Indicators		
Tidal Range > 2 m	10 ± 6	8 ± 7
Salinity (Bottom Waters)		
• Oligohaline (< 5 ‰)	17 ± 10	17 ± 13
• Mesohaline (5–18 ‰)	9 ± 12	23 ± 16
• Polyhaline (>18–30 ‰)	52 ± 13	55 ± 4
• Euhaline (> 30 ‰)	**22 ± 12**	**5 ± 4**
Sig. Water Stratification, $\|\Delta\sigma_t\| > 2$	14 ± 7	20 ± 12
Silt-Clay Content		
• Silt-clay < 20 %	66 ± 12	54 ± 14
• Silt-clay > 80 %	22 ± 10	27 ± 14
Total Organic Carbon (TOC) > 2 %	20 ± 9	30 ± 14
Exposure Indicators		
Low DO (Bottom Waters)		
• DO < 5 mg/L (Instantaneous)	12 ± 8	20 ± 10
• DO < 2 mg/L (Instantaneous)	2 ± 3	3 ± 2
• Sig. low DO (Chronic and Acute) [a]	5 ± 7	3 ± 2
Sediment Toxicity		
• Sig. Amphipod (A. abdita) Toxicity [b]	2 ± 5	0.2 ± 1
• Sig. Microtox® Toxicity [c]	19 ± 9	19 ± 11
Sediment Contamination		
• ≥ 3 ER-L/TEL or ≥ 1 ER-M/PEL Exceedance [d]	12 ± 8	30 ± 12
• Total Alkanes ≥ 7000 ng/g	**1 ± 1**	**17 ± 12**
• Tributyltin > 5 ng/g	23 ± 12	6 ± 10

[a] DO < 2 mg/L for > 20% of continuous datasonde record or DO < 5 mg/L throughout entire continuous record or DO < 0.3 mg/L at any time during continuous record.

[b] Mortality relative to control ≥ 20 % and sig. at $\alpha = 0.05$.

[c] $EC_{50} \leq 0.2$ if silt-clay ≥ 20 %, or $EC_{50} \leq 0.5$ % if silt-clay < 20 %.

[d] Note that overlapping 95% C.I.s occurred for all individual chemicals (or chemical groups) that have ER-L, ER-M, TEL, or PEL sediment quality guidelines. Therefore, these analytes are not reported in this table.

TABLE 3.6-1 (Continued).

Indicators and Characteristics	1994 (N = 84)	1995 (N = 88)
Biotic Condition Indicators		
Infauna		
• Mean Species Richness/Grab ≤ 3	9 ± 5	19 ± 12
• Mean Abundance/Grab ≤ 25	22 ± 10	32 ± 14
• Mean H′(Diversity)/Grab ≤ 1	12 ± 7	15 ± 9
• Benthic Index ≤ 1.5	17 ± 9	21 ± 12
Demersal Biota		
• Mean Species Richness/Trawl ≤ 2	6 ± 7	7 ± 7
• Mean Abundance/Trawl ≤ 5	7 ± 7	9 ± 9
• Mean # Pathologies/Trawl > 1	1 ± 1	4 ± 7
• Mean H′ (Diversity)/Trawl ≤ 0.5	6 ± 7	11 ± 9
Aesthetic Indicators		
Anthropogenic Marine Debris Present		
• At Sea Surface	< 1 ± < 1	7 ± 8
• On Bottom	10 ± 7	22 ± 13
Secchi depth < 0.5 m	1 ± 1	12 ± 10
Noxious Sediment Odors Present	14 ± 9	18 ± 1
Oil Present		
• At Sea Surface	0	0
• In Sediments	2 ± 1	6 ± 10
Combined Indicators		
Degraded based on any biotic, exposure, or aesthetic indicator [e]	**49 ± 14**	**82 ± 12**
Degraded biota (infaunal or demersal), accompanied by sig. pollution exposure [e]	13 ± 8	29 ± 12
Degraded sediment quality (degraded benthos, sig. contamination, and sig. toxicity in ≥ 50% of assays). [e]	5 ± 5	7 ± 10

[e] See table 3.5-1 for detailed descriptions of the biotic, exposure, and aesthetic indicators considered, as well as definitions of sig. contamination and sig. toxicity.

between the two years. The larger percentage of estuaries in 1995 with high sediment contamination (noted above) accounted for much of this difference.

Co-occurrences of degraded biological and exposure conditions at the same site were found in much smaller proportions in either year. For example, degraded infauna or demersal biota, in association with some indication of adverse exposure condition (i.e., significant sediment toxicity in ≥ 50% of assays, high sediment contamination in excess of bioeffect guidelines, and/or low DO in bottom waters), occurred in 29 ± 12 % of the province in 1995 and 13 ± 8 % in 1994 (Table 3.6-1). Highly degraded sediment quality (degraded infauna accompanied by both sediment contamination and toxicity) was observed in similar proportions each year: 7 ± 10% of the province area in 1995 and 5 ± 5% in 1994 (based on significant toxicity in ≥ 50% of assays) (Table 3.6-1, 3.5-3). As discussed in the previous section, the combined data from both years suggested that strong contaminant-induced effects on the benthos (based on this weight-of-evidence approach) were limited to a fairly small percentage of estuarine area province-wide.

4. SUMMARY

1. The Carolinian Province, one of 12 national EMAP-Estuaries regions, extends from Cape Henry Virginia through the southern end of the Indian River Lagoon along the east coast of Florida.

2. This study was conducted to identify the estuarine resources of this region and assess their condition based on a variety of synoptically measured indicators of environmental quality. A stratified random sampling approach was incorporated to support probabilistic estimates of the aerial extent of degraded vs. undegraded resources.

3. Estuaries were stratified into three classes based on physical dimensions: large estuaries (area > 260 km^2 and length/width < 20), small estuaries (2.6–260 km^2), and large tidal rivers (tidally influenced portion of a river with detectable tides > 2.5 cm, area > 260 km^2, and length/width > 20). This classification scheme resulted in the identification of 200 estuaries with an overall surface area of 11,622 km^2. The total comprised three large estuaries (Currituck, Albemarle, and Pamlico Sounds in NC), three large tidal rivers (Pamlico and Neuse Rivers in North Carolina; Indian River Lagoon in FL), and 194 small estuaries with corresponding subpopulation areas of 5581.1 km^2, 1134 km^2, and 4907 km^2 respectively.

4. A total of 87 random base stations and 21 non-random supplemental stations was sampled from July 5 to September 14, 1995. Base stations made up the probability-based monitoring design. By estuarine class, there were 16 base stations in large estuaries, 54 in small estuaries, and 17 in large tidal rivers. By subregion, there were 47 base stations in VA/NC, 21 in SC/GA, and 19 in FL. One additional small estuary in NC (Rattan Bay, containing station 137) was part of the original probabilistic design, but was unsamplable for all variables.

5. Depths standardized to mean lower low water (MLLW) ranged from 0 to 12.7 m at base stations across the province. Eighty-nine percent of the province area had MLLW-corrected depths < 6.4 m (lower half of the depth range) indicating that most of these estuaries are fairly shallow coastal systems.

6. Large tidal ranges in excess of 2 m were observed in about 8% of the province. Such conditions were the most characteristic of the SC/GA portion of the province, where 49% of the area of these estuaries had tidal fluctuations of this magnitude.

7. Bottom salinities ranged from 0.1 to 36.8 ‰. Most estuaries (55% of province area) were within the polyhaline salinity zone (> 18–30 ‰). High-salinity, euhaline waters (> 30 ‰) were observed over a significantly smaller proportion of the province in 1995 than in 1994 (5% vs. 22%, respectively) suggesting a possible increase in freshwater inputs between sampling periods.

8. High density stratification (defined in this study as σ_t differences between surface and bottom waters > 2) was observed in 19% of the province area. Stratified waters were the most pronounced in large tidal rivers and the least pronounced in the large estuaries of NC.

9. Most bottom substrates across the province (54% of total province area) were composed of sands (silt-clay content < 20%). Sands dominated large estuaries (75% of total area for this class); muds (> 80% silt-clay) dominated large tidal rivers (68%); and small estuaries contained sands, muds, and intermediate muddy sands in nearly equal proportions. By subregion, muddy substrates dominated FL sites (52% of this subregion's estuarine area) and sandy substrates dominated sites in VA/NC (55%) and SC/GA (69%).

10. TOC in bottom substrates ranged from 0.04 to 14.8% across the province. Most estuaries (57% of province area) had low to normal levels of TOC (< 1%). Higher levels (> 2%), suggestive of organic enrichment either from natural or anthropogenic inputs, occurred in 30% of the province. Such organically enriched sediments dominated large tidal rivers (72% of total area for this class) and were the least pronounced in large estuaries (13%). Florida had the highest proportion of estuarine area with TOC > 2% (52% of this subregion's total estuarine area) and the SC/GA subregion had the least (0%).

11. DO concentrations in the Carolinian Province, based on instantaneous daytime measurements, ranged from 4.4 to 10.3 mg/L in surface waters and from 0.3 to 10.2 mg/L in bottom waters. Bottom DO concentrations were below the general water quality standard of 5 mg/L in 20% of the province, including sites in all estuarine classes and subregions. Such conditions were the most pronounced in large tidal rivers. DO concentrations < 2 mg/L (a more probable bioeffect range) were rare, found only in 3% of the province (five sites). All five sites were in NC: three in the Pamlico River (Stations 121, 122, and 124) and two in small estuaries (Stations 114 and 120).

12. Minimum near-bottom DO concentrations based on continuous 24-hr records ranged from 0 to 10.6 mg/L across the province, which was very close to the range of daytime instantaneous measurements. Sites were classified as degraded with respect to DO by comparison of the continuous records against the following three criteria: DO < 0.3 mg/L at any time (to represent short-term exposure to severe hypoxic conditions), DO < 2.0 mg/L for more than 20% of the measurement period, or DO < 5.0 mg/L throughout the measurement period (to represent extended exposure to higher chronic effect levels). Only four sites (Station 124 and replicate Stations 121 and 122 in the Pamlico River, NC; and Station 167 in the Hampton River, GA) were classified as degraded based on these criteria. These four sites represented only 3% of the total province area.

13. Carolinian Province estuaries exhibited a wide range of DO patterns. In some places, DO followed cyclical patterns consisting of both diurnal and tidal components (with highest DO concentrations occurring at late afternoon to early evening during high tide, and the lowest concentrations occurring during early morning low tides). In other places, DO followed a pattern consisting of large day-night variations without any significant tidal influences. The contribution of the tidal component to variations in DO was the most pronounced in the SC/GA portion of the province.

14. Over half of the province (54%) showed low levels of sediment contamination with all of the measured contaminants falling below corresponding threshold ER-L or TEL bioeffect guidelines. Still, a sizable portion (30%) showed high sediment contamination defined by the presence of three or more contaminants in excess of the lower ER-L/TEL values, or one or more contaminants in excess of the higher ER-M/PEL values. Sites with such exceedances represented a much smaller portion of the province (12%) in 1994.

15. By estuarine class, high sediment contamination was the most widespread in large tidal rivers (72% of total area for this class, vs. 48% for small estuaries, and only 6% for large estuaries). The Neuse and Pamlico Rivers accounted for 95% of the sediment contamination in the large tidal river class. Most Florida estuaries (65% of area) had high sediment contamination. In contrast, most estuaries in the VA/NC and SC/GA subregions (75% and 70% respectively) had low to moderate levels of sediment contamination. Of the total area with high contamination (30% of province, or 3,487 km^2), 60% was in VA/NC estuaries, 26% was in FL estuaries, and 14% was in SC/GA estuaries.

16. Dominant contaminants in the Carolinian Province in 1995 were arsenic, chromium, nickel, pyrene, total PCBs, DDT and derivatives, lindane, and dieldrin. These contaminants were found either at concentrations in excess of ER-M/PEL values in at least one estuary, or at concentrations in excess of the lower ER-L/TEL values in three or more estuaries. The most pronounced contaminant group was pesticides — especially lindane, DDT and derivatives, and dieldrin. PCBs, dieldrin, DDT and derivatives, arsenic, chromium, and nickel also were dominant contaminants during the 1994 survey. However, PCBs rather than pesticides appeared to be the most pronounced contaminant group in 1994. The moderately high concentrations of arsenic (between ER-L and ER-M values) found at many of the sites may be the result of natural geologic processes.

17. Additional evidence of sediment contamination was observed in this study at some non-random supplemental stations near potential contaminant sources. For example, a very high chromium concentration of 20,660 µg/g was found in sediments at Shipyard Creek, SC. The chromium concentration at this site (CP95SPY) exceeds the ER-M bioeffect value for chromium (370 µg/g, Long et al. 1995) by a factor of 56 and is much greater than concentrations considered to be "high" in national and worldwide chromium databases (Cantillo and O'Connor 1992). This result is consistent with the high chromium concentration (1,911 µg/g) recorded at this same site in 1994.

18. Sediment toxicity was measured using up to four different assays: (i) the Microtox® solid-phase assay (Bulich 1979, Microbics 1992a,b); (ii) the 10-day, solid-phase test for survival of the marine amphipod *Ampelisca abdita* (ASTM 1993); (iii) a similar amphipod test with the congeneric species *Ampelisca verrilli* (Ringwood et al. 1995); and (iv) a one-week, solid-phase test for sublethal effects of sediment exposure on growth of juvenile clams *Mercenaria mercenaria* (Ringwood and Keppler In Press).

19. The seed-clam test appeared to be the most sensitive of the four assays to contaminant-associated sediment toxicity. This assay resulted in the highest percentage of correct positives (i.e., detecting toxicity where concentrations of measured contaminants were high) and the lowest percentage of false negatives (not detecting toxicity where contamination was high). However, the seed-clam assay also gave the highest percentage of false

positives (detecting toxicity where contamination was low), thus suggesting oversensitivity or responses to other toxicants not included in the analysis. The Microtox® assay was slightly less sensitive in detecting toxicity in contaminated sediments, but better at minimizing false positives. Both the seed-clam and Microtox® assays, in comparison to either of the amphipod assays, showed greater concordance with predictions of toxicity based on sediment chemistry. Co-occurrences of sediment toxicity and contamination were found at 10 of 86 base stations (representing 15% of province area) using the seed-clam assay, at eight stations (14% of province) using the Microtox® assay, at two stations (4% of province) using the *A. verrilli* assay, and at only one base station (representing 1% of the province area) using the *A. abdita* assay.

20. Sediment toxicity also was evaluated using three different criteria for combining the multiple test results. Co-occurrences of sediment toxicity and contamination were found at 13 base stations (representing 19% of the province area) when the evaluation criterion was toxicity in any one of the four tests performed; at eight stations (14% of province) when based on toxicity in either the Microtox® or *A. abdita* assays (the only two assays run province-wide since the beginning of the program); and at five stations (11% of province) when based on toxicity in ≥ 50% of assays performed on a sample. The relatively low incidence of sediment toxicity and contamination in these samples agreed well with observations of Long et al. (1998b) who found that most samples from a survey of selected estuaries in South Carolina and Georgia were less contaminated and toxic than those analyzed by NOAA from other US estuaries nationwide.

21. High toxicity in samples with low chemical contamination (false positives) may have been attributable in some cases to high ammonia concentrations in sediment porewater. Seven of 17 seed-clam false positives contained unionized ammonia nitrogen (UAN) above the EPA (1989) acute Water Quality Criterion value of 233 µg/L. Moreover, the only sample that was toxic to *A. abdita* also had a UAN concentration of 2,628 µg/L, which is well above the EC_{50} value of 800 µg/L for UAN and *A. abdita* (Kohn et al. 1994). Chemical contaminants not included in the analysis may also have contributed to toxicity in these samples.

22. Concentrations of unionized hydrogen sulfide in sediment porewater (< 1–18 µg/L across all stations) were well below the reported bioeffect range (52–26,460 µg/L for sublethal and lethal effects on 12 species of marine invertebrates, Sims and Moore 1995). Thus, sulfide was not implicated as a major contributor to the toxicity of Carolinian Province samples.

23. A total of 23,055 macroinfaunal organisms (> 0.5 mm), representing 388 different taxa, was identified from 171 grabs (0.04 m^2 each) collected at base stations throughout the province. Mean richness (number of species), H′ diversity (derived with base 2 logarithms), and abundance of all taxa per grab ranged from 0 to 42, 0 to 4.4, and 0 to 1,570, respectively.

24. Infaunal species richness and H′ showed significant positive correlations with salinity and significant to marginally significant negative correlations with latitude, % silt-clay, and % TOC. Total faunal abundance also showed significant to marginally significant correlations with latitude % silt-clay, and % TOC.

25. Infaunal abundance was distributed among major taxonomic groups in the following proportions: annelids (43.9%), arthropods (27.4%), molluscs (18.9%), and other taxa (9.9%). By species numbers, the major taxa were: annelids (39.9%), arthropods (32.0%), molluscs (19.3%), and other taxa (8.8%). The relative proportions of these broad taxonomic groups were fairly consistent across the three estuarine classes with a few exceptions. In large estuaries, the contribution of molluscs increased with respect to abundance; in large tidal rivers, arthropods (rather than annelids) represented the most dominant group based on abundance.

26. The five most abundant infaunal taxa province-wide (in decreasing order of dominance) were the tanaid *Halmyrapseudes bahamensis*, the polychaete *Mediomastus* spp., the polychaete *Streblospio benedicti*, unidentified oligochaetes, and the bivalve *Mulinia lateralis*. This list was fairly similar to the previous year, with four of the five dominants (all except the tanaid) being common to both years. Within a year, the dominance structure showed distinct shifts among the various estuarine classes and subregions. For example, in 1995 only one of the above taxa (*Mediomastus*) was dominant in all classes and subregions.

27. A multimetric index of biotic integrity was developed for evaluating the condition of macroinfaunal assemblages from southeastern estuaries. This index — consisting of measures of abundance, number of species, dominance, and relative abundance of pollution-sensitive taxa — correctly classified stations across the province, as degraded or undegraded, 93% of the time in a 1994 development data set and 75% of the time in an independent 1993/1995 validation data set. The index also detected a higher percentage of samples where bioeffects were expected (based on contaminant bioeffect exceedances) than did any of the four individual sediment bioassays or individual infaunal attributes.

28. A total of 14,586 demersal organisms, representing 91 different taxa, was identified from 169 trawls (4.9-m otter trawls with 2.5-cm mesh) conducted throughout the Carolinian Province. Mean richness (number of species), H′ diversity (derived with base 2 logarithms), and abundance per trawl ranged from 0 to 19, 0 to 3.2, and 0 to 636.5, respectively, at various base stations.

29. Mean number of demersal species and H′ diversity both showed significant positive correlations with salinity and negative correlations with latitude, which are common zoogeographic patterns observed in studies of demersal fauna. There were no significant correlations between demersal abundance and these two abiotic variables.

30. The five most abundant demersal species province-wide (in decreasing order of dominance) were white shrimp (*Penaeus setiferus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), pinfish (*Lagodon rhomboides*), and brown shrimp (*Penaeus aztecus*). All of these species except white shrimp were among the top-five, province-wide dominants in the 1994 survey as well. There were distinct differences in dominance structure among the various estuarine classes and subregions. Atlantic croaker and spot were the only dominants in all three estuarine classes and Atlantic croaker was the only dominant in all three subregions. All of the above dominants except pinfish are harvested commercially and/or recreationally.

31. There were very few pathological disorders noted in samples of demersal biota. Of a total of 14,586 animals that were examined, only 11 (representing 0.08% of the sample population) showed visible signs of pathological disorders. There were three cases of fin rot, two cases of external growths in fishes, two cases of ulcers in fishes, three cases of shrimp cotton disease, and one case of crab shell disease. These pathologies were recorded from six stations, representing 6% of the province area. Three of these stations were in areas that showed other clear evidence of environmental degradation based on exposure indicators.

32. Analysis of chemical contaminants was conducted on edible tissues of spot, croaker, blue crab, and penaeid shrimp obtained from a subset of 14 base stations around the province, including sites where high levels of sediment contamination had been found. All measured analytes in these samples were below corresponding FDA tissue guidelines — i.e., "Action Levels" for PCBs, pesticides, and mercury and "Levels of Concern" in shellfish for five additional metals (arsenic, cadmium, chromium, lead, and nickel).

33. Four aesthetic indicators were monitored: presence of anthropogenic debris (sea surface and in bottom trawls), presence of oil (sea surface and in bottom sediments), noxious sediment odors (smell of sulfur, oil, or sewage in bottom sediments), and water clarity (secchi depths). Floating debris was observed in about 7% of the province and bottom debris was observed in about 22%. Oil was observed only in 6% of bottom sediments and in none of the surface waters. Noxious odors were detectable in 18% of province sediments. Low water clarity, represented by secchi depths < 0.5 m, was observed in 12% of the province.

34. Degraded condition of infaunal assemblages was more closely coupled with sediment contamination than with low dissolved oxygen (DO). Overall, 17 of 86 stations that were sampled exhibited evidence of a degraded benthos (low abundance, low number of species, low H′ diversity, or low benthic index score) accompanied by adverse exposure conditions (high sediment contamination, low DO, or significant toxicity in ≥ 50% of assays at a station). Degraded infaunal condition was accompanied by high sediment contamination at all but one of these stations and by low DO at only three of them. There were no stations where degraded benthic condition co-occurred with low DO alone. The three stations with low DO and degraded infauna also had high sediment contamination. Low DO may have contributed to the observed benthic impacts, however, at the few sites where such conditions occurred.

35. Other adverse sediment conditions related to organic over-enrichment may also have contributed to observed infaunal bioeffects. Of the 17 degraded infaunal sites, all but two had TOC concentrations above 2%. Only three of the total 18 base stations with TOC > 2% did not show some concomitant evidence of a degraded benthos. High levels of TOC above this criterion may be suggestive of organic over-enrichment, either from natural or anthropogenic inputs.

36. Co-occurrences of degraded demersal biota (low abundance, low number of species, low H′ diversity, or high number of pathologies) and adverse exposure conditions (defined as in Point 34) were found at eight of the 85 base stations where trawls were obtained. Five

of these stations had either high sediment contamination (two stations) or a combination of high sediment contamination and low DO (three stations).

37. About 82% of the province area, represented by 76 of the 87 base stations, showed some indication of environmental stress based on any one of the multiple indicators of biotic, exposure, or aesthetic conditions that were measured in this study. However, co-occurrences of adverse biological conditions, either in infauna or demersal biota, and evidence of adverse exposure conditions were observed in a much smaller proportion of the province — 29% (represented by 20 stations). Over half of these sites (12) were in North Carolina, as were most degraded sites during the 1994 survey. The majority of these sites were characterized by degraded infaunal assemblages accompanied by high sediment contamination and/or sediment toxicity based on *Mercenaria* ("seed clam") and Microtox® assays.

38. Large tidal rivers appeared to be the most degraded class of estuaries. The following indicators of degraded condition consistently were the most pronounced in this estuarine class: high sediment contamination (≥ 3 ER-L/TEL exceedances, or ≥ 1 ER-M/PEL exceedance), sediment TOC > 2%, bottom DO < 2 mg/L, mean infaunal abundance per grab ≤ 25, mean infaunal H′ per grab ≤ 1, mean number of infaunal species per grab ≤ 3, benthic index score ≤ 1.5, mean number of demersal species per trawl ≤ 2, presence of noxious sediment odor, and poor to intermediate water clarity (secchi depths ≤ 1 m).

39. Selected data on sediment contamination, sediment toxicity, and macroinfaunal composition also were examined to evaluate conditions of Carolinian Province estuaries from the perspective of sediment quality. Each year a sizable portion of the province — 36% in 1994 and 51% in 1995 — showed some evidence of either degraded benthic assemblages, contaminated sediment in excess of bioeffect guidelines, or high sediment toxicity (based on significant toxicity in ≥ 50% of assays at a station). However, co-occurrences of a degraded benthos and adverse exposure conditions (sediment contamination and/or toxicity) were much less extensive. Such conditions were found at 16 of 82 stations with substrates that could be sampled in 1994 (representing 17% of the province area) and 17 of 86 stations in 1995 (25% of province).

40. Only four sites in 1994 (representing 5% of the province area) and three sites in 1995 (7% of province) had degraded infauna accompanied by both high sediment contamination and toxicity (based on significant toxicity in ≥ 50% of assays at a station). These data suggest that strong contaminant-induced effects on the benthos are probably limited to a fairly small percentage of estuarine area province-wide. A similar conclusion would have been reached if two alternative criteria for evaluating the multiple sediment toxicity data were used. For example, the 1995 estimate for percent area of estuaries with a degraded benthos, sediment contamination, and sediment toxicity would shift only from 7 to 8% (due to the addition of one station) if the determination of toxicity were based on a significant response in either the *Ampelisca abdita* or Microtox® assays (the two bioassays performed province-wide in both years). This estimate would shift to 13% (due to the addition of six more stations) if the determination of toxicity were based on a significant response in any one of the four assays performed on 1995 samples.

41. It must be understood that the above estimates of degraded estuarine area were derived from the broad-scale probabilistic sampling framework of EMAP-Estuaries. This design was not intended to support detailed characterizations of pollutant distributions and sources within individual estuarine systems. In fact, only one station was sampled in many of these estuaries. Thus, some estuaries classified as undegraded may include additional degraded portions outside the immediate vicinity of randomly selected sites. Such localized impacts were detected in this study at some nonrandom supplemental sites near suspected contaminant sources.

42. A strength of the EMAP-E probability-based sampling design is its ability to support unbiased estimates of ecological condition with known confidence at regional scales. Further sampling in the Carolinian Province should improve the accuracy of these estimates and provide a basis for beginning to assess temporal trends.

Table 4-1 summarizes the general characteristics of the Carolinian Province and the areal extent of selected indicators within specific ranges of interest.

TABLE 4–1. Summary of the general characteristics of the Carolinian Province and the percent area (and 95% C.I.s) exhibiting designated levels of selected indicators.

Indicators and Characteristics	Province	Estuarine Class			Subregion		
		Large	Small	Tidal	VA-NC	SC-GA	FL
General Characteristics							
Size (km^2)	11,622.1	5,581.1	4,907	1,134	8,834.9	1,688.2	1,099
No. of Estuaries	200	3	194	3	90	79	25
Base Stations Sampled in 1995	88	16	55	17	48	21	19
Habitat Indicators							
Tidal Range > 2 m	8 ± 7	0	20 ± 16	0	2 ± 6	49 ± 25	0
Salinity (Bottom Waters)							
• Oligohaline (< 5 ‰)	17 ± 13	19 ± 20	19 ± 20	0	22 ± 16	2 ± 4	4 ± 12
• Mesohaline (5–18 ‰)	23 ± 16	13 ± 23	28 ± 24	54 ± 38	25 ± 17	24 ± 23	13 ± 22
• Polyhaline (>18–30 ‰)	55 ± 4	69 ± 23	41 ± 9	43 ± 23	49 ± 4	63 ± 16	76 ± 14
• Euhaline (> 30 ‰)	5 ± 4	0	11 ± 9	3 ± 23	4 ± 4	11 ± 16	7 ± 14
Sig. Water Stratification, $\|\Delta\sigma_t\| > 2$	20 ± 12	7 ± 13	31 ± 24	35 ± 27	12 ± 11	33 ± 27	52 ± 42
Silt-Clay Content							
• Silt-clay < 20 %	54 ± 14	75 ± 22	38 ± 22	22 ± 27	55 ± 16	69 ± 25	29 ± 18
• Silt-clay > 80 %	27 ± 14	13 ± 17	34 ± 26	68 ± 19	28 ± 15	0	52 ± 35
Total Organic Carbon (TOC) > 2 %	30 ± 14	13 ± 17	41 ± 25	72 ± 33	28 ± 15	0	52 ± 35
Exposure Indicators							
Low DO (Bottom Waters)							
• DO < 5 mg/L (Instantaneous)	20 ± 10	6 ± 12	23 ± 19	74 ± 33	22 ± 12	23 ± 20	6 ± 9
• DO < 2 mg/L (Instantaneous)	3 ± 2	0	1 ± 1	32 ± 19	5 ± 4	0	0
• Sig. low DO (Chronic and Acute) [a]	3 ± 2	0	1 ± 2	32 ± 14	4 ± 4	3 ± 5	0
Sediment Toxicity							
• Sig. Amphipod (A. abdita) Toxicity [b]	0.2 ± 1	0	0.5 ± 2	0	0	0	2 ± 8
• Sig. Amphipod (A. verrilli) Toxicity [b]	7 ± 9	6 ± 12	10 ± 17	0	10 ± 12	0	2 ± 8
• Sig. Seed Clam Toxicity [b]	39 ± 16	33 ± 25	49 ± 25	25 ± 34	38 ± 19	21 ± 23	68 ± 31
• Sig. Microtox® Toxicity [c]	20 ± 11	0	41 ± 25	22 ± 34	9 ± 3	33 ± 26	69 ± 22

TABLE 4–1. (Continued).

Indicators and Characteristics	Province	Estuarine Class			Subregion		
		Large	Small	Tidal	VA-NC	SC-GA	FL
Exposure Indicators (Continued)							
Sediment Contamination							
• ≥ 1 ER-L/TEL Exceedance	45 ± 15	31 ± 23	54 ± 23	72 ± 20	41 ± 18	45 ± 26	64 ± 19
• ≥ 1 ER-M/PEL Exceedance	9 ± 8	0	20 ± 18	4 ± 14	7 ± 9	24 ± 20	6 ± 5
• ≥ 3 ER-L/TEL or ≥ 1 ER-M/PEL Exceedance	30 ± 1	6 ± 12	48 ± 24	72 ± 14	25 ± 3	30 ± 22	65 ± 5
• Alkanes ≥ 7000 ng/g	17 ± 12	6 ± 12	27 ± 23	26 ± 27	23 ± 13	0	4 ± 12
• Tributyltin > 5 ng/g	6 ± 10	0	15 ± 24	0	0	0	52 ± 35
Biotic Condition Indicators							
Infauna							
• Mean Species Richness/Grab ≤ 3	19 ± 12	6 ± 12	25 ± 25	55 ± 19	16 ± 12	6 ± 11	52 ± 35
• Mean Abundance/Grab ≤ 25	32 ± 14	19 ± 20	42 ± 25	55 ± 19	27 ± 16	43 ± 25	48 ± 41
• Mean H′(Diversity)/Grab ≤ 1	15 ± 9	6 ± 12	12 ± 15	68 ± 19	18 ± 11	6 ± 11	4 ± 12
Demersal Biota							
• Mean Species Richness/Trawl ≤ 2	7 ± 7	6 ± 12	1 ± 2	36 ± 29	9 ± 9	0	3 ± 8
• Mean Abundance/Trawl ≤ 5	9 ± 9	13 ± 17	2 ± 3	17 ± 29	10 ± 12	0	6 ± 13
• Mean # Pathologies/Trawl > 1	4 ± 7	0	9 ± 17	0	5 ± 9	0	0
Aesthetic Indicators							
Anthropogenic Marine Debris Present							
• At Sea Surface	7 ± 8	13 ± 17	3 ± 5	0	9 ± 11	1 ± 7	0
• On Bottom	22 ± 13	13 ± 17	32 ± 22	22 ± 28	20 ± 3	40 ± 25	16 ± 18
Secchi depth < 0.5 m	12 ± 10	7 ± 13	21 ± 19	0	9 ± 12	38 ± 26	0
Noxious Sediment Odors Present	18 ± 1	6 ± 12	24 ± 23	54 ± 14	11 ± 9	2 ± 4	89 ± 5
Oil Present							
• At Sea Surface	0	0	0	0	0	0	0
• In Sediments	6 ± 10	0	15 ± 24	0	1 ± 1	0	48 ± 41

[a] DO < 2 mg/L for > 20% of continuous datasonde record or DO < 5 mg/L throughout entire continuous record or DO < 0.3 mg/L at any time during continuous record.
[b] Mortality relative to control ≥ 20 % and sig. at $\alpha = 0.05$.
[c] $EC_{50} \leq 0.2$ if silt-clay ≥ 20 %, or $EC_{50} \leq 0.5$ % if silt-clay < 20 %.

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6. APPENDICES

APPENDIX A. Depth, dissolved oxygen, salinity, temperature, and pH records by station for 1995 EMAP in the Carolinian Province.

	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
Station	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95101	1.4	1.1 (1.0–1.2)	8.9 (8.7–9.0)	8.8 (8.2–9.5)	5.0 (5.0–5.0)	5.0 (4.9–5.0)	24.6 (24.0–24.7)	24.4 (24.2–24.9)	8.2 (8.2–8.2)	8.1 (8.0–8.3)
CP95102	1.1	0.7 (0.7–0.8)	8.4 (8.4–8.5)	9.1 (8.0–10.6)	5.0 (5.0–5.0)	4.9 (4.9–4.9)	23.6 (23.6–23.6)	24.2 (23.5–24.6)	8.5 (8.5–8.5)	8.6 (8.5–8.7)
CP95103	3.6	3.5 (3.4–3.7)	6.9 (6.8–7.3)	6.5 (5.7–6.7)	0.1 (0.1–0.1)	0.1 (0.1–0.1)	28.1 (27.8–28.3)	27.8 (27.2–28.0)	7.4 (7.4–7.6)	– –
CP95104	2.0	1.6 (1.4–1.7)	7.3 (7.2–7.6)	7.3 (6.4–8.2)	2.1 (2.1–2.2)	2.2 (2.1–2.3)	26.3 (25.6–26.3)	26.5 (26.1–26.7)	9.1 (8.9–9.1)	9.0 (8.9–9.1)
CP95105	2.1	1.1 (1.1–1.3)	8.1 (7.9–8.1)	8.4 (7.8–8.8)	3.9 (3.8–4.2)	3.5 (2.7–4.3)	26.0 (26.0–26.1)	25.5 (25.2–25.9)	8.3 (8.3–8.3)	8.3 (8.1–8.5)
CP95106	1.5	0.8 (0.7–1.1)	7.6 (7.6–7.6)	7.8 (7.5–8.3)	4.7 (4.7–4.7)	4.7 (4.6–4.7)	26.3 (26.3–26.3)	25.5 (25.0–26.2)	8.2 (8.2–8.3)	8.2 (8.1–8.3)
CP95107	6.3	6.3 (6.1–6.4)	8.2 (7.5–8.3)	7.9 (7.5–8.2)	1.5 (1.4–1.9)	1.8 (1.6–2.2)	27.0 (27.0–27.0)	26.8 (26.5–27.0)	8.1 (7.8–8.1)	7.9 (7.8–8.0)
CP95108	1.0	0.8 (0.7–1.0)	7.7 (7.5–7.9)	8.3 (7.4–9.1)	0.2 (0.2–0.2)	0.3 (0.2–0.3)	24.6 (23.3–24.6)	25.5 (24.4–26.1)	7.5 (7.4–7.7)	– –
CP95109	2.2	2.5 (1.9–2.5)	9.5 (6.8–9.7)	7.1 (5.7–8.7)	3.4 (3.4–3.5)	3.6 (3.4–3.6)	28.0 (26.6–29.2)	26.2 (26.1–28.0)	8.2 (7.3–8.3)	7.2 (7.0–7.7)
CP95110	1.3	0.8 (0.8–0.9)	9.4 (9.3–9.4)	9.5 (7.7–10.2)	3.6 (3.6–3.6)	3.7 (3.6–3.7)	27.5 (27.0–27.7)	28.3 (27.3–29.5)	8.3 (8.2–8.3)	8.4 (7.7–8.5)
CP95111	1.3	0.6 (0.6–0.7)	8.0 (7.9–8.0)	8.2 (7.9–8.7)	4.3 (4.2–4.3)	4.3 (4.3–4.4)	26.8 (26.6–26.8)	27.8 (26.5–28.5)	7.5 (7.4–7.5)	7.7 (7.5–7.9)
CP95112	0.8	0.7 (0.6–0.8)	8.3 (7.9–8.3)	8.1 (7.2–10.1)	13.3 (13.3–13.4)	16.2 (13.0–17.3)	26.0 (26.0–26.1)	26.7 (26.0–27.8)	8.0 (8.0–8.0)	8.1 (8.0–8.3)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95113	3.7	3.6 (3.4–3.8)	7.5 (6.6–8.0)	6.6 (5.6–6.9)	18.5 (17.2–26.8)	25.4 (24.9–26.5)	25.5 (24.8–26.4)	25.1 (24.9–25.4)	8.0 (7.8–8.0)	8.0 (7.9–8.0)
CP95114	2.0	1.6 (1.5–1.7)	7.4 (0.8–9.1)	– –	7.5 (7.4–7.9)	7.5 (7.5–7.9)	30.3 (29.4–30.5)	31.1 (29.5–31.6)	8.1 (7.0–8.5)	8.5 (7.3–8.7)
CP95115	4.2	3.7 (3.5–3.8)	6.3 (6.2–7.0)	6.8 (6.4–7.1)	24.2 (24.1–24.2)	22.3 (22.2–22.3)	29.5 (29.0–29.5)	29.1 (28.8–29.5)	8.0 (8.0–8.0)	8.1 (8.1–8.1)
CP95116	3.4	2.7 (2.7–2.9)	6.6 (4.4–7.5)	5.7 (4.3–6.9)	10.2 (10.0–10.4)	10.2 (10.0–10.4)	30.1 (29.6–30.5)	29.4 (28.9–30.1)	8.0 (7.7–8.2)	7.9 (7.6–8.2)
CP95117	5.9	6.3 (5.9–6.4)	6.9 (4.8–7.0)	5.6 (3.9–6.2)	22.7 (22.6–23.8)	22.9 (22.7–23.6)	29.5 (29.2–29.7)	29.4 (29.2–29.7)	8.1 (7.9–8.1)	8.1 (7.9–8.1)
CP95118	1.5	0.7 (0.6–0.8)	6.3 (5.7–7.0)	7.5 (7.0–7.8)	20.4 (20.3–20.5)	20.3 (20.3–20.4)	27.6 (27.2–28.2)	28.5 (27.6–28.8)	7.9 (7.8–7.9)	8.0 (7.9–8.0)
CP95119	4.9	4.0 (3.9–4.1)	6.6 (5.5–6.9)	– –	21.0 (20.9–21.2)	20.7 (20.5–20.8)	27.6 (27.6–27.6)	27.8 (27.7–28.0)	8.0 (7.9–8.0)	8.0 (8.0–8.0)
CP95120	1.4	0.8 (0.7–0.8)	3.8 (0.2–4.9)	7.5 (3.1–10.7)	4.8 (4.7–10.1)	4.9 (4.7–5.1)	28.5 (28.2–28.7)	29.5 (27.8–30.5)	7.2 (7.1–7.3)	7.8 (6.9–8.4)
CP95121	3.6	3.1 (3.0–3.2)	7.0 (1.0–7.5)	0.0 (0.0–3.7)	7.0 (6.3–15.3)	15.0 (13.1–15.2)	28.5 (28.1–29.3)	– –	7.9 (7.2–8.1)	7.2 (7.1–7.3)
CP95122	3.7	3.5 (3.5–3.6)	7.0 (1.1–7.8)	0.0 (0.0–0.3)	7.5 (6.7–15.4)	15.7 (12.7–15.9)	28.4 (28.2–31.1)	28.5 (28.4–28.6)	7.9 (7.2–8.0)	– –
CP95123	–	4.4 (4.3–4.5)	– –	6.3 (5.9–6.7)	– –	– –	– –	29.2 (29.0–29.6)	– –	8.1 (8.1–8.2)
CP95124	4.7	4.0 (3.9–4.4)	7.6 (1.3–8.1)	2.5 (1.7–3.6)	8.7 (8.0–15.4)	15.9 (14.2–16.0)	29.8 (28.7–30.2)	29.0 (28.9–29.1)	8.1 (7.2–8.2)	7.2 (7.1–7.3)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95125	2.3	2.4 (2.2–2.5)	6.4 (6.3–7.2)	11.3 (10.6–12.2)	20.7 (20.5–20.8)	20.9 (20.7–21.0)	27.6 (26.9–27.6)	27.9 (27.6–28.5)	7.8 (7.8–7.8)	7.8 (7.8–7.9)
CP95126	1.5	0.7 (0.5–1.1)	6.3 (6.2–6.5)	6.2 (5.4–7.4)	17.7 (17.5–17.7)	17.8 (17.6–18.2)	27.6 (27.6–27.9)	28.5 (27.6–29.5)	7.7 (7.7–7.7)	7.4 (7.3–7.6)
CP95127	2.4	2.7 (2.6–2.8)	7.1 (6.9–7.3)	6.6 (3.7–8.0)	16.6 (16.3–16.7)	16.3 (16.0–16.6)	28.2 (28.0–28.9)	28.2 (28.0–28.8)	7.9 (7.9–8.0)	7.9 (7.5–8.1)
CP95128	1.7	1.1 (1.1–1.2)	6.4 (2.3–6.6)	6.3 (4.8–7.8)	14.0 (13.9–15.4)	14.4 (14.0–15.0)	29.9 (28.9–30.0)	29.7 (28.4–30.8)	7.8 (7.4–7.8)	7.8 (7.5–8.0)
CP95129	0.9	1.1 (1.0–1.2)	5.2 (5.2–5.3)	9.4 (7.9–11.3)	16.2 (16.1–16.2)	16.1 (15.8–16.2)	29.4 (29.3–29.5)	29.6 (28.6–30.6)	7.6 (7.6–7.6)	7.7 (7.6–7.9)
CP95130	4.9	3.8 (3.7–4.2)	6.4 (6.3–6.5)	6.3 (6.0–6.8)	21.9 (21.9–21.9)	22.5 (22.1–22.8)	29.7 (29.7–29.8)	29.4 (28.7–29.9)	8.1 (8.1–8.2)	8.2 (8.1–8.2)
CP95131	6.2	5.9 (5.4–6.0)	6.7 (6.5–7.1)	10.6 (8.7–11.8)	19.0 (18.4–19.4)	19.8 (18.8–20.5)	29.9 (29.8–30.1)	29.2 (28.8–29.9)	8.0 (8.0–8.1)	8.2 (8.1–8.2)
CP95132	3.9	3.8 (3.3–4.1)	6.7 (6.6–6.7)	6.7 (6.4–7.4)	24.9 (24.8–24.9)	23.9 (23.6–24.3)	29.1 (29.0–29.1)	29.6 (29.2–30.0)	8.2 (8.2–8.2)	8.1 (8.1–8.2)
CP95133	2.1	1.5 (1.1–2.5)	6.7 (6.3–6.8)	– –	25.6 (25.4–25.8)	35.5 (25.1–38.9)	28.9 (28.7–29.2)	27.3 (26.2–30.4)	8.2 (8.1–8.2)	8.2 (8.1–8.4)
CP95134	0.9	0.9 (0.8–1.0)	7.3 (6.1–7.8)	6.1 (3.3–7.7)	14.6 (14.5–14.6)	15.6 (15.4–16.0)	31.0 (30.0–31.6)	30.4 (29.7–31.2)	8.0 (7.8–8.1)	8.0 (7.8–8.1)
CP95135	0.8	0.8 (0.6–1.4)	6.3 (6.1–6.7)	6.8 (6.3–7.5)	27.9 (27.7–28.0)	38.0 (31.9–38.3)	27.9 (27.9–28.0)	26.1 (25.4–29.2)	8.2 (8.1–8.2)	7.8 (7.8–7.9)
CP95136	5.7	5.8 (5.7–5.9)	6.0 (4.1–8.0)	3.9 (3.2–6.2)	19.3 (19.1–19.4)	19.2 (19.0–19.8)	27.4 (27.1–29.2)	26.8 (26.6–27.5)	7.9 (7.7–8.0)	7.7 (7.6–7.9)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95137	–	–	–	–	–	–	–	–	–	–
		–	–	–	–	–	–	–	–	–
CP95138	0.6	0.8 (0.6–0.9)	6.5 (6.2–6.7)	6.9 (5.8–8.0)	17.1 (17.0–17.2)	17.6 (17.5–17.7)	27.3 (27.1–27.7)	27.8 (27.2–28.6)	7.7 (7.7–7.8)	7.7 (7.4–7.8)
CP95139	6.5	6.2 (5.9–6.2)	6.0 (4.3–8.1)	4.6 (3.6–6.5)	17.6 (16.2–18.0)	19.0 (18.4–19.2)	26.8 (26.4–28.0)	27.2 (26.9–27.9)	7.8 (7.7–8.0)	7.7 (7.6–7.8)
CP95140	1.7	1.1 (0.9–1.2)	6.6 (6.1–7.1)	6.7 (5.6–8.4)	16.6 (16.4–16.7)	– –	27.0 (26.9–28.0)	29.9 (29.3–31.0)	7.8 (7.7–7.9)	8.0 (7.8–8.1)
CP95141	1.6	0.9 (0.2–1.0)	5.8 (5.4–6.1)	5.6 (4.5–7.6)	36.5 (36.4–36.6)	37.1 (14.7–37.3)	31.5 (31.3–31.5)	30.9 (21.8–32.7)	8.0 (8.0–8.0)	8.0 (8.0–8.0)
CP95142	0.5	1.0 (0.6–1.5)	5.5 (5.2–5.7)	6.5 (4.0–7.4)	36.2 (36.0–36.4)	37.6 (37.3–37.8)	30.3 (30.0–30.3)	30.8 (29.7–32.2)	7.9 (7.9–7.9)	8.0 (7.8–8.0)
CP95143	1.1	1.0 (0.8–1.1)	5.5 (5.5–5.6)	– –	36.8 (36.0–36.8)	38.0 (37.8–38.3)	30.5 (30.5–30.5)	30.8 (30.2–31.9)	8.0 (8.0–8.0)	8.0 (8.0–8.1)
CP95144	0.1	< 0.1 (< 0.1–< 0.1)	6.4 (6.3–6.4)	6.0 (4.7–7.0)	33.5 (33.4–33.5)	– –	30.9 (30.5–30.9)	30.7 (30.4–32.4)	8.0 (8.0–8.0)	7.9 (7.8–8.0)
CP95145	0.0	0.1 (< 0.1–0.2)	5.7 (5.5–6.1)	5.8 (4.5–8.1)	33.3 (33.3–33.4)	34.6 (34.0–35.2)	30.7 (30.4–30.8)	31.4 (30.2–33.6)	7.9 (7.9–7.9)	7.8 (7.8–7.9)
CP95146	12.7	12.3 (11.6–14.3)	4.0 (3.6–4.6)	5.1 (4.3–5.7)	9.6 (2.9–23.1)	27.3 (17.0–32.2)	26.3 (25.8–27.1)	27.6 (27.0–28.0)	6.9 (6.6–7.7)	7.9 (7.4–8.0)
CP95147	5.2	5.6 (4.6–6.3)	3.6 (3.4–5.0)	9.2 (8.5–9.8)	2.4 (0.3–4.4)	4.0 (0.1–12.1)	25.4 (25.0–25.8)	26.1 (24.9–26.7)	6.4 (6.2–6.5)	6.4 (6.1–6.9)
CP95148	1.4	1.5 (0.3–2.0)	10.2 (10.0–10.5)	7.8 (4.1–11.3)	29.2 (28.5–29.3)	26.3 (21.1–29.2)	29.1 (29.1–29.2)	29.7 (29.2–30.8)	8.2 (8.2–8.2)	8.1 (7.6–8.3)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95149	4.9	5.9 (5.1–6.4)	7.1 (6.3–9.4)	5.2 (4.2–6.1)	16.4 (11.6–16.7)	15.9 (12.8–19.2)	30.6 (30.4–31.6)	30.1 (29.5–30.7)	7.8 (7.7–8.3)	7.5 (7.3–7.7)
CP95150	3.0	0.9 (0.7–4.5)	7.2 (6.5–7.7)	6.5 (4.9–7.7)	3.2 (2.2–3.8)	2.1 (0.1–4.0)	31.0 (30.7–31.7)	23.2 (22.3–32.9)	7.7 (7.5–8.1)	7.2 (6.8–7.5)
CP95151	6.9	8.2 (7.1–8.9)	5.8 (5.7–6.2)	5.9 (4.9–6.7)	22.1 (21.8–22.2)	23.4 (21.4–27.2)	30.3 (30.0–30.3)	29.6 (29.3–30.3)	7.7 (7.7–7.7)	7.8 (7.6–7.9)
CP95152	8.2	8.4 (7.3–9.1)	5.8 (5.8–6.0)	5.8 (4.3–6.3)	22.9 (22.7–23.3)	23.1 (20.8–27.0)	30.0 (29.4–30.1)	29.5 (29.2–30.1)	7.7 (7.7–7.7)	7.9 (7.6–8.0)
CP95153	2.4	4.0 (3.0–4.6)	6.6 (6.6–6.7)	6.3 (3.9–7.7)	34.4 (34.3–34.4)	31.9 (31.2–34.6)	28.6 (28.6–28.6)	29.1 (28.6–30.2)	7.9 (7.9–8.0)	7.9 (7.8–8.0)
CP95154	0.8	1.3 (0.3–2.2)	5.9 (5.9–6.0)	5.9 (4.9–8.0)	31.7 (31.6–31.9)	32.1 (29.6–34.3)	28.9 (28.7–28.9)	30.1 (28.8–31.2)	7.8 (7.8–7.8)	7.9 (7.7–8.1)
CP95155	9.7	10.8 (9.8–11.7)	5.7 (5.6–6.1)	5.6 (4.5–6.4)	31.7 (27.1–31.8)	30.1 (27.6–32.6)	29.6 (29.6–29.9)	30.1 (29.6–30.7)	7.9 (7.8–7.9)	7.8 (7.6–8.0)
CP95156	5.1	6.4 (5.2–7.2)	5.0 (4.7–6.8)	5.3 (4.3–6.1)	11.7 (9.5–12.6)	11.7 (5.3–20.0)	30.0 (29.5–30.1)	30.3 (29.7–30.5)	7.3 (7.3–7.4)	7.3 (7.0–7.7)
CP95157	9.7	10.0 (8.3–10.7)	4.2 (4.1–5.3)	4.7 (3.6–5.2)	22.9 (22.4–23.4)	23.9 (20.8–26.0)	30.8 (30.7–30.9)	31.0 (30.4–32.3)	7.3 (7.3–7.4)	7.5 (7.3–7.7)
CP95158	3.4	4.3 (3.0–5.3)	4.6 (4.5–5.8)	4.5 (4.0–5.8)	23.7 (23.6–23.8)	24.4 (23.6–25.2)	30.9 (30.7–30.9)	31.4 (30.8–32.7)	7.4 (7.4–7.4)	7.4 (7.3–7.5)
CP95159	9.0	10.1 (8.7–11.3)	6.1 (6.0–6.3)	6.0 (5.8–6.4)	29.2 (28.9–29.5)	27.9 (22.4–30.0)	28.1 (28.1–28.1)	28.0 (27.7–28.2)	7.8 (7.7–7.8)	7.8 (7.8–8.0)
CP95160	0.0	3.1 (1.6–4.3)	5.2 (5.2–6.3)	5.5 (4.8–6.9)	25.9 (25.6–26.0)	25.8 (24.2–27.4)	27.9 (27.6–27.9)	27.8 (27.1–28.4)	7.5 (7.5–7.6)	7.6 (7.5–7.7)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95161	3.2	4.4 (3.4–5.4)	5.9 (5.7–6.7)	5.7 (4.3–6.5)	22.4 (21.3–26.4)	20.6 (14.1–25.7)	27.5 (27.1–27.5)	27.6 (27.0–29.0)	7.6 (7.6–7.8)	7.7 (7.3–7.9)
CP95162	1.4	3.3 (1.6–4.2)	5.9 (5.8–6.6)	5.0 (4.2–6.4)	11.9 (11.3–12.1)	8.9 (7.0–17.8)	26.3 (26.1–26.3)	26.9 (26.4–27.2)	7.5 (7.5–7.6)	7.2 (6.8–7.6)
CP95163	6.5	7.4 (5.7–8.4)	6.2 (6.0–6.4)	5.4 (4.5–6.4)	26.1 (25.8–26.6)	23.8 (21.1–26.4)	27.3 (27.2–27.5)	27.8 (27.2–28.2)	7.8 (7.8–7.9)	7.6 (7.4–7.9)
CP95164	6.3	8.3 (7.4–9.3)	5.3 (5.3–6.4)	5.2 (4.9–6.2)	20.2 (18.8–20.4)	22.3 (18.9–28.0)	29.6 (29.6–29.7)	29.6 (29.2–29.9)	7.4 (7.3–7.4)	7.5 (7.4–7.9)
CP95165	5.5	6.8 (5.4–8.0)	5.8 (5.6–6.9)	4.6 (3.6–5.8)	23.9 (22.6–24.3)	19.9 (16.5–23.8)	25.4 (24.7–25.4)	25.8 (25.3–26.9)	7.6 (7.5–7.6)	7.3 (7.2–7.7)
CP95166	2.1	4.1 (2.3–5.3)	5.1 (4.2–6.3)	4.0 (2.5–5.2)	20.1 (19.5–21.0)	19.9 (18.2–22.5)	25.3 (24.7–29.9)	25.5 (24.7–26.2)	7.3 (7.2–7.4)	7.2 (7.1–7.5)
CP95167	3.4	4.7 (3.5–5.8)	4.3 (4.1–5.0)	4.8 (< 0.1–7.0)	14.3 (12.9–14.9)	18.4 (12.7–22.8)	26.9 (26.5–27.0)	26.0 (25.2–27.1)	7.2 (7.2–7.2)	7.4 (7.1–7.9)
CP95168	5.8	6.3 (5.0–7.6)	5.1 (5.1–6.3)	5.0 (4.3–7.0)	25.4 (25.0–25.6)	22.6 (20.4–25.4)	25.4 (24.5–25.4)	24.8 (24.6–25.3)	7.4 (7.4–7.4)	7.4 (7.3–7.8)
CP95169	4.3	5.2 (3.8–6.3)	6.2 (6.2–6.5)	5.5 (4.6–6.4)	26.5 (26.0–26.9)	23.3 (19.9–26.5)	25.2 (24.9–25.2)	25.5 (25.1–25.7)	7.7 (7.7–7.7)	7.6 (7.4–7.8)
CP95170	4.2	5.9 (4.9–6.8)	5.9 (5.6–6.1)	6.3 (5.2–6.9)	33.7 (33.2–33.8)	33.4 (31.9–35.7)	27.3 (27.2–27.4)	27.8 (27.3–28.5)	7.7 (7.7–7.7)	7.8 (7.6–8.1)
CP95171	10.0	11.1 (9.8–11.8)	5.9 (5.6–6.8)	– –	25.4 (22.1–25.8)	24.7 (17.7–29.9)	28.4 (28.3–28.6)	28.7 (28.3–29.9)	7.9 (7.9–7.9)	7.7 (7.5–8.0)
CP95172	2.8	2.8 (2.7–3.0)	8.5 (6.8–8.7)	5.9 (3.2–7.3)	1.2 (1.2–1.2)	1.2 (1.2–1.3)	31.2 (31.0–31.2)	30.6 (30.3–31.0)	8.9 (8.7–8.9)	8.5 (7.6–8.8)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95173	4.8	4.9 (4.7–5.1)	5.6 (5.5–5.9)	5.3 (4.4–6.1)	34.3 (34.2–34.3)	34.7 (34.2–35.3)	32.2 (32.1–32.3)	31.7 (31.1–32.2)	7.7 (7.7–7.7)	7.7 (7.6–7.7)
CP95174	1.4	1.2 (1.1–1.3)	5.5 (5.4–5.5)	4.9 (3.9–6.6)	21.8 (21.8–21.8)	23.1 (22.5–24.4)	31.7 (31.7–31.9)	31.9 (31.2–32.6)	7.6 (7.6–7.6)	7.6 (7.5–7.7)
CP95175	1.7	1.7 (1.6–1.7)	6.5 (6.3–6.6)	4.8 (3.8–6.7)	25.4 (25.3–25.4)	25.8 (25.5–26.0)	30.6 (30.6–30.6)	30.2 (29.5–31.0)	8.0 (8.0–8.1)	8.0 (7.9–8.1)
CP95176	1.5	1.2 (1.2–1.2)	6.5 (6.5–6.6)	7.1 (6.4–8.2)	19.0 (19.0–19.0)	19.1 (18.8–19.5)	29.1 (29.1–29.2)	29.1 (28.3–30.2)	8.0 (8.0–8.0)	8.1 (8.0–8.1)
CP95177	1.7	1.3 (1.3–1.3)	6.0 (6.0–6.1)	6.7 (5.7–9.0)	17.7 (17.7–17.7)	19.6 (19.3–19.7)	32.1 (32.1–32.1)	29.3 (28.7–30.1)	7.9 (7.9–7.9)	8.0 (7.9–8.2)
CP95178	1.3	1.5 (1.3–2.5)	5.3 (5.1–5.4)	5.4 (4.1–7.9)	16.3 (16.3–16.3)	16.6 (16.3–16.7)	29.2 (29.1–29.3)	28.9 (27.9–29.9)	7.9 (7.9–7.9)	8.0 (7.9–8.2)
CP95179	0.9	0.8 (0.7–0.9)	7.8 (7.7–7.9)	6.2 (4.5–8.9)	17.2 (17.1–17.2)	17.2 (16.9–17.4)	32.3 (32.3–32.3)	30.5 (29.0–32.7)	8.1 (8.1–8.2)	8.2 (8.0–8.3)
CP95180	2.2	2.7 (2.3–2.7)	5.2 (4.9–5.5)	4.5 (2.9–6.3)	17.9 (17.9–17.9)	18.2 (18.1–18.3)	30.4 (30.2–30.5)	30.3 (29.8–30.8)	7.6 (7.5–7.6)	– –
CP95181	3.4	3.3 (3.1–3.3)	6.7 (6.0–6.9)	6.0 (5.2–7.9)	18.6 (18.6–18.6)	18.8 (18.7–19.0)	30.6 (30.1–30.6)	30.3 (30.1–31.1)	7.6 (7.6–7.8)	7.9 (7.7–8.1)
CP95182	2.0	1.9 (1.8–2.0)	7.0 (5.9–7.9)	4.1 (2.2–6.3)	11.4 (10.5–13.8)	16.5 (13.7–19.4)	30.4 (30.0–30.6)	30.8 (30.4–31.2)	8.0 (7.9–8.1)	7.9 (7.7–8.1)
CP95183	1.6	1.7 (1.5–1.8)	5.6 (4.3–5.7)	4.4 (1.6–8.9)	28.9 (28.5–30.4)	32.8 (31.7–34.0)	31.1 (30.5–31.4)	31.2 (30.8–31.9)	8.0 (8.0–8.0)	8.0 (7.9–8.2)
CP95184	0.6	0.7 (0.6–0.8)	5.4 (5.4–5.4)	5.5 (1.9–6.8)	20.9 (20.8–20.9)	21.2 (20.9–21.6)	32.7 (32.7–32.8)	32.0 (30.3–33.7)	7.8 (7.8–7.8)	7.8 (7.6–7.9)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95185	1.1	1.5 (1.3–1.7)	4.8 (4.7–5.3)	5.9 (4.8–7.2)	23.3 (22.7–23.8)	23.7 (22.0–25.4)	30.8 (30.5–30.8)	31.5 (30.5–33.0)	7.9 (7.9–7.9)	8.0 (7.9–8.0)
CP95186	1.3	1.3 (0.9–1.5)	5.8 (5.7–5.8)	6.4 (4.9–7.8)	24.4 (24.4–24.4)	24.1 (24.0–24.3)	30.6 (30.6–30.7)	31.0 (30.5–32.4)	8.1 (8.0–8.1)	8.2 (8.1–8.3)
CP95187	1.8	2.2 (1.8–2.5)	7.5 (7.4–7.6)	6.1 (5.2–6.9)	24.0 (24.0–24.1)	24.5 (23.1–25.2)	27.3 (27.3–27.3)	27.7 (27.0–30.7)	8.0 (8.0–8.0)	8.0 (7.9–8.1)
CP95188	2.0	2.2 (2.0–2.5)	6.6 (6.4–6.8)	4.4 (3.3–6.2)	15.1 (14.7–17.3)	20.1 (16.1–22.6)	27.2 (25.1–27.2)	27.3 (27.1–27.4)	7.9 (7.8–7.9)	7.7 (7.6–7.8)
CP95CB_	0.8	0.6 (0.5–0.7)	8.2 (8.1–8.2)	8.9 (7.0–11.4)	5.0 (5.0–5.0)	4.9 (4.9–5.1)	24.7 (24.7–24.7)	25.6 (24.7–27.6)	8.2 (8.1–8.2)	8.3 (8.0–8.7)
CP95CF_	1.3	1.5 (0.5–2.1)	6.0 (5.9–6.1)	5.8 (4.8–8.2)	19.4 (19.1–19.7)	21.4 (19.6–23.7)	29.2 (29.0–29.4)	28.8 (27.9–29.9)	7.6 (7.5–7.6)	7.5 (7.5–7.7)
CP95MI_	0.0	0.6 (0.0–1.2)	4.9 (4.9–5.0)	6.1 (2.7–6.7)	34.3 (33.5–34.4)	35.5 (30.6–37.1)	29.6 (29.6–29.6)	30.3 (28.7–32.4)	7.8 (7.8–7.8)	7.8 (7.6–8.0)
CP95PR1	2.9	– –	8.0 (6.7–8.2)	– –	11.8 (11.7–12.5)	– –	25.5 (25.2–25.6)	– –	7.9 (7.7–8.0)	– –
CP95PR2	4.8	– –	6.7 (2.1–7.7)	– –	12.1 (11.9–16.3)	– –	25.1 (25.0–25.2)	– –	7.8 (7.2–7.9)	– –
CP95PR3	4.6	– –	8.2 (5.5–9.7)	– –	9.7 (9.2–11.3)	– –	25.5 (24.9–26.3)	– –	8.2 (7.5–8.4)	– –
CP95PR4	4.0	– –	6.8 (4.2–11.1)	– –	9.6 (8.0–11.0)	– –	25.6 (25.1–27.5)	– –	8.0 (7.4–8.5)	– –
CP95PR5	4.3	– –	2.7 (0.4–11.7)	– –	9.1 (7.0–10.8)	– –	25.3 (25.1–28.2)	– –	7.5 (7.0–8.7)	– –

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX A. (Continued).

Station	Bottom Depth (m)		Dissolved Oxygen (mg/L)		Salinity (‰)		Temperature (°C)		pH	
	Profile[a]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]	Profile[b]	Time Series[c]
CP95RC_	0.0	1.8 (1.0–3.1)	5.6 (5.4–5.7)	11.4 (9.5–11.7)	36.6 (36.0–36.7)	37.1 (36.8–37.2)	30.0 (29.9–30.0)	30.2 (29.8–32.2)	7.9 (7.9–7.9)	8.1 (8.0–8.1)
CP95ZI_	0.7	0.8 (0.7–1.2)	3.3 (3.2–3.5)	4.1 (1.8–7.7)	31.4 (31.3–31.5)	31.4 (31.0–31.8)	26.7 (26.7–27.1)	28.0 (26.7–29.4)	7.4 (7.4–7.5)	7.5 (7.1–7.8)

[a] Bottom depths corrected to Mean Lower Low Water. Each value is the mean of two replicate bottom-depth measurements from instantaneous profile records.

[b] Data from instantaneous, surface-to-bottom depth profiles (taken at 1-m intervals for bottom depths > 3m; 0.5-m intervals for depths < 3m). Number outside parentheses is the mean bottom value (average of two replicates); numbers inside parentheses are the range of values from surface to bottom.

[c] Data from continuous, time-series measurements taken at 30-min. intervals typically over a 24-hr period at a single near-bottom depth. Number outside parentheses is the median value from the time series; numbers inside parentheses are the range.

APPENDIX B. Sediment total organic carbon (TOC), percent silt-clay, porewater unionized ammonia nitrogen (UAN), and porewater unionized hydrogen sulfide (H_2S) by station in 1995.

Station	TOC (%)	Silt-clay (%)	UAN (mg/L)	H_2S (mg/L)
CP95101	1.519	75.11	0.0400	0.015
CP95102	1.155	37.34	0.0266	0.010
CP95103	6.830	99.63	0.0416	–
CP95104	0.295	2.41	0.1428	0.002
CP95105	0.241	2.12	0.3887	0.002
CP95106	0.374	8.56	0.2025	0.003
CP95107	2.473	97.24	0.0453	0.005
CP95108	0.347	0.73	0.3722	0.003
CP95109	11.783	98.92	0.0266	0.007
CP95110	0.514	13.07	0.2244	0.003
CP95111	0.874	12.38	0.0508	0.018
CP95112	0.313	0.33	–	–
CP95113	0.114	2.18	–	0.000
CP95114	2.409	43.29	0.1850	0.005
CP95115	0.221	2.33	0.2393	0.001
CP95116	3.949	94.77	0.1095	0.003
CP95117	2.426	98.44	0.1314	0.001
CP95118	0.241	4.32	0.1380	0.002
CP95119	1.639	67.50	0.0681	0.002
CP95120	4.521	76.95	0.2010	0.009
CP95121	3.635	97.69	0.1885	0.001
CP95122	3.632	96.48	0.3407	0.002
CP95123	0.404	2.52	–	–
CP95124	3.231	98.10	0.2090	0.002
CP95125	0.493	3.63	0.1314	0.002
CP95126	0.327	7.61	0.1679	0.003
CP95127	0.378	5.37	0.1124	0.001
CP95128	0.713	16.21	0.1610	0.002
CP95129	0.389	1.71	0.3378	0.001
CP95130	0.247	1.83	0.1131	0.001
CP95131	1.666	70.66	0.1062	0.001
CP95132	0.385	1.04	0.3077	0.000
CP95133	0.153	1.68	0.1505	0.000
CP95134	0.192	0.78	0.2604	0.002
CP95135	0.152	2.24	–	–

APPENDIX B. (Continued).

Station	TOC (%)	Silt-clay (%)	UAN (mg/L)	H_2S (mg/L)
CP95136	3.036	88.62	0.0821	0.003
CP95137	–	–	–	–
CP95138	0.297	3.19	0.7024	0.004
CP95139	4.745	96.18	0.0950	0.003
CP95140	2.642	78.90	0.2228	0.001
CP95141	1.653	62.91	0.1040	0.003
CP95142	0.653	18.31	0.0632	0.003
CP95143	1.594	89.87	0.0246	0.002
CP95144	–	–	–	–
CP95145	1.403	49.96	0.0277	0.002
CP95146	0.112	2.14	0.1017	0.002
CP95147	0.634	33.22	0.0355	0.000
CP95148	0.169	5.14	0.3897	–
CP95149	2.158	46.40	0.0111	0.007
CP95150	0.333	15.39	0.0799	0.001
CP95151	0.774	19.04	0.0859	0.002
CP95152	0.648	33.73	0.0788	0.003
CP95153	0.091	4.29	0.1183	0.003
CP95154	1.471	45.88	0.1301	0.001
CP95155	0.243	2.38	–	–
CP95156	3.324	77.38	0.0039	0.009
CP95157	0.064	2.42	0.0398	0.008
CP95158	0.352	6.19	0.1688	0.001
CP95159	0.042	1.40	–	–
CP95160	0.548	19.82	0.1901	0.003
CP95161	0.090	2.81	0.1061	0.000
CP95162	0.095	1.23	0.0349	0.000
CP95163	0.111	5.18	0.2405	0.001
CP95164	0.046	1.46	0.1143	0.000
CP95165	0.111	3.41	0.1741	0.000
CP95166	1.760	64.21	0.1510	0.001
CP95167	0.430	8.72	0.0940	0.000
CP95168	0.244	5.90	0.1138	0.000
CP95169	0.824	25.35	0.1019	0.001
CP95170	0.085	2.59	0.1526	0.002

APPENDIX B. (Continued).

Station	TOC (%)	Silt-clay (%)	UAN (mg/L)	H_2S (mg/L)
CP95171	6.384	89.92	0.0788	0.003
CP95172	14.802	96.33	0.1090	0.010
CP95173	1.223	25.33	0.1431	0.002
CP95174	1.370	46.07	0.1288	0.003
CP95175	0.163	6.38	0.4098	0.007
CP95176	0.127	3.47	0.6716	0.001
CP95177	0.127	3.72	0.4455	0.003
CP95178	0.237	9.42	2.6276	0.011
CP95179	0.176	19.11	0.4591	0.002
CP95180	0.749	23.10	0.7675	0.002
CP95181	3.329	69.29	0.4738	0.001
CP95182	0.266	8.85	0.4039	0.010
CP95183	0.134	6.17	0.2202	0.004
CP95184	0.270	12.26	0.7883	0.002
CP95185	0.336	17.29	0.5849	0.001
CP95186	0.106	4.75	0.2967	0.001
CP95187	0.246	16.27	0.4888	0.001
CP95188	0.387	20.70	0.2251	0.000
CP95ASM	0.892	33.50	0.2299	0.000
CP95CB_	0.589	23.52	0.1323	0.010
CP95CF_	2.086	37.62	0.0475	0.000
CP95DIE	4.089	94.59	0.0871	0.000
CP95FOS	1.210	28.89	0.1193	–
CP95KIA	1.724	37.18	0.0484	–
CP95KOP	4.568	92.68	0.1002	0.003
CP95LON	1.434	20.10	0.0070	–
CP95LTH	0.172	3.06	0.0080	–
CP95MI_	0.170	2.17	0.4208	0.003
CP95NMK	3.057	46.67	0.0548	0.007
CP95NV1	0.994	19.45	0.0777	0.002
CP95NV2	2.916	93.26	0.1358	0.000
CP95PR1	0.293	4.73	–	–
CP95PR2	3.752	98.32	0.0915	0.000
CP95PR3	4.388	99.29	0.0756	0.000
CP95PR4	3.519	99.43	0.0832	0.000

APPENDIX B. (Continued).

Station	TOC (%)	Silt-clay (%)	UAN (mg/L)	H_2S (mg/L)
CP95PR5	3.737	98.94	–	–
CP95RC_	0.121	2.86	0.2234	0.005
CP95SPY	2.202	14.26	0.0627	0.002
CP95ZI_	0.478	6.90	0.3251	0.001

APPENDIX C. Sediment concentrations of selected aliphatic and aromatic hydrocarbons (ng/g dry wt) at EMAP sites in the Carolinian Province during summer 1995. Samples with analytes in excess of reported bioeffect levels (listed at end for reference) are bolded.

Station	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]-anthracene	Benzo[a]-pyrene	Chrysene	Dibenz[a,h]-anthracene	Fluoranthene	Fluorene	2-Methyl-naphthalene	Naphthalene	Phenanthrene	Pyrene	Total Alkanes	Total PAHs w/o Perylene
CP95101	0.2	0.4	1.1	2.1	2.9	3.1	0.7	8.6	4.6	1.3	2.7	3.2	6.3	**9732**[c]	101.0
CP95102	0.3	0.2	0.7	1.3	1.7	2.1	0.3	6.3	1.2	0.7	1.8	1.7	5.8	3035	120.8
CP95103	3.7	22.2	12.5	67.4	82.0	86.7	12.0	142.3	11.1	10.3	38.6	32.2	191.2	**24622**[c]	**5933.0**[a]
CP95104	0.1	0.2	0.1	0.3	0.4	0.4	0.1	0.6	0.1	0.4	1.3	0.3	0.8	659	22.9
CP95105	0.1	0.1	0.3	0.7	0.8	1.1	0.3	1.8	0.1	0.2	1.5	1.0	1.5	449	31.7
CP95106	0.3	0.2	0.3	0.5	0.7	0.7	0.2	2.1	0.5	0.4	1.7	0.8	1.7	924	43.3
CP95107	0.8	6.7	3.7	18.6	28.0	28.2	5.7	45.9	1.8	3.1	8.1	11.7	66.3	6732	533.0
CP95108	0.1	0.2	0.2	0.6	0.8	0.9	0.2	1.8	0.1	0.3	1.6	0.7	2.4	527	33.4
CP95109	2.5	25.4	16.3	76.5	127.7	112.6	17.8	266.9	8.2	4.4	13.9	46.9	325.4	**82621**[c]	2173.7
CP95110	0.2	0.4	0.2	0.4	0.7	0.5	0.1	1.3	0.4	0.9	2.3	0.4	1.5	906	29.7
CP95111	0.3	2.5	1.9	19.7	22.3	18.9	2.9	39.9	0.5	1.3	3.7	4.6	39.1	3302	321.3
CP95112	N.D.	0.1	0.4	0.2	0.2	0.3	N.D.	0.8	0.3	0.2	1.1	0.7	1.5	412	18.1
CP95113	0.2	0.1	0.1	0.1	0.3	0.3	0.1	0.5	0.2	0.1	1.4	0.3	0.6	235	20.8
CP95114	0.6	2.5	2.8	6.5	11.0	9.7	1.9	16.4	1.5	1.5	7.6	5.5	17.7	5009	264.5
CP95115	0.5	0.8	0.3	1.3	1.8	1.9	0.3	2.7	0.5	0.9	2.9	1.0	3.1	178	48.5
CP95116	2.7	7.3	7.1	41.5	50.6	47.5	7.6	95.1	3.7	6.3	14.5	33.3	88.9	**10048**[c]	913.6
CP95117	1.2	5.4	2.3	12.7	19.4	17.6	2.8	29.0	1.8	3.8	8.1	10.7	36.3	9959	376.7
CP95118	0.5	0.4	0.5	0.4	0.2	0.4	0.1	0.8	0.5	0.3	1.6	0.7	0.8	1225	13.8
CP95119	0.6	3.0	1.6	12.7	16.0	13.4	2.2	22.6	1.2	2.9	5.4	6.1	27.4	3089	276.9
CP95120	0.6	6.3	5.0	14.9	27.5	22.6	4.6	40.3	3.3	3.0	8.2	11.4	46.4	**10661**[c]	565.6
CP95121	1.6	8.5	7.2	28.4	44.2	43.9	7.5	61.0	5.2	8.1	14.7	18.8	76.0	**9774**[c]	817.6

[a] In excess of ER-L.
[b] In excess of ER-M.
[c] In excess of potential sediment toxicity level for total alkanes.

APPENDIX C. (Continued).

Station	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]-anthracene	Benzo[a]-pyrene	Chrysene	Dibenz[a,h]-anthracene	Fluoranthene	Fluorene	2-Methyl-naphthalene	Naphthalene	Phenanthrene	Pyrene	Total Alkanes	Total PAHs w/o Perylene
CP95122	0.6	5.9	4.3	21.0	33.2	30.8	5.9	49.8	2.7	3.3	8.8	12.7	56.5	6793	609.5
CP95123	0.1	0.1	0.3	1.3	1.7	1.5	0.3	2.4	0.2	0.3	1.9	0.8	2.4	254	35.1
CP95124	0.7	5.8	3.7	20.6	33.4	30.7	5.4	48.3	2.5	3.3	10.9	13.8	60.7	5717	603.7
CP95125	0.1	0.1	0.1	0.2	0.3	0.3	0.1	0.5	0.2	0.4	2.2	0.4	0.6	298	21.7
CP95126	0.1	N.D.	N.D.	0.1	0.1	0.1	N.D.	0.3	0.2	0.5	2.1	0.3	0.5	685	21.8
CP95127	0.1	N.D.	0.1	0.1	0.1	0.2	N.D.	0.2	0.1	0.4	2.5	0.4	0.3	164	18.0
CP95128	0.1	0.3	0.3	1.5	1.9	2.0	0.3	3.2	0.3	0.6	2.1	0.9	3.4	919	51.4
CP95129	0.2	0.1	0.2	0.1	0.2	0.3	N.D.	0.6	0.3	0.5	3.5	0.5	0.8	583	33.6
CP95130	0.6	0.6	0.5	1.0	1.2	1.8	0.2	2.4	1.0	2.7	12.9	2.0	3.5	1209	111.0
CP95131	0.3	2.3	1.2	7.5	8.6	9.7	1.5	15.9	1.2	1.7	5.5	5.5	19.2	2181	214.2
CP95132	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.4	0.2	0.7	3.2	0.5	0.5	217	26.8
CP95133	0.3	0.1	0.1	0.1	0.1	0.2	N.D.	0.4	0.2	0.8	3.6	0.6	0.4	116	25.0
CP95134	0.2	0.2	0.2	0.1	0.2	0.3	N.D.	0.4	0.4	1.0	5.1	0.8	0.9	442	50.0
CP95135	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.4	0.5	1.2	4.8	0.8	0.5	330	43.3
CP95136	0.9	11.7	6.1	51.2	53.8	57.9	8.7	92.8	3.8	4.4	13.4	19.8	106.9	5792	1053.1
CP95137	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CP95138	0.2	0.1	0.3	0.2	0.2	0.4	N.D.	2.1	0.4	0.7	2.1	4.4	1.7	824	65.4
CP95139	2.2	7.4	5.6	28.5	30.4	35.7	7.1	62.9	4.7	4.7	13.3	16.7	71.6	**12260**[c]	875.9
CP95140	1.4	0.7	4.1	15.1	17.0	23.4	2.4	34.3	1.8	0.2	23.3	5.8	34.8	3640	347.3
CP95141	0.3	1.0	1.5	2.5	4.3	4.1	0.6	9.6	1.1	1.4	4.0	3.1	8.8	1412	153.3
CP95142	1.2	3.7	23.7	33.4	33.5	46.4	4.9	92.7	4.6	1.5	4.1	25.5	63.6	1138	645.3
CP95143	0.4	2.0	3.1	8.3	11.4	11.8	1.8	22.5	1.5	1.7	4.8	6.1	18.2	1538	230.5
CP95144	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CP95145	0.3	0.9	1.4	1.6	2.8	2.9	0.5	6.3	1.0	1.1	2.8	2.0	6.0	908	83.4

[a] In excess of ER-L.
[b] In excess of ER-M.
[c] In excess of potential sediment toxicity level for total alkanes.

APPENDIX C. (Continued).

Station	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]-anthracene	Benzo[a]-pyrene	Chrysene	Dibenz[a,h]-anthracene	Fluoranthene	Fluorene	2-Methyl-naphthalene	Naphthalene	Phenanthrene	Pyrene	Total Alkanes	Total PAHs w/o Perylene
CP95146	0.2	0.1	0.6	0.4	0.3	0.4	0.3	1.4	0.2	0.6	2.2	0.6	4.5	495	35.4
CP95147	0.9	0.6	0.6	0.6	0.7	0.8	0.1	2.2	0.8	1.5	3.8	1.2	2.2	2659	57.0
CP95148	0.5	0.4	0.2	N.D.	0.2	0.2	0.1	0.7	0.3	0.5	3.3	0.8	0.5	539	25.6
CP95149	1.0	1.1	1.6	3.5	4.6	5.5	0.8	14.7	1.9	1.8	7.8	8.6	13.9	2724	170.5
CP95150	0.3	1.7	3.5	**301.5**[a]	103.2	164.7	8.1	229.5	0.7	0.6	3.1	1.9	198.7	1986	1952.1
CP95151	7.9	18.3	48.9	114.5	226.0	212.0	29.7	122.8	11.8	2.9	19.0	36.7	477.7	1113	2939.8
CP95152	**53.2**[a]	**56.3**[a]	**142.4**[a]	**333.2**[a]	**685.9**[a]	**620.5**[a]	**71.4**[a]	**701.6**[a]	**45.6**[a]	12.0	39.9	114.6	**3855.4**[b]	2418	**12307.9**[a]
CP95153	0.2	0.2	0.4	0.7	1.0	1.6	0.2	1.0	0.2	0.4	1.8	0.5	0.9	174	25.2
CP95154	1.6	6.2	10.8	37.5	47.0	48.0	7.2	61.2	2.7	2.3	9.2	11.3	62.5	1425	647.8
CP95155	0.3	0.1	0.2	0.5	0.2	0.5	0.1	1.5	0.2	0.5	1.9	0.6	1.6	610	29.7
CP95156	0.6	1.5	2.6	7.9	9.0	11.5	1.4	16.3	2.4	1.8	8.0	5.2	15.4	4675	204.2
CP95157	0.1	0.1	0.2	0.1	0.1	0.1	N.D.	0.3	0.1	0.2	1.6	0.3	0.4	150	13.4
CP95158	0.1	0.2	0.2	0.3	0.5	0.6	0.1	0.9	0.2	0.6	2.1	0.4	0.9	370	21.6
CP95159	0.1	N.D.	0.1	N.D.	N.D.	N.D.	N.D.	0.1	0.1	0.2	1.5	0.2	0.3	72	10.4
CP95160	0.1	0.3	0.9	1.2	1.6	1.6	0.3	3.2	0.3	0.7	3.3	1.3	3.2	465	47.4
CP95161	0.1	0.1	0.2	0.2	0.2	0.2	N.D.	0.6	0.1	0.3	2.9	0.5	0.7	177	28.9
CP95162	0.1	0.1	0.3	0.3	0.3	0.8	0.1	2.5	0.3	0.3	1.9	1.2	2.0	142	25.4
CP95163	0.1	0.2	0.3	0.5	0.6	0.7	0.1	1.3	0.2	0.2	1.7	0.6	1.3	322	22.7
CP95164	0.1	N.D.	0.1	N.D.	0.1	0.1	N.D.	0.3	0.1	0.1	1.6	0.3	0.3	181	14.6
CP95165	0.1	0.1	0.1	0.1	0.2	0.2	N.D.	0.3	0.1	0.3	1.5	0.4	0.4	310	14.6
CP95166	0.4	1.6	1.4	4.8	5.5	5.4	1.0	14.6	1.2	1.2	6.3	6.0	12.2	1740	159.2
CP95167	0.2	0.2	0.2	0.3	0.5	0.7	0.1	1.2	0.2	0.4	2.3	0.6	1.1	639	28.5
CP95168	0.1	0.3	0.2	0.3	0.5	0.5	0.1	1.2	0.2	0.4	1.9	0.6	1.1	328	23.6
CP95169	0.2	0.6	0.6	1.9	2.6	2.6	0.6	4.8	0.5	0.7	3.4	2.0	4.4	991	75.8

[a] In excess of ER-L.
[b] In excess of ER-M.
[c] In excess of potential sediment toxicity level for total alkanes.

APPENDIX C. (Continued).

Station	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]-anthracene	Benzo[a]-pyrene	Chrysene	Dibenz[a,h]-anthracene	Fluoranthene	Fluorene	2-Methyl-naphthalene	Naphthalene	Phenanthrene	Pyrene	Total Alkanes	Total PAHs w/o Perylene
CP95170	0.1	0.2	0.3	0.3	0.3	0.4	0.1	1.7	0.2	0.3	2.2	0.8	1.3	215	21.1
CP95171	7.9	20.0	48.3	108.4	143.4	160.3	24.5	247.0	13.6	8.7	21.5	55.0	252.7	6342	2462.0
CP95172	8.4	21.2	30.6	88.4	118.2	110.5	20.0	195.4	17.7	11.1	30.4	45.9	215.9	**44321**[c]	2482.4
CP95173	0.3	0.7	1.4	3.5	5.2	5.2	1.0	10.8	0.5	0.7	3.2	2.3	10.1	1077	125.0
CP95174	4.1	8.0	15.3	139.9	256.4	225.9	43.3	326.3	4.6	2.2	6.2	63.1	288.6	858	2972.6
CP95175	0.1	0.1	0.2	0.1	0.2	0.3	0.1	0.7	0.2	0.4	1.9	0.7	0.5	2787	22.1
CP95176	0.1	0.1	0.2	0.1	0.2	0.3	0.1	0.6	0.2	0.4	1.7	0.3	0.5	179	15.0
CP95177	0.3	0.1	0.3	0.2	0.3	0.4	0.1	0.9	0.2	0.6	1.4	0.5	0.9	167	9.1
CP95178	0.1	0.3	0.5	2.9	6.7	7.2	1.3	10.6	0.3	0.4	1.7	2.0	8.8	574	108.8
CP95179	0.4	0.2	0.3	2.1	3.6	3.5	0.7	4.6	0.3	0.5	2.1	1.1	4.1	314	46.4
CP95180	0.9	1.7	1.9	5.5	7.7	6.7	1.8	12.0	0.8	1.8	4.6	2.4	10.5	298	125.6
CP95181	0.9	4.7	5.8	18.0	28.4	27.0	6.7	39.1	3.2	2.5	5.2	7.2	33.6	809	422.3
CP95182	0.4	0.3	0.3	1.4	2.3	1.7	0.4	2.8	0.6	0.6	1.8	0.8	2.4	299	35.0
CP95183	0.3	0.5	0.2	0.4	0.5	0.9	0.2	0.8	0.4	0.8	2.0	0.3	0.8	305	13.0
CP95184	0.3	0.3	0.6	3.1	4.2	4.2	0.7	5.6	0.9	0.9	2.1	1.0	5.1	366	74.3
CP95185	1.2	0.3	0.4	2.2	3.0	2.9	0.6	3.4	0.7	1.2	2.4	0.9	3.6	242	42.4
CP95186	0.5	0.3	N.D.	0.3	0.4	0.3	0.1	0.4	0.1	0.6	1.9	0.3	0.7	142	9.2
CP95187	0.2	0.3	0.3	0.4	0.6	1.0	0.2	2.0	0.8	1.1	2.9	0.9	1.8	138	19.1
CP95188	0.9	0.7	1.0	3.2	3.8	3.8	0.8	7.3	1.0	1.2	2.0	1.5	5.9	249	74.0
CP95ASM	4.5	22.6	39.3	109.2	170.4	179.9	31.0	166.7	6.4	6.7	11.9	29.7	281.1	2080	2258.6
CP95CB_	0.6	0.5	1.3	1.1	1.4	1.8	0.3	4.6	2.6	2.6	3.1	2.3	3.4	**14440**[c]	80.1
CP95CF_	2.3	8.5	7.4	64.9	85.5	61.1	11.6	63.4	3.8	5.2	9.6	9.0	95.1	1871	1167.2
CP95DIE	10.6	**78.9**[a]	**120.8**[a]	181.4	**515.1**[a]	250.4	**86.3**[a]	221.2	13.9	9.9	27.4	49.1	**718.7**[a]	5828	**5809.7**[a]
CP95FOS	0.9	2.0	3.3	6.8	10.3	9.0	1.8	18.6	1.6	1.6	4.9	3.3	16.6	1916	194.3

[a] In excess of ER-L.
[b] In excess of ER-M.
[c] In excess of potential sediment toxicity level for total alkanes.

APPENDIX C. (Continued).

Station	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]-anthracene	Benzo[a]-pyrene	Chrysene	Dibenz[a,h]-anthracene	Fluoranthene	Fluorene	2-Methyl-naphthalene	Naphthalene	Phenanthrene	Pyrene	Total Alkanes	Total PAHs w/o Perylene
CP95KIA	1.3	2.8	4.3	26.9	27.3	20.4	5.4	30.0	1.9	1.5	4.2	7.6	26.4	991	363.4
CP95KOP	**85.5**[a]	**68.9**[a]	**353.1**[a]	**553.1**[a]	**457.2**[a]	**682.2**[a]	**81.0**[a]	**868.8**[a]	**94.7**[a]	26.3	38.0	**269.8**[a]	**796.6**[a]	**8711**[c]	**8287.0**[a]
CP95LON	0.5	0.9	0.9	3.1	2.5	2.5	0.6	5.7	0.8	1.3	2.8	1.3	5.2	**29747**[c]	76.9
CP95LTH	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CP95MI_	0.4	0.4	0.4	0.1	0.1	0.2	0.1	0.6	0.3	0.4	1.6	0.3	0.6	142	7.7
CP95NMK	**73.9**[a]	**45.1**[a]	**159.5**[a]	**656.8**[a]	**434.6**[a]	**829.3**[a]	**78.7**[a]	**905.3**[a]	**73.1**[a]	**362.3**[a]	**207.3**[a]	**341.0**[a]	**683.3**[a]	**7319**[c]	**10708.9**[a]
CP95NV1	**28.8**[a]	7.4	**100.2**[a]	203.3	208.7	253.6	27.9	**612.2**[a]	**34.8**[a]	18.4	44.1	**246.0**[a]	503.6	3184	**4312.7**[a]
CP95NV2	13.2	**83.4**[a]	**442.8**[a]	**569.5**[a]	**631.9**[a]	**846.6**[a]	**93.2**[a]	**677.9**[a]	**66.5**[a]	14.0	18.7	166.0	**829.5**[a]	5754	**8803.5**[a]
CP95PR1	0.1	3.5	2.1	46.3	60.9	46.7	10.4	67.7	0.5	0.6	2.4	3.4	63.2	370	664.9
CP95PR2	1.0	4.9	3.9	14.8	23.4	19.8	5.0	35.0	2.5	4.0	7.8	10.1	41.1	5194	420.4
CP95PR3	2.1	15.9	13.7	47.0	71.3	73.9	15.8	117.8	7.8	8.0	15.6	33.9	159.1	**13892**[c]	1446.1
CP95PR4	1.5	13.7	8.3	32.7	48.9	43.0	11.0	73.2	4.2	5.2	10.8	23.1	88.5	**8120**[c]	1023.2
CP95PR5	1.7	12.2	11.8	52.5	74.2	66.4	16.3	108.8	5.3	9.8	13.4	27.5	120.2	**10330**[c]	1296.4
CP95RC_	0.2	0.2	0.3	0.5	0.4	0.5	0.1	1.5	0.3	0.3	2.1	0.6	0.9	219	10.3
CP95SPY	13.2	9.7	34.9	76.3	84.9	121.6	15.0	174.3	15.1	18.6	58.9	53.3	173.8	1879	2041.6
CP95ZI_	0.2	0.6	0.4	0.8	1.0	1.0	0.2	1.7	0.5	1.5	2.3	1.1	1.8	509	23.5
Bioeffect Values:															
ER-L[d]	16	44	85.3	261	430	384	63.4	600	19	70	160	240	665	–	4022
ER-M[d]	500	640	1100	1600	1600	2800	260	5100	540	670	2100	1500	2600	–	44792
Total alkane potential toxicity level[e]														[7000]	

[a] In excess of ER-L.
[b] In excess of ER-M.
[c] In excess of potential sediment toxicity level for total alkanes.
[d] From Long et al. (1995).
[e] From Macauley et al. (1994). Not used in estimates of percent contaminated vs. uncontaminated area.

APPENDIX D. Sediment concentrations (ng/g dry wgt.) of total PCBs and selected pesticides at EMAP sites in the Carolinian Province during summer 1995. Samples with analytes in excess of reported bioeffect levels (listed at the end for reference) are bolded. N.D. = Not detected.

Station	Total PCB	Dieldrin	Endrin	Lindane	Total Chlordane	Total DDT	4,4′-DDD	4,4′-DDE	4,4′-DDT
CP95101	3.44	N.D.	N.D.	N.D.	0.14	0.60	0.18	N.D.	0.42
CP95102	2.83	N.D.	N.D.	N.D.	0.08	0.27	0.06	N.D.	0.21
CP95103	**32.30**[a]	**1.35**[a]	N.D.	N.D.	1.71	**18.06**[a]	**8.54**[b]	N.D.	**4.76**[a]
CP95104	2.79	N.D.	N.D.	N.D.	N.D.	0.09	0.09	N.D.	N.D.
CP95105	2.78	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95106	2.91	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95107	6.26	N.D.	N.D.	N.D.	0.27	**1.63**[a]	0.84	N.D.	0.42
CP95108	5.27	0.06	N.D.	**0.38**[a]	0.15	N.D.	N.D.	N.D.	N.D.
CP95109	**33.78**[a]	**3.66**[a]	N.D.	N.D.	1.03	**213.17**[b]	**150.91**[b]	N.D.	**24.63**[b]
CP95110	2.29	0.03	N.D.	N.D.	0.03	0.92	0.33	0.36	0.17
CP95111	3.39	0.03	N.D.	N.D.	0.06	0.59	0.28	0.29	N.D.
CP95112	2.68	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95113	3.19	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95114	7.56	**1.55**[a]	1.15	**1.85**[b]	0.31	**5.24**[a]	1.00	**2.46**[a]	0.77
CP95115	2.22	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95116	10.91	N.D.	N.D.	**0.68**[a]	0.29	**2.76**[a]	0.68	1.72	0.29
CP95117	4.33	0.09	N.D.	N.D.	0.15	0.67	0.19	0.32	N.D.
CP95118	2.33	N.D.	N.D.	N.D.	N.D.	0.01	N.D.	0.01	N.D.
CP95119	3.88	N.D.	N.D.	N.D.	N.D.	0.33	0.11	0.22	N.D.
CP95120	16.63	**1.81**[a]	2.23	**2.06**[b]	1.18	**7.64**[a]	**1.35**[a]	**3.33**[a]	**1.65**[a]
CP95121	17.78	0.19	N.D.	N.D.	0.65	**6.29**[a]	**1.73**[a]	**3.67**[a]	0.47
CP95122	6.82	N.D.	N.D.	N.D.	N.D.	**3.48**[a]	0.61	2.13	0.36
CP95123	2.68	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95124	5.74	N.D.	N.D.	N.D.	N.D.	1.52	0.47	1.05	N.D.
CP95125	2.29	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95126	2.23	N.D.	0.04	N.D.	N.D.	0.34	N.D.	N.D.	0.02
CP95127	2.48	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95128	2.32	N.D.	N.D.	N.D.	N.D.	0.23	N.D.	0.07	N.D.
CP95129	2.47	N.D.	N.D.	N.D.	N.D.	0.11	N.D.	0.11	N.D.
CP95130	4.18	N.D.	N.D.	N.D.	N.D.	0.55	N.D.	N.D.	N.D.
CP95131	2.33	N.D.	N.D.	N.D.	N.D.	0.36	N.D.	0.14	0.23
CP95132	2.26	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95133	2.46	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95134	5.35	N.D.	N.D.	0.04	0.40	0.65	N.D.	0.18	N.D.
CP95135	2.43	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95136	5.09	N.D.	N.D.	0.28	0.02	**3.68**[a]	0.40	1.81	N.D.
CP95137	–	–	–	–	–	–	–	–	–
CP95138	**72.82**[a]	**15.22**[b]	20.54	**13.10**[b]	0.52	**78.07**[b]	**19.34**[b]	**24.00**[a]	**18.38**[b]

[a] In excess of ER-L or TEL.

[b] In excess of ER-M or PEL.

APPENDIX D. (Continued).

Station	Total PCB	Dieldrin	Endrin	Lindane	Total Chlordane	Total DDT	4,4′-DDD	4,4′-DDE	4,4′-DDT
CP95139	9.52	N.D.	N.D.	N.D.	0.53	**2.68**[a]	0.47	**2.22**[a]	N.D.
CP95140	9.96	0.09	N.D.	0.07	0.37	**3.04**[a]	0.36	0.76	**1.33**[a]
CP95141	3.80	0.12	N.D.	0.11	0.06	0.64	N.D.	0.18	0.33
CP95142	4.32	0.13	N.D.	0.03	0.13	0.81	0.18	0.29	0.23
CP95143	6.37	0.04	0.30	0.05	0.12	**1.59**[a]	0.07	0.69	0.28
CP95144	–	–	–	–	–	–	–	–	–
CP95145	3.49	0.30	0.44	**0.76**[a]	0.04	0.77	0.05	0.31	0.24
CP95146	2.87	0.23	0.26	N.D.	N.D.	0.15	0.02	0.01	N.D.
CP95147	2.61	N.D.	N.D.	N.D.	N.D.	0.02	N.D.	0.02	N.D.
CP95148	2.34	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95149	7.64	N.D.	N.D.	0.10	0.11	0.65	0.07	0.14	0.12
CP95150	6.01	0.14	N.D.	0.06	0.18	0.17	0.03	0.08	0.03
CP95151	12.39	N.D.	N.D.	0.06	0.78	0.66	0.27	0.23	0.10
CP95152	17.92	N.D.	N.D.	0.07	1.06	**2.66**[a]	**1.47**[a]	0.62	0.37
CP95153	2.66	N.D.	0.07	0.04	0.17	0.15	0.01	0.02	N.D.
CP95154	10.94	N.D.	N.D.	0.20	0.25	1.55	0.18	0.57	0.40
CP95155	5.06	0.02	0.01	0.01	0.23	0.32	0.04	0.13	0.01
CP95156	7.77	N.D.	N.D.	0.08	0.13	**7.46**[a]	**5.18**[a]	1.52	0.12
CP95157	2.65	N.D.	N.D.	0.06	0.16	0.10	0.01	0.01	< 0.01
CP95158	4.07	N.D.	N.D.	0.04	0.14	0.06	0.01	0.03	N.D.
CP95159	3.25	N.D.	N.D.	0.02	0.08	0.03	0.01	0.02	N.D.
CP95160	3.74	N.D.	0.07	0.02	0.30	0.20	0.07	0.04	N.D.
CP95161	2.65	N.D.	0.19	0.03	0.08	0.18	0.03	0.05	N.D.
CP95162	2.97	0.01	N.D.	0.03	0.13	0.08	0.01	0.05	0.01
CP95163	3.25	0.15	0.11	**1.27**[b]	0.08	0.12	0.03	0.09	N.D.
CP95164	4.43	**7.92**[b]	7.12	**8.00**[b]	0.06	**20.68**[a]	**6.23**[a]	**6.69**[a]	**6.05**[b]
CP95165	4.44	**0.76**[a]	0.59	**2.07**[b]	0.04	1.27	0.31	0.50	0.28
CP95166	20.70	**38.53**[b]	36.92	**30.52**[b]	0.33	**127.31**[b]	**35.65**[b]	**34.16**[b]	**35.01**[b]
CP95167	4.58	N.D.	N.D.	0.05	0.20	0.13	N.D.	0.02	N.D.
CP95168	6.87	0.19	0.15	**0.39**[a]	0.08	0.49	0.13	0.14	0.10
CP95169	16.74	**33.32**[b]	33.14	**25.27**[b]	0.48	**121.91**[b]	**33.71**[b]	**31.61**[b]	**34.72**[b]
CP95170	3.14	N.D.	0.04	0.01	0.01	N.D.	N.D.	N.D.	N.D.
CP95171	**42.21**[a]	0.53	N.D.	0.31	1.30	**3.55**[a]	0.80	1.08	N.D.
CP95172	**80.88**[a]	**1.74**[a]	3.52	**0.87**[a]	**3.12**[a]	**12.77**[a]	**2.62**[a]	**4.28**[a]	**1.39**[a]
CP95173	10.97	0.07	0.05	0.02	0.06	0.76	0.09	N.D.	0.21
CP95174	21.14	0.12	N.D.	0.11	0.22	**4.60**[a]	**1.41**[a]	2.09	0.31
CP95175	6.05	**9.82**[b]	8.83	**11.80**[b]	0.08	**24.78**[a]	**7.26**[a]	**7.71**[a]	**6.83**[b]
CP95176	3.36	N.D.	0.29	0.02	N.D.	0.15	N.D.	N.D.	N.D.
CP95177	3.20	N.D.	N.D.	N.D.	N.D.	0.17	N.D.	< 0.01	N.D.
CP95178	4.84	0.45	0.30	**2.58**[b]	0.27	0.81	0.09	0.23	0.06

[a] In excess of ER-L or TEL.

[b] In excess of ER-M or PEL.

APPENDIX D. (Continued).

Station	Total PCB	Dieldrin	Endrin	Lindane	Total Chlordane	Total DDT	4,4′-DDD	4,4′-DDE	4,4′-DDT
CP95179	3.94	N.D.	N.D.	N.D.	0.58	0.39	0.05	0.11	0.10
CP95180	4.86	N.D.	N.D.	N.D.	0.29	0.33	0.02	0.07	N.D.
CP95181	7.35	N.D.	1.01	N.D.	1.27	1.07	0.01	0.12	N.D.
CP95182	4.40	N.D.	N.D.	0.01	0.50	0.17	N.D.	N.D.	N.D.
CP95183	3.55	N.D.	N.D.	N.D.	0.21	N.D.	N.D.	N.D.	N.D.
CP95184	5.45	N.D.	0.08	N.D.	0.14	0.25	N.D.	0.05	N.D.
CP95185	3.40	N.D.	N.D.	N.D.	0.20	0.05	N.D.	0.04	N.D.
CP95186	4.11	N.D.	0.04	N.D.	0.27	N.D.	N.D.	N.D.	N.D.
CP95187	3.67	N.D.	N.D.	N.D.	0.05	0.06	< 0.01	0.01	0.04
CP95188	5.02	N.D.	N.D.	N.D.	0.18	0.06	N.D.	0.06	N.D.
CP95ASM	21.03	0.15	N.D.	0.17	0.84	**2.01**[a]	0.51	1.13	0.22
CP95CB_	3.14	0.04	N.D.	N.D.	0.09	0.35	0.20	0.13	N.D.
CP95CF_	11.95	0.29	N.D.	N.D.	0.56	0.74	0.28	0.46	N.D.
CP95DIE	**44.85**[a]	**1.26**[a]	N.D.	0.37	1.38	**3.91**[a]	0.44	**2.56**[a]	0.59
CP95FOS	5.65	0.11	N.D.	0.08	0.07	0.54	0.05	0.21	0.14
CP95KIA	7.20	0.07	N.D.	0.03	0.14	0.83	0.07	0.34	0.23
CP95KOP	**30.59**[a]	0.67	0.11	N.D.	1.64	**5.43**[a]	1.05	1.71	0.33
CP95LON	7.11	0.43	N.D.	N.D.	**4.14**[a]	**44.24**[a]	6.59	**18.85**[a]	**12.13**[b]
CP95LTH	–	–	–	–	–	–	–	–	–
CP95MI_	2.33	N.D.	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.
CP95NMK	**216.00**[b]	**4.72**[b]	N.D.	0.76	**18.45**[b]	**21.71**[a]	6.91	**8.78**[a]	**2.25**[a]
CP95NV1	**166.40**[a]	N.D.	N.D.	0.51	**3.32**[a]	**20.05**[a]	5.50	**7.06**[a]	**2.19**[a]
CP95NV2	**72.11**[a]	0.17	N.D.	0.14	**3.22**[a]	**1.89**[a]	0.42	0.75	0.46
CP95PR1	2.25	N.D.	N.D.	N.D.	N.D.	0.94	0.02	N.D.	N.D.
CP95PR2	8.86	N.D.	N.D.	N.D.	0.16	0.90	0.39	N.D.	0.41
CP95PR3	20.34	N.D.	N.D.	N.D.	0.53	**8.92**[a]	2.50	N.D.	**5.36**[b]
CP95PR4	14.63	N.D.	N.D.	N.D.	0.15	**3.35**[a]	1.11	N.D.	0.98
CP95PR5	17.71	0.44	N.D.	N.D.	0.86	**4.79**[a]	1.80	N.D.	**1.40**[a]
CP95RC_	2.39	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CP95SPY	**32.06**[a]	0.52	N.D.	0.59	1.59	**2.42**[a]	0.91	1.32	0.18
CP95ZI_	2.77	N.D.	N.D.	N.D.	N.D.	0.03	N.D.	0.03	N.D.
Bioeffect Values:									
ER-L	22.7 [c]	–	[0.02 [d]]	–	–	1.58 [c]	–	2.2 [c]	–
ER-M	180 [c]	–	[45 [d]]	–	–	46.1 [c]	–	27 [c]	–
TEL	–	0.715 [e]	–	0.32 [e]	2.26 [e]	–	1.22 [e]	–	1.19 [e]
PEL	–	4.3 [e]	–	0.99 [e]	4.79 [e]	–	7.81 [e]	–	4.77 [e]

[a] In excess of ER-L or TEL.
[b] In excess of ER-M or PEL.
[c] From Long et al. 1995
[d] From Long and Morgan 1990. Not used in estimates of percent contaminated vs. uncontaminated area.
[e] From MacDonald 1994

APPENDIX E. Sediment concentrations of selected inorganic metals (µg/g dry wgt.) and tributyltin (TBT, as ng Sn/g dry weight) at EMAP sites in the Carolinian Province during summer 1995. Samples with analytes in excess of reported bioeffect values (listed at the end for reference) are bolded. N.D. = Not detectable.

Station	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95101	0.04	7.05	0.07	50.63	7.00	0.04	11.20	21.39	0.39	N.D.	43.23
CP95102	0.03	5.31	0.06	36.75	4.25	0.02	8.40	15.14	0.22	N.D.	36.11
CP95103	0.16	7.67	0.45	**83.11**[a]	27.92	0.02	**29.80**[a]	21.78	0.74	N.D.	**156.73**[a]
CP95104	0.02	N.D.	N.D.	12.61	1.61	0.02	2.50	6.99	N.D.	N.D.	16.38
CP95105	0.02	0.96	0.01	11.00	2.01	N.D.	2.20	5.19	N.D.	N.D.	14.88
CP95106	0.03	1.55	0.04	23.14	2.61	0.01	4.90	9.55	N.D.	N.D.	25.26
CP95107	0.10	**8.40**[a]	0.15	**95.31**[a]	**35.41**[a]	0.13	**40.30**[a]	38.31	0.82	N.D.	134.47
CP95108	0.02	N.D.	0.04	16.80	1.48	0.01	3.80	8.49	N.D.	N.D.	26.22
CP95109	0.09	**8.50**[a]	0.33	66.57	15.65	0.11	**23.20**[a]	40.28	0.48	N.D.	97.81
CP95110	0.01	N.D.	N.D.	10.17	1.30	N.D.	1.70	6.66	N.D.	N.D.	11.74
CP95111	0.02	1.85	0.04	25.78	3.03	0.02	4.40	11.45	N.D.	N.D.	28.82
CP95112	N.D.	N.D.	N.D.	0.79	0.86	0.01	0.50	0.90	N.D.	N.D.	5.83
CP95113	0.01	0.80	N.D.	4.88	1.47	N.D.	1.90	3.98	N.D.	N.D.	16.35
CP95114	0.04	6.39	0.16	51.38	6.35	0.05	13.40	20.29	0.36	N.D.	70.13
CP95115	N.D.	2.48	N.D.	9.35	1.40	0.01	2.10	6.77	N.D.	N.D.	16.79
CP95116	0.07	**10.39**[a]	0.33	**82.66**[a]	13.78	0.08	**24.50**[a]	30.15	0.60	N.D.	119.67
CP95117	0.06	**12.28**[a]	0.07	71.55	11.64	0.06	**22.50**[a]	29.55	0.25	N.D.	83.09
CP95118	0.01	1.52	0.02	19.27	1.27	0.01	1.50	6.30	N.D.	N.D.	13.92
CP95119	0.05	**9.91**[a]	0.06	56.33	8.05	0.05	13.60	21.92	0.30	N.D.	61.19
CP95120	0.12	7.30	0.56	61.68	14.73	0.10	16.90	29.91	0.90	N.D.	85.40
CP95121	0.20	**11.25**[a]	**1.30**[a]	**92.11**[a]	21.52	0.12	**24.70**[a]	38.45	0.89	N.D.	132.67
CP95122	0.18	**11.33**[a]	1.12	**98.07**[a]	22.24	0.12	**24.20**[a]	39.41	0.84	N.D.	133.89
CP95123	0.02	1.94	0.02	22.98	1.78	0.01	4.60	8.26	N.D.	N.D.	28.73
CP95124	0.11	**9.77**[a]	0.39	**83.01**[a]	15.81	0.08	**25.30**[a]	33.21	0.86	N.D.	106.04

[a] In excess of ER-L.

[b] In excess of ER-M.

[c] In excess of TBT potential sediment toxicity level.

APPENDIX E. (Continued).

Station	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95125	N.D.	1.32	N.D.	18.79	1.08	0.01	1.80	7.81	N.D.	N.D.	14.76
CP95126	0.01	1.71	0.01	29.31	0.94	0.01	2.30	8.10	N.D.	N.D.	19.03
CP95127	0.01	1.93	N.D.	20.91	1.33	0.01	1.90	8.01	N.D.	N.D.	17.48
CP95128	0.02	1.72	0.07	37.08	2.77	0.01	3.70	9.44	0.23	N.D.	28.19
CP95129	N.D.	1.08	0.02	18.46	1.22	N.D.	1.40	7.33	N.D.	N.D.	24.10
CP95130	N.D.	N.D.	N.D.	6.16	0.97	N.D.	2.00	7.36	N.D.	N.D.	15.37
CP95131	0.04	**8.34**[a]	0.06	56.20	8.06	0.04	14.90	21.40	0.39	N.D.	67.38
CP95132	N.D.	1.44	0.01	19.25	1.12	N.D.	2.40	7.00	N.D.	N.D.	27.11
CP95133	N.D.	1.48	N.D.	20.99	0.59	N.D.	1.50	4.57	N.D.	N.D.	15.11
CP95134	N.D.	N.D.	N.D.	15.25	0.84	N.D.	1.00	5.48	N.D.	N.D.	17.35
CP95135	N.D.	1.27	N.D.	7.90	0.63	N.D.	1.10	4.05	N.D.	N.D.	10.80
CP95136	0.10	**11.86**[a]	0.19	72.75	13.21	0.06	**21.40**[a]	30.85	0.63	N.D.	87.81
CP95137	–	–	–	–	–	–	–	–	–	–	–
CP95138	N.D.	N.D.	0.02	28.01	0.95	0.01	1.80	8.04	N.D.	N.D.	22.05
CP95139	0.26	**11.12**[a]	0.41	75.54	21.95	0.11	**23.50**[a]	36.62	0.61	N.D.	122.21
CP95140	0.07	**9.98**[a]	0.15	57.82	9.42	0.05	14.30	19.26	0.33	1.75	66.37
CP95141	0.04	8.04	0.06	47.48	6.38	0.04	15.20	18.44	0.32	N.D.	48.51
CP95142	0.01	2.34	0.02	20.91	2.11	0.02	3.40	7.61	0.22	N.D.	21.36
CP95143	0.04	7.83	0.04	58.37	7.30	0.03	12.70	19.48	0.42	N.D.	60.95
CP95144	–	–	–	–	–	–	–	–	–	–	–
CP95145	0.04	6.44	0.05	45.36	3.76	0.02	6.20	13.24	0.38	N.D.	36.50
CP95146	N.D.	3.39	0.03	27.05	1.14	N.D.	1.60	5.00	N.D.	N.D.	20.46
CP95147	0.02	4.41	0.03	44.85	4.20	0.01	8.50	9.97	N.D.	N.D.	36.23
CP95148	N.D.	3.03	N.D.	10.01	0.66	N.D.	1.00	3.23	N.D.	N.D.	11.50
CP95149	0.04	**15.15**[a]	0.05	71.13	22.97	0.07	**24.40**[a]	21.68	N.D.	N.D.	79.28
CP95150	0.03	6.56	0.04	39.94	16.97	0.03	12.60	16.74	N.D.	N.D.	47.59

[a] In excess of ER-L.

[b] In excess of ER-M.

[c] In excess of TBT potential sediment toxicity level.

APPENDIX E. (Continued).

Station	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95151	0.08	7.58	0.10	43.90	10.70	0.06	8.70	15.78	N.D.	N.D.	51.02
CP95152	0.10	**10.74**[a]	0.13	65.24	15.30	0.08	13.90	25.23	0.45	N.D.	68.89
CP95153	0.01	3.11	0.03	30.20	1.37	0.01	3.30	10.30	N.D.	N.D.	24.10
CP95154	0.06	**12.47**[a]	0.15	54.21	11.07	0.04	13.40	18.89	N.D.	2.77	56.44
CP95155	0.03	8.16	0.10	28.70	2.38	0.02	4.70	5.69	N.D.	N.D.	21.66
CP95156	0.07	**22.29**[a]	0.14	**84.75**[a]	14.70	0.09	**22.00**[a]	25.02	N.D.	N.D.	86.57
CP95157	0.02	1.20	0.06	23.36	0.60	N.D.	1.00	5.13	N.D.	N.D.	16.57
CP95158	0.03	5.32	0.10	25.53	1.66	0.02	4.60	6.63	0.33	N.D.	26.71
CP95159	0.01	2.05	0.17	13.30	0.52	N.D.	1.00	4.83	N.D.	N.D.	13.08
CP95160	0.02	5.98	0.06	38.12	3.63	0.02	6.20	10.30	N.D.	N.D.	31.25
CP95161	N.D.	2.93	0.10	13.31	1.25	0.01	2.00	6.35	N.D.	N.D.	19.03
CP95162	N.D.	4.27	0.04	13.36	0.93	0.01	2.60	8.58	N.D.	N.D.	24.81
CP95163	0.02	4.43	0.16	52.33	1.65	0.02	3.00	8.87	N.D.	N.D.	28.57
CP95164	0.02	1.34	0.06	9.64	0.59	N.D.	0.80	3.82	N.D.	N.D.	11.47
CP95165	0.02	2.47	0.05	9.26	1.15	0.01	1.50	6.01	N.D.	N.D.	12.45
CP95166	0.05	**13.67**[a]	0.10	63.09	10.12	0.04	17.00	20.39	N.D.	N.D.	69.50
CP95167	0.02	4.19	0.04	20.50	2.52	0.02	4.40	6.53	N.D.	N.D.	23.74
CP95168	0.01	1.65	0.02	20.36	1.10	0.02	1.80	5.82	N.D.	N.D.	17.19
CP95169	0.03	7.15	0.05	36.02	3.57	0.02	6.50	7.89	N.D.	N.D.	33.16
CP95170	0.02	1.43	0.04	15.35	0.92	0.01	1.30	4.03	N.D.	N.D.	16.25
CP95171	0.23	**11.11**[a]	0.25	68.54	23.75	0.14	16.80	30.52	0.36	**39.68**[c]	109.09
CP95172	0.38	6.22	0.74	67.66	24.70	**0.19**[a]	15.80	43.30	0.49	**27.90**[c]	119.78
CP95173	0.02	3.27	0.05	30.84	5.86	0.03	4.90	10.31	N.D.	4.51	29.22
CP95174	0.51	4.78	0.18	48.89	17.59	**0.18**[a]	8.20	39.54	0.23	2.61	84.70
CP95175	N.D.	N.D.	0.02	8.49	0.97	0.01	1.00	4.32	N.D.	N.D.	9.25
CP95176	0.01	N.D.	0.01	5.79	1.71	0.01	0.90	3.08	N.D.	N.D.	8.84

[a] In excess of ER-L.

[b] In excess of ER-M.

[c] In excess of TBT potential sediment toxicity level.

APPENDIX E. (Continued).

Station	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95177	N.D.	N.D.	0.03	6.72	1.71	0.01	0.90	2.29	N.D.	N.D.	9.23
CP95178	0.02	0.92	0.02	10.28	2.43	0.02	1.40	5.09	N.D.	N.D.	13.22
CP95179	N.D.	N.D.	0.03	9.19	1.44	0.01	1.30	5.03	N.D.	N.D.	11.10
CP95180	0.11	1.06	0.08	21.66	12.30	0.05	4.80	11.68	N.D.	N.D.	32.24
CP95181	0.35	4.11	0.36	71.92	33.07	0.14	16.50	45.62	N.D.	3.71	104.79
CP95182	0.06	N.D.	0.05	15.12	2.56	0.03	1.80	9.00	N.D.	N.D.	16.88
CP95183	0.02	1.33	0.05	13.76	1.29	0.01	1.70	7.41	N.D.	N.D.	13.69
CP95184	0.03	1.71	0.03	23.48	4.61	0.02	2.00	8.87	N.D.	N.D.	24.90
CP95185	0.04	1.77	0.03	19.84	5.19	0.02	2.30	8.50	N.D.	N.D.	23.33
CP95186	0.01	N.D.	0.03	12.79	1.06	0.01	1.40	5.56	N.D.	N.D.	10.81
CP95187	0.04	1.93	0.24	21.24	2.03	0.02	2.90	9.45	N.D.	N.D.	17.16
CP95188	0.02	2.16	0.03	22.91	3.02	0.02	3.50	9.43	N.D.	N.D.	20.48
CP95ASM	0.20	**9.77**[a]	0.15	**112.25**[a]	33.20	0.10	12.70	41.70	N.D.	–	83.57
CP95CB_	0.01	N.D.	0.05	26.41	3.19	0.02	6.00	10.32	0.24	–	30.73
CP95CF_	0.08	6.52	0.16	49.84	8.70	0.06	11.00	15.01	0.51	–	68.86
CP95DIE	0.30	**19.73**[a]	0.27	**119.62**[a]	33.50	0.13	**27.10**[a]	51.18	N.D.	–	**151.33**[a]
CP95FOS	0.04	6.67	0.06	37.81	8.77	0.03	8.30	14.00	N.D.	–	43.38
CP95KIA	0.03	**10.47**[a]	0.05	58.21	7.52	0.03	11.70	18.35	N.D.	–	52.15
CP95KOP	0.21	**21.49**[a]	0.25	**123.27**[a]	41.53	0.14	**26.40**[a]	57.59	1.03	–	**156.94**[a]
CP95LON	0.02	2.47	0.04	41.37	3.51	0.03	5.20	13.52	N.D.	–	29.45
CP95LTH	–	–	–	–	–	–	–	–	–	–	–
CP95MI_	N.D.	1.77	0.01	7.85	0.69	0.01	0.80	2.47	0.08	–	11.60
CP95NMK	0.44	**11.81**[a]	1.07	**259.84**[a]	**69.26**[a]	**0.27**[a]	18.90	**163.83**[a]	**2.17**[a]	–	**306.61**[a]
CP95NV1	**1.20**[a]	5.57	0.29	80.79	**40.54**[a]	0.03	**22.80**[a]	**107.26**[a]	1.58	–	129.00
CP95NV2	0.13	**16.21**[a]	0.16	**109.65**[a]	26.42	0.07	**25.40**[a]	28.56	N.D.	–	75.28
CP95PR1	0.02	0.96	0.09	9.81	1.65	0.02	2.10	7.21	0.27	–	18.73

[a] In excess of ER-L.

[b] In excess of ER-M.

[c] In excess of TBT potential sediment toxicity level.

APPENDIX E. (Continued).

Station	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95PR2	0.17	**9.66**[a]	0.86	**82.09**[a]	20.18	0.11	**25.20**[a]	36.27	0.67	–	125.91
CP95PR3	0.27	**8.84**[a]	**1.66**[a]	**83.30**[a]	26.24	0.13	**26.20**[a]	41.86	0.87	–	**152.60**[a]
CP95PR4	0.22	**10.97**[a]	0.28	**86.49**[a]	31.19	0.14	**26.20**[a]	42.79	1.03	–	**156.98**[a]
CP95PR5	0.29	**10.06**[a]	0.99	76.61	**36.42**[a]	**0.15**[a]	**23.90**[a]	**47.43**[a]	1.54	–	**154.73**[a]
CP95RC_	0.02	1.73	0.02	18.62	1.10	0.01	1.70	5.36	N.D.	–	17.23
CP95SPY	0.18	7.18	0.48	**20660.00**[b]	23.95	0.08	**112.00**[b]	**82.04**[a]	0.61	–	**193.74**[a]
CP95ZI_	0.02	2.40	0.04	19.93	1.60	0.01	1.70	5.14	0.21	–	19.73
Bioeffect Values:											
ER-L	1.0 [d]	8.2 [d]	1.2 [d]	81 [d]	34 [d]	0.15 [d]	20.9 [d]	46.7 [d]	2.0 [e]	–	150 [d]
ER-M	3.7 [d]	70.0 [d]	9.6 [d]	370 [d]	270 [d]	0.71 [d]	51.6 [d]	218.0 [d]	25 [e]	–	410 [d]
TBT potential toxicity range		–	–	–	–	–	–	–	–	[>5 [f]]	–

[a] In excess of ER-L.
[b] In excess of ER-M.
[c] In excess of TBT potential sediment toxicity level.
[d] From Long et al. 1995
[e] From Long and Morgan 1990
[f] From Macauley 1994. Not used in estimates of percent contaminated vs. uncontaminated area.

APPENDIX F. Concentration ranges for all analytes measured in sediments at probabilistic base stations in the Carolinian Province during the summer 1995 (N = 86). Bolded analytes are those for which sediment quality guidelines are available (ER-L/ER-M or TEL/PEL) and which were used in determinations of contaminated vs. uncontaminated stations throughout this report.

Contaminant	Minimum	Maximum
Metals (µg/g)		
Aluminum	572.00	120,210.00
Antimony	N.D.	0.90
Arsenic	N.D.	22.29
Cadmium	N.D.	1.30
Chromium	0.79	98.07
Copper	0.52	35.41
Iron	419.00	60,900.00
Lead	0.90	45.62
Manganese	N.D.	1,128.50
Mercury	N.D.	0.19
Nickel	0.50	40.30
Selenium	N.D.	2.76
Silicon	192,857.00	527,376.00
Silver	N.D.	0.51
Tin	0.02	3.33
Zinc	5.83	156.73
Organotins (ng/g)		
Monobutyltin	N.D.	3.51
Dibutyltin	N.D.	2.39
Tributyltin	N.D.	39.68
Tetrabutyltin	N.D.	5.21
Pesticides (ng/g)		
Aldrin	N.D.	23.41
Total Chlordane [a]	N.D.	3.12
Alpha Chlordane	N.D.	2.45
cis-Nonachlor	N.D.	0.70
Gamma Chlordane	N.D.	0.95
Heptachlor	N.D.	30.27
Heptachlor epoxide	N.D.	35.91
Oxychlordane	N.D.	1.21
trans-Nonachlor	N.D.	2.68
Total BHC [b]	N.D.	128.92
Alpha BHC (toxaphene)	N.D.	26.74
Beta BHC	N.D.	40.50
Delta BHC	N.D.	31.16
Gamma BHC (Lindane)	N.D.	30.52

Contaminant	Minimum	Maximum
Pesticides continued (ng/g)		
Dieldrin	N.D.	38.53
Endosulfan II (Beta-Endosulfan)	N.D.	20.39
Endrin	N.D.	36.92
Hexachlorobenzene (HCB)	N.D.	0.21
Mirex	N.D.	0.57
2,4'-DDD (o,p'-DDD)	N.D.	35.36
4,4'-DDD (p,p'-DDD)	N.D.	150.91
2,4'-DDE (o,p'-DDE)	N.D.	21.87
4,4'-DDE (p,p'-DDE)	N.D.	34.16
2,4'-DDT (o,p'-DDT)	N.D.	2.54
4,4'-DDT (p,p'-DDT)	N.D.	35.01
Total DDTs [c]	N.D.	213.17
PCBs (ng/g)		
PCB 101/90	N.D.	4.87
PCB 105	N.D.	0.31
PCB 118	N.D.	1.63
PCB 128	N.D.	0.67
PCB 138/160	N.D.	3.85
PCB 153/132	N.D.	6.01
PCB 170/190	N.D.	4.88
PCB 18/17	N.D.	2.14
PCB 180	N.D.	2.35
PCB 187	N.D.	1.44
PCB 195/208	N.D.	0.81
PCB 206	N.D.	16.27
PCB 209	N.D.	13.96
PCB 28	N.D.	4.35
PCB 44	N.D.	1.05
PCB 52	N.D.	3.78
PCB 66	N.D.	0.36
PCB 8/5	N.D.	4.10
Total PCBs [d]	2.22	80.88

[a] Total Chlordane: Alpha-, Gamma-, Oxychlordane
[b] Total BHC: Alpha-, Beta-, Delta-, Gamma BHC. BHC=HCH.
[c] Total DDTs: all six DDDs, DDEs, and DDTs
[d] Total PCBs: ((Sum of 18 PCB congeners) * 2.19) + 2.19

APPENDIX F. (Continued).

Contaminant	Minimum	Maximum
Aromatic Hydrocarbons (ng/g)		
Total PAHs (without Perylene) [e]	9.10	12,307.90
Naphthalene	1.10	39.90
C1-Naphthalenes	0.20	18.50
C2-Naphthalenes	N.D.	136.00
C3-Naphthalenes	N.D.	211.20
C4-Naphthalenes	N.D.	128.00
Biphenyl	0.30	6.80
Acenaphthene	N.D.	53.20
Acenaphthylene	N.D.	56.30
Fluorene	0.10	45.60
C1-Fluorenes	N.D.	58.60
C2-Fluorenes	N.D.	137.60
C3-Fluorenes	N.D.	231.40
Phenanthrene	0.20	114.60
Anthracene	N.D.	142.40
C1-Phenanthrenes	N.D.	381.30
C2-Phenanthrenes	N.D.	400.20
C3-Phenanthrenes	N.D.	505.90
C4-Phenanthrenes	N.D.	405.30
Dibenzothiophene	N.D.	14.40
C1-Dibenzothiophenes	N.D.	61.10
C2-Dibenzothiophenes	N.D.	117.60
C3-Dibenzothiophenes	N.D.	192.50
Fluoranthene	0.10	701.60
Pyrene	**0.30**	**3,855.40**
C1-Fluoranthene pyrene	N.D.	1,143.60
Benzo[a]anthracene	N.D.	333.20
Chrysene	N.D.	620.50
C1-Chrysenes	N.D.	442.50
C2-Chrysenes	N.D.	303.60
C3-Chrysenes	N.D.	40.40
C4-Chrysenes	N.D.	65.10
Benzo[a]pyrene	N.D.	685.90
Benzo[e]pyrene	0.10	426.20
Benzo[b]fluoranthene	0.10	1,221.60
Benzo[k]fluoranthene	N.D.	1,178.40
Benzo[ghi]perylene	N.D.	238.10
Indeno[1,2,3-cd]pyrene	N.D.	271.20
Dibenz[a,h]anthracene	N.D.	71.40

Contaminant	Minimum	Maximum
Aromatic Hydrocarbons continued (ng/g)		
Perylene	0.10	872.40
2-Methylnaphthalene	0.10	12.00
1-Methylnaphthalene	0.10	7.50
2,6-Dimethylnaphthalene	0.10	12.30
1,6,7-Trimethylnaphthalene	0.10	6.40
1-Methylphenanthrene	N.D.	20.80
Aliphatic Hydrocarbons (ng/g)		
Total Alkanes [f]	72.00	82,621.00
C10-Alkane (n-Decane)	N.D.	N.D.
C11-Alkane (n-Undecane)	N.D.	5.00
C12-Alkane (n-Dodecane)	N.D.	495.00
C13-Alkane (n-Tridecane)	N.D.	17.00
C14-Alkane (n-Tetradecane)	2.00	180.00
C15-Alkane (n-Pentadecane)	1.00	956.00
C16-Alkane (n-Hexadecane)	2.00	109.00
C17-Alkane (n-Heptadecane)	1.00	3,524.00
C18-Alkane (n-Octadecane)	1.00	326.00
C19-Alkane (n-Nonadecane)	1.00	1,086.00
C20-Alkane (n-Eicosane)	1.00	2,225.00
C21-Alkane (n-Heneicosane)	1.00	846.00
C22-Alkane (n-Docosane)	1.00	595.00
C23-Alkane (n-Tricosane)	2.00	2,377.00
C24-Alkane (n-Tetracosane)	1.00	1,035.00
C25-Alkane (n-Pentacosane)	4.00	4,046.00
C26-Alkane (n-Hexacosane)	1.00	1,554.00
C27-Alkane (n-Heptacosane)	4.00	7,062.00
C28-Alkane (n-Octacosane)	1.00	3,119.00
C29-Alkane (n-Nonacosane)	5.00	26,116.00
C30-Alkane (n-Triacontane)	N.D.	3,563.00
C31-Alkane (n-Hentriacontane)	1.00	19,666.00
C32-Alkane (n-Dotriacontane)	N.D.	1,148.00
C33-Alkane (n-Tritriacontane)	N.D.	4,113.00
C34-Alkane (n-Tetratriacontane)	N.D.	1,434.00
Pristane	N.D.	111.00
Phytane	N.D.	285.00

[e] Total PAHs: Sum of 38 PAHs
[f] Total Alkanes: Sum of 27 aliphatic hydrocarbons

APPENDIX G. Summary of toxicity testing results by station in the Carolinian Province in 1995. Significant toxicity test results are bolded. Silt-clay fraction, numbers of contaminant bioeffect guideline exceedances, porewater unionized ammonia nitrogen (UAN), and porewater hydrogen sulfide (H_2S) concentrations are also reported. Microtox results are corrected for water content. *A. abdita* and *A. verrilli* results reported as percent survival relative to control. *M. mercenaria* results reported as percent growth relative to control.

Station	Microtox®[a] (EC_{50} , %)	*A. abdita*[b] (%)	*A. verrilli*[b] (%)	*M. mercenaria*[c] (%)	Silt-clay (%)	Exceedances[d] ER-L/TEL, ER-M/PEL	UAN (mg/L)	H_2S (mg/L)
CP95101	0.36	100.00	103.00	**66.64**	75.11	0, 0	0.0400	0.015
CP95102	**0.18**	98.90	98.00	62.69	37.34	0, 0	0.0266	0.010
CP95103	**0.17**	76.80	**63.00**	**-28.39**	99.63	8, 1	0.0416	–
CP95104	0.70	101.10	103.00	**17.05**	2.41	0, 0	0.1428	0.002
CP95105	9.38	104.30	97.00	**-25.39**	2.12	0, 0	0.3887	0.002
CP95106	10.00	103.20	107.00	**-32.84**	8.56	0, 0	0.2025	0.003
CP95107	0.28	102.10	94.00	**37.18**	97.24	5, 0	0.0453	0.005
CP95108	5.19	96.80	**60.00**	**21.24**	0.73	1, 0	0.3722	0.003
CP95109	**0.06**	97.90	93.00	**-8.78**	98.92	4, 3	0.0266	0.007
CP95110	5.63	101.10	108.00	**-32.91**	13.07	0, 0	0.2244	0.003
CP95111	2.22	105.40	110.00	**-17.98**	12.38	0, 0	0.0508	0.018
CP95112	10.00	91.60	94.00	–	0.33	0, 0	–	–
CP95113	10.00	95.80	100.00	**-6.52**	2.18	0, 0	–	0.000
CP95114	0.97	98.90	100.00	**70.02**	43.29	3, 1	0.1850	0.005
CP95115	10.00	92.50	105.00	107.81	2.33	0, 0	0.2393	0.001
CP95116	0.50	95.60	101.00	98.02	94.77	5, 0	0.1095	0.003
CP95117	0.36	109.80	100.00	127.33	98.44	2, 0	0.1314	0.001
CP95118	10.00	89.00	97.00	155.35	4.32	0, 0	0.1380	0.002
CP95119	0.90	97.80	98.00	147.22	67.50	1, 0	0.0681	0.002
CP95120	0.77	104.90	94.00	**-26.29**	76.95	5, 1	0.2010	0.009
CP95121	0.55	104.20	103.00	135.32	97.69	7, 0	0.1885	0.001
CP95122	0.64	100.00	97.00	**78.71**	96.48	4, 0	0.3407	0.002
CP95123	9.52	92.50	104.00	**52.54**	2.52	0, 0	–	–
CP95124	0.56	94.50	96.00	62.82	98.10	3, 0	0.2090	0.002
CP95125	3.83	87.90	96.00	161.25	3.63	0, 0	0.1314	0.002
CP95126	2.19	89.00	97.00	152.74	7.61	0, 0	0.1679	0.003
CP95127	4.81	93.40	101.00	86.00	5.37	0, 0	0.1124	0.001
CP95128	0.80	92.30	96.00	79.61	16.21	0, 0	0.1610	0.002
CP95129	3.77	86.80	95.00	83.02	1.71	0, 0	0.3378	0.001
CP95130	10.00	92.50	98.00	60.46	1.83	0, 0	0.1131	0.001
CP95131	0.51	102.20	103.00	96.59	70.66	1, 0	0.1062	0.001
CP95132	10.00	93.50	107.00	110.87	1.04	0, 0	0.3077	0.000

[a] Significant Microtox® toxicity: $EC_{50} \leq 0.2\%$ if sediment silt-clay content $\geq 20\%$, or $EC_{50} \leq 0.5\%$ if sediment silt-clay content $< 20\%$.

[b] Significant *Ampelisca abdita* or *Ampelisca verrilli* toxicity: survival in sample significantly less than survival in negative control (at $\alpha = 0.05$), and survival in sample $\leq 80\%$ of control survival.

[c] Significant *Mercenaria mercenaria* toxicity: mean growth rate in test sediment significantly different than in control sediment (at $\alpha = 0.05$), and mean growth in test sediment $< 80\%$ of the mean growth in control sediment.

[d] First number is the number of contaminants at or exceeding ER-L/TEL bioeffect guideline values but below ER-M/PEL guidelines. Second number is the number of contaminants at or exceeding ER-M/PEL bioeffect guideline values.

APPENDIX G. (Continued).

Station	Microtox®[a] (EC_{50} , %)	*A. abdita*[b] (%)	*A. verrilli*[b] (%)	*M. mercenaria*[c] (%)	Silt-clay (%)	Exceedances[d] ER-L/TEL, ER-M/PEL	UAN (mg/L)	H_2S (mg/L)
CP95133	10.00	81.50	100.00	167.36	1.68	0, 0	0.1505	0.000
CP95134	10.00	104.90	102.00	83.71	0.78	0, 0	0.2604	0.002
CP95135	10.00	109.80	97.00	133.34	2.24	0, 0	–	–
CP95136	0.64	96.80	96.00	94.08	88.62	3, 0	0.0821	0.003
CP95137	–	–	–	–	–	–, –	–	–
CP95138	10.00	100.00	101.00	–	3.19	2, 5	0.7024	0.004
CP95139	**0.17**	100.00	98.00	113.91	96.18	4, 0	0.0950	0.003
CP95140	0.60	104.30	92.00	98.05	78.90	3, 0	0.2228	0.001
CP95141	0.32	97.90	97.00	113.59	62.91	0, 0	0.1040	0.003
CP95142	1.38	93.50	99.00	89.58	18.31	0, 0	0.0632	0.003
CP95143	**0.16**	96.90	96.00	98.56	89.87	1, 0	0.0246	0.002
CP95144	–	–	–	–	–	–, –	–	–
CP95145	**0.12**	102.20	91.00	99.63	49.96	1, 0	0.0277	0.002
CP95146	4.29	98.90	100.00	**31.69**	2.14	0, 0	0.1017	0.002
CP95147	0.45	102.20	101.00	81.55	33.22	0, 0	0.0355	0.000
CP95148	2.42	102.20	101.00	117.61	5.14	0, 0	0.3897	–
CP95149	**0.04**	102.10	84.00	**22.74**	46.40	2, 0	0.0111	0.007
CP95150	0.88	93.70	99.00	**27.50**	15.39	1, 0	0.0799	0.001
CP95151	**0.17**	98.90	89.00	109.78	19.04	0, 0	0.0859	0.002
CP95152	**0.08**	95.80	89.00	96.00	33.73	13, 1	0.0788	0.003
CP95153	5.08	98.90	95.00	145.12	4.29	0, 0	0.1183	0.003
CP95154	**0.17**	97.90	101.00	127.32	45.88	1, 0	0.1301	0.001
CP95155	10.00	94.80	97.00	169.65	2.38	0, 0	–	–
CP95156	**0.02**	100.00	97.00	**-1.69**	77.38	5, 0	0.0039	0.009
CP95157	10.00	100.00	92.00	90.02	2.42	0, 0	0.0398	0.008
CP95158	0.89	105.40	98.00	129.58	6.19	0, 0	0.1688	0.001
CP95159	10.00	99.00	102.00	109.22	1.40	0, 0	–	–
CP95160	**0.36**	96.90	100.00	134.55	19.82	0, 0	0.1901	0.003
CP95161	4.99	96.90	104.00	116.94	2.81	0, 0	0.1061	0.000
CP95162	10.00	90.80	96.00	139.10	1.23	0, 0	0.0349	0.000
CP95163	1.25	93.90	95.00	140.07	5.18	0, 1	0.2405	0.001
CP95164	10.00	100.00	98.00	81.87	1.46	3, 3	0.1143	0.000
CP95165	5.31	99.00	94.00	131.48	3.41	1, 1	0.1741	0.000
CP95166	0.23	97.90	101.00	138.19	64.21	1, 6	0.1510	0.001
CP95167	**0.49**	99.00	104.00	126.65	8.72	0, 0	0.0940	0.000
CP95168	0.93	100.00	106.00	98.36	5.90	1, 0	0.1138	0.000
CP95169	0.60	97.90	102.00	116.12	25.35	0, 6	0.1019	0.001

[a] Significant Microtox® toxicity: $EC_{50} \leq 0.2\%$ if sediment silt-clay content $\geq 20\%$, or $EC_{50} \leq 0.5\%$ if sediment silt-clay content $< 20\%$.

[b] Significant *Ampelisca abdita* or *Ampelisca verrilli* toxicity: survival in sample significantly less than survival in negative control (at $\alpha = 0.05$), and survival in sample $\leq 80\%$ of control survival.

[c] Significant *Mercenaria mercenaria* toxicity: mean growth rate in test sediment significantly different than in control sediment (at $\alpha = 0.05$), and mean growth in test sediment $< 80\%$ of the mean growth in control sediment.

[d] First number is the number of contaminants at or exceeding ER-L/TEL bioeffect guideline values but below ER-M/PEL guidelines. Second number is the number of contaminants at or exceeding ER-M/PEL bioeffect guideline values.

APPENDIX G. (Continued).

Station	Microtox®[a] (EC_{50} , %)	*A. abdita*[b] (%)	*A. verrilli*[b] (%)	*M. mercenaria*[c] (%)	Silt-clay (%)	Exceedances[d] ER-L/TEL, ER-M/PEL	UAN (mg/L)	H_2S (mg/L)
CP95170	10.00	97.90	98.00	138.42	2.59	0, 0	0.1526	0.002
CP95171	**0.09**	98.90	94.00	**35.59**	89.92	3, 0	0.0788	0.003
CP95172	3.21	97.90	95.00	**7.72**	96.33	9, 0	0.1090	0.010
CP95173	0.32	103.20	97.00	118.02	25.33	0, 0	0.1431	0.002
CP95174	**0.20**	100.00	98.00	175.90	46.07	3, 0	0.1288	0.003
CP95175	0.65	93.70	98.00	74.91	6.38	3, 3	0.4098	0.007
CP95176	1.11	103.30	99.00	87.72	3.47	0, 0	0.6716	0.001
CP95177	1.50	103.30	99.00	63.52	3.72	0, 0	0.4455	0.003
CP95178	**0.31**	**53.80**	**59.00**	**0.38**	9.42	0, 1	2.6276	0.011
CP95179	**0.23**	91.40	99.00	**-8.51**	19.11	0, 0	0.4591	0.002
CP95180	0.26	90.20	102.00	**15.71**	23.10	0, 0	0.7675	0.002
CP95181	**0.11**	91.30	99.00	103.33	69.29	0, 0	0.4738	0.001
CP95182	0.58	100.00	97.00	63.78	8.85	0, 0	0.4039	0.010
CP95183	0.85	98.90	78.00	72.08	6.17	0, 0	0.2202	0.004
CP95184	**0.47**	101.00	94.00	**-1.72**	12.26	0, 0	0.7883	0.002
CP95185	**0.26**	92.90	97.00	**56.62**	17.29	0, 0	0.5849	0.001
CP95186	1.02	101.10	99.00	**64.07**	4.75	0, 0	0.2967	0.001
CP95187	0.52	104.30	94.00	113.25	16.27	0, 0	0.4888	0.001
CP95188	0.21	103.20	100.00	93.28	20.70	0, 0	0.2251	0.000
CP95ASM	0.22	97.90	93.00	101.97	33.50	3, 0	0.2299	0.000
CP95CB_	10.00	102.10	105.00	**74.72**	23.52	0, 0	0.1323	0.010
CP95CF_	0.35	97.80	93.00	**-26.33**	37.62	0, 0	0.0475	0.000
CP95DIE	**0.13**	99.00	98.00	84.86	94.59	16, 0	0.0871	0.000
CP95FOS	**0.14**	–	98.00	106.71	28.89	0, 0	0.1193	–
CP95KIA	**0.19**	–	93.00	111.35	37.18	1, 0	0.0484	–
CP95KOP	**0.18**	103.20	90.00	**65.02**	92.68	20, 0	0.1002	0.003
CP95LON	1.17	–	99.00	101.20	20.10	4, 1	0.0070	–
CP95LTH	4.00	–	100.00	116.08	3.06	–, –	0.0080	–
CP95MI_	3.97	90.20	82.00	**41.88**	2.17	0, 0	0.4208	0.003
CP95NMK	0.23	97.90	81.00	75.41	46.67	26, 3	0.0548	0.007
CP95NV1	**0.24**	102.10	86.00	89.71	19.45	17, 0	0.0777	0.002
CP95NV2	**0.05**	100.00	101.00	97.20	93.26	16, 0	0.1358	0.000
CP95PR1	–	–	–	**53.63**	4.73	0, 0	–	–
CP95PR2	0.58	101.00	104.00	**62.48**	98.32	3, 0	0.0915	0.000
CP95PR3	0.24	102.10	105.00	**61.67**	99.29	7, 1	0.0756	0.000
CP95PR4	0.54	99.00	103.00	**58.63**	99.43	5, 0	0.0832	0.000
CP95PR5	–	–	–	**67.19**	98.94	9, 0	–	–

[a] Significant Microtox® toxicity: $EC_{50} \leq 0.2\%$ if sediment silt-clay content ≥ 20%, or $EC_{50} \leq 0.5\%$ if sediment silt-clay content < 20%.

[b] Significant *Ampelisca abdita* or *Ampelisca verrilli* toxicity: survival in sample significantly less than survival in negative control (at $\alpha = 0.05$), and survival in sample ≤ 80% of control survival.

[c] Significant *Mercenaria mercenaria* toxicity: mean growth rate in test sediment significantly different than in control sediment (at $\alpha = 0.05$), and mean growth in test sediment < 80% of the mean growth in control sediment.

[d] First number is the number of contaminants at or exceeding ER-L/TEL bioeffect guideline values but below ER-M/PEL guidelines. Second number is the number of contaminants at or exceeding ER-M/PEL bioeffect guideline values.

APPENDIX G. (Continued).

Station	Microtox®[a] (EC_{50} , %)	*A. abdita*[b] (%)	*A. verrilli*[b] (%)	*M. mercenaria*[c] (%)	Silt-clay (%)	Exceedances[d] ER-L/TEL, ER-M/PEL	UAN (mg/L)	H_2S (mg/L)
CP95RC_	9.41	103.30	95.00	**-13.43**	2.86	0, 0	0.2234	0.005
CP95SPY	0.74	99.00	98.00	108.51	14.26	5, 2	0.0627	0.002
CP95ZI_	0.60	102.20	98.00	69.93	6.90	0, 0	0.3251	0.001

[a] Significant Microtox® toxicity: $EC_{50} \leq 0.2\%$ if sediment silt-clay content $\geq 20\%$, or $EC_{50} \leq 0.5\%$ if sediment silt-clay content $< 20\%$.

[b] Significant *Ampelisca abdita* or *Ampelisca verrilli* toxicity: survival in sample significantly less than survival in negative control (at $\alpha = 0.05$), and survival in sample $\leq 80\%$ of control survival.

[c] Significant *Mercenaria mercenaria* toxicity: mean growth rate in test sediment significantly different than in control sediment (at $\alpha = 0.05$), and mean growth in test sediment $< 80\%$ of the mean growth in control sediment.

[d] First number is the number of contaminants at or exceeding ER-L/TEL bioeffect guideline values but below ER-M/PEL guidelines. Second number is the number of contaminants at or exceeding ER-M/PEL bioeffect guideline values.

APPENDIX H. A. Mean Shannon-Weaver diversity (H′), species richness, and abundance per infaunal grab, and benthic infaunal index score for the station. B. Mean Shannon-Weaver diversity (H′), species richness, and abundance per demersal trawl.

	A. Infaunal Grabs				B. Demersal Trawls		
Station	Mean H′ per Grab	Mean Richness per Grab	Mean Abundance per Grab	Benthic Index Score	Mean H′ per Trawl	Mean Richness per Trawl	Mean Abundance per Trawl
CP95101	1.23	4.50	74.00	1.5	1.7	5.0	64.5
CP95102	2.56	7.00	39.00	2.5	0.0	1.0	1.0
CP95103	2.16	8.00	35.50	3.0	0.3	3.0	64.5
CP95104	1.78	7.50	134.50	3.5	1.2	3.5	184.5
CP95105	2.32	9.50	144.00	5.0	1.4	8.0	232.0
CP95106	2.47	11.00	171.00	5.0	1.7	7.5	244.5
CP95107	0.59	2.50	33.50	1.0	1.2	3.5	42.0
CP95108	2.62	7.50	37.00	3.5	1.9	5.5	59.0
CP95109	1.60	5.00	13.00	2.5	1.9	6.5	45.5
CP95110	1.85	6.50	165.00	3.5	1.8	5.0	41.5
CP95111	2.77	10.50	114.50	5.0	1.8	6.0	59.5
CP95112	1.66	10.00	125.00	4.5	1.4	7.0	104.0
CP95113	3.34	17.50	50.50	4.5	1.6	3.5	8.5
CP95114	0.72	5.00	86.00	2.5	0.8	2.5	43.5
CP95115	3.36	21.00	117.00	5.0	1.8	5.0	18.0
CP95116	0.69	2.00	3.00	2.0	0.4	4.0	111.0
CP95117	2.55	7.00	24.00	2.0	1.3	4.5	37.5
CP95118	2.94	19.00	226.00	4.0	2.1	6.5	24.0
CP95119	2.62	6.50	13.50	2.0	1.8	4.5	58.5
CP95120	0.32	2.00	86.50	1.5	0.9	2.5	15.0
CP95121	0.00	0.50	0.50	1.0	0.0	0.0	0.0
CP95122	0.00	0.50	0.50	1.0	0.0	0.0	0.0

APPENDIX H. (Continued).

Station	A. Infaunal Grabs				B. Demersal Trawls		
	Mean H′ per Grab	Mean Richness per Grab	Mean Abundance per Grab	Benthic Index Score	Mean H′ per Trawl	Mean Richness per Trawl	Mean Abundance per Trawl
CP95123	3.41	20.00	120.00	5.0	1.7	4.0	9.5
CP95124	0.00	0.00	0.00	1.0	0.7	2.0	72.0
CP95125	2.40	26.50	416.00	4.5	1.9	8.0	104.5
CP95126	3.30	17.00	86.00	4.5	1.3	5.5	90.0
CP95127	2.72	16.00	121.50	5.0	0.9	5.0	130.0
CP95128	2.07	18.00	262.50	3.5	1.5	9.0	267.5
CP95129	2.17	11.50	112.50	5.0	1.6	10.0	316.5
CP95130	3.94	25.50	84.50	4.5	2.4	11.0	95.0
CP95131	2.67	7.50	20.50	3.5	2.4	7.0	28.0
CP95132	3.37	23.50	107.00	4.0	0.7	1.5	3.5
CP95133	2.43	11.00	34.50	3.5	1.8	4.0	5.5
CP95134	2.64	10.00	31.50	3.5	1.8	9.5	148.5
CP95135	1.33	8.50	182.50	3.5	1.0	2.5	2.5
CP95136	0.00	0.00	0.00	1.0	1.3	4.5	50.5
CP95137	–	–	–	–	–	–	–
CP95138	2.60	10.50	58.00	4.0	1.2	7.5	140.5
CP95139	0.70	4.50	41.50	1.0	1.0	3.5	23.5
CP95140	2.12	6.00	23.50	2.0	1.2	4.5	47.0
CP95141	3.62	17.00	57.50	4.0	2.0	11.0	109.5
CP95142	4.36	24.00	41.00	4.0	2.3	13.0	138.0
CP95143	3.33	14.00	60.50	3.5	0.9	6.0	104.5
CP95144	–	–	–	–	0.9	6.5	47.0
CP95145	1.68	5.00	14.00	1.5	2.1	9.5	186.0

APPENDIX H. (Continued).

Station	A. Infaunal Grabs				B. Demersal Trawls		
	Mean H′ per Grab	Mean Richness per Grab	Mean Abundance per Grab	Benthic Index Score	Mean H′ per Trawl	Mean Richness per Trawl	Mean Abundance per Trawl
CP95146	2.41	9.50	41.50	3.0	2.1	7.5	27.0
CP95147	2.20	6.00	12.50	3.0	1.4	4.0	49.0
CP95148	0.75	6.50	148.50	3.0	1.4	3.0	4.0
CP95149	2.38	6.00	14.00	2.0	0.3	8.0	636.5
CP95150	1.65	5.00	19.50	1.5	1.1	4.5	81.0
CP95151	3.75	23.00	85.00	3.5	3.0	12.0	77.0
CP95152	3.16	11.50	27.00	4.0	2.8	14.0	90.0
CP95153	3.27	25.50	243.50	4.0	3.1	19.0	168.0
CP95154	3.58	18.50	56.50	3.5	2.9	9.0	22.0
CP95155	2.69	12.50	64.50	4.0	1.9	8.5	72.0
CP95156	0.75	2.50	13.00	1.0	1.8	7.0	134.0
CP95157	2.53	8.50	20.50	4.0	1.0	8.0	152.0
CP95158	3.67	25.00	204.00	4.5	1.9	5.0	19.0
CP95159	2.52	8.00	25.50	3.5	2.1	6.5	19.5
CP95160	4.21	30.50	151.00	4.0	1.8	10.0	33.0
CP95161	2.07	15.00	332.50	3.5	2.0	14.0	145.5
CP95162	1.52	3.50	11.00	1.5	0.4	2.5	37.0
CP95163	3.08	31.50	422.50	4.5	2.2	10.5	62.5
CP95164	3.07	9.00	12.50	3.0	1.4	5.5	39.0
CP95165	1.75	4.00	7.50	3.0	2.4	14.5	135.5
CP95166	1.20	7.00	43.50	2.5	0.9	9.0	225.0
CP95167	1.88	11.50	129.00	4.0	1.7	12.0	161.5
CP95168	2.37	6.00	10.00	2.0	2.3	15.0	227.0

APPENDIX H. (Continued).

Station	A. Infaunal Grabs				B. Demersal Trawls		
	Mean H′ per Grab	Mean Richness per Grab	Mean Abundance per Grab	Benthic Index Score	Mean H′ per Trawl	Mean Richness per Trawl	Mean Abundance per Trawl
CP95169	3.70	25.50	141.00	4.0	2.5	10.0	80.5
CP95170	2.82	10.00	29.50	4.0	3.0	13.0	50.0
CP95171	1.44	3.00	7.00	1.5	1.3	7.0	137.0
CP95172	0.00	1.00	27.50	1.0	1.2	10.5	415.5
CP95173	3.63	32.50	175.50	3.5	1.6	3.5	7.0
CP95174	3.11	16.00	94.50	2.5	3.2	11.5	33.5
CP95175	3.53	41.50	263.00	3.0	1.7	6.5	54.5
CP95176	3.32	21.50	163.50	2.5	2.5	8.0	39.0
CP95177	3.72	28.50	154.50	5.0	2.3	5.5	10.0
CP95178	2.68	31.00	721.00	4.5	–	–	–
CP95179	2.51	25.00	440.50	4.5	1.4	3.0	4.5
CP95180	1.48	25.50	725.00	4.0	2.5	8.5	32.0
CP95181	2.01	7.00	36.00	2.0	1.9	6.0	46.0
CP95182	2.86	20.50	101.50	5.0	1.7	7.0	58.0
CP95183	3.75	40.50	237.00	4.0	2.2	5.5	10.0
CP95184	1.20	27.50	1569.50	3.0	0.8	2.0	2.0
CP95185	3.58	30.00	138.00	2.5	–	–	–
CP95186	4.25	32.00	102.00	3.5	2.8	11.0	35.0
CP95187	3.88	40.50	363.00	4.5	2.6	10.5	45.0
CP95188	3.74	39.00	381.50	5.0	2.7	10.5	48.5
CP95ASM	1.78	5.00	19.00	2.0	–	–	–
CP95CB_	1.73	7.00	32.50	3.0	0.4	2.0	7.5
CP95CF_	0.81	10.00	398.00	2.5	1.3	4.0	29.5

APPENDIX H. (Continued).

Station	A. Infaunal Grabs				B. Demersal Trawls		
	Mean H′ per Grab	Mean Richness per Grab	Mean Abundance per Grab	Benthic Index Score	Mean H′ per Trawl	Mean Richness per Trawl	Mean Abundance per Trawl
CP95DIE	0.73	2.00	4.00	1.0	–	–	–
CP95FOS	1.21	6.50	91.00	2.0	–	–	–
CP95KIA	–	–	–	–	–	–	–
CP95KOP	0.48	2.00	10.00	1.0	–	–	–
CP95LON	–	–	–	–	–	–	–
CP95LTH	2.27	17.00	161.00	3.5	–	–	–
CP95MI_	2.36	9.00	43.00	3.5	1.0	5.0	48.5
CP95NMK	0.31	2.00	27.00	1.5	–	–	–
CP95NV1	2.74	8.00	23.00	3.5	–	–	–
CP95NV2	1.71	4.50	11.00	2.5	–	–	–
CP95PR1	1.89	9.00	126.50	4.0	–	–	–
CP95PR2	0.50	1.50	1.50	1.0	–	–	–
CP95PR3	1.10	2.50	11.50	1.5	–	–	–
CP95PR4	1.10	2.50	12.00	1.0	–	–	–
CP95PR5	0.50	1.50	1.50	2.0	–	–	–
CP95RC_	3.31	12.50	30.50	4.0	0.6	2.5	6.5
CP95SPY	2.17	10.00	211.50	2.5	–	–	–
CP95ZI_	1.73	10.00	308.50	3.0	1.7	11.0	112.0

APPENDIX I. Concentrations of aliphatic and aromatic hydrocarbons (ng/g dry wt.) in edible tissues of target demersal species from selected contaminated and uncontaminated stations (based on sediment chemistry) in the Carolinian Province in 1995.

Station	Organism	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]-anthracene	Benzo[a]-pyrene	Chrysene	Dibenz[a,h]-anthracene	Fluoranthene	Fluorene	2-Methyl-naphthalene	Naphthalene	Phenanthrene	Pyrene	Total PAHs w/o Perylene
CP95152	White Shrimp	25.4	3.2	30.4	16.4	6.7	20.4	0.2	168.8	22.2	11.6	36.6	77.7	178.7	802.2
CP95156	White Shrimp	8.1	1.7	3.1	1.6	0.8	2.3	0.9	2.0	4.9	7.5	28.2	3.6	3.4	162.4
CP95158	White Shrimp	4.3	2.2	2.6	0.7	0.6	0.7	0.3	1.2	4.2	6.7	28.2	4.7	4.4	74.9
CP95162	White Shrimp	2.9	2.2	2.2	1.1	0.6	3.9	0.5	6.6	10.7	4.2	25.6	5.0	9.9	153.6
CP95164	White Shrimp	2.8	4.0	1.2	0.6	0.8	1.2	0.5	1.7	4.2	5.5	26.6	2.1	3.1	73.1
CP95165	Blue Crab	2.1	3.7	2.9	1.1	2.8	0.9	1.3	2.1	6.4	17.5	53.2	3.4	4.2	183.5
CP95165	White Shrimp	7.6	2.1	2.8	1.9	1.1	0.8	0.6	2.6	2.7	2.7	32.2	4.2	5.3	83.7
CP95166	Blue Crab	7.1	1.7	2.1	1.2	0.2	1.0	0.7	1.1	4.3	4.4	41.8	2.9	2.2	90.9
CP95166	White Shrimp	3.9	2.1	2.0	1.4	0.7	1.4	0.5	3.7	2.9	10.2	43.4	4.3	5.1	100.6
CP95169	White Shrimp	4.7	3.0	2.3	0.6	1.0	1.2	0.4	2.1	4.6	13.0	41.3	4.2	3.7	114.7
CP95172	White Shrimp	2.1	2.4	3.2	1.2	1.1	1.0	0.7	1.0	5.7	11.7	48.4	5.1	3.1	109.7
CP95SPY	Blue Crab (Rep 1)	24.7	10.0	6.5	14.9	0.6	3.5	0.9	45.8	9.5	6.0	50.4	5.9	41.8	357.9
CP95SPY	Blue Crab (Rep 2)	34.8	3.5	5.8	1.5	2.3	3.2	0.9	26.6	11.4	12.8	51.4	19.5	19.1	401.4
CP95SPY	White Shrimp (Rep 1)	9.1	3.9	6.7	5.7	3.1	6.5	0.5	26.0	11.1	10.0	18.0	25.6	32.9	482.9
CP95SPY	White Shrimp (Rep 2)	3.3	0.7	0.2	0.8	0.3	1.3	0.2	6.1	2.4	2.8	8.9	2.3	9.2	71.6

APPENDIX J. Concentrations of pesticides and PCBs (ng/g dry wt.) in edible tissues of target demersal species from selected contaminated and uncontaminated stations (based on sediment chemistry) in the Carolinian Province in 1995. N.D. = Not detectable.

Station	Organism	Total PCBs [a]	Aldrin	Total Chlordane [b]	Dieldrin	Endrin	Heptachlor	Heptachlor Epoxide	Heptachlor + Heptachlor Epoxide	Mirex	Lindane	Total DDTs [c]	DDD [d]	DDE [e]	DDT [f]
CP95114	Croaker	343.40	N.D.	22.83	6.61	N.D.	N.D.	0.93	0.93	4.35	0.84	123.03	35.59	79.37	8.08
CP95114	Spot	51.37	0.17	6.25	10.21	N.D.	N.D.	0.91	0.91	0.25	1.55	56.67	9.57	43.37	3.73
CP95115	Croaker	74.08	N.D.	4.37	3.44	N.D.	N.D.	0.50	0.50	0.54	N.D.	19.18	3.19	14.22	1.78
CP95115	Spot	141.60	N.D.	6.70	2.58	N.D.	N.D.	0.35	0.35	0.20	0.49	21.25	5.51	14.45	1.29
CP95117	Croaker	83.57	N.D.	5.18	4.22	N.D.	N.D.	0.37	0.37	0.31	0.60	20.99	5.10	14.40	1.49
CP95125	Croaker	85.14	N.D.	5.76	6.46	N.D.	N.D.	0.43	0.43	0.84	0.76	21.73	3.24	17.29	1.19
CP95125	Spot	89.49	N.D.	6.89	4.27	N.D.	N.D.	0.79	0.79	0.57	0.60	27.41	4.33	20.60	2.48
CP95152	White Shrimp	125.46	N.D.	2.41	1.06	N.D.	N.D.	N.D.	N.D.	0.95	N.D.	5.02	1.50	3.52	N.D.
CP95156	Croaker	48.70	N.D.	1.31	N.D.	N.D.	N.D.	N.D.	N.D.	3.22	N.D.	5.96	0.39	5.57	N.D.
CP95156	White Shrimp	27.46	N.D.	0.44	N.D.	N.D.	N.D.	N.D.	N.D.	1.31	N.D.	2.82	N.D.	2.82	N.D.
CP95158	White Shrimp	28.63	N.D.	0.22	N.D.	N.D.	N.D.	N.D.	N.D.	0.25	N.D.	1.56	N.D.	1.56	N.D.
CP95162	White Shrimp	39.34	N.D.	1.11	1.24	N.D.	N.D.	N.D.	N.D.	2.66	N.D.	1.47	N.D.	1.47	N.D.
CP95164	White Shrimp	19.41	N.D.	0.44	N.D.	N.D.	N.D.	N.D.	N.D.	1.84	N.D.	1.37	N.D.	1.37	N.D.
CP95165	Blue Crab	26.39	N.D.	N.D.	1.08	N.D.	N.D.	N.D.	N.D.	3.08	N.D.	4.67	N.D.	4.67	N.D.
CP95165	White Shrimp	27.47	N.D.	0.29	0.41	N.D.	N.D.	N.D.	N.D.	0.99	N.D.	1.08	N.D.	1.08	N.D.

[a] From FDA 1984.

[b] Total Chlordane defined by FDA 1994 as: ∑(cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane, alpha-chlordene, beta-chlordene, gamma-chlordene, chlordene). Note, however, that only cis-nonachlor, trans-nonachlor, oxychlordane, and cis-chlordane (alpha-chlordane) were measured and are reported in these summary values.

[c] Total DDTs defined by FDA (1994) as: ∑(2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT, 4,4′-DDT).

[d] DDD defined by FDA (1994) as:∑(2,4′-DDD, 4,4′-DDD).

[e] DDE defined by FDA (1994) as:∑(2,4′-DDE, 4,4′-DDE).

[f] DDT defined by FDA (1994) as: ∑(2,4′-DDT, 4,4′-DDT).

APPENDIX J. (Continued)

Station	Organism	Total PCBs [a]	Aldrin	Total Chlordane [b]	Dieldrin	Endrin	Heptachlor	Heptachlor Epoxide	Heptachlor + Heptachlor Epoxide	Mirex	Lindane	Total DDTs [c]	DDD [d]	DDE [e]	DDT [f]
CP95166	Blue Crab	21.25	N.D.	0.32	N.D.	N.D.	N.D.	0.22	0.22	0.61	N.D.	1.94	N.D.	1.94	N.D.
CP95166	Croaker	71.98	N.D.	1.67	0.98	N.D.	N.D.	0.09	0.09	1.06	0.24	6.22	1.47	4.47	0.29
CP95166	White Shrimp	23.03	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.37	N.D.	1.33	N.D.	1.33	N.D.
CP95169	Croaker	116.04	N.D.	0.39	0.26	N.D.	N.D.	N.D.	N.D.	1.49	N.D.	3.56	1.44	1.86	0.26
CP95169	White Shrimp	54.16	N.D.	0.20	N.D.	N.D.	N.D.	N.D.	N.D.	0.52	N.D.	1.81	0.99	0.82	N.D.
CP95172	Croaker	292.70	N.D.	13.39	0.97	N.D.	N.D.	0.13	0.13	N.D.	N.D.	20.44	5.40	14.05	0.98
CP95172	White Shrimp	55.87	N.D.	1.53	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.90	N.D.	1.90	N.D.
CP95SPY	Blue Crab (Rep. 1)	386.88	N.D.	9.60	4.12	N.D.	N.D.	2.60	2.60	2.16	N.D.	21.00	7.58	13.42	N.D.
CP95SPY	Blue Crab (Rep. 2)	191.84	N.D.	11.24	3.21	N.D.	N.D.	2.42	2.42	3.13	0.35	31.56	11.16	20.40	N.D.
CP95SPY	Croaker (Rep. 1)	135.69	N.D.	6.54	2.44	N.D.	N.D.	0.55	0.55	1.24	0.46	30.58	10.66	17.39	2.55
CP95SPY	Croaker (Rep. 2)	140.08	N.D.	5.63	2.29	N.D.	N.D.	0.51	0.51	1.03	0.35	23.74	10.20	10.44	3.10
CP95SPY	White Shrimp (Rep. 1)	91.01	N.D.	3.05	0.60	2.85	N.D.	N.D.	N.D.	1.16	N.D.	2.77	0.86	1.91	N.D.
CP95SPY	White Shrimp (Rep. 2)	75.62	N.D.	1.69	1.13	N.D.	N.D.	N.D.	N.D.	0.72	0.08	5.57	1.52	3.91	0.14
FDA Action Levels [g]		10,000	1,500	1,500	1,500	1,500	1,500	1,500	1,500	500	–	25,000	25,000	25,000	25,000

[a] From FDA 1984.

[b] Total Chlordane defined by FDA 1994 as: ∑(cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane, alpha-chlordene, beta-chlordene, gamma-chlordene, chlordene). Note, however, that only cis-nonachlor, trans-nonachlor, oxychlordane, and cis-chlordane (alpha-chlordane) were measured and are reported in these summary values.

[c] Total DDTs defined by FDA (1994) as: ∑(2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT, 4,4′-DDT).

[d] DDD defined by FDA (1994) as:∑(2,4′-DDD, 4,4′-DDD).

[e] DDE defined by FDA (1994) as:∑(2,4′-DDE, 4,4′-DDE).

[f] DDT defined by FDA (1994) as: ∑(2,4′-DDT, 4,4′-DDT).

[g] Values reported by FDA in wet weight were converted by applying a multiplication factor of five.

APPENDIX K. Concentrations of metals (µg/g dry wt.) and tributyltin (TBT, as Sn/g dry weight) in edible tissues of target demersal species from selected contaminated and uncontaminated stations (based on sediment contamination) in the Carolinian Province in 1995. N.D. = Not detectable.

Station	Organism	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95114	Croaker	N.D.	1.70	0.50	0.57	0.90	0.15	0.12	0.09	N.D.	N.D.	29.00
CP95114	Spot	N.D.	2.70	0.02	0.43	1.30	0.08	0.12	0.08	N.D.	N.D.	28.00
CP95115	Croaker	N.D.	24.20	0.02	0.31	1.00	0.13	0.06	0.03	0.01	N.D.	19.00
CP95115	Spot	N.D.	4.20	0.05	0.48	2.30	0.10	0.16	0.24	0.01	N.D.	24.00
CP95117	Croaker	N.D.	3.40	0.13	N.D.	1.10	0.10	0.19	0.20	N.D.	N.D.	23.00
CP95125	Croaker	N.D.	6.80	0.36	0.27	0.93	0.08	0.12	0.09	N.D.	7.16	18.00
CP95125	Spot	N.D.	4.60	0.26	N.D.	1.40	0.10	0.60	0.21	N.D.	N.D.	22.00
CP95152	White Shrimp	0.37	28.70	0.03	1.00	33.00	0.05	0.29	0.27	N.D.	N.D.	60.00
CP95156	Croaker	N.D.	2.10	0.10	1.00	1.70	0.28	0.37	0.36	N.D.	N.D.	36.00
CP95156	White Shrimp	0.03	5.30	0.10	0.53	28.00	0.11	0.29	0.14	0.07	N.D.	61.00
CP95158	White Shrimp	N.D.	12.00	1.10	0.84	26.00	0.05	0.31	0.28	0.07	11.59	63.00
CP95162	White Shrimp	0.15	12.80	0.11	0.45	28.00	0.07	0.17	0.21	0.04	46.85	59.00
CP95164	White Shrimp	0.31	15.80	0.05	N.D.	26.00	0.07	0.20	0.12	N.D.	N.D.	62.00
CP95165	Blue Crab	0.16	20.40	0.06	0.34	75.00	0.24	0.05	0.16	0.03	N.D.	57.00
CP95165	White Shrimp	0.21	14.80	0.04	0.35	31.00	0.11	0.15	0.29	N.D.	14.35	59.00
CP95166	Blue Crab	0.85	22.80	0.85	N.D.	56.00	0.31	0.20	0.16	N.D.	N.D.	168.00
CP95166	Croaker	N.D.	5.70	0.30	0.35	1.20	0.10	0.36	0.17	N.D.	N.D.	20.00
CP95166	White Shrimp	0.32	20.10	0.11	N.D.	23.00	0.06	0.34	0.36	N.D.	N.D.	58.00
CP95169	Croaker	N.D.	9.70	0.04	1.10	1.40	0.17	0.25	0.13	N.D.	N.D.	22.00
CP95169	White Shrimp	0.43	21.20	0.30	N.D.	27.00	0.07	0.26	0.35	N.D.	N.D.	59.00
CP95172	Croaker	N.D.	N.D.	0.03	0.44	1.90	0.03	0.41	0.21	N.D.	N.D.	26.00
CP95172	White Shrimp	N.D.	N.D.	0.04	0.41	15.80	0.03	0.50	0.11	N.D.	N.D.	57.00

APPENDIX K. (Continued).

Station	Organism	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	TBT	Zn
CP95SPY	Blue Crab (Rep. 1)	0.21	8.00	0.31	3.70	65.00	0.18	0.13	0.38	0.03	N.D.	174.00
CP95SPY	Blue Crab (Rep. 2)	0.56	14.50	0.21	12.90	89.00	0.26	0.16	0.25	N.D.	8.87	165.00
CP95SPY	Croaker (Rep. 1)	N.D.	12.50	N.D.	2.60	1.10	0.10	N.D.	0.04	N.D.	N.D.	20.00
CP95SPY	Croaker (Rep. 2)	N.D.	8.70	0.04	0.53	1.30	0.07	0.05	0.08	N.D.	6.60	20.00
CP95SPY	White Shrimp (Rep. 1)	0.15	30.00	1.45	1.40	30.00	0.07	0.16	0.16	0.01	N.D.	53.00
CP95SPY	White Shrimp (Rep. 2)	0.10	37.00	0.02	0.31	29.00	0.07	0.08	0.17	0.03	15.59	58.00
FDA Action Level [a]		–	–	–	–	–	5.00	–	–	–	–	–
FDA Levels of Concern [b]		–	215.00	15.00	55.00	–	–	350.00	3.00	–	–	–

[a] Action Level for Hg in edible portion of fish. Wet-weight value reported by FDA (1994) was converted to dry weight by applying a multiplication factor of five.

[b] FDA Level of Concern for contaminant in shellfish. Value is lowest of multiple values reported by FDA for humans of various ages consuming either crustaceans or molluscs at the 90th percentile consumption rate. Values (converted from wet weight to dry weight by applying a multiplication factor of five) are from: FDA 1993a-As, FDA 1993b-Cd, FDA 1993c-Cr, FDA 1993d-Pb, FDA 1993e-Ni.