OLD DOMINION UNIVERSITY

Department of Biological Sciences
Old Dominion University, Norfolk, Virginia 23529

SWIMMING POINT
BENTHIC COMMUNITY CONDITION
ELIZABETH RIVER (2019)

Prepared by

Principal Investigator:

Dr. Daniel M. Dauer

Submitted to:

Roger Hathaway
GEI Consultants
455 Winding Brook Drive, Suite 201
Glastonbury, CT 06033

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EXECUTIVE SUMMARY

The subtidal macrobenthic communities off Swimming Point in the Elizabeth River were quantitatively sampled in summer 2019. The primary objective of this study was to characterize the ecological condition of the benthos compared to benthic data collected in summer 2010 (Dauer 2011).

The estimated the level of degraded benthic bottom of the Swimming Point stratum (BIBI < 3.0) in 2019 was 64% ± 18.8% a decrease from the 2010 value of 84% ± 14.0%. The level of severely degraded bottom (BIBI ≤ 2.0) in 2019 was 28% ± 17.6% compared to the 2010 value of 52% ± 19.6%. The ecological condition of benthic communities at Swimming Point in 2019 were comparable to the values for the Mainstem segment of the Elizabeth River in 2019 which had an estimated degraded benthic bottom of 52% ± 19.6% and a value of 36% ± 18.8 of severely degraded bottom.

The BIBI and its metrics showed a mixture of improvements and degradations in benthic community condition. Compared to the previous benthic community condition reported in Dauer (2011) the 2019 Swimming Point benthos: (1) the average BIBI value improved significantly from 2.2 ± 0.1 in 2010 to 2.6 ± 0.1 in 2019 ($p = 0.04$), (2) total community abundance also improved with a decrease from an over-abundance value of 6,508 ± 993 individuals per m^2 in 2010 to 4,482 ± 482 individuals per m^2 in 2010 ($p = 0.08$) – an improvement in ecological condition for polyhaline sand habitats, (3) a significant decrease in the Shannon Diversity Index value from 1.92 ± 0.15 in 2010 to 1.49 ± 0.11 in 2019 ($p = 0.03$), and (4) a significant decrease in the number of species per sample from 13.6 ± 0.7 in 2010 to 9.4 ± 0.6 in 2019 ($p < 0.01$).

A comparison of the temporal changes in benthic community condition at Swimming Point (2010 data to 2019 data) to the patterns throughout the Elizabeth River (1999 data compared to 2019) in Dauer (2020) shows (1) the BIBI values significantly improved only in the Southern Branch and at Swimming Point with the highest BIBI values in the Mainstem of the river and at Swimming Point, (2) the BIBI values decreased in the Lafayette River, Eastern Branch and Western Branch in 2019, (3) abundance values increased in the Lafayette River, the Eastern Branch and the Western Branch, above or near the over-abundance threshold of 5,000 individuals per m^2 while significantly declining below the threshold at Swimming Point, and (4) the decrease in the Shannon Diversity Index and species richness at Swimming Point also occurred in the Lafayette River, the Eastern Branch and the Western Branch.

Indicative of improved benthic ecological condition was the appearance in the density dominants of 2019 of (1) two gastropod species - the glassy bubble shell *Haminoea solitaria* and the barrel bubble shell *Acteocina canaliculate*, (2) the bivalve *Macoma balthica*, (3) the amphipod *Ampelisca abdita*, and the shrimp *Ogyrides alphaeorostris*. All these species are generally associated with unstressed estuarine and/or coastal habitats.

INTRODUCTION

The subtidal macrobenthic communities of a designated portion off Swimming Point in the Elizabeth River were quantitatively sampled in summer 2010 (Dauer 2011). The primary objective of that study was to characterize the ecological condition of the benthos. In the summer of 2019, this same designated area off Swimming Point was re-sampled. The primary purpose of this study is to characterize any changes in the benthic community condition that might have occurred due to restoration actions at the site. This study emphasizes using the Benthic Index of Biotic Integrity (B-IBI), and its metrics, developed for the Chesapeake Bay (Ranasinghe et al. 1994; Weisberg et al. 1997; Alden et al. 2002) and probability-based sampling to calculate confidence intervals around estimates of condition of the benthic communities and allowing estimates of the areal extent of degradation of the benthic communities.

The macrobenthic communities of the Elizabeth River have been studied since the 1969 sampling of Boesch (1973) with three stations in the Mainstem of the river. Other important studies were limited to the Southern Branch of the river including seasonal sampling at 10 sites in 1977-1978 (Hawthorne and Dauer 1983), seasonal sampling at the same 10 sites a decade later in 1987-1988 by Hunley (1993), the establishment of two long-term monitoring stations in 1989 as part of the Virginia Chesapeake Bay Benthic Monitoring Program (Dauer et al. 1999) and summarizations of the two Southern Branch long-term monitoring stations (Dauer 1993; Dauer et al. 1993). The condition of the benthic community of the Elizabeth River watershed was characterized by spatially extensive sampling of the river in 1999 with 175 locations sampled among seven strata (Dauer 2000; Dauer and Llansó 2003). Beginning in 2000 the Elizabeth River watershed was sampled as a single stratum with the benthic community condition characterized at 25 random locations through 2007 (Dauer 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009). Since 1996 the entire tidal Chesapeake Bay had been sampled for benthos using a random stratified design (Dauer and Llansó 2003) consisting of ten strata each with 25 random sites each summer index period (July 15 – September 30). The tidal James River is one of the ten strata and typically 0-3 random samples are allocated within the Elizabeth River watershed each summer index period. Finally, in the summer of 2019 another spatially extensive sampling of 125 locations among five strata occurred (Dauer 2020).

RATIONALE

Characterizing Benthic Community Condition

Coastal seas, bays, lagoons and estuaries have become increasingly degraded due to anthropogenic stresses (Nixon 1995). Relationships between land use, levels of nutrients and contaminants, and the condition of the biotic communities of receiving waters are well studied in freshwater ecosystems (Allan et al. 1997) with fewer studies addressing these relationships in estuarine ecosystems (Comeleo et al. 1996; Valiela et al. 1997; Dauer et. al. 2000).
Land use patterns in a watershed influence the delivery of nutrients, sediments and contaminants into receiving waters through surface flow, groundwater flow, and atmospheric deposition (Correll 1983; Correll et al. 1987; Hinga et al. 1991; Correll et al. 1992; Lajtha et al. 1995;

Jordan et al. 1997c). Increased nutrient loads are associated with high levels of agricultural and urban land use in both freshwater and coastal watersheds compared to forested watersheds (Klein 1979; Ostry 1982; Duda 1982; Novotny et al. 1985; Ustach et al. 1986; Valiela and Costa 1988; Benzie et al. 1991; Fisher and Oppenheimer 1991; Turner and Rabalais 1991; Correll et al. 1992; Hall et al. 1994; Jaworski et al. 1992; Lowrance 1992; Weiskel and Howes 1992; Balls 1994; Hopkinson and Vallino 1995; Nelson et al. 1995; Hall et al. 1996; Hill 1996; Allan et al. 1997; Correll 1997; Correl et al. 1997; Valiela et al. 1997; Verchot et al. 1997a, 1997b; Gold et al. 1998). At smaller spatial scales, riparian forests and wetlands may ameliorate the effects of agricultural and urban land use (Johnston et al 1990; Correll et al. 1992; Osborne and Kovacic 1993).

Aquatic biotic communities associated with watersheds with high agricultural and urban land use are generally characterized by lower species diversity, less trophic complexity, altered food webs, altered community composition and reduced habitat diversity (Fisher and Likens 1973; Boynton et al. 1982; Conners and Naiman 1984; Malone et al. 1986, 1988, 1996; Mangum 1989; Howarth et al. 1991; Fisher et al. 1992; Grubaugh and Wallace 1995; Lamberti and Berg 1995; Roth et al 1996; Correll 1997). High nutrient loads in coastal ecosystems result in increased algal blooms (Boynton et al. 1982; Malone et al. 1986, 1988; Fisher et al. 1992), increased low dissolved oxygen events (Taft et al. 1980; Officer et al. 1984; Malone et al. 1996), alterations in the food web (Malone 1992) and declines in valued fisheries species (Kemp et al. 1983; USEPA 1983). Sediment and contaminant loads are also increased in watersheds dominated by agricultural and urban development mainly due to storm-water runoff (Wilber and Hunter 1979; Hoffman et al. 1983; Medeiros et al. 1983; Schmidt and Spencer 1986; Beasley and Granillo 1988; Howarth et al. 1991; Vernberg et al. 1992; Lenat and Crawford 1994; Corbett et al. 1997).

Benthic invertebrates are used extensively as indicators of estuarine environmental status and trends because numerous studies have demonstrated that benthos respond predictably to many kinds of natural and anthropogenic stress (Pearson and Rosenberg 1978; Tapp et al. 1993; Wilson and Jeffrey 1994; Dauer et al. 2000). Many characteristics of benthic assemblages make them useful indicators (Bilyard 1987; Dauer 1993), the most important of which are related to their exposure to stress and the diversity of their responses to stress. Exposure to hypoxia is typically greatest in near-bottom waters and anthropogenic contaminants often accumulate in sediments where benthos live. Benthic organisms generally have limited mobility and cannot avoid these adverse conditions. This immobility is advantageous in environmental assessments because, unlike most pelagic fauna, benthic assemblages reflect local environmental conditions (Gray 1979). The structure of benthic assemblages responds to many kinds of stress because these assemblages typically include organisms with a wide range of physiological tolerances, life history strategies, feeding modes, and trophic interactions (Pearson and Rosenberg 1978; Rhoads et al. 1978; Boesch and Rosenberg 1981; Dauer 1993). Benthic community condition in the Chesapeake Bay watershed has been related in a quantitative manner to water quality, sediment quality, nutrient loads, and land use patterns (Dauer et al. 2000).

Estuarine Contaminant Perspective

Historically our nations' estuarine and coastal waters have been repositories of potentially toxic contaminants through municipal sewage, agricultural runoff, industrial effluents, and various other routes. The accumulation of these contaminants varies between different components of coastal ecosystems and their ecological effects are depended upon the different chemical/biological states of each contaminant.

The ultimate fate of all organisms, particles and compounds is to reside at some time in the benthos.

Most contaminant entities become attached to very small, suspended particles in the water (e.g. clay sized particles). As these particles sink to the bottom, they carry the toxicants with them. The natural interaction of currents, waves, and tides results in the accumulation in fine-grained sedimentary deposits. Typically, the concentrations of toxicants are much higher in sediments than in the overlying water. High winds, shallow water depth, strong currents, or changes in ambient chemistry, result in the release, resuspension or dispersion of accumulated contaminants are released. Sediments are both sinks and sources of contaminants and therefore, can pose serious threats to the health of resident marine life.

METHODS

A glossary of selected terms used in this report is found in Appendix A.

Probability-based Sampling

A wide variety of sampling designs have been used in marine and estuarine environmental monitoring programs (e.g., see case studies reviewed recently in Kramer, 1994; Kennish, 1998; Livingston, 2001). Allocation of samples in space and time varies depending on the environmental problems and issues addressed (Kingsford and Battershill, 1998) and the type of variables measured (e.g., water chemistry, phytoplankton, zooplankton, benthos, nekton). In the Chesapeake Bay, the benthic monitoring program consists of both fixed-point stations and probability-based samples. The fixed-point stations are used primarily for the determination of long-term trends (e.g., Dauer and Alden, 1995; Dauer, 1997; Dauer et al. 2006a,b,c) and the probability-based samples for the determination of the areal extent of degraded benthic community condition (Llansó et al. 2003; Dauer and Llansó 2003). The probability-based sampling design consists of equal replication of random samples among strata and is, therefore, a stratified simple random design (Kingsford, 1998). Sampling design and methodologies for probability-based sampling are based upon procedures developed by EPA's Environmental Monitoring and Assessment Program (EMAP, Weisberg et al. 1993) and allow unbiased comparisons of conditions between strata (Dauer and Llansó 2003).

Within the Swimming Point Stratum 25 random locations were sampled using a 0.04 m^2 Young grab. Table 1 lists the sampling coordinates. The minimum acceptable depth of penetration of the grab was 7 cm. At each station one grab sample was taken for macrobenthic community analysis and an additional grab sample for sediment particle size analysis and the determination of total volatile solids. A 50 g subsample of the surface sediment was taken for sediment analyses. Salinity, temperature, and dissolved oxygen were measured at the bottom and water depth was recorded.

Probability-Based Estimation of Degradation

Areal estimates of degradation of benthic community condition within a stratum can be made because all locations in each stratum are randomly selected. The estimate of the proportion of a stratum failing the Benthic Restoration Goals developed for Chesapeake Bay (Ranasinghe et al. 1994; updated in Weisberg et al. 1997) is the proportion of the 25 samples with B-IBI values of less than 3.0. The process produces a binomial distribution: the percentage of the stratum attaining goals versus the percentage not attaining the goals. With a binomial distribution the 95% confidence interval for these percentages can be calculated as:

$$95\%\ \text{Confidence Interval} \quad = \quad p \pm 1.96\ (\text{SQRT}(pq/N))$$

where p = percentage attaining goal, q = percentage not attaining goal and N = number of samples. This interval reflects the precision of measuring the level of degradation and indicates that with a 95% certainty the true level of degradation is within this interval. Differences between levels of degradation using a binomial distribution can be tested using the procedure of Schenker and Gentleman (2001).

50 random points were selected using the GIS system of Versar, Inc. Decimal degree reference coordinates were used with a precision of 0.000001 degrees (approximately 1 meter) which is a smaller distance than the accuracy of positioning; therefore, no area of a stratum is excluded from sampling and every point within a stratum has a chance of being sampled. In the field the first 25 acceptable sites are sampled. Sites may be rejected because of inaccessibility by boat, inadequate water depth or inability of the grab to obtain an adequate sample (e.g., on hard bottoms).

Laboratory Analysis

Each replicate was sieved on a 0.5 mm screen, relaxed in dilute isopropyl alcohol, and preserved with a buffered formalin-rose bengal solution. In the laboratory each replicate was sorted and all the individuals identified to the lowest possible taxon and enumerated. Biomass was estimated for each taxon as ash-free dry weight (AFDW) by drying to constant weight at 60 ^{o}C and ashing at 550 ^{o}C for four hours. Biomass was expressed as the difference between the dry and ashed weight.

Particle-size analysis was conducted using the techniques of Folk (1974). Each sediment sample is first separated into a sand fraction (> 63 µm) and a silt-clay fraction (< 63 µm). The sand fraction was dry sieved, and the silt-clay fraction quantified by pipette analysis. For random stations, only the percent sand and percent silt-clay fraction were estimated. Total volatile solids of the sediment were estimated by the loss upon ignition method as described above and presented as percentage of the weight of the sediment.

Benthic Index of Biotic Integrity

B-IBI and Benthic Community Status Designations

The B-IBI is a multiple-metric index developed to identify the degree to which a benthic community meets the Chesapeake Bay Program's Benthic Community Restoration Goals (Ranasinghe et al. 1994; Weisberg et al. 1997; Alden et al. 2002). The B-IBI provides a means for comparing relative condition of benthic invertebrate communities across habitat types. It also provides a validated mechanism for integrating several benthic community attributes indicative of community health into a single number that measures overall benthic community condition.

The B-IBI is scaled from 1 to 5, and sites with values of 3 or more are considered to meet the Restoration Goals. The index is calculated by scoring each of several attributes as either 5, 3, or 1 depending on whether the value of the attribute at a site approximates, deviates slightly from, or deviates strongly from the values found at reference sites in similar habitats, and then averaging these scores across attributes. The criteria for assigning these scores are numeric and dependent on habitat type. Application of the index is limited to a summer index period from July 15th through September 30th.

Benthic community condition was classified into four levels based on the B-IBI. Values ≥ 2 were classified as **severely degraded**; values from 2.1 to 2.6 were classified as **degraded**; values greater than 2.6 but less than 3.0 were classified as **marginal**; and values of 3.0 or more were classified as **meeting the goal**. Values in the marginal category do not meet the Restoration Goals, but they differ from the goals within the range of measurement error typically recorded between replicate samples. These categories are used in annual characterizations of the condition of the benthos in the Chesapeake Bay (e.g. Dauer et al. 2002a,b; Llansó et al 2004).

Further Information concerning the B-IBI

The analytical approach used to develop the B-IBI was similar to the one Karr et al. (1986) used to develop comparable indices for freshwater fish communities. Selection of benthic community metrics and metric scoring thresholds were habitat-dependent but by using categorical scoring comparisons between habitat types were possible. A six-step procedure was used to develop the index: (1) acquiring and standardizing data sets from a number of monitoring programs, (2) temporally and spatially stratifying data sets to identify seasons and habitat types, (3) identifying reference conditions, (4) selecting benthic community metrics, (5) selecting metric thresholds for scoring, and (6) validating the index with an independent data set (Weisberg et al. 1997). The B-IBI developed for Chesapeake Bay is based upon subtidal, unvegetated, infaunal macrobenthic communities. Hard-bottom communities, e.g., oyster beds, were not sampled because the sampling gears could not obtain adequate samples to characterize the associated infaunal communities. Infaunal communities associated with submerged aquatic vegetation (SAV) were not avoided but were rarely sampled due to the limited spatial extent of SAV in Chesapeake Bay.

Only macrobenthic data sets based on processing with a sieve of 0.5 mm mesh aperture and identified to the lowest possible taxonomic level were used. A data set of over 2,000 samples collected from 1984 through 1994 was used to develop, calibrate and validate the index (see Table 1 in Weisberg et al. 1997). Because of inherent temporal sampling limitations in some of the data sets, only data from the period of July 15 through September 30 were used to develop the index. A multivariate cluster analysis of the biological data was performed to define habitat types. Salinity and sediment type were the two important factors defining habitat types and seven habitats were identified - tidal freshwater, oligohaline, low mesohaline, high mesohaline sand, high mesohaline mud, polyhaline sand and polyhaline mud habitats (see Table 5 in Weisberg et al. 1997).

Reference conditions were determined by selecting samples which met all three of the following criteria: no sediment contaminant exceeded Long et al.'s (1995) effects range-median (ER-M) concentration, total organic content of the sediment was less than 2%, and bottom dissolved oxygen concentration was consistently high.

A total of 11 metrics representing measures of species diversity, community abundance and biomass, species composition, depth distribution within the sediment, and trophic composition were used to create the index. The habitat-specific metrics were scored and combined into a single value of the B-IBI. Thresholds for the selected metrics were based on the distribution of values for the metric at the reference sites. Data used for validation were collected between 1992 and 1994 and were independent of data used to develop the index. The B-IBI classified 93% of the validation sites correctly (Weisberg et al. 1997).

RESULTS AND SUMMARY

Benthic Community Condition using Probability-Based Sampling

Environmental Parameters

Physical-chemical parameters are summarized in Table 2. Salinity was in the polyhaline range (18-32) for all samples. Sediments were a mixture of sands and mud (Table 3). The sedimentary data are presented as two broad groups - a sand group with silt-clay content < 40% and a mud group with silt-clay content > 40%.

Benthic Community Level of Degraded Area

The estimated the level of degraded benthic bottom of the Swimming Point stratum (BIBI < 3.0) in 2019 was 64% ± 18.8% a decrease from the 2010 value of 84% ± 14.0%. The level of severely degraded bottom (BIBI ≤ 2.0) in 2019 was 28% ± 17.6% compared to the 2010 value of 52% ± 19.6%. The ecological condition of benthic communities at Swimming Point in 2019 were comparable to the values for the Mainstem segment of the Elizabeth River in 2019 which had an estimated degraded benthic bottom of 52% ± 19.6% and a value of 36% ± 18.8 of severely degraded bottom.

Benthic Community Condition

Benthic community parameters including the B-IBI value, abundance, biomass, and Shannon diversity index are presented in Table 4. A complete list of all taxa collected is presented in Appendix B and all raw benthic community data is presented in Appendix C. Results of this study are compared to the 2019 spatially intensive sampling of five strata (Mainstem, Southern Branch, Lafayette River, Western Branch and Eastern Branch) (Figures 4-8 modified from Dauer 2020). The primary ecological diagnostic approach applies the B-IBI developed for the Chesapeake Bay and selected metrics of the index that provide insight into possible impairments from natural ecosystem status and functions (Dauer et al. 2000).

The BIBI and its metrics showed a mixture of improvements and degradations in benthic community condition. Compared to the previous benthic community condition reported in Dauer (2011) the 2019 Swimming Point benthos: (1) the average BIBI value improved significantly from 2.2 ± 0.1 in 2010 to 2.6 ± 0.1 in 2019 ($p = 0.04$), (2) total community abundance also improved with a decrease from an over-abundance value of 6,508 ± 993 individuals per m^2 in 2010 to 4,482 ± 482 individuals per m^2 in 2010 ($p = 0.08$) – an improvement in ecological condition for polyhaline sand habitats, (3) a significant decrease in the Shannon Diversity Index value from 1.92 ± 0.15 in 2010 to 1.49 ± 0.11 in 2019 ($p = 0.03$), and (4) a significant decrease in the number of species per sample from 13.6 ± 0.7 in 2010 to 9.4 ± 0.6 in 2019 ($p < 0.01$).

A comparison of the temporal changes in benthic community condition at Swimming Point (2010 data to 2019 data) to the patterns throughout the Elizabeth River (1999 data compared to 2019) in Dauer (2020) shows (1) the BIBI values significantly improved only in the Southern Branch and at Swimming Point with the highest BIBI values in the Mainstem of the river and at Swimming Point, (2) the BIBI values decreased in the Lafayette River, Eastern Branch and Western Branch in 2019, (3) abundance values increased in the Lafayette River, the Eastern Branch and the Western Branch, above or near the over-abundance threshold of 5,000 individuals per m^2 while significantly declining below the threshold at Swimming Point, and (4) the decrease in the Shannon Diversity Index and species richness at Swimming Point also occurred in the Lafayette River, the Eastern Branch and the Western Branch.

Benthic Community Dominant Species

The dominant taxa of Swimming Point are summarized in Table 6 (2019 data) and Table 7 (2010 data). In both years, the Swimming Point benthos was dominated by annelid species including the polychaete species *Mediomastus ambiseta*, *Streblospio benedicti*, *Paraprionospio pinnata*, *Leitoscoloplos* spp., *Glycinde solitaire*, and the oligochaete taxon *Tubificoides* spp. In the 2010 data there were several additional polychaete dominants including *Capitella capitata*, *Laeonereis culveri*, *Brania clavata*, *Tharyx* sp., *Capitellides jonesi* and *Podarke obscura*. Most of these dominants are characteristic of either shallower water depth and/or sandy sediments than generally sampled by random samples applied at the watershed level. However, none of these species were in the top 20 density dominants collected in 2019 (Table 6). The non-indigenous polychaete species *Hermundura americana* first reported in the Chesapeake Bay in 2009 in the Southern Branch of the Elizabeth River was a new dominant in the 2019 data at Swimming Point. This species was widespread in all branches of the Elizabeth River in the intensive 2019 data study of Dauer (2020).

Indicative of improved benthic ecological condition was the appearance in the density dominants of 2019 (1) of two gastropod species the glassy bubble shell *Haminoea solitaria* and the barrel bubble shell *Acteocina canaliculate*, (2) the bivalve *Macoma balthica*, (3) the amphipod *Ampelisca abdita*, and the shrimp *Ogyrides alphaeorostris*. All these species are generally associated with unstressed estuarine and/or coastal habitats.

REFERENCES

ALDEN, R.W. III, D.M. DAUER, J.A. RANASINGHE, L.C. SCOTT, AND R.J. LLANSÓ. 2002. Statistical verification of the Chesapeake Bay Benthic Index of Biotic Integrity. *Environmetrics*13: 473- 498.

ALLAN, J. D., D. L. ERICKSON, AND J. FAY. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. *Freshwater Biology* 37:149–161.

BALLS, P. W. 1994. Nutrient inputs to estuaries from nine Scottish east coast rivers: Influence of estuarine processes on inputs to the North Sea. *Estuarine Coastal and Shelf Science* 39: 329–352.

BEASLEY, R. S. AND A. B. GRANILLO. 1988. Sediment and water yields from managed forests on flat coastal plain sites. *Water Resources Bulletin* 24:361–366.

BENZIE, J. A. H., K. B. PUGH, AND M. B. DAVIDSON. 1991. The rivers of North East Scotland (UK): Physicochemical characteristics. *Hydrobiologia* 218:93–106.

BILYARD, G. R. 1987. The value of benthic infauna in marine pollution monitoring studies. *Marine Pollution Bulletin* 18:581-585.

BOESCH, D. F. AND R. ROSENBERG. 1981. Response to stress in marine benthic communities, p. 179-200. In G. W. Barret and R. Rosenberg (eds.), Stress Effects on Natural Ecosystems. John Wiley & Sons, New York.

BOYNTON, W. R., W. M. KEMP, AND C. W. KEEFE. 1982. A comparative analysis of nutrients and other factors influencing estuarine phytoplankton production, p. 69–90. *In* V. S. Kennedy (ed.), Estuarine Comparisons. Academic Press, New York.

COMELEO, R. L., J. F. PAUL, P. V. AUGUST, J. COPELAND, C. BAKER, S. S. HALE, AND R. W. LATIMER. 1996. Relationships between watershed stressors and sediment contamination in Chesapeake Bay estuaries. *Landscape Ecology* 11:307–319.

CONNERS, M. E. AND R. J. NAIMAN. 1984. Particulate allochthonous inputs: Relationships with stream size in an undisturbed watershed. *Canadian Journal of Fisheries and Aquatic Sciences* 41: 1473–1488.

CORBETT, C. W., M. WAHL, D. E. PORTER, D. EDWARDS, AND C. MOISE. 1997. Nonpoint source runoff modeling: A comparison of a forested watershed and an urban watershed on the South Carolina coast. *Journal of Experimental Marine Biology and Ecology* 213:133–149.

CORRELL, D. L. 1983. N and P in soils and runoff of three coastal plain land uses, p. 207–224. *In* R. Lowrance, R. Todd, L. Asmussen, and R. Leonard (eds.), Nutrient Cycling in Agricultural Ecosystems. University of Georgia Press, Athens, Georgia.

CORREL, D. L. 1997. Buffer zones and water quality protection: General principles, p. 7–20. *In* N. E. Haycock, T. P. Burt, K. W. T. Goulding, and G. Pinay (eds.), Buffer Zones: Their Processes and Potential in Water Protection. Quest Environmental, Hertfordshire, United Kingdom.

CORRELL, D. L., T. E. JORDAN, AND D. E. WELLER. 1992. Nutrient flux in a landscape: Effects of coastal land use and terrestrial community mosaic on nutrient transport to coastal waters. *Estuaries* 15:431–442.

CORRELL, D. L., T. E. JORDAN, AND D. E. WELLER. 1997. Livestock and pasture land effects on the water quality of Chesapeake Bay watershed streams, p. 107–116. *In* K. Steele (ed.), Animal Waste and the Land-Water Interface. Lewis Publishers, New York.

CORRELL, D. L., J. J. MIKLAS, A. H. HINES, AND J. J. SCHAFER. 1987. Chemical and biological trends associated with acidic atmospheric deposition in the Rhode River watershed and estuary (Maryland, USA). *Water Air and Soil Pollution* 35:63–86.

DAUER, D. M. 1993. Biological criteria, environmental health and estuarine macrobenthic community structure. *Marine Pollution Bulletin* 26:249–257.

DAUER, D.M. 1997. Dynamics of an estuarine ecosystem: Long-term trends in the macrobenthic communities of the Chesapeake Bay, USA (1985-1993). *Oceanologica Acta* 20: 291-298.

DAUER, D. M 2000. Benthic Biological Monitoring Program of the Elizabeth River Watershed (1999). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 73 pp.

DAUER, D. M 2001. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2000). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 35 pp. Plus Appendix.

DAUER, D. M 2002. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2001) with a study of Paradise Creek. Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 45 pp.

DAUER, D. M 2003. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2002). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 56 pp.

DAUER, D. M 2004. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2003). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 88 pp.

DAUER, D. M 2005. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2004). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 178 pp.

DAUER, D. M 2006. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2005). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 171 pp.

DAUER, D. M 2007. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2006). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 40 pp.

DAUER, D. M 2008. Benthic Biological Monitoring Program of the Elizabeth River Watershed (2007). Final Report to the Virginia Department of Environmental Quality, Chesapeake Bay Program, 112 pp.

DAUER, D. M 2009. Benthic Biological Monitoring Program of the Elizabeth River

Watershed (2008). Final Report to the Virginia Department of Environmental Quality,

DAUER, D.M. 2011. Swimming Point benthic community condition - Elizabeth River (2010). Final report to GEI Consultants, Glastonbury, CT. 64 pp.

DAUER, D.M. 2020. Benthic biological monitoring program of the Elizabeth River watershed (1999 and 2019). Final Report to the Elizabeth River Project. 72 pp. Plus appendages.

DAUER, D.M. AND R.W. ALDEN III. 1995. Long-term trends in the macrobenthos and water quality of the lower Chesapeake Bay (1985-1991). *Marine Pollution Bulletin* 30: 840-850.

DAUER, D.M. AND W.G. CONNER. 1980. Effects of moderate sewage input on benthic polychaete populations. *Estuarine and Coastal Marine Science* 10: 335-346.

DAUER, D.M., R.M. EWING, G.H. TOURTELLOTTE, W.T. HARLAN, J.W. SOURBEER, AND H. R. BARKER JR. 1982a. Predation pressure, resource limitation and the structure of benthic infaunal communities. *Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology)* 67: 477-489.

DAUER, D.M. AND R. J. LLANSÓ. 2003. Spatial scales and probability based sampling in determining levels of benthic community degradation in the Chesapeake Bay. *Environmental Monitoring and Assessment* 81: 175-186.

DAUER, D.M., H.G. MARSHALL, J.R. DONAT, M. F. LANE, S. DOUGHTEN, P.L. MORTON AND F.J. HOFFMAN. 2006a. Status and trends in water quality and living resources in the Virginia Chesapeake Bay: James River (1985-2004). Final report to the Virginia Department of Environmental Quality. 73 pp.

DAUER, D.M., H.G. MARSHALL, J.R. DONAT, M. F. LANE, S. DOUGHTEN, P.L. MORTON AND F.J. HOFFMAN. 2006b. Status and trends in water quality and living resources in the Virginia Chesapeake Bay: York River (1985-2004). Final report to the Virginia Department of Environmental Quality. 63 pp.

DAUER, D.M., H.G. MARSHALL, J.R. DONAT, M. F. LANE, S. DOUGHTEN, P.L. MORTON AND F.J. HOFFMAN. 2006c. Status and trends in water quality and living resources in the Virginia Chesapeake Bay: Rappahannock River (1985-2004). Final report to the Virginia Department of Environmental Quality. 66 pp.

DAUER, D.M., J. A. RANASINGHE, AND S. B. WEISBERG. 2000. Relationships between benthic community condition, water quality, sediment quality, nutrient loads, and land use patterns in Chesapeake Bay. *Estuaries* 23: 80-96.

DAUER, D.M., W.W. ROBINSON, C.P. SEYMOUR, AND A.T. LEGGETT, JR. 1979. The environmental impact of nonpoint pollution on benthic invertebrates in the Lynnhaven River System. *Virginia Water Resources Research Center Bulletin* 117, 112 pp.

DAUER, D.M., M.W. LUCHENBACK, AND A.J. RODI, JR. 1993. Abundance biomass comparisons (ABC method): Effects of an estuary gradient, effects of an estuarine gradient, anoxic/hypoxic events and contaminated sediments. *Marine Biology* 116: 507-518.

DAUER, D.M., G.H. TOURTELLOTTE, AND R.M. EWING. 1982b. Oyster shells and artificial worm tubes: the role of refuges in structuring benthic infaunal communities. *Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology)* 67: 661-677.

DUDA, A. M. 1982. Municipal point source and agricultural nonpoint source contributions to coastal eutrophication. *Water Resources Bulletin* 18:397–407.

EWING, R.M. AND D.M. DAUER 1982. Macrobenthic communities of the lower Chesapeake Bay. I. Old Plantation Flats, Old Plantation Creek, Kings Creek and Cherrystone Inlet. *Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology)* 67: 777-791.

FISHER, S. G. AND G. E. LIKENS. 1973. Energy flow in Bear Brook, New Hampshire: An integrative approach to stream ecosystem metabolism. *Ecological Monographs* 43:421–439.

FISHER, D. C. AND M. OPPENHEIMER 1991. Atmospheric deposition and the Chesapeake Bay estuary. *Ambio* 20:102–108.

FISHER, D. C., E. R. PEELE, J. W. AMMERMAN, AND L. W. HARDING, JR. 1992. Nutrient limitation of phytoplankton in Chesapeake Bay. *Marine Ecology Progress Series* 82:51–64.

FOLK, R.L. 1974. Petrology of sedimentary rocks. Hemphills, Austin, 170 pp.

GOLD, A. A., P. A. JACINTHE, P. M. GROFFMAN, W. R. WRIGHT, AND P. H. PUFFER. 1998. Patchiness in groundwater nitrate removal in a riparian forest. *Landscape Ecology* 27:146–155.

GRAY, J. S. 1979. Pollution-induced changes in populations. *Transactions of the Royal Philosophical Society of London (B)* 286:545-561.

GRUBAUGH, J. W. AND J. B. WALLACE. 1995. Functional structure and production of the benthic community in a Piedmont river: 1956–1957 and 1991–1992. *Limnology and Oceanography* 40: 490–501.

HALL, JR., L. W., S. A. FISCHER, W. D. KILLEN, JR., M. C. SCOTT, M. C. ZIEGENFUSS,

AND R. D. ANDERSON. 1994. Status assessment in acid-sensitive and non-acid-sensitive Maryland coastal plain streams using an integrated biological, chemical, physical, and land-use approach. *Journal of Aquatic Ecosystem Health*
3:145–167.

HALL, JR., L. W., M. C. SCOTT, W. D. KILLEN, AND R. D. ANDERSON. 1996. The effects of land-use characteristics and acid sensitivity on the ecological status of Maryland coastal plain streams. *Environmental Toxicology and Chemistry* 15:384–394.

HAWTHORNE, S.D. AND D.M. DAUER. 1983. Macrobenthic communities of the lower Chesapeake Bay. III. Southern Branch of the Elizabeth River. *Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology)* 68: 193-205.

HILL, A. 1996. Nitrate removal in stream riparian zones. *Journal of Environmental Quality* 25:743–755.

HINGA, K. R., A. A. KELLER, AND C. A. OVIATT. 1991. Atmospheric deposition and nitrogen inputs to coastal waters. *Ambio* 20: 256–260.

HOFFMAN, E. J., G. L. MILLS, J. S. LATIMER, AND J. G. QUINN. 1983. Annual inputs of petroleum hydrocarbons to the coastal environment via urban runoff. *Canadian Journal of Fisheries and Aquatic Sciences* 40:41–53.

HOPKINSON, JR., C. S. AND J. J. VALLINO. 1995. The relationships among man's activities in watersheds and estuaries: A model of runoff effects on patterns of estuarine community metabolism. *Estuaries* 18:598–621.

HOWARTH, R. W., J. R. FRUCI, AND D. SHERMAN. 1991. Inputs of sediment and carbon to an estuarine ecosystem: Influence of land use. *Ecological Applications* 1:27–39.

HUNLEY, W.S. 1993. Evaluation of long term changes in the macrobenthic community of the Southern Branch of the Elizabeth River, Virginia. Master's Thesis. Old Dominion University. 120 pp.

JAWORSKI, N. A., P. M. GROFFMAN, A. A. KELLER, AND J. C. PRAGER. 1992. A watershed nitrogen and phosphorus balance: The Upper Potomac River Basin. *Estuaries* 15:83–95.

JOHNSTON, C. A., N. E. DETENBECK, AND G. J. NIEMI. 1990. The cumulative effect of wetlands on stream water quality and quantity: A landscape approach. *Biogeochemistry* 10:105–142.

JORDAN, T. E., D. L. CORRELL, AND D. E. WELLER. 1997. Relating nutrient discharges from watersheds to land use and stream-flow variability. *Water Resources Research* 33:2579–2590.

KARR, J. R., K. D. FAUSCH, P. L. ANGERMEIER, P. R. YANT, AND I. J. SCHLOSSER. 1986. Assessing Biological Integrity in Running Waters: A Method and Its Rationale. Special Publication 5. Illinois Natural History Survey, Champaign, Illinois.

KEMP, W. M., R. R. TWILLEY, J. C. STEVENSON, W. R. BOYNTON, AND J. C. MEANS. 1983. The decline of submerged vascular plants in Upper Chesapeake Bay: Summary of results concerning possible causes. *Marine Technology Society Journal* 17:
78–89.

KENNISH, M.J. 1998, *Pollution impacts on marine biotic communities,* CRC Press, Boca Raton, 310 pp.

KINGSFORD, M.J. 1998, 'Analytical aspects of sampling design', in Kingsford, M. and Battershill, C. (eds), *Studying temperate marine environments. A handbook for ecologists*, CRC Press, Boca Raton, p. 49–83.

KINGSFORD, M.J. AND BATTERSHILL, C. N. 1998, 'Procedures for establishing a study', in Kingsford, M. and Battershill, C. (eds), *Studying temperate marine environments. A handbook for ecologists*, CRC Press, Boca Raton, p. 29–48.

KRAMER, K.J.M. 1994, *Biomonitoring of coastal waters and estuaries,* CRC Press, Boca Raton, 327 pp.

LAJTHA, K., B. SEELY, AND I. VALIELA. 1995. Retention and leaching of atmospherically-derived nitrogen in the aggrading coastal watershed of Waquiot Bay, MA. *Biogeochemistry* 28:33–54.

LAMBERTI, G. A. AND M. B. BERG. 1995. Invertebrates and other benthic features as indicators of environmental change in Juday Creek, Indiana. *Natural Areas Journal* 15:249–258.

LENAT, D. R. AND J. K. CRAWFORD. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. *Hydrobiologia* 294:185–199.

LIVINGSTON, R.J. 2001, *Eutrophication processes in coastal systems,* CRC Press, Boca Raton, 327 pp.

LLANSÓ, R.J., D.M. DAUER, J.H. VØLSTAD, AND L.S. SCOTT. 2003. Application of the Benthic Index of Biotic Integrity to environmental monitoring in Chesapeake Bay. *Environmental Monitoring and Assessment* 81: 163-174.

LLANSÓ, R.J., F.S. KELLEY AND L.S. SCOTT. 2004. Long-term benthic monitoring and assessment component. Level I Comprehensive Report. July 1984 – December 2003. Final report to the Maryland Department of Natural Resources.

LONG, E. R., D. D. MCDONALD, S. L. SMITH, AND F. D. CALDER. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management* 19:81–97.

LOWRANCE, R. 1992. Groundwater nitrate and denitrification in a coastal plain riparian forest. *Journal of Environmental Quality* 21:401–405.

MALONE, T. C. 1992. Effects of water column processes on dissolved oxygen, nutrients, phytoplankton and zooplankton, p. 61–112. *In* D. E. Smith, M. Leffler, and G. Mackiernan (eds.), Oxygen Dynamics in the Chesapeake Bay. A Synthesis of Recent Research. Maryland Sea Grant College, College Park, Maryland.

MALONE, T. C., D. J. CONLEY, T. R. FISHER, P. M. GILBERT, AND L. W. HARDING. 1996. Scales of nutrient-limited phytoplankton productivity in Chesapeake Bay. *Estuaries* 19:371–385.

MALONE, T. C., L. H. CROCKER, S. E. PIKE, AND B. A. WENDLER. 1988. Influences of river flow on the dynamics of phytoplankton production in a partially stratified estuary. *Marine Ecology Progress Series* 48:235–249.

MALONE, T. C., W. M. KEMP, H. W. DUCKLOW, W. R. BOYNTON, J. H. TUTTLE, AND R. B. JONAS. 1986. Lateral variation in the production and fate of phytoplankton in a partially stratified estuary. *Marine Ecology Progress Series* 32:149–160.

MANGUN, W. R. 1989. A comparison of five Northern Virginia (USA) watersheds in contrasting land use patterns. *Journal of Environmental Systems* 18:133–151.

MEDEIROS, C., R. LEBLANC, AND R. A. COLER. 1983. An in situ assessment of the acute toxicity of urban runoff to benthic macroinvertebrates. *Environmental Toxicology and Chemistry* 2: 119–126.

NELSON, W. M., A. A. GOLD, AND P. M. GROFFMAN. 1995. Spatial and temporal variation in groundwater nitrate removal in a riparian forest. *Journal of Environmental Quality* 24:691–699.

NIXON, S. W. 1995. Coastal marine eutrophication: A definition, social causes, and future consequences. *Ophelia* 41:199–219.

NOVOTNY, V., H. M. SUNG, R. BANNERMAN, AND K. BAUM. 1985. Estimating nonpoint pollution from small urban watersheds. *Journal of the Water Pollution Control Federation* 57:339–348.

OFFICER, C. B., R. B. BIGGS, J. L. TAFT, L. E. CRONIN, M. A. TYLER, AND W. R. BOYNTON. 1984. Chesapeake Bay anoxia: Origin, development, and significance. *Science* 223:22–27.

OSBORNE, L. L. AND D. A. KOVACIC. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology* 29:243–25.

OSTRY, R. C. 1982. Relationship of water quality and pollutant loads to land uses in adjoining watersheds. *Water Resources Bulletin* 18:99–104.

OVIATT, C., P. DOERING, B. NOWICKI, L. REED, J. COLE, AND J. FRITHSEN. 1995. An ecosystem level experiment on nutrient limitation in temperate coastal marine environments. *Marine Ecology Progress Series* 116:171–179.

PEARSON, T. H. AND R. ROSENBERG. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology*: *An Annual Review* 16:229–311.

RANASINGHE, J. A., S. B. WEISBERG, D. M. DAUER, L. C. SCHAFFNER, R. J. DIAZ, AND J. B. FRITHSEN. 1994. Chesapeake Bay Benthic Community Restoration Goals. Report for the U.S. Environmental Protection Agency, Chesapeake Bay Office and the Maryland Department of Natural Resources. Versar, Inc., Columbia, Maryland.

RHOADS, D. C., P. L. MCCALL, AND J. Y. YINGST. 1978. Disturbance and production on the estuarine sea floor. *American Scientist* 66:577-586.

ROTH, N. E., J. D. ALLAN, AND D. L. ERICKSON. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. *Landscape Ecology* 11:141–156.

SCHENKER, N. AND J.F. GENTLEMAN. 2001. On judging the significance of differences by examining the overlap between confidence intervals. *The American Statistician* 55: 182-186

SCHMIDT, S. D. AND D. R. SPENCER. 1986. The magnitude of improper waste discharges in an urban stormwater system. *Journal of the Water Pollution Control Federation* 58:744–748.

TAFT, J. L., W. R. TAYLOR, E. O. HARTWIG, AND R. LOFTUS. 1980. Seasonal oxygen depletion in Chesapeake Bay. *Estuaries* 3: 242–247.

TAPP, J. F., N. SHILLABEER, AND C. M. ASHMAN. 1993. Continued observation of the benthic fauna of the industrialized Tees estuary, 1979-1990. *Journal of Experimental Marine*

Biology and Ecology 172:67-80.

TOURTELLOTTE, G.H. AND D.M. DAUER. 1983. Macrobenthic communities of the lower Chesapeake Bay. II. Lynnhaven Roads, Lynnhaven River, Broad Bay, and Linkhorn Bay. *Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology)* 68: 59-72.

TURNER, R. E. AND N. N. RABALAIS 1991. Changes in Mississippi water quality this century. *Bioscience* 41:140–147.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY. 1983. Chesapeake Bay: A Framework for Action. Philadelphia, Pennsylvania.

VALIELA, I., G. COLLINS, J. KREMER, K. LAJTHA, M. GEIST, B. SEELY, J. BRAWLEY, AND C. H. SHAM. 1997. Nitrogen loading from coastal watersheds to receiving estuaries: New method and application. *Ecological Applications* 7:358–380.

VALIELA, I. AND J. COSTA. 1988. Eutrophication of Buttermilk Bay, a Cape Cod coastal embayment: Concentrations of nutrients and watershed nutrient budgets. *Environmental Management* 12:539–551.

VERCHOT, L. V., E. C. FRANKLIN, AND J. W. GILLIAM. 1997a. Nitrogen cycling in Piedmont vegetated filter zones: I. Surface soil processes. *Journal of Environmental Quality* 26:327–336.

VERCHOT, L. V., E. C. FRANKLIN, AND J. W. GILLIAM. 1997b. Nitrogen cycling in Piedmont vegetated filter zones: II. Subsurface nitrate removal. *Journal of Environmental* 26:337–347.

VERNBERG, F. J., W. B. VERNBERG, E. BLOOD, A. FORTNER, M. FULTON, H. MCKELLAR, AND W. MICHENER, G. SCOTT, T. SIEWICKI, AND K. EL FIGI. 1992. Impact of urbanization on highsalinity estuaries in the southeastern United States. *Netherlands Journal of Sea Research* 30:239–248.

WEISBERG, S.B., J.A. RANASINGHE, D.M. DAUER, L.C. SCHAFFNER, R.J. DIAZ AND J.B. FRITHSEN. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* 20: 149-158.

WEISKEL, P. K. AND B. L. HOWES. 1992. Differential transport of sewage-derived nitrogen and phosphorus through a coastal watershed. *Environmental Science and Technology* 26:352–360.

WILBER, W. G. AND J. V. HUNTER. 1979. Aquatic transport of heavy metals in the urban environment. *Water Resources Bulletin* 13:721–734.USEPA 1983

WILSON, J. G. AND D. W. JEFFREY. 1994. Benthic biological pollution indices in estuaries, p. 311-327. In J. M. Kramer (ed.), Biomonitoring of Coastal Waters and Estuaries. CRC Press, Boca Raton, Florida.

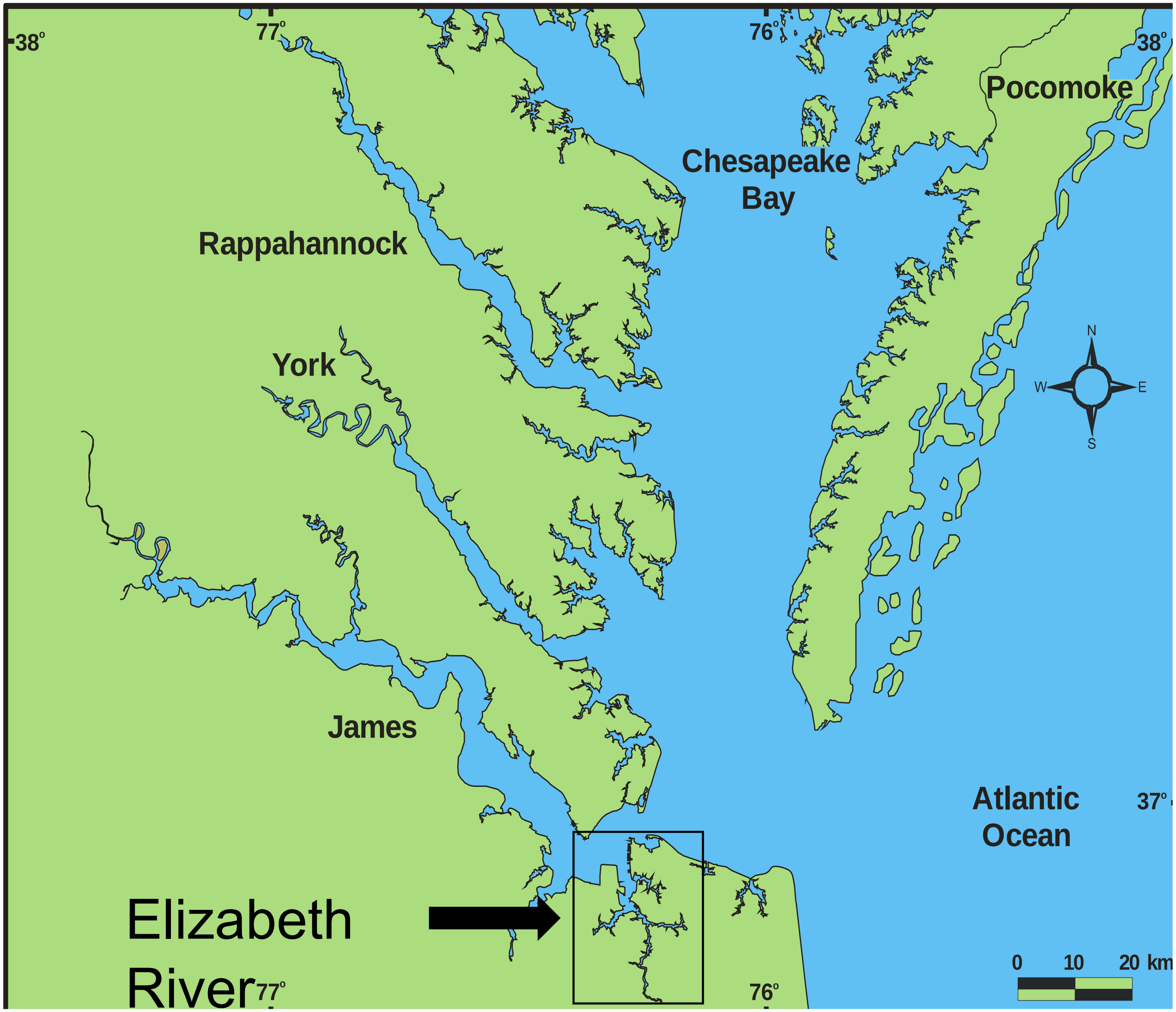

Figure 1. Lower Chesapeake Bay indicating the Elizabeth River watershed.

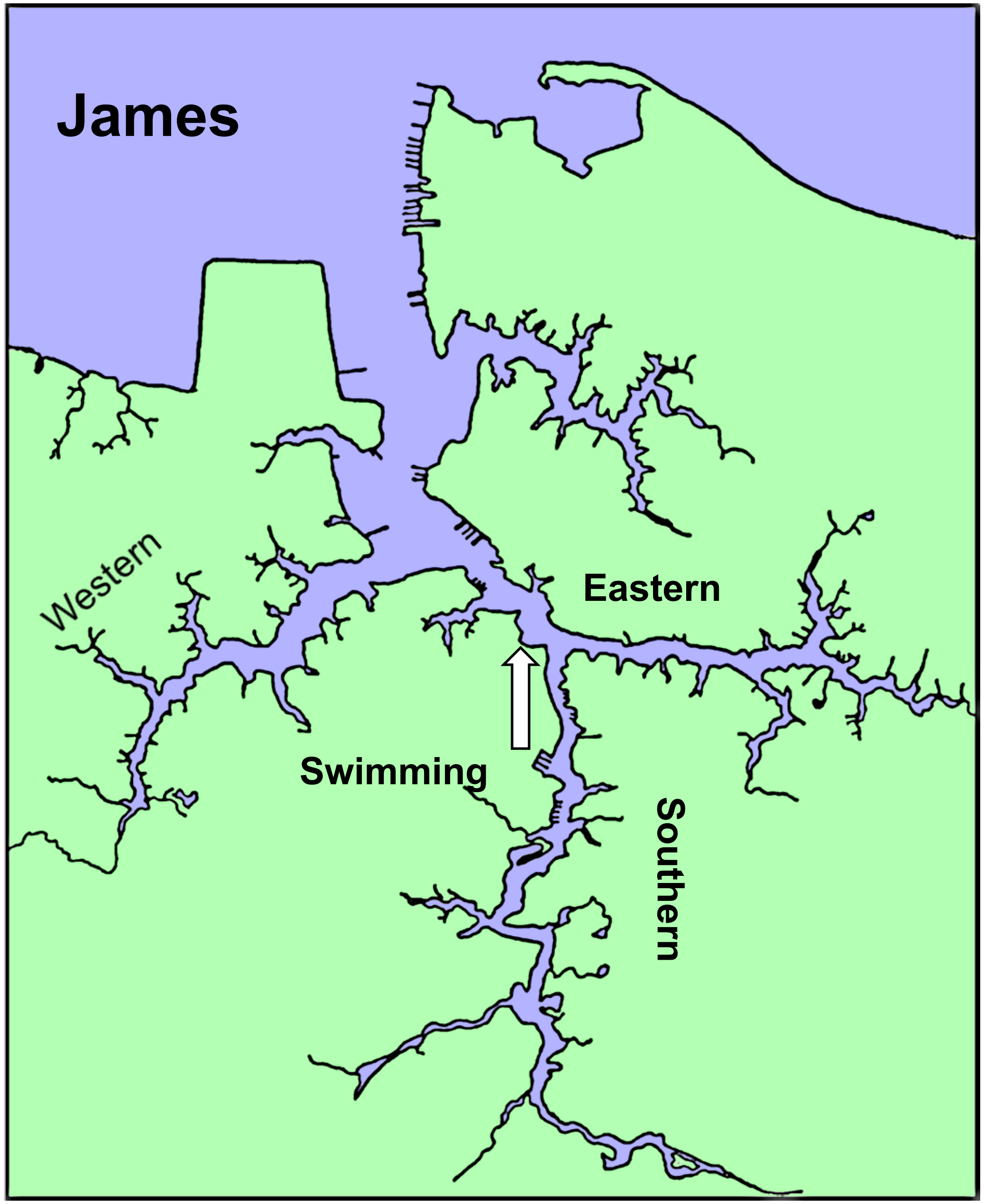

Figure 2. Elizabeth River Watershed indicating the Swimming Point region.

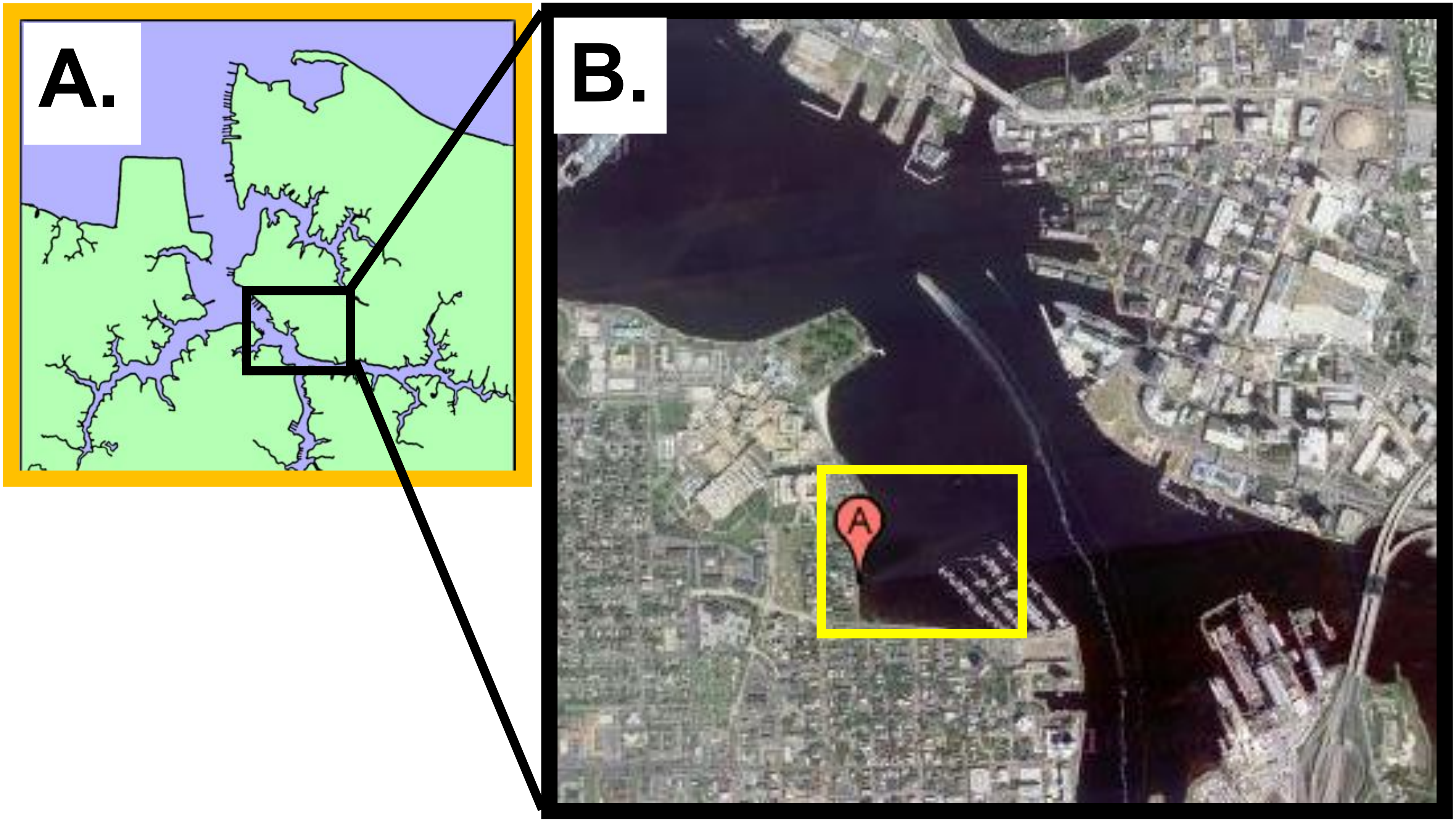

Figure 3. Swimming Point region of the Elizabeth River. A. Upper Elizabeth River Watershed. B. The Swimming Point region off the downtown Portsmouth area.

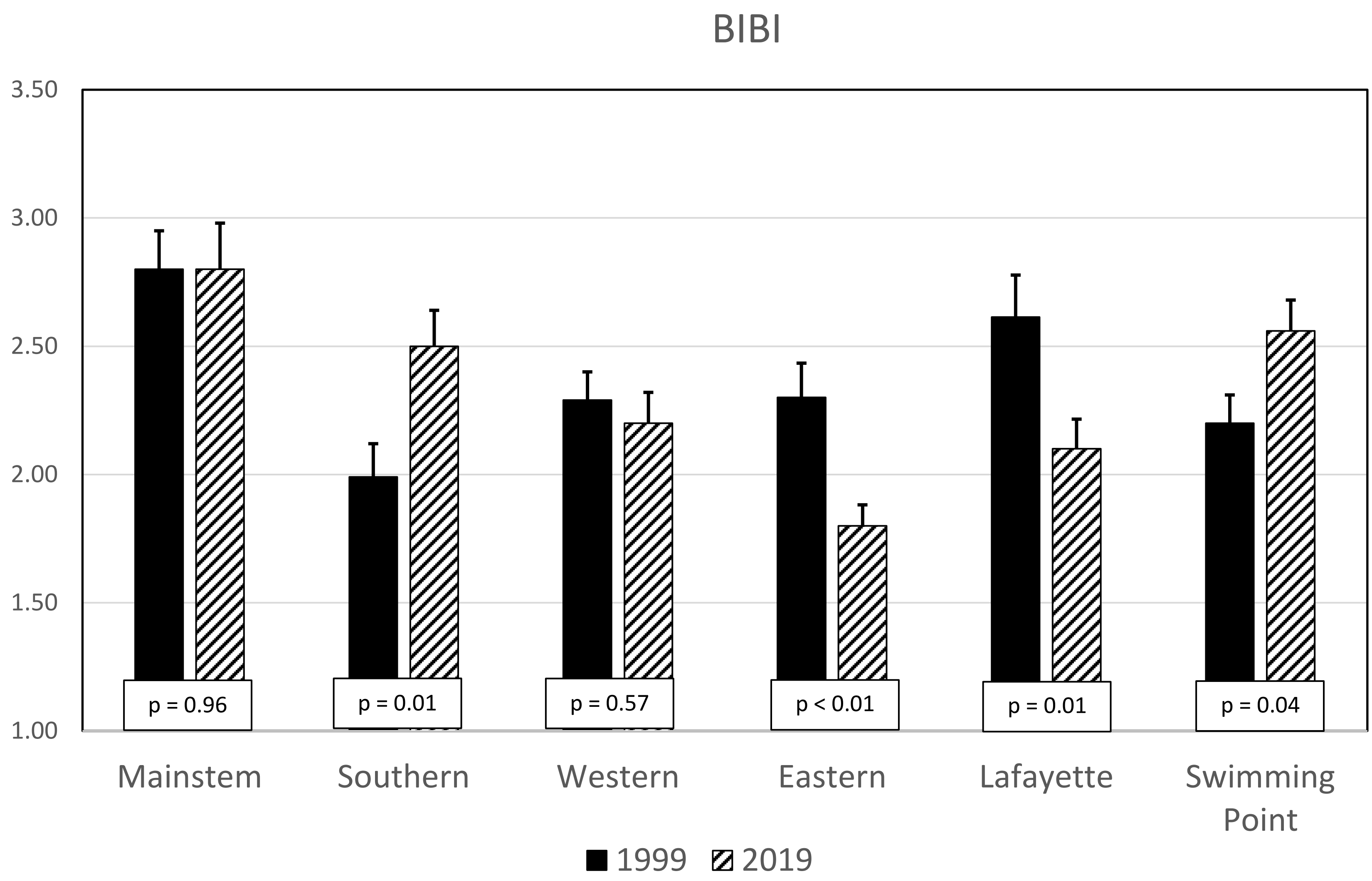

Figure 4. Average values for the Benthic Index of Biotic Integrity (BIBI of Weisberg et al. 1997; Alden et al. 2002) in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings (Dauer 2020). Data for Swimming Point compare 2010 and 2019. Values below 3.0 indicate degraded benthic community condition. Results for t-test show p-values comparing the 1999 and 2019 means of the Elizabeth River strata from Dauer 2020 and Swimming Point comparing 2010 and 2019.

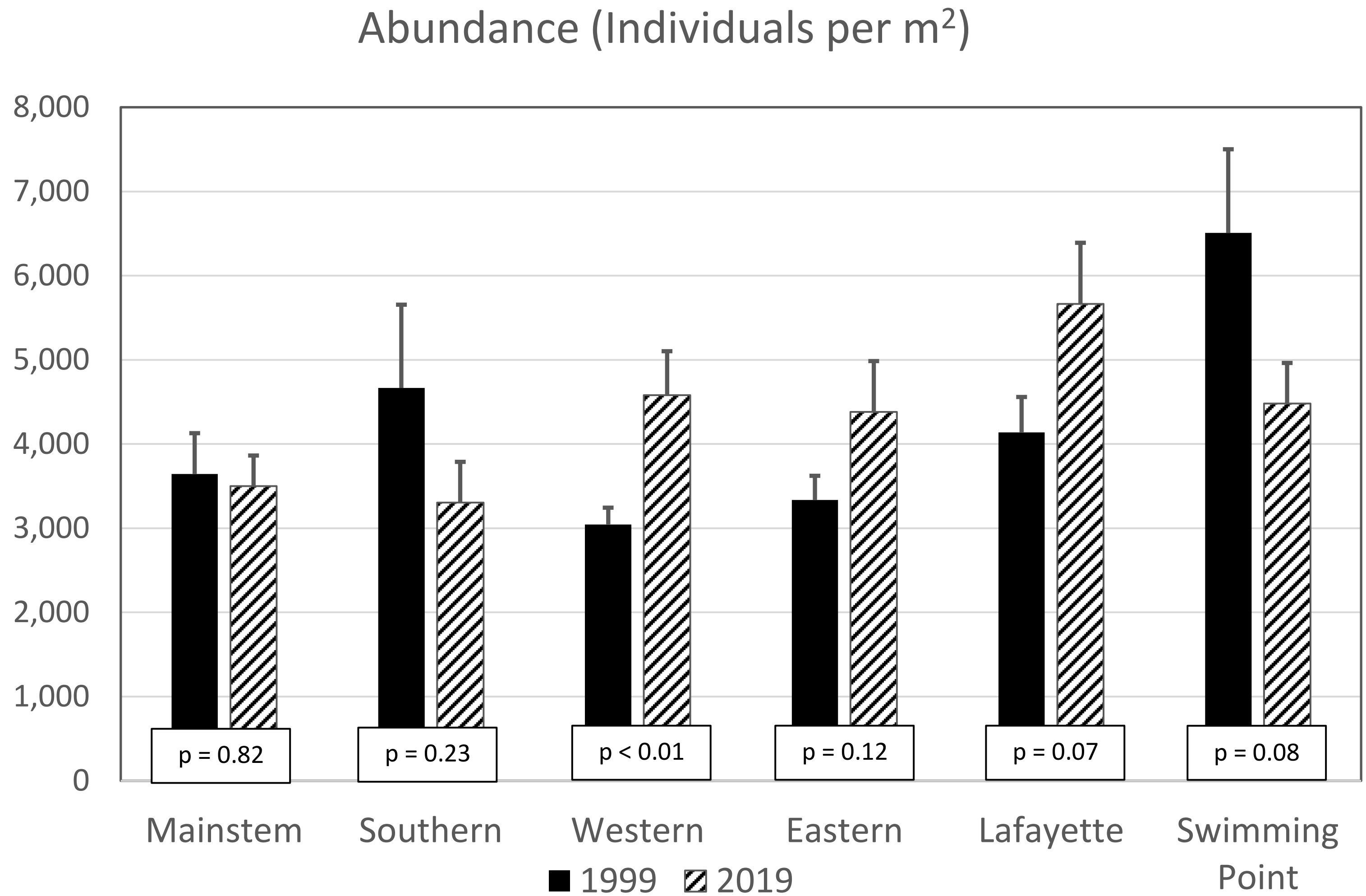

Figure 5. Average abundance of individuals per m² in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings (Dauer 2020). Data for Swimming Point compare 2010 and 2019. Results for t-test show p-values comparing the 1999 and 2019 means of the Elizabeth River strata from Dauer 2020 and Swimming Point comparing 2010 and 2019.

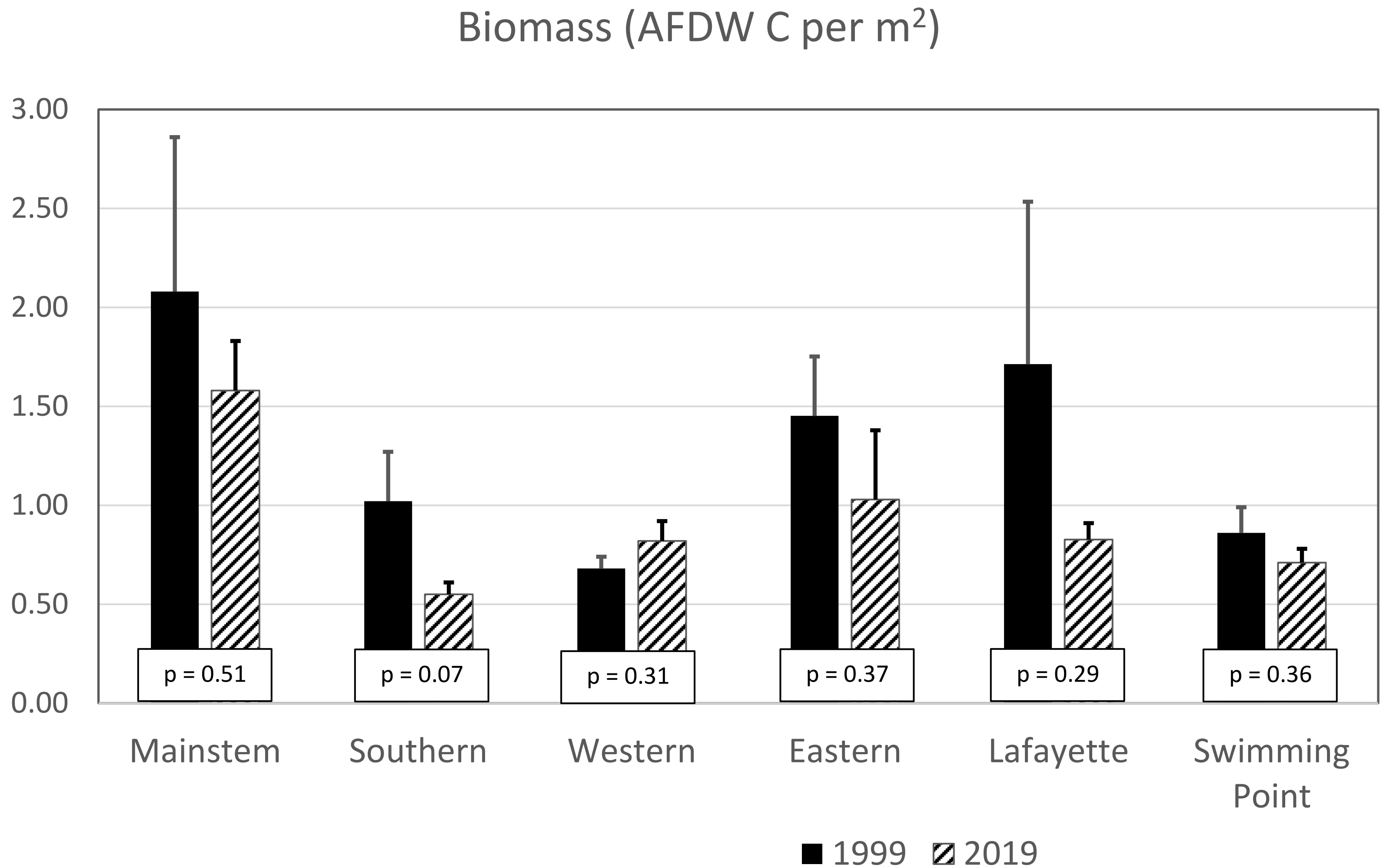

Figure 6. Biomass (AFDW C) per m² in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings (Dauer 2020). Data for Swimming Point compare 2010 and 2019. Results for t-test show p-values comparing the 1999 and 2019 means of the Elizabeth River strata from Dauer 2020 and Swimming Point comparing 2010 and 2019.

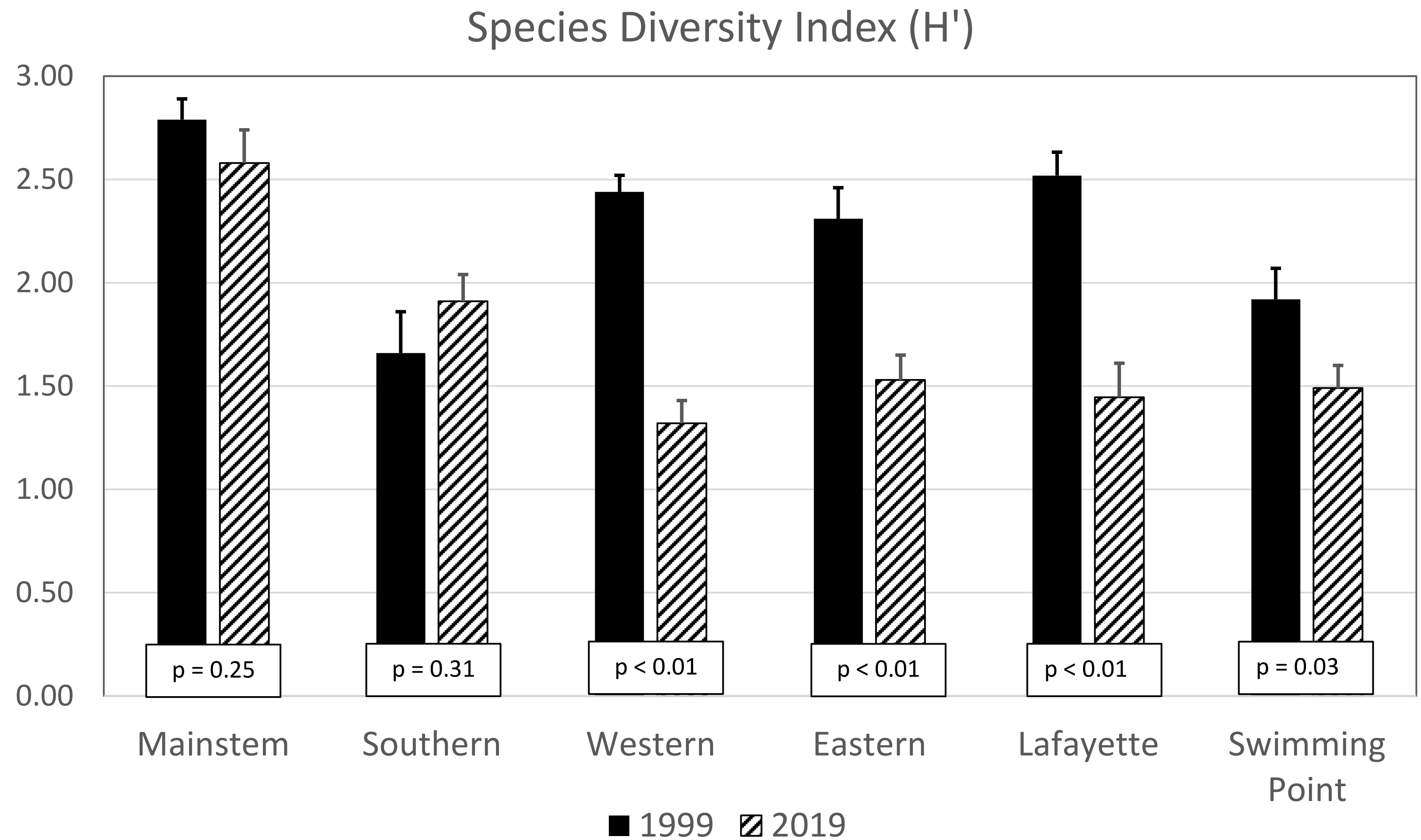

Figure 7. Shannon Diversity Index (H’) in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings (Dauer). Data for Swimming Point compare 2010 and 2019. Results for t-test show p-values comparing the 1999 and 2019 means of the Elizabeth River strata from Dauer 2020 and Swimming Point comparing 2010 and 2019.

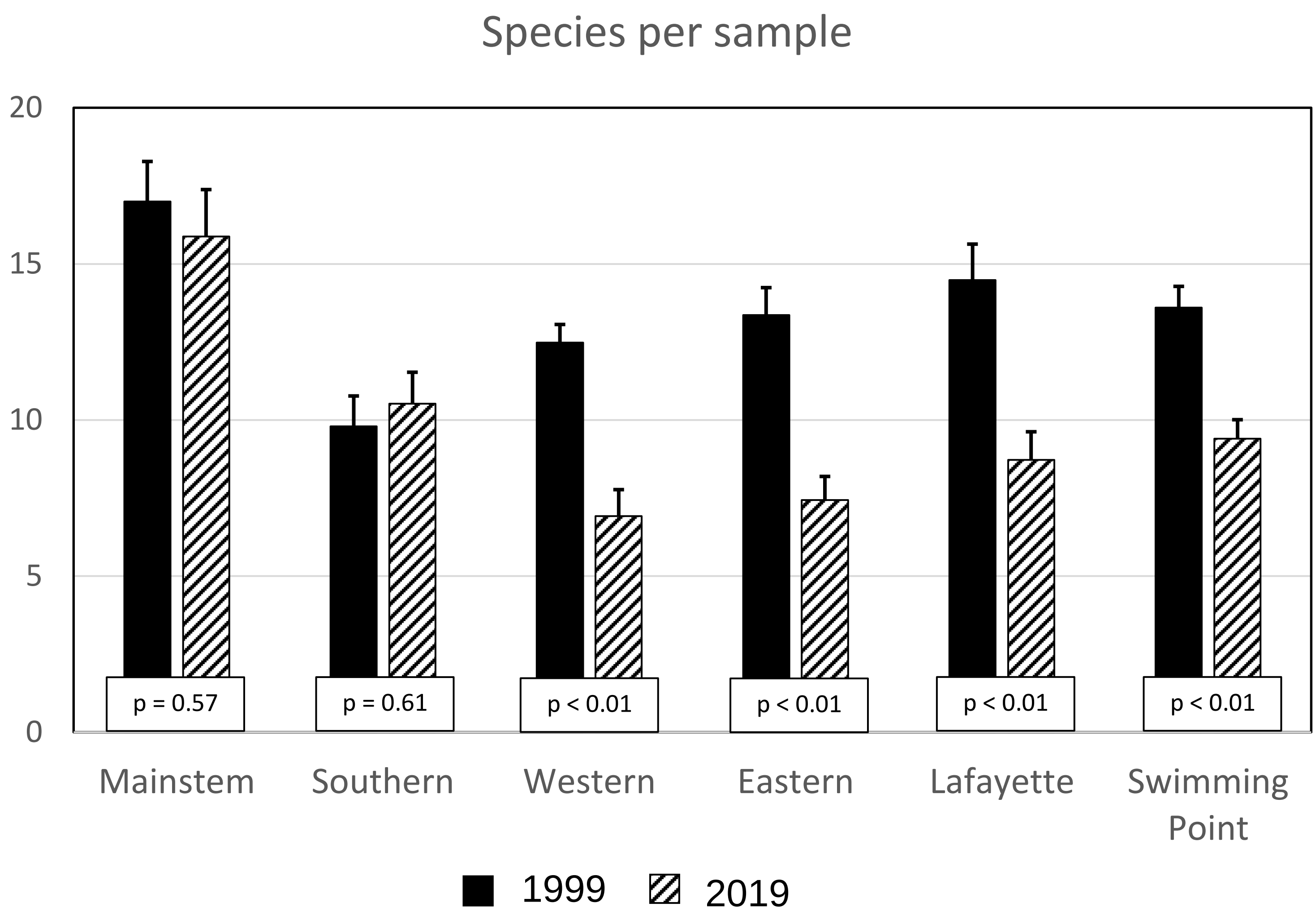

Figure 8. Species per sample in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings (Dauer 2020). Data for Swimming Point compare 2010 and 2019. Results for t-test show p-values comparing the 1999 and 2019 means of the Elizabeth River strata from Dauer 2020 and Swimming Point comparing 2010 and 2019.

Table 1. Station Coordinates for Swimming Point 2019 sampling.

Stratum=SWP

Station	Latitude in Decimal Degrees	Longitude in Decimal Degrees
26SP02	36.842501	-76.302121
26SP03	36.840842	-76.301853
26SP04	36.842815	-76.300731
26SP05	36.841564	-76.301985
26SP06	36.842687	-76.302389
26SP07	36.841893	-76.301735
26SP08	36.842091	-76.301337
26SP09	36.842541	-76.301549
26SP10	36.841935	-76.301635
26SP11	36.842444	-76.301160
26SP12	36.842271	-76.301644
26SP13	36.841940	-76.302119
26SP14	36.842408	-76.300881
26SP15	36.841718	-76.301152
26SP16	36.841228	-76.300777
26SP17	36.841436	-76.301035
26SP18	36.842689	-76.301501
26SP19	36.842455	-76.301923
26SP20	36.842693	-76.302247
26SP21	36.840972	-76.301914
26SP22	36.842127	-76.301088
26SP23	36.842778	-76.302214
26SP24	36.842967	-76.301265
26SP26	36.840924	-76.300815
26SP27	36.841205	-76.301438

Table 2. Physical Data for Swimming Point 2019 sampling.

Stratum=SWP

CBP Station Name	Sampling Date	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Temperature (deg. C)
26SP02	2019-09-20	2.1	20.9	4.93	24.9
26SP03	2019-09-20	1.5	20.9	4.85	25.4
26SP04	2019-09-20	3.1	20.9	4.46	24.6
26SP05	2019-09-20	3.5	20.4	4.12	24.5
26SP06	2019-09-20	1.9	20.9	5.10	25.3
26SP07	2019-09-20	3.5	21.0	4.86	24.6
26SP08	2019-09-20	2.6	20.9	4.78	25.1
26SP09	2019-09-20	2.3	20.9	4.72	25.3
26SP10	2019-09-20	3.8	20.9	4.40	24.5
26SP11	2019-09-20	2.7	21.0	5.03	25.2
26SP12	2019-09-20	2.7	21.0	5.06	25.3
26SP13	2019-09-20	2.3	20.9	5.01	25.4
26SP14	2019-09-20	2.5	21.0	4.87	25.0
26SP15	2019-09-20	2.5	20.9	4.87	25.1
26SP16	2019-09-23	1.7	20.7	4.84	24.3
26SP17	2019-09-23	1.7	20.6	4.66	24.2
26SP18	2019-09-23	1.1	20.5	5.03	24.3
26SP19	2019-09-23	1.2	20.5	5.26	24.5
26SP20	2019-09-23	1.2	20.6	5.34	24.4
26SP21	2019-09-23	1.2	20.7	5.81	25.2
26SP22	2019-09-23	2.0	20.7	5.45	25.2
26SP23	2019-09-23	1.5	20.6	5.72	25.2
26SP24	2019-09-23	1.5	20.8	5.80	25.5
26SP26	2019-09-23	1.7	20.7	5.78	24.9
26SP27	2019-09-23	2.3	20.7	5.10	24.7

Table 3. Sedimentary Data for Swimming Point 2019 sampling.

Station	Sand (% Weight)	Silt-Clay (% Weight)	Volatile Solids (%)
Sand Sites			
26SP09	87.7	12.3	0.47
26SP03	86.0	14.0	1.65
26SP02	84.3	15.7	0.67
26SP21	82.5	17.5	1.54
26SP18	82.3	17.7	0.87
26SP24	78.8	21.2	1.08
26SP12	77.4	22.6	1.25
26SP06	76.6	23.4	4.75
26SP13	75.7	24.3	1.24
26SP19	73.8	26.2	0.60
26SP23	72.5	27.5	3.23
26SP11	72.4	27.6	1.16
26SP14	71.7	28.3	2.71
26SP22	69.7	30.3	1.84
26SP20	65.9	34.1	1.28
26SP04	62.6	37.4	3.02
Mean	**76.2**	**23.8**	**1.71**
Mud Sites			
26SP08	57.6	42.4	3.11
26SP26	57.5	42.5	4.80
26SP07	43.1	56.9	8.44
26SP27	42.9	57.1	5.24
26SP15	41.2	58.8	5.80
26SP17	33.9	66.1	5.83
26SP16	28.7	71.3	6.58
26SP10	26.7	73.3	13.38
26SP05	18.9	81.1	16.66
Mean	**38.9**	**61.1**	**7.8**

Table 4. Random Stations of the Swimming Point Sampling Stratum 2019. Summary of benthic community parameters. Abundance in individuals/m^2, biomass as AFDW gC/m^2, Shannon Index in bits/ind, all other abundance and biomass parameters are percentages. PI – pollution indicative species. PS – pollution sensitive species.

STATION	B_IBI	Abundance	Biomass	Shannon Index	PI-Abundance	PS-Abundance	PI-Biomass	BS-Biomass	Carnivore Omnivore
SWP-26SP02	2.7	11,795	0.545	0.89	13.5	85.0	12.5	66.7	1.7
SWP-26SP03	2.3	6,091	0.636	2.01	39.2	16.0	14.3	10.7	3.4
SWP-26SP04	3.0	2,205	1.500	2.42	17.5	50.5	4.5	25.8	35.1
SWP-26SP05	1.7	1,795	0.091	0.17	97.5	2.5	75.0	25.0	0.0
SWP-26SP06	2.0	1,091	1.500	1.50	77.1	14.6	51.5	1.5	6.3
SWP-26SP07	1.7	6,477	0.955	1.43	36.1	62.1	73.8	23.8	2.5
SWP-26SP08	2.3	6,091	0.614	1.03	8.6	89.9	18.5	48.1	2.6
SWP-26SP09	3.3	3,159	0.727	1.41	3.6	90.6	6.3	40.6	5.8
SWP-26SP10	1.3	3,500	0.136	0.37	95.5	4.5	83.3	16.7	0.0
SWP-26SP11	2.7	6,750	0.455	1.20	12.1	85.2	20.0	65.0	6.4
SWP-26SP12	2.3	8,977	0.523	0.81	12.7	86.6	26.1	65.2	1.0
SWP-26SP13	3.3	4,682	0.432	1.24	14.6	81.1	10.5	52.6	4.4
SWP-26SP14	3.0	4,886	0.409	1.34	10.7	86.0	38.9	50.0	7.9
SWP-26SP15	1.7	3,568	0.841	1.89	22.3	68.8	37.8	27.0	9.6
SWP-26SP16	2.0	5,295	1.023	1.64	17.2	75.5	37.8	31.1	8.6
SWP-26SP17	2.7	2,295	1.068	2.41	16.8	62.4	21.3	29.8	25.7
SWP-26SP18	2.7	6,795	0.773	1.28	1.7	87.3	26.5	41.2	10.7
SWP-26SP19	3.7	4,864	0.477	1.10	6.1	91.1	4.8	47.6	5.1
SWP-26SP20	2.7	2,500	0.295	1.42	13.6	82.7	15.4	53.8	3.6
SWP-26SP21	3.0	2,091	0.386	1.54	27.2	70.7	5.9	70.6	4.3
SWP-26SP22	3.0	3,682	0.455	1.76	10.5	84.6	30.0	40.0	10.5
SWP-26SP23	3.0	3,614	0.773	2.05	38.4	52.2	35.3	23.5	4.4
SWP-26SP24	3.3	4,659	0.955	1.87	4.9	86.8	7.1	73.8	10.7
SWP-26SP26	2.7	2,114	0.977	2.38	20.4	63.4	18.6	32.6	19.4
SWP-26SP27	2.0	3,068	1.273	2.04	12.6	55.6	35.7	14.3	30.4
Mean	**2.6**	**4,482**	**0.713**	**1.49**	**25.2**	**65.4**	**28.5**	**39.1**	**8.8**

Table 5. Random Stations of the Swimming Point Sampling Stratum 2010. Summary of benthic community parameters. Abundance in individuals/m^2, biomass as AFDW gC/m^2, Shannon Index in bits/ind, all other abundance and biomass parameters are percentages. PI – pollution indicative species. PS – pollution sensitive species.

Station	BIBI	Abundance	Biomass	Shannon Index	PI-Abundance	PS-Abundance	PI-Biomass	PS-Biomass	Carnivore Omnivore Abundance
SP01	2.3	3,039	0.726	2.53	41.0	2.2	21.9	6.2	8.2
SP02	1.7	14,288	0.726	0.81	10.5	87.9	28.1	53.1	1.3
SP03	2.0	2,223	0.227	1.82	19.4	1.0	20.0	10.0	14.3
SP04	2.0	10,093	0.544	2.35	21.3	37.8	20.8	8.3	3.6
SP05	1.7	8,346	0.907	2.69	25.0	9.8	25.0	7.5	19.8
SP06	3.3	3,788	0.612	2.75	31.7	42.5	11.1	29.6	15.0
SP07	3.0	3,515	0.703	2.44	30.3	51.6	25.8	12.9	11.0
SP08	1.7	1,293	0.476	2.73	50.9	29.8	33.3	19.0	10.5
SP09	1.7	13,767	1.746	0.76	10.0	88.3	15.6	13.0	1.5
SP10	2.3	4,944	3.334	2.04	23.9	61.5	5.4	3.4	12.8
SP11	2.0	8,777	0.998	2.74	38.0	22.5	15.9	9.1	15.5
SP12	2.7	4,785	0.544	2.48	31.3	42.7	16.7	20.8	4.3
SP13	2.7	2,903	0.522	2.03	12.5	68.8	26.1	21.7	3.1
SP14	2.0	7,779	1.928	1.17	17.5	81.6	11.8	15.3	2.0
SP15	3.0	4,150	0.680	2.36	12.0	67.2	23.3	13.3	10.4
SP16	1.7	9,367	0.522	1.31	16.2	77.2	30.4	39.1	1.5
SP17	1.3	544	0.068	0.97	75.0	4.2	33.3	33.3	0.0
SP18	1.67	4,853	0.408	1.07	11.7	86.4	33.3	33.3	1.0
SP19	1.7	6,713	0.499	1.02	13.2	83.4	22.7	36.4	0.3
SP20	2.3	4,060	0.499	2.05	29.6	1.1	31.8	4.5	20.1
SP21	2.7	23,655	1.202	0.37	2.5	96.2	24.5	45.3	0.5
SP22	2.7	5,058	0.726	1.94	16.1	59.2	37.5	28.1	1.8
SP23	2.7	2,926	0.658	2.94	31.8	27.1	17.2	24.1	12.4
SP24	1.3	9,117	1.633	1.98	13.9	53.0	26.4	4.2	3.2
SP25	3.0	2,722	0.544	2.74	15.0	63.3	29.2	25.0	6.7
Mean	**2.2**	**6,508**	**0.860**	**1.92**	**24.0**	**49.9**	**23.5**	**20.7**	**7.2**

Table 6. Density dominants for Swimming Point 2019. Taxon code: A – amphipod, B – bivalve, C – cumacean, D- decapod, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

	Taxon	Density ($\#/m^2$)	Biomass ($AFDW/m^2$)
1	*Mediomastus ambiseta* (P)	2,915	0.084
2	*Streblospio benedicti* (P)	735	0.031
3	*Spiochaetopterus costarum* (P)	163	0.111
4	*Hermundura americana* (P)	161	0.122
5	*Paraprionospio pinnata* (P)	121	0.042
6	*Capitomastus aciculatus* (P)	94	0.014
7	*Glycinde solitaria* (P)	60	0.020
8	*Leitoscoloplos* spp. (P)	47	0.117
9	*Phoronis* spp. (Ph)	31	0.014
10	*Haminoea solitaria* (G)	23	0.004
11	*Acteocina canaliculate* (G)	18	0.006
12	*Macoma balthica* (B)	17	0.007
13	*Ogyrides alphaerostris* (D)	16	0.008
14	*Tubificoides* spp. Group I (O)	16	0.003
15	*Neanthes succinea* (P)	7	0.005
16	*Podarkeopsis levifuscina* (P)	5	0.002
17	*Ampelisca abdita* (A)	5	0.004
18	*Gemma gemma* (B)	5	0.002
19	*Grandidierella* spp. (A)	5	0.004
20	Nemertea (N)	5	0.027

Table 7. Density dominants for Swimming Point 2010. Taxon code: A – amphipod, B – bivalve, C – cumacean, D- decapod, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

	Taxon	Density ($\#/m^2$)	Biomass ($AFDW/m^2$)
1	*Mediomastus ambiseta* (P)	3,970	0.096
2	*Streblospio benedicti* (P)	971	0.042
3	*Capitella capitata* (P)	608	0.054
4	*Laeonereis culveri* (P)	161	0.039
5	*Tubificoides* spp. Group I (O)	122	0.011
6	*Leitoscoloplos* spp. (P)	81	0.086
7	*Gemma gemma* (B)	72	0.015
8	*Paraprionospio pinnata* (P)	72	0.034
9	*Podarkeopsis levifuscina* (P)	46	0.013
10	*Phoronis* spp. (Ph)	39	0.019
11	*Spiochaetopterus costarum* (P)	37	0.017
12	*Brania clavata* (P)	35	0.006
13	*Heteromastus filiformis* (P)	34	0.027
14	*Neanthes succinea* (P)	22	0.020
15	*Polydora cornuta* (P)	21	0.006
16	*Eteone heteropoda* (P)	20	0.009
17	*Glycinde solitaria* (P)	16	0.006
18	*Tharyx* sp. A Doner (P)	15	0.010
19	*Capitella jonesi* (P)	13	0.003
20	*Podarke obscura* (P)	12	0.005

Appendix A. Glossary of Terms
Glossary of selected terms

Benthos - refers to organisms that dwell on or within the bottom. Includes both hard substratum habitats (e.g. oyster reefs) and sedimentary habitats (sand and mud bottoms).

B-IBI - the benthic index of biotic integrity of Weisberg et al. (1997). The is a multi-metric index that compares the condition of a benthic community to reference conditions.

Fixed Point Stations - stations for long-term trend analysis whose location is unchanged over time.

Habitat - a local environment that has a benthic community distinct for other such habitat types. For the B-IBI of Chesapeake Bay seven habitat types were defined as combinations of salinity and sedimentary types - tidal freshwater, oligohaline, low mesohaline, high mesohaline sand, high mesohaline mud, polyhaline sand and polyhaline mud.

Macrobenthos - a size category of benthic organisms that are retained on a mesh of 0.5 mm.

Metric - a parameter or measurement of benthic community structure (e.g., abundance, biomass, species diversity).

Probability based sampling - all locations within a stratum have an equal chance of being sampled. Allows estimation of the percent of the stratum meeting or failing the benthic restoration goals.

Random Station - a station selected randomly within a stratum. In every succeeding sampling event new random locations are selected.

Reference condition - the structure of benthic communities at reference sites.

Reference sites - sites determined to be minimally impacted by anthropogenic stress. Conditions at these sites are considered to represent goals for restoration of impacted benthic communities. Reference sites were selected by Weisberg et al. (1997) as those outside highly developed watersheds, distant from any point-source discharge, with no sediment contaminant effect, with no low dissolved oxygen effect and with a low level of organic matter in the sediment.

Restoration Goal - refers to obtaining an average B-IBI value of 3.0 for a benthic community indicating that values for metrics approximate the reference condition.

Stratum - a geographic region of unique ecological condition or managerial interest. In this study the primary stratum is a designated region off Swimming Point..

Threshold - a value of a metric that determines the B-IBI scoring. For all metrics except abundance and biomass, two thresholds are used - the lower 5th percentile and the 50th percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5th percentile are scored as a 1. Samples with values between the 5th and 50th metrics are scored as 3 and values greater than the 50th percentile are scored as 5. For abundance and biomass, values below the 5th and above the 95th percentile are scored as 1, values between the 5th and 25th and the 75th and 95th percentiles are scored as 3 and values between the 25th and 75th percentiles are scored as 5.

Appendix B. Taxa collected at Swimming Point Summer 2019

Taxonomic Group	**Taxon** • **- epifaunal taxon not included in BIBI calculations**
Nemertea	Nemertina
Annelida : Polychaeta	Capitella capitata Fabricius
	Capitella jonesi (Hartman)
	Capitomastus aciculatus Hartman
	Clymenella torquata Leidy
	Demonax microphthalmus (Verrill)
	Drilonereis longa Webster
	Eteone heteropoda Hartman
	Eteone lactea Claparede
	Glycera dibranchiata Ehlers
	Glycera spp.
	Glycinde solitaria Webster
	Hermundura sp. A (Hartman)
	Hobsonia florida Hartman
	Leitoscoloplos spp.
	Loimia medusa Savigny
	Mediomastus ambiseta Hartman
	Neanthes succinea Frey and Leuckart
	Parahesione luteola Webster
	Paraprionospio pinnata Ehlers
	Pectinaria gouldii Verrill
	Phyllodoce arenae Webster
	Podarkeopsis levifuscina Hartmann-Schroder
	Spiochaetopterus costarum Webster
	Streblospio benedicti Webster
	Tharyx sp. A Doner
Annelida : Oligochaeta	Tubificoides spp. Group I
Mollusca : Gastropoda	Acteocina canaliculata Say
	Crepidula fornicata Linnaeus*
	Haminoea solitaria Say
	Mitrella lunata Say*
	Nassarius vibex Say
Mollusca : Bivalvia	Gemma gemma Totten
	Macoma balthica Linnaeus
	Mulinia lateralis Say
	Tellina agilis Stimpson

Taxonomic Group	Taxon • - epifaunal taxon not included in BIBI calculations
Arthropoda : Isopoda	Edotea triloba Say*
Taxonomic Group	**Taxon**
Arthropoda : Amphipoda	Ampelisca abdita Mills
	Cymadusa compta (Smith)*
	Eobrolgus spinosus (Holmes)
	Grandidierella spp.
	Melita nitida Smith*
Arthropoda : Mysidacea	Americamysis bigelowi (Tattersall)*
Arthropoda : Decapoda	Alpheus heterochaelis Say
	Callinectes sapidus Rathbun*
	Crangon septemspinosa Say*
	Ogyrides alphaerostris Kingsley
	Palaemonetes pugio Holthuis*
	Upogebia affinis Say
Phoronida	Phoronis spp.

*

Appendix C. Raw Data per sample site collected at Swimming Point Summer 2019

Table1.   Station Coordinates for Swimming Point 2019

Stratum=SWP

Station	Latitude in Decimal Degrees	Longitude in Decimal Degrees
26SP02	36.842501	-76.302121
26SP03	36.840842	-76.301853
26SP04	36.842815	-76.300731
26SP05	36.841564	-76.301985
26SP06	36.842687	-76.302389
26SP07	36.841893	-76.301735
26SP08	36.842091	-76.301337
26SP09	36.842541	-76.301549
26SP10	36.841935	-76.301635
26SP11	36.842444	-76.301160
26SP12	36.842271	-76.301644
26SP13	36.841940	-76.302119
26SP14	36.842408	-76.300881
26SP15	36.841718	-76.301152
26SP16	36.841228	-76.300777
26SP17	36.841436	-76.301035
26SP18	36.842689	-76.301501
26SP19	36.842455	-76.301923
26SP20	36.842693	-76.302247
26SP21	36.840972	-76.301914
26SP22	36.842127	-76.301088
26SP23	36.842778	-76.302214
26SP24	36.842967	-76.301265
26SP26	36.840924	-76.300815

Table2. Physical Data for Swimming Point 2019

Stratum=SWP

CBP Station Name	Sampling Date	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Temperature (deg. C)
26SP02	2019-09-20	2.1	20.9	4.93	24.9
26SP03	2019-09-20	1.5	20.9	4.85	25.4
26SP04	2019-09-20	3.1	20.9	4.46	24.6
26SP05	2019-09-20	3.5	20.4	4.12	24.5
26SP06	2019-09-20	1.9	20.9	5.10	25.3
26SP07	2019-09-20	3.5	21.0	4.86	24.6
26SP08	2019-09-20	2.6	20.9	4.78	25.1
26SP09	2019-09-20	2.3	20.9	4.72	25.3
26SP10	2019-09-20	3.8	20.9	4.40	24.5
26SP11	2019-09-20	2.7	21.0	5.03	25.2
26SP12	2019-09-20	2.7	21.0	5.06	25.3
26SP13	2019-09-20	2.3	20.9	5.01	25.4
26SP14	2019-09-20	2.5	21.0	4.87	25.0
26SP15	2019-09-20	2.5	20.9	4.87	25.1
26SP16	2019-09-23	1.7	20.7	4.84	24.3
26SP17	2019-09-23	1.7	20.6	4.66	24.2
26SP18	2019-09-23	1.1	20.5	5.03	24.3
26SP19	2019-09-23	1.2	20.5	5.26	24.5
26SP20	2019-09-23	1.2	20.6	5.34	24.4
26SP21	2019-09-23	1.2	20.7	5.81	25.2
26SP22	2019-09-23	2.0	20.7	5.45	25.2
26SP23	2019-09-23	1.5	20.6	5.72	25.2
26SP24	2019-09-23	1.5	20.8	5.80	25.5
26SP26	2019-09-23	1.7	20.7	5.78	24.9
26SP27	2019-09-23	2.3	20.7	5.10	24.7

Table 4. Sedimentary Data for RZP Project Monitoring Stations (Cruise #5 2019) (Continued).

Stratum=SWP

Station	Sand (% Weight)	Silt-Clay (% Weight)	Volatile Solids (%)
26SP02	84.3	15.7	0.67
26SP03	86.0	14.0	1.65
26SP04	62.6	37.4	3.02
26SP05	18.9	81.1	16.66
26SP06	76.6	23.4	4.75
26SP07	43.1	56.9	8.44
26SP08	57.6	42.4	3.11
26SP09	87.7	12.3	0.47
26SP10	26.7	73.3	13.38
26SP11	72.4	27.6	1.16
26SP12	77.4	22.6	1.25
26SP13	75.7	24.3	1.24
26SP14	71.7	28.3	2.71
26SP15	41.2	58.8	5.80
26SP16	28.7	71.3	6.58
26SP17	33.9	66.1	5.83
26SP18	82.3	17.7	0.87
26SP19	73.8	26.2	0.60
26SP20	65.9	34.1	1.28
26SP21	82.5	17.5	1.54
26SP22	69.7	30.3	1.84
26SP23	72.5	27.5	3.23
26SP24	78.8	21.2	1.08
26SP26	57.5	42.5	4.80
26SP27	42.9	57.1	5.24

Table 5. Total Community Parameters for RZP Project Monitoring Stations (Cruise #5 2019).

Yearly Cruise #=5

CBP Station Name	Total Species	Ind/sq.m	Total #	# of bivalves
26SP02	9	11818.18	0.568	0.545
26SP03	11	6136.36	0.659	0.636
26SP04	11	2204.55	1.500	1.477
26SP05	2	1795.45	0.091	0.091
26SP06	10	1431.82	1.932	1.932
26SP07	6	6477.27	0.955	0.955
26SP08	12	6090.91	0.614	0.591
26SP09	13	3159.09	0.727	0.705
26SP10	3	3500.00	0.136	0.136
26SP11	9	6772.73	0.477	0.477
26SP12	12	9022.73	0.568	0.545
26SP13	7	4681.82	0.432	0.432
26SP14	12	4909.09	0.432	0.386
26SP15	9	3568.18	0.841	0.841
26SP16	9	5295.45	1.023	1.000
26SP17	9	2295.45	1.068	1.068
26SP18	17	6863.64	0.818	0.773
26SP19	11	4886.36	0.500	0.455
26SP20	10	2545.45	0.318	0.318
26SP21	8	2090.91	0.386	0.386
26SP22	14	3704.55	0.477	0.455
26SP23	15	3704.55	0.818	0.795
26SP24	13	4659.09	0.955	0.955
26SP26	9	2113.64	0.977	0.977
26SP27	12	3090.91	1.295	1.295

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP02

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycera spp.	1	0.001
	Glycinde solitaria	1	0.001
	Hermundura sp. A	7	0.004
	Mediomastus ambiseta	431	0.012
	Paraprionospio pinnata	4	0.001
	Spiochaetopterus costarum	6	0.002
	Streblospio benedicti	66	0.002
Mollusca : Bivalvia	Macoma balthica	3	0.001
Arthropoda : Isopoda	Edotea triloba	1	0.001
STATION		**520**	**0.025**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP03

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Nemertea	Nemertina	1	0.002
Annelida : Polychaeta	Capitomastus aciculatus	97	0.011
	Eteone heteropoda	2	0.001
	Hermundura sp. A	5	0.004
	Mediomastus ambiseta	41	0.002
	Neanthes succinea	1	0.001
	Streblospio benedicti	103	0.003
Annelida : Oligochaeta	Tubificoides spp. Group I	15	0.002
Mollusca : Bivalvia	Macoma balthica	2	0.001
Arthropoda : Amphipoda	Grandidierella spp.	1	0.001
Arthropoda : Mysidacea	Americamysis bigelowi	2	0.001
STATION		**270**	**0.029**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP04

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Nemertea	Nemertina	1	0.025
Annelida : Polychaeta	Glycinde solitaria	3	0.001
	Hermundura sp. A	26	0.009
	Leitoscoloplos spp.	1	0.001
	Mediomastus ambiseta	8	0.001
	Parahesione luteola	2	0.001
	Paraprionospio pinnata	16	0.002
	Spiochaetopterus costarum	36	0.014
Mollusca : Bivalvia	Macoma balthica	2	0.001
Arthropoda : Decapoda	Ogyrides alphaerostris	1	0.001
	Upogebia affinis	1	0.010
STATION		**97**	**0.066**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).
Data have not been validated

Stratum=SWP Station=26SP05

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Mediomastus ambiseta	2	0.001
	Streblospio benedicti	77	0.003
STATION		**79**	**0.004**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP06

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Nemertea	Nemertina	1	0.001
Annelida : Polychaeta	Capitomastus aciculatus	1	0.001
	Leitoscoloplos spp.	4	0.033
	Mediomastus ambiseta	7	0.001
	Streblospio benedicti	33	0.001
Mollusca : Gastropoda	Mitrella lunata	2	0.001
Arthropoda : Amphipoda	Cymadusa compta	9	0.002
Arthropoda : Decapoda	Alpheus heterochaelis	2	0.029
	Callinectes sapidus	1	0.008
	Palaemonetes pugio	3	0.008
STATION		**63**	**0.085**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP07

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	2	0.002
	Leitoscoloplos spp.	9	0.023
	Mediomastus ambiseta	175	0.008
	Paraprionospio pinnata	10	0.005
	Podarkeopsis levifuscina	5	0.001
	Streblospio benedicti	84	0.003
STATION		**285**	**0.042**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP08

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Nemertea	Nemertina	1	0.001
Annelida : Polychaeta	Drilonereis longa	1	0.002
	Glycinde solitaria	2	0.002
	Hermundura sp. A	1	0.002
	Mediomastus ambiseta	227	0.006
	Paraprionospio pinnata	9	0.004
	Spiochaetopterus costarum	3	0.001
	Streblospio benedicti	14	0.001
Mollusca : Gastropoda	Acteocina canaliculata	1	0.001
	Nassarius vibex	1	0.004
Mollusca : Bivalvia	Macoma balthica	1	0.001
Phoronida	Phoronis spp.	7	0.002
STATION		**268**	**0.027**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP09

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Demonax microphthalmus	1	0.001
	Glycera dibranchiata	1	0.011
	Glycinde solitaria	1	0.001
	Hermundura sp. A	3	0.003
	Leitoscoloplos spp.	1	0.001
	Mediomastus ambiseta	110	0.004
	Spiochaetopterus costarum	4	0.004
	Streblospio benedicti	4	0.001
Mollusca : Gastropoda	Acteocina canaliculata	1	0.001
	Haminoea solitaria	2	0.001
Mollusca : Bivalvia	Macoma balthica	3	0.001
Arthropoda : Amphipoda	Ampelisca abdita	1	0.001
Phoronida	Phoronis spp.	7	0.002
STATION		**139**	**0.032**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP10

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Mediomastus ambiseta	7	0.001
	Paraprionospio pinnata	2	0.001
	Streblospio benedicti	145	0.004
STATION		**154**	**0.006**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP11

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
	Glycinde solitaria	8	0.002
	Hermundura sp. A	1	0.001
	Mediomastus ambiseta	236	0.006
	Paraprionospio pinnata	8	0.003
	Spiochaetopterus costarum	6	0.004
	Streblospio benedicti	28	0.001
Mollusca : Gastropoda	Acteocina canaliculata	3	0.001
Arthropoda : Mysidacea	Americamysis bigelowi	1	0.001
Arthropoda : Decapoda	Ogyrides alphaerostris	7	0.002
STATION		**298**	**0.021**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP12

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	1	0.001
	Hermundura sp. A	2	0.001
	Hobsonia florida	1	0.001
	Leitoscoloplos spp.	1	0.003
	Mediomastus ambiseta	337	0.008
	Paraprionospio pinnata	3	0.001
	Spiochaetopterus costarum	3	0.005
	Streblospio benedicti	45	0.001
Mollusca : Gastropoda	Acteocina canaliculata	1	0.001
Mollusca : Bivalvia	Mulinia lateralis	1	0.001
Arthropoda : Mysidacea	Americamysis bigelowi	1	0.001
Arthropoda : Decapoda	Palaemonetes pugio	1	0.001
STATION		**397**	**0.025**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP13

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Nemertea	Nemertina	1	0.001
Annelida : Polychaeta	Hermundura sp. A	7	0.005
	Mediomastus ambiseta	154	0.004
	Paraprionospio pinnata	1	0.001
	Phyllodoce arenae	1	0.001
	Spiochaetopterus costarum	13	0.006
	Streblospio benedicti	29	0.001
STATION		**206**	**0.019**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP14

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
	Glycinde solitaria	7	0.001
	Hermundura sp. A	4	0.001
	Loimia medusa	1	0.001
	Mediomastus ambiseta	170	0.004
	Paraprionospio pinnata	12	0.005
	Streblospio benedicti	10	0.001
Mollusca : Gastropoda	Acteocina canaliculata	3	0.001
Mollusca : Bivalvia	Macoma balthica	2	0.001
	Mulinia lateralis	1	0.001
Arthropoda : Mysidacea	Americamysis bigelowi	1	0.001
Arthropoda : Decapoda	Ogyrides alphaerostris	3	0.001
Phoronida	Phoronis spp.	2	0.001
STATION		**216**	**0.019**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP15

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	2	0.001
	Hermundura sp. A	10	0.010
	Leitoscoloplos spp.	6	0.009
	Mediomastus ambiseta	100	0.003
	Paraprionospio pinnata	12	0.004
	Spiochaetopterus costarum	6	0.006
	Streblospio benedicti	17	0.001
Arthropoda : Amphipoda	Ampelisca abdita	1	0.001
Arthropoda : Decapoda	Ogyrides alphaerostris	3	0.002
STATION		**157**	**0.037**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP16

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	3	0.001
	Hermundura sp. A	16	0.013
	Leitoscoloplos spp.	5	0.012
	Mediomastus ambiseta	163	0.005
	Paraprionospio pinnata	17	0.004
	Spiochaetopterus costarum	9	0.007
	Streblospio benedicti	18	0.001
Mollusca : Bivalvia	Tellina agilis	1	0.001
Arthropoda : Decapoda	Ogyrides alphaerostris	1	0.001
STATION		**233**	**0.045**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP17

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	5	0.001
	Hermundura sp. A	19	0.015
	Leitoscoloplos spp.	2	0.006
	Mediomastus ambiseta	41	0.002
	Paraprionospio pinnata	11	0.003
	Spiochaetopterus costarum	17	0.011
	Streblospio benedicti	4	0.001
Mollusca : Gastropoda	Haminoea solitaria	1	0.001
Arthropoda : Decapoda	Upogebia affinis	1	0.007
STATION		**101**	**0.047**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP18

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Clymenella torquata	1	0.001
	Glycinde solitaria	7	0.001
	Hermundura sp. A	6	0.004
	Hobsonia florida	1	0.001
	Leitoscoloplos spp.	5	0.009
	Mediomastus ambiseta	243	0.005
	Spiochaetopterus costarum	5	0.005
	Tharyx sp. A Doner	1	0.001
Annelida : Oligochaeta	Tubificoides spp. Group I	2	0.001
Mollusca : Gastropoda	Crepidula fornicata	2	0.001
	Haminoea solitaria	19	0.001
Mollusca : Bivalvia	Gemma gemma	1	0.001
	Macoma balthica	2	0.001
Arthropoda : Amphipoda	Ampelisca abdita	1	0.001
	Grandidierella spp.	2	0.001
Arthropoda : Decapoda	Callinectes sapidus	1	0.001
Phoronida	Phoronis spp.	3	0.001
STATION		**302**	**0.036**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP19

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycera dibranchiata	1	0.008
	Glycinde solitaria	1	0.001
	Hermundura sp. A	1	0.001
	Mediomastus ambiseta	178	0.005
	Spiochaetopterus costarum	3	0.001
	Streblospio benedicti	13	0.001
Mollusca : Gastropoda	Acteocina canaliculata	8	0.001
Mollusca : Bivalvia	Gemma gemma	4	0.001
	Tellina agilis	3	0.001
Arthropoda : Mysidacea	Americamysis bigelowi	1	0.001
Phoronida	Phoronis spp.	2	0.001
STATION		**215**	**0.022**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP20

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	1	0.001
	Hermundura sp. A	2	0.002
	Mediomastus ambiseta	80	0.002
	Neanthes succinea	1	0.001
	Paraprionospio pinnata	1	0.001
	Pectinaria gouldii	1	0.001
	Spiochaetopterus costarum	9	0.003
	Streblospio benedicti	14	0.001
Arthropoda : Mysidacea	Americamysis bigelowi	2	0.001
Phoronida	Phoronis spp.	1	0.001
STATION		**112**	**0.014**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP21

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Capitomastus aciculatus	1	0.001
	Glycinde solitaria	3	0.002
	Hermundura sp. A	1	0.003
	Loimia medusa	1	0.001
	Mediomastus ambiseta	57	0.003
	Spiochaetopterus costarum	3	0.005
	Streblospio benedicti	25	0.001
Phoronida	Phoronis spp.	1	0.001
STATION		**92**	**0.017**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP22

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	6	0.001
	Hermundura sp. A	4	0.003
	Leitoscoloplos spp.	2	0.001
	Mediomastus ambiseta	117	0.003
	Neanthes succinea	1	0.001
	Paraprionospio pinnata	12	0.004
	Phyllodoce arenae	1	0.001
	Spiochaetopterus costarum	4	0.001
	Streblospio benedicti	3	0.001
Mollusca : Gastropoda	Acteocina canaliculata	3	0.001
Mollusca : Bivalvia	Macoma balthica	4	0.001
Arthropoda : Decapoda	Crangon septemspinosa	1	0.001
	Ogyrides alphaerostris	2	0.001
Phoronida	Phoronis spp.	3	0.001
STATION		**163**	**0.021**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP23

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Capitella capitata	2	0.001
	Capitella jonesi	1	0.001
	Capitomastus aciculatus	4	0.002
	Eteone lactea	1	0.001
	Hermundura sp. A	3	0.007
	Leitoscoloplos spp.	3	0.009
	Mediomastus ambiseta	73	0.002
	Neanthes succinea	3	0.001
	Paraprionospio pinnata	1	0.001
	Spiochaetopterus costarum	9	0.005
	Streblospio benedicti	57	0.002
Mollusca : Bivalvia	Tellina agilis	1	0.001
Arthropoda : Amphipoda	Cymadusa compta	3	0.001
	Grandidierella spp.	1	0.001
	Melita nitida	1	0.001
STATION		**163**	**0.036**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP24

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	8	0.001
	Hermundura sp. A	7	0.003
	Leitoscoloplos spp.	2	0.001
	Mediomastus ambiseta	139	0.002
	Neanthes succinea	2	0.001
	Paraprionospio pinnata	4	0.001
	Phyllodoce arenae	2	0.001
	Spiochaetopterus costarum	24	0.024
	Streblospio benedicti	4	0.001
	Tharyx sp. A Doner	1	0.001
Mollusca : Gastropoda	Haminoea solitaria	3	0.001
Arthropoda : Amphipoda	Ampelisca abdita	2	0.001
Phoronida	Phoronis spp.	7	0.004
STATION		**205**	**0.042**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP26

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Glycinde solitaria	4	0.001
	Hermundura sp. A	13	0.019
	Leitoscoloplos spp.	4	0.005
	Mediomastus ambiseta	42	0.001
	Paraprionospio pinnata	3	0.002
	Podarkeopsis levifuscina	1	0.001
	Spiochaetopterus costarum	13	0.012
	Streblospio benedicti	12	0.001
Arthropoda : Amphipoda	Grandidierella spp.	1	0.001
STATION		**93**	**0.043**

Table 6. Numbers of individuals and Ash-Free Dry Weight Biomass at RZP Project Monitoring Stations (Random Cruise 2019) (Continued).

Stratum=SWP Station=26SP27

Taxonomic Group	Taxon	Abundance	Ash Free Dry Wt. (g C)
Annelida : Polychaeta	Hermundura sp. A	39	0.024
	Leitoscoloplos spp.	7	0.016
	Mediomastus ambiseta	68	0.001
	Parahesione luteola	1	0.001
	Paraprionospio pinnata	7	0.003
	Pectinaria gouldii	1	0.001
	Spiochaetopterus costarum	6	0.006
	Streblospio benedicti	3	0.001
Arthropoda : Amphipoda	Eobrolgus spinosus	1	0.001
	Melita nitida	1	0.001
Arthropoda : Decapoda	Ogyrides alphaerostris	1	0.001
Phoronida	Phoronis spp.	1	0.001
STATION		**136**	**0.057**