OLD DOMINION UNIVERSITY

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

BENTHIC BIOLOGICAL MONITORING PROGRAM OF THE ELIZABETH RIVER WATERSHED (1999 and 2019)

Prepared by

Principal Investigator:
Dr. Daniel M. Dauer

Submitted to:
Josef Rieger
Deputy Director of Restoration
The Elizabeth River Project
5205 Colley Ave
Norfolk, Virginia 23508

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EXECUTIVE SUMMARY

A study of the macrobenthic communities of the Elizabeth River watershed was conducted in summer 1999 and again in summer 2019 – a 20-year span. The primary objective of the Benthic Biological Monitoring Program of the Elizabeth River watershed was to characterize the ecological condition of regional areas of the tidal waters of the Elizabeth River watershed as indicated by the structure of the benthic communities. These characterizations are based upon application of the Benthic Index of Biotic Integrity (BIBI) developed for the Chesapeake Bay to five primary strata - the Mainstem of the river, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch. Within each stratum 25 samples were randomly allocated in a probability-based sampling design.

Comparing 1999 data with 2019 data the best benthic community condition was in the Mainstem of the river. The Mainstem had the highest average B-IBI value in both 1999 and 2019; the B-IBI value did not change (B-IBI = 2.8). The area of degraded benthic community condition declined from 52% (1999) to 44% (2019). The Southern Branch was the only stratum to show a significant improvement in benthic community condition compared to the 1999 data. The 1999 average B-IBI value of 2.0 significantly increased to 2.5 in 2019. This B-IBI value is near the marginal category for the Chesapeake Bay of 2.6 – 2.9. In addition, the area of degraded benthic community condition declined from 96% (1999) to 64% (2019). Especially significant was the decline in the Southern Branch of severely degraded bottom from 64% (1999) to 36% (2019). The Lafayette River average B-IBI declined significantly from 2.6 (1999) to 2.1 (2019) and the area of degraded benthic community condition increased from 72% (1999) to 92% (2019). The Eastern Branch average B-IBI declined significantly from 2.3 (1999) to 1.8 (2019) and the area of degraded benthic community condition increased from 80% (1999) to 100% (2019). The Western Branch average B-IBI declined slightly from 2.3 (1999) to 2.2 (2019) and the area of degraded benthic community condition decreased slightly from 84% (1999) to 80% (2019).

The general pattern of increased degradation in the Elizabeth River watershed comparing the 1999 data to the 2019 data was also found outside the watershed. The polyhaline benthic communities of the Elizabeth River watershed are most comparable to the benthic communities of the lower James River and to the Virginia Mainstem. Both regions showed a similar increase in levels of degraded benthic community condition comparing 1999 to 2019 using the Chesapeake Bay random monitoring program data.

In summary, the increased benthic community degradation seen in the 2019 data also occurred outside of the Elizabeth River watershed. Clearly larger scale drivers of ecosystem condition affected the patterns observed in the Elizabeth River watershed comparing 1999 and 2019. Further analyses of large-scale and long-term patterns in water column parameters (e.g. bottom dissolved oxygen, salinity, temperature, suspended solids and nutrients) are required.

INTRODUCTION

A study of the macrobenthic communities of the Elizabeth River watershed was conducted in summer 1999 and again in summer 2019. The objective of the Benthic Biological Monitoring Program of the Elizabeth River watershed was to characterize the ecological condition of regional areas of the tidal waters of the Elizabeth River watershed of the Chesapeake Bay as indicated by the structure of the benthic communities. These characterizations are based upon application of benthic restoration goals and the Benthic Index of Biotic Integrity (BIBI) developed for the Chesapeake Bay to five primary strata - the Mainstem of the River, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch. Within each stratum samples are randomly allocated in a probability-based sampling design. A probability-based sampling design allows calculation of areal estimates of the ecological condition 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 (Dauer 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009).

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).

The Chesapeake Bay Index of Biotic Integrity

The Benthic Index of Biotic Integrity (B-IBI) was developed for macrobenthic communities of the Chesapeake Bay (Weisberg et al. 1997). The index defines expected conditions based upon the distribution of metrics from reference samples. Reference samples were collected from locations relatively free of anthropogenic stress. In calculating the index, categorical values are assigned for various descriptive metrics by comparison with thresholds of the distribution of metrics from reference samples. The result is a multi-metric index of biotic condition, frequently referred to as an index of biotic integrity (IBI). The analytical approach is 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 are possible.

A six-step procedure was used to develop the index: acquire and standardize data sets from a number of monitoring programs; temporally and spatially stratify data sets to identify seasons and habitat types; identify reference sites; select benthic community metrics; select metric thresholds for scoring; and validate 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 as part of the monitoring program 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 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).

Metrics to include in the index were selected from a candidate list proposed by benthic experts of the Chesapeake Bay. Selected metrics had to (1) differ significantly between reference and all other sites in the data set and (2) differ in an ecologically meaningful manner. Reference sites were selected as those sites 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 (see Table 2 in Weisberg et al. 1997).

The habitat-specific metrics are 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. The IBI approach involves scoring each metric as 5, 3, or 1, depending on whether its value at a site approximates, deviates slightly, or deviates greatly from conditions at reference sites (Karr et al. 1986). Threshold values are established as approximately the 5th and 50th (median) percentile values for reference sites in each habitat. For each metric, values below the 5th percentile are scored as 1; values between the 5th and 50th percentiles are scored as 3, and values above the 50th percentile are scored as 5. Metric scores are combined into an index by computing the mean score across all metrics for which thresholds were developed. Assemblages with an average score less than three are considered stressed, as they have metric values that on average are less than values at the poorest reference sites. Two of the metrics, abundance and biomass, respond bimodally; that is, the response can be greater than at reference sites with moderate degrees of stress and less than at reference sites with higher degrees of stress (Pearson and Rosenberg 1978; Dauer and Conner 1980; Ferraro et al. 1991). For these metrics, the scoring is modified so that both exceptionally high (those exceeding the 95th percentile at reference sites) and low (<5th percentile) responses are scored as a 1. Values between the 5th and 25th percentiles or between the 75th and 95th percentiles are scored as 3, and values between the 25th and 75th percentiles of the values at reference sites are scored as 5. The index was validated by examining its response at a new set of reference sites and a new set of sites with known environmental stress. Data used for validation were collected between 1992 and 1994 and were independent of data used to calibrate the index. The B-IBI classified 93% of the validation sites correctly (Weisberg et al. 1997).

Values for the B-IBI range from 1.0 to 5.0. 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 (Dauer et al. 2006a,b,c).

METHODS

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

Strata Sampled

The Elizabeth River watershed was divided into five primary strata - the Mainstem of the river, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch (Figure 1).

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 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 each stratum 25 random locations were sampled using a 0.04 m^2 Young grab. 014). 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:

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

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).

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 ^oC and ashing at 550 ^oC 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 was estimated by the loss upon ignition method as described above and presented as percentage of the weight of the sediment.

RESULTS

Mainstem

Environmental Parameters

All physical, chemical, and sedimentary parameters are summarized in Table 1 for the 1999 data and Table 2 for the 2019 data. Water depths varied from 0.7 to 18 m reflecting shoal and channel depths and a mean depth of 5.8m in 1999 and 7.8m in 2019. All salinity values were in the polyhaline range with values from 19.3 to 26.4 ppt, and a mean value of 22.4 ppt in 1999 and 21.8 ppt in 2019. Bottom dissolved oxygen was generally high with values from 4.5 to 10.4 ppm, and a mean value of 6.4 ppm in 1999 and 5.2 ppm in 2019. Silt-clay content varied widely from 1.0 to 95.1 %, and a mean value of 52.6% in 1999 and 48.4% in 2019. Consistent with the wide variation in silt-clay content, total volatile solids also varied widely from 0.2 to 14.0%, and a mean value of 4.8% in 1999 and 5.4% in 2019.

Benthic Community

Benthic community parameters of the Mainstem including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 3 for the 1999 data and

Table 4 for the 2019 data. In general, the Mainstem of the river had the best benthic community condition as indicated by the highest mean B-IBI value, biomass and Shannon Index (Table 31). In addition, the composition of the community was generally the best balanced with pollution indicative species being low and pollution sensitive species having the highest values among the strata studied (Table 31). There were no significant differences comparing the 1999 and 2019 data in the value of B-IBI, abundance, biomass, Shannon Index or species richness (Figure 2-6).

The Mainstem of the river had the lowest level of degraded bottom (B-IBI values less than 3.0) among the primary strata (Table 32) with a slight decline in the area of degraded bottom from 52% (1999) to 44% (2019. In addition, the percent of bottom with severely degraded benthos (B-IBI l ≤ 2.0) was the lowest of the Elizabeth River strata and unchanged between 1999 and 2019 (Table 32). The top two density dominants were the same in both 1999 and 2019, the polychaete species *Mediomastus ambiseta* and *Paraprionspio pinnata* (Tables 5 and 6).

Southern Branch

Environmental Parameters

All physical, chemical, and sedimentary parameters are summarized in Table 7 for the 1999 data and Table 8 for the 2019 data. Water depths varied from 1 to 14 m reflecting shoal and channel depths and a mean depth of 4.7m in 1999 and 6.1m in 2019. Most salinity values were in the polyhaline range (20 of 25 stations in both years), and a mean value of 18.9 ppt in 1999 and 19.3 ppt in 2019. Bottom dissolved oxygen values were the lowest among the five strata with a mean value of 2.4 ppm in 1999 and 13 stations below 2.0 ppm. The 2019 bottom dissolved oxygen values were higher with an average of 3.9 ppm and no stations below 2.0 ppm. Silt-clay content varied widely from 4.6 to 97.4%, and a mean value of 46.6% in 1999 and 47.0 in 2019. Consistent with the wide variation in silt-clay content, total volatile solids also varied widely from 1.0 to 19.3%, and a mean value of 6.4% in 1999 and 7.8% in 2019.

Benthic Community

Benthic community parameters of the Southern Branch including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 9 for the 1999 data and Table 10 for the 2019 data. In general, the Southern Branch had the lowest B-IBI value in 1999 (2.0) and increased significantly to a value of 2.5 in 2019 (Table 31 and Figure 2). There were no significant differences comparing the 1999 and 2019 data in the value of abundance, biomass, Shannon Index or species richness (Figure 3-6).

The Southern Branch of the river had the highest level of degraded bottom (B-IBI values less than 3.0) among the primary strata in 1999 with a value of 96% (Table 32). The 2019 value of degraded bottom declined to 64% with a large decline in the area with severely degraded benthic condition – 64% in 1999 and 36% in 2019. There were major changes in the density dominant species including (1) the top four density dominant species of 1999 all decreased in abundance in 2019 (the polychate *Streblospio benedicti* from 2,086 to 225 individuals per m^2, the polychaete *Paraprionospio pinnata* from 527 to 69 individuals per m^2, the oligochaete *Tubificoides* spp Group I from 229 to 100 individuals per m^2, and the polychaete *Glycinde solitaria* from 154 to 44 individuals per m^2), (2) the large increase in abundance of the polychaete *Mediomastus ambiseta* from 124 to 1,766 individuals per m^2, and (3) the dominance of the non-indigenous polychaete *Hermundura americana* with 472 individuals per m^2.

Lafayette River

Environmental Parameters

All physical, chemical, and sedimentary parameters are summarized in Table 13 for the 1999 data and Table 14 for the 2019 data. Water depths varied from 0.5 to 4.9 m with a mean depth of 1.4m in 1999 and 2.1m in 2019. Most salinity values were in the polyhaline range with a mean value of 21.1 in both 1999 and 2019. Bottom dissolved oxygen values were generally high with a mean value of 7.3 ppm in 1999 and 5.3 ppm in 2019. Silt-clay content varied widely from 2.2 to 99.0%, and a mean value of 57.7% in 1999 and 63.4% in 2019. Consistent with the wide variation in silt-clay content, total volatile solids also varied widely from 0.4 to 16.1%, and a mean value of 5.8% in 1999 and 7.3% in 2019.

Benthic Community

Benthic community parameters of the Lafayette River including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 15 for the 1999 data and Table 16 for the 2019 data. The Lafayette River had the second highest B-IBI value in 1999 (2.6) but had a significant decrease to the second worst value (2.1) in 2019 (Table 31 and Figure 2). Abundance increased (Table 31, Figure 3) but biomass values decreased (Table 31, Figure 5). Both the Shannon diversity index and species richness significantly decreased (Table 31, Figures 4 and 6).

For the Lafayette River the level of degraded bottom (B-IBI values less than 3.0) increased from 72% in 1999 to 92% in 2019 (Table 32). Only the Eastern Branch had a higher level of degraded benthic community condition. The percentage of severely degraded bottom increased from a value of 28% in 1999 to 60% in 2019 (Table 32).

Comparing the 1999 density dominants to those of 2019: (1) the density of the polychate *Streblospio benedicti* was similar with 1,105 and 998 individuals per m^2, (2) there was a large increase in abundance of the polychaete *Mediomastus ambiseta* from 684 to 3,933 individuals per m^2, (3) the amphipod *Leptocheirus plumulosus* averaged 633 individuals per m^2 in 1999 and none were collected in 2019, (4) the oligochaete *Tubificoides heterochaetus* averaged 172 individuals per m^2 in 1999 and none were collected in 2019, (5) the oligochaete *Tubificoides* spp Group I decreased from 508 to 55 individuals per m^2, and (6) the increase in the polychaete *Paraprionospio pinnata* from 44 to 214 individuals per m^2. The non-indigenous polychaete species *Hermundura americana* was found with low abundance at 84 individuals per m^2.

Western Branch

Environmental Parameters

All physical, chemical, and sedimentary parameters are summarized in Table 19 for the 1999 data and Table 20 for the 2019 data. Water depths varied from 1.0 to 7.0m with a mean depth of 1.7m in 1999 and 2.9m in 2019. All salinity values were in the polyhaline range with a mean value of 22.5 in 1999 and 22.8 in 2019. Bottom dissolved oxygen values were generally high with a mean value of 6.8 ppm in 1999 and 5.9 ppm in 2019. Silt-clay content varied widely from 0.9 to 99.1%, and a mean value of 73.5% in 1999 and 59.1% in 2019. Consistent with the wide variation in silt-clay content, total volatile solids also varied widely from 0.3 to 9.6%, and a mean value of 5.4% in 1999 and 5.9% in 2019.

Benthic Community

Benthic community parameters of the Western Branch including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 21 for the 1999 data and Table 22 for the 2019 data. The Western Branch B-IBI value was intermediate in value both in 1999 (2.3) and in 2019 (2.2) (Table 31 and Figure 2). Abundance increased significantly in 2019 (Table 31, Figure 3) but biomass values did not change significantly (Table 31, Figure 5). Both the Shannon diversity index and species richness significantly decreased (Table 31, Figures 4 and 6).

For the Western Branch the level of degraded bottom (B-IBI values less than 3.0) did not change much with a value of 84% in 1999 and 80% in 2019 (Table 32). Consistent with the Lafayette River and Eastern Branch, the percentage of severely degraded bottom increased from a value of 40% in 1999 to 52% in 2019 (Table 32).

Comparing the 1999 density dominants to those of 2019: (1) there was a large increase in abundance of the polychaete *Mediomastus ambiseta* from 632 to 3,218 individuals per m^2, (2) the density of the polychate *Streblospio benedicti* decreased from 1,081 to 611 individuals per m^2, (3) the oligochaete *Tubificoides* spp Group I decreased from 125 to 4 individuals per m^2, (4) the amphipod *Leptocheirus plumulosus* averaged 85 individuals per m^2 in 1999 and none were collected in 2019, (5) the oligochaete *Tubificoides heterochaetus* averaged 240 individuals per m^2 in 1999 and none were collected in 2019, and (6) the polychaete *Heteromstus filiformis* averaged 127 individuals per m^2 in 1999 and none were collected in 2019. The non-indigenous polychaete species *Hermundura americana* had the third highest density in 2019 with 235 individuals per m^2.

Eastern Branch

Environmental Parameters

All physical, chemical, and sedimentary parameters are summarized in Table 25 for the 1999 data and Table 26 for the 2019 data. Water depths varied from 0.7 to 11.9m with a mean depth of 3.6m in 1999 and 3.0m in 2019. Most salinity values were in the polyhaline range but with several high mesohaline values in 2019 for stations sampled on August 23, 2019. Mean salinity values were 19.7 in 1999 and 17.7 in 2019. Bottom dissolved oxygen values were generally high with a mean value of 4.5 ppm in 1999 and 4.6 ppm in 2019; however, stations near the mouth of the Eastern Branch (latitudes between 76.27 and 76. 29) in 2019 had values below 3.0 ppm. Silt-clay content varied widely from 4.6 to 97.1%, and a mean value of 64.9% in 1999 and 75.0% in 2019. Consistent with the wide variation in silt-clay content, total volatile solids also varied widely from 0.6 to 22.8%, and a mean value of 9.4% in 1999 and 8.3% in 2019. The Eastern Branch average total volatile solids were the highest of the five strata of the Elizabeth River watershed.

Benthic Community

Benthic community parameters of the Eastern Branch including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 27 for the 1999 data and Table 28 for the 2019 data. The Eastern Branch B-IBI value was the lowest in the watershed and significantly decreased from 1999 (2.3) to 2019 (1.8) (Table 31 and Figure 2). Consistent with the patterns in the Lafayette River and Western Branch, abundance increased in 2019 (Table 31, Figure 3) but biomass values did not change significantly (Table 31, Figure 5). Also consistent with the patterns in the Lafayette River and Western Branch, both the Shannon diversity index and species richness significantly decreased (Table 31, Figures 4 and 6).

For the Eastern Branch, the level of degraded bottom (B-IBI values less than 3.0) increased from 80% in 1999 to 100% in 2019 (Table 32). Consistent with the Lafayette River and Western Branch, the percentage of severely degraded bottom increased from a value of 48% in 1999 to 84% in 2019 (Table 32).

Comparing the 1999 density dominants to those of 2019, the pattern in the Eastern Branch was very similar to the Western Branch : (1) there was a large increase in abundance of the polychaete *Mediomastus ambiseta* from 146 to 2,137 individuals per m^2, (2) the density of the polychate *Streblospio benedicti* decreased from 1,661 to 1,179 individuals per m^2, (3) the amphipod *Leptocheirus plumulosus* decreased from 289 to 20 individuals per m^2 , (4) the oligochaete *Tubificoides heterochaetus* averaged 116 individuals per m^2 in 1999 and none were collected in 2019, and (5) the polychaete *Heteromstus filiformis* averaged 228 individuals per m^2 in 1999 and none were collected in 2019. The non-indigenous polychaete species *Hermundura americana* was found with low abundance at 95 individuals per m^2.

Discussion

The condition of the macrobenthic communities of the Elizabeth River watershed was characterized for five strata consisting of the Mainstem of the River, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch with data collected in summer 1999 compared to data collected in summer 2019. Comparing 1999 data with 2019 data the major patterns were:

(1) the best benthic community condition is in the Mainstem of the river. The Mainstem had the highest average B-IBI value in both 1999 and 2019, the B-IBI value did not change (B-IBI = 2.8). This B-IBI value is near the goal of a value of 3.0 for the Chesapeake Bay. The Mainstem also had the lowest areal level of degradation and this estimate declined from 52% to 44% comparing 1999 and 2019. None of the major benthic metrics (abundance, biomass, species diversity and species richness) changed significantly.

(2) the Southern Branch was the only stratum to show a significant improvement in benthic community condition compared to the 1999 data. The 1999 average B-IBI value of 2.0 significantly increased to 2.5 in 2019. This B-IBI value is near the marginal category for the Chesapeake Bay of 2.6 – 2.9. The areal estimate of degraded bottom declined greatly from 96% to 64%. Among the major benthic metrics (abundance, biomass, species diversity and species richness) only biomass had a marginally significant change – a decrease.

(3) for the other three branches (Lafayette River, Western Branch, Eastern Branch) the average B-IBI value declined from 1999 to 2019 and significantly so for the Lafayette River and the Eastern Branch. The areal level of degradation increased in both the Lafayette River and the Eastern Branch (to 92% and 100%, respectively) and the areal estimate of severely degraded bottom increased in all three branches.

(4) Abundance increased in the Lafayette River, Western Branch, Eastern Branch, primarily to the large increase in density of the polychaete *Mediomastus ambiseta* in all three branches.

(5) Species diversity and species richness significantly decreased in the Lafayette River, Western Branch, Eastern Branch.

(6) The areal estimates of bottom degradation in all branches except the Mainstem was higher in than the 2019 estimate for all Virginia tidal waters of 48% except for the Mainstem (44%).

The general pattern of increased degradation in the Elizabeth River watershed comparing the 1999 data to the 2019 data was also found outside the watershed. Indeed, seven of the ten benthic strata (Figure 7) showed increased levels of degradation in 2019 (Figure 8). The polyhaline benthic communities of the Elizabeth River watershed are most comparable to the benthic communities of the lower James River and to the Virginia Mainstem. Both strata showed a similar increase in levels of degraded benthic community condition (Figures 8, 9, and 10). The patterns of change in benthic community composition seen in the Lafayette River, Western Branch and Eastern Branch were also seen in the lower James River benthic communities (Tables 33 and 34): (1) a large increase in abundance of the polychaete *Mediomastus ambiseta* from 783 to 1,823 individuals per m^2, (2) decrease in abundance of the polychate *Streblospio benedicti* from 737 to 79 individuals per m^2, (3) the oligochaete *Tubificoides* spp Group I decreased from 129 to 73 individuals per m^2, (4) the oligochaete *Tubificoides heterochaetus* averaged 310 individuals per m^2 in 1999 and none were collected in 2019, and (5) the polychaete *Heteromstus filiformis* averaged 119 individuals per m^2 in 1999 and none were collected in 2019. The non-indigenous polychaete species *Hermundura americana* had the fourth highest density in 2019 with 127 individuals per m^2.

In summary, the increased benthic community degradation seen in the 2019 data also occurred outside of the Elizabeth River watershed. Clearly larger scale drivers of ecosystem condition affected the patterns observed in the Elizabeth River watershed comparing 1999 and 2019.

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Figures

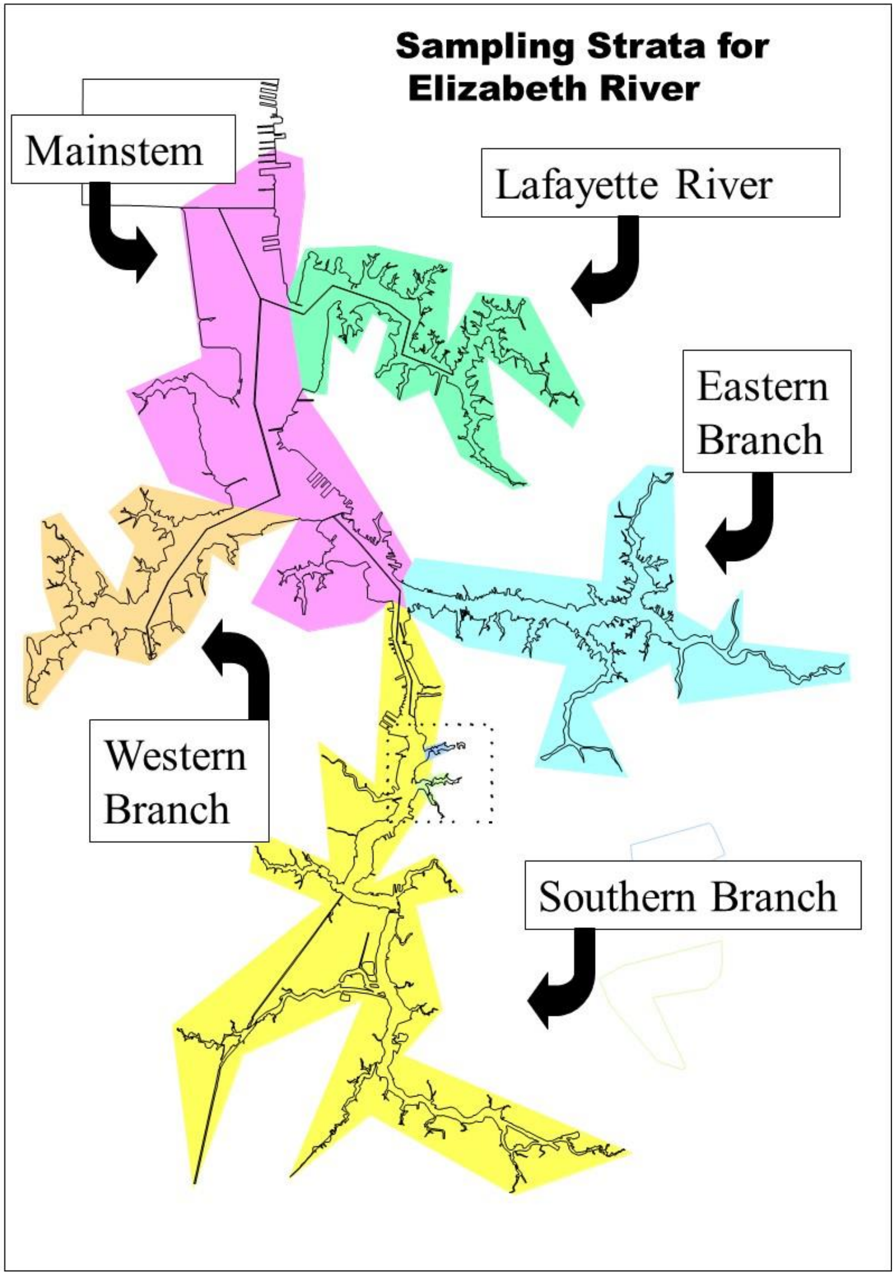


Figure 1. Elizabeth River watershed showing the five sampling strata.

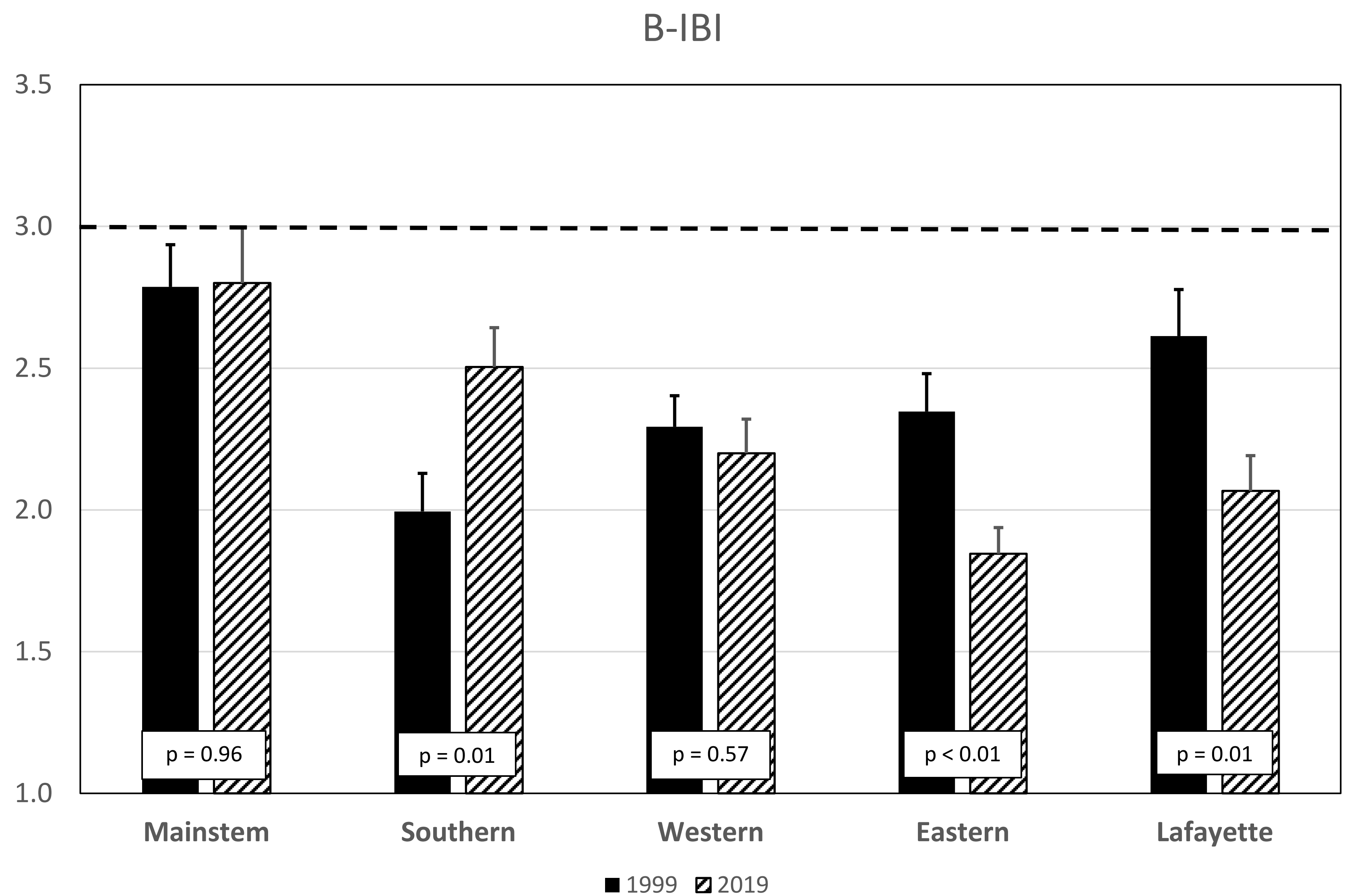


Figure 2. Average values for the Benthic Index of Biotic Integrity (BIBI of Weisberg et al. 1997; Alden et al, 2002) in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings. Values below 3.0 indicate degraded benthic community condition. P values for t-test indicated comparing the 1999 and 2019 means.

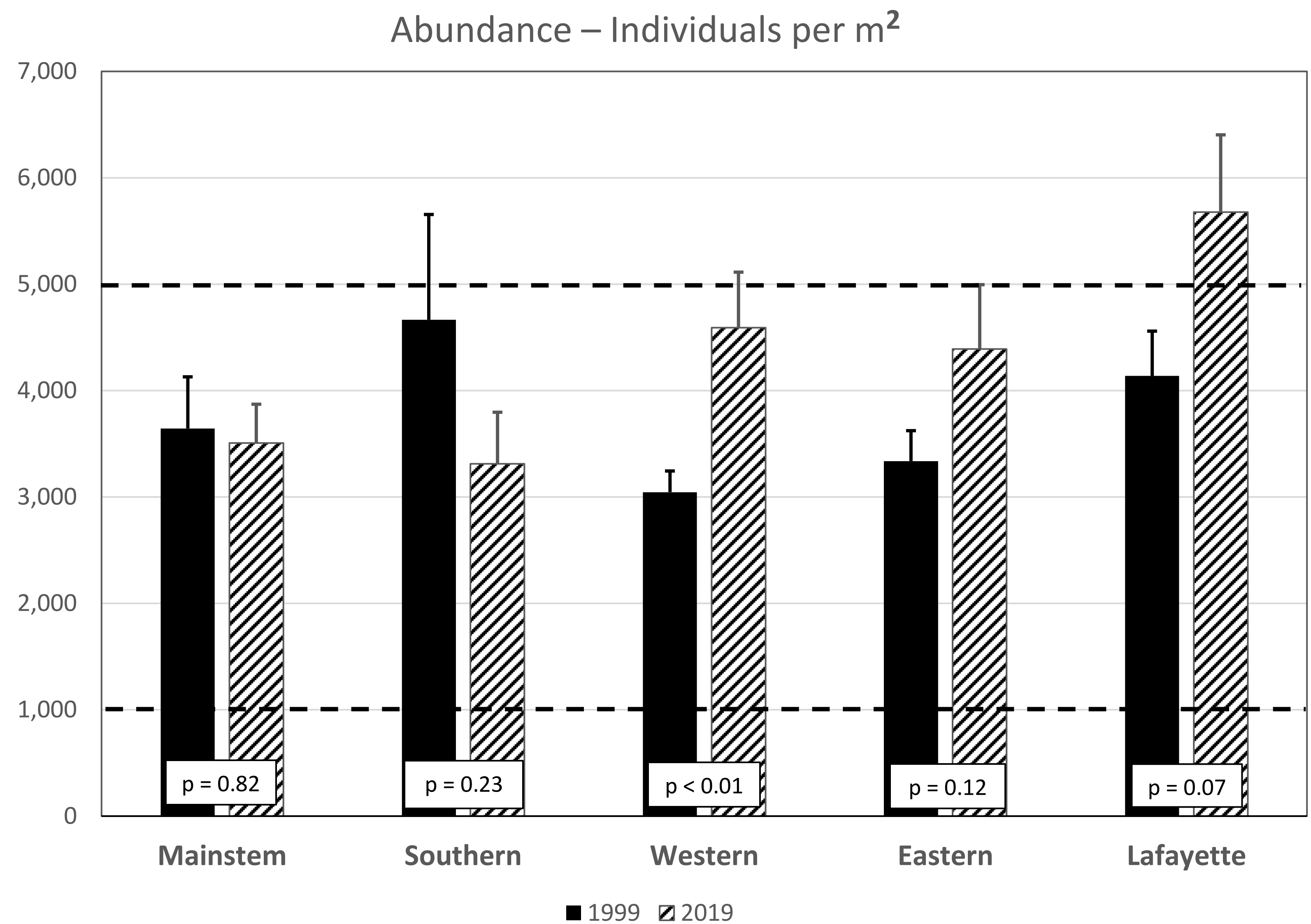


Figure 3. Average abundance of individuals per m^2 in each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings. Dashed lines indicate values of abundances that indicate too much or too little abundance relative to the restoration goals in Weisberg et al. 1997. P values for t-test indicated comparing the 1999 and 2019 means.

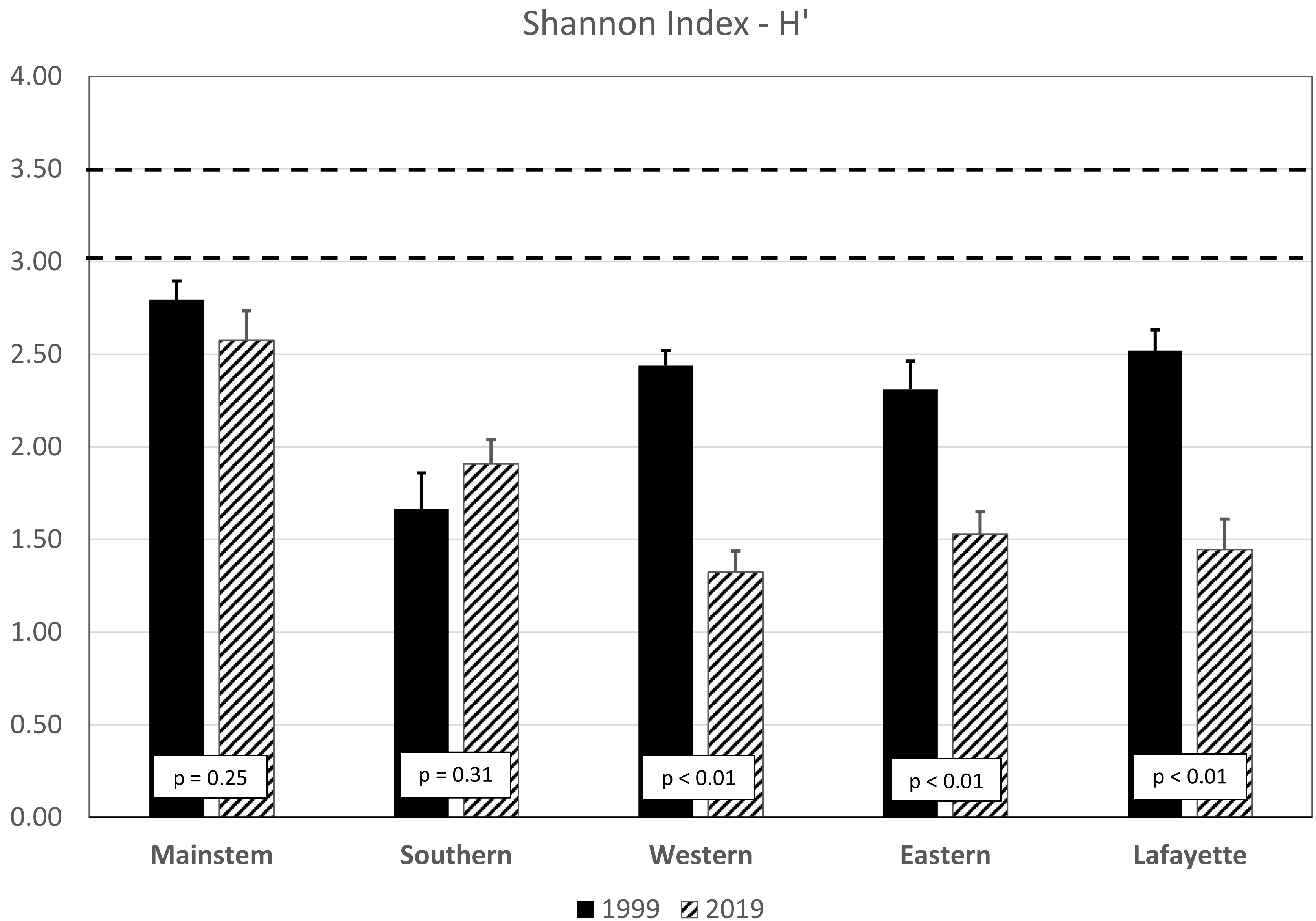


Figure 4. Average values for the Shannon diversity index for each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings. Dashed lines indicate values below which degraded benthic community condition is indicated (Weisberg et al. 1997). P values for t-test indicated comparing the 1999 and 2019 means.

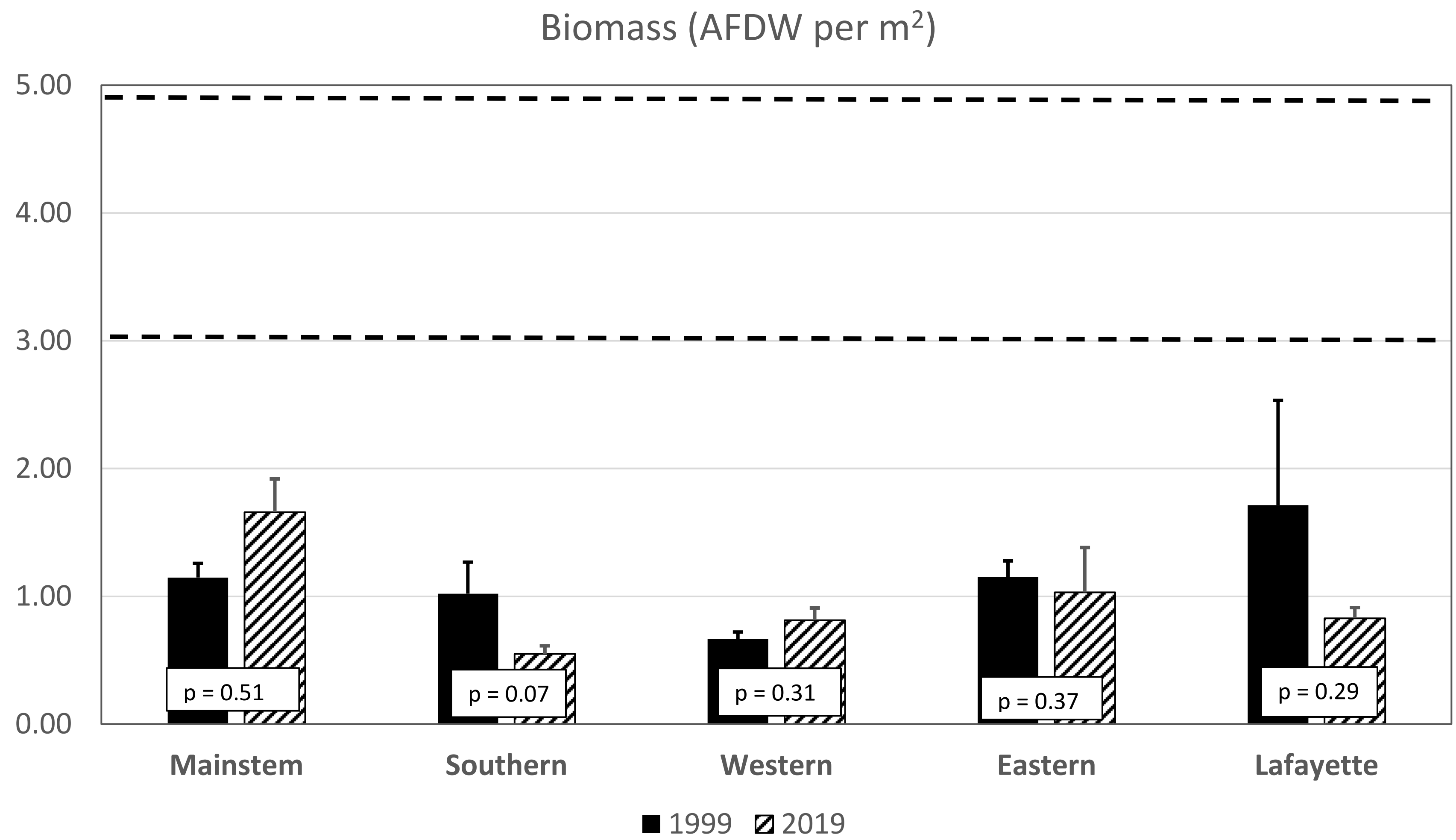


Figure 5. Average values for biomass (AFDW per m2) for each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings. Dashed lines indicate values below which degraded benthic community condition is indicated (Weisberg et al. 1997). P values for t-test indicated comparing the 1999 and 2019 means.

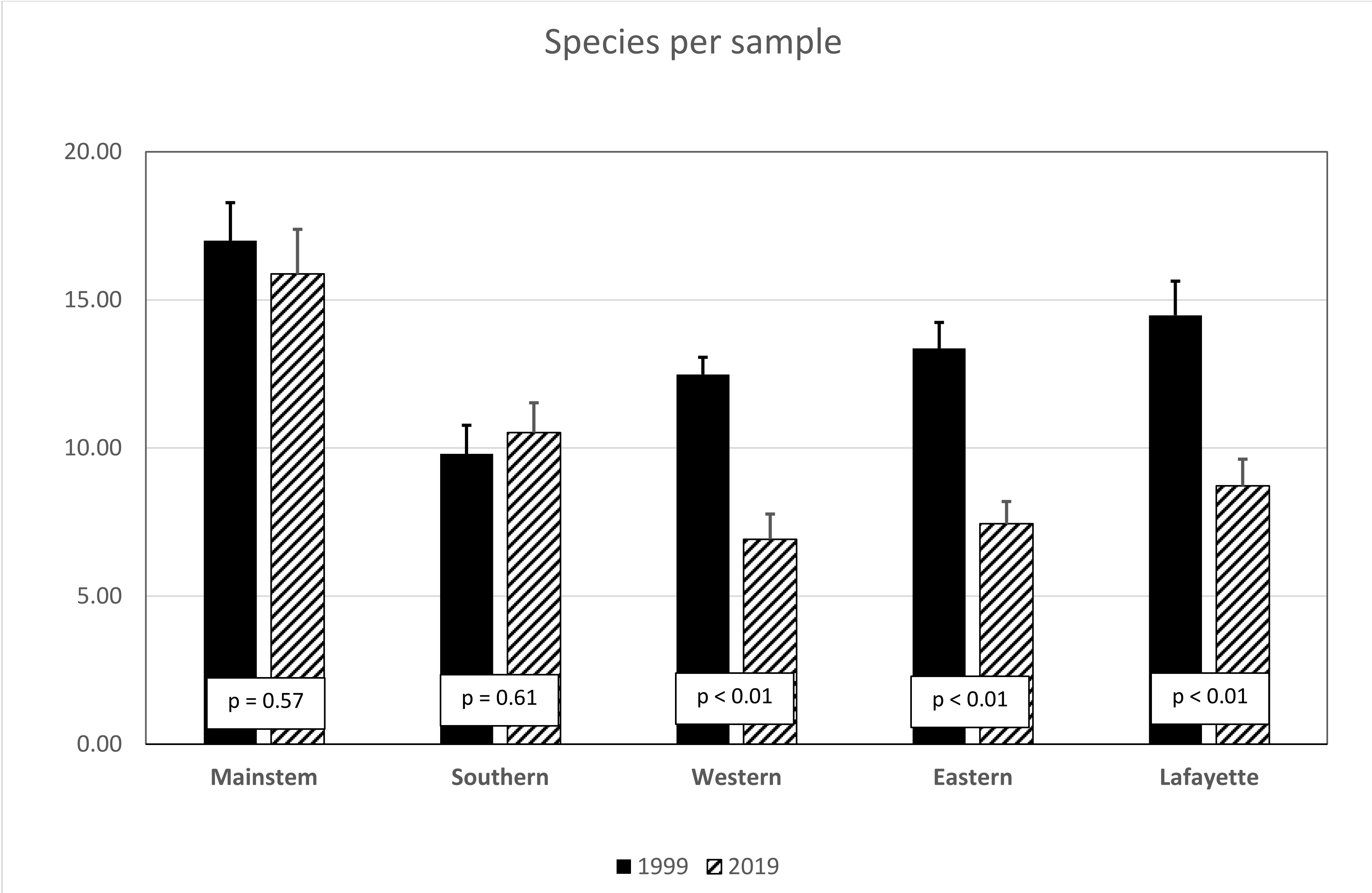


Figure 6. Average species per sample indicative of species richness for each of the five strata of the Elizabeth River watershed for the 1999 and 2019 samplings. P values for t-test indicated comparing the 1999 and 2019 means.

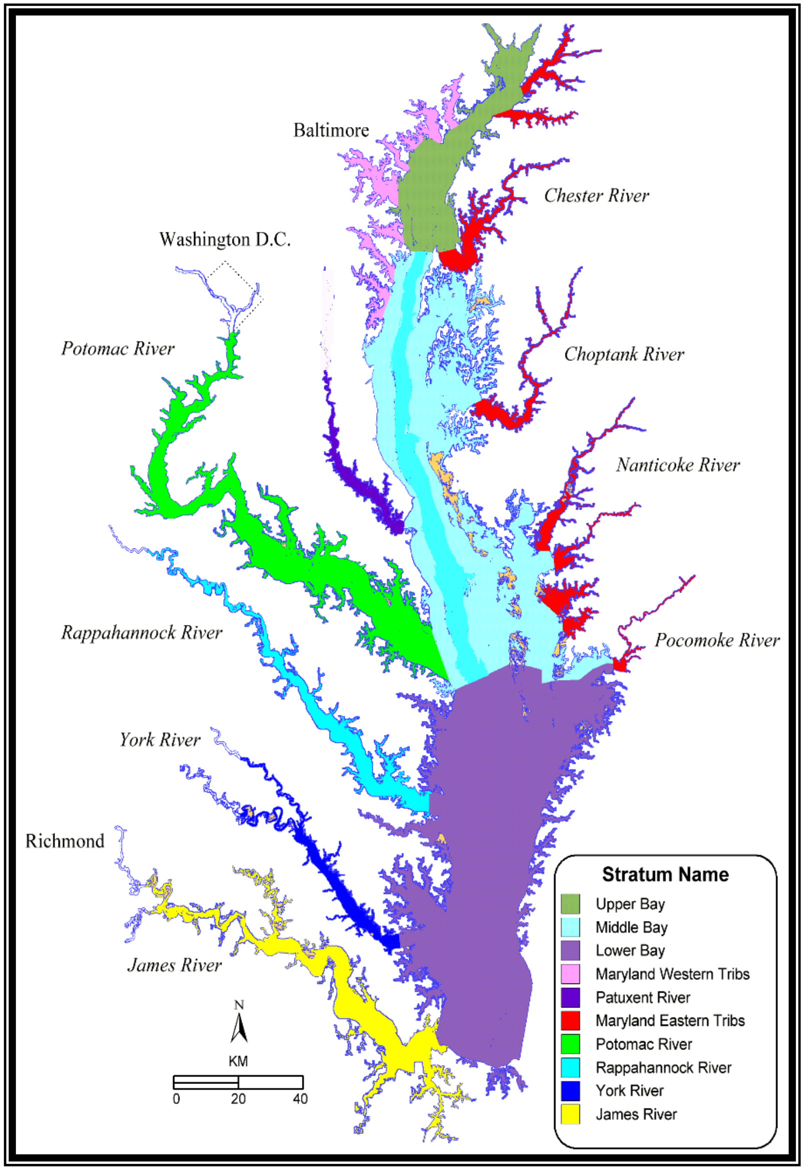


Figure 7. The ten benthic sampling strata of the Chesapeake Bay random monitoring program. Each year since 1996 each statum is sampled with 25 random stations.

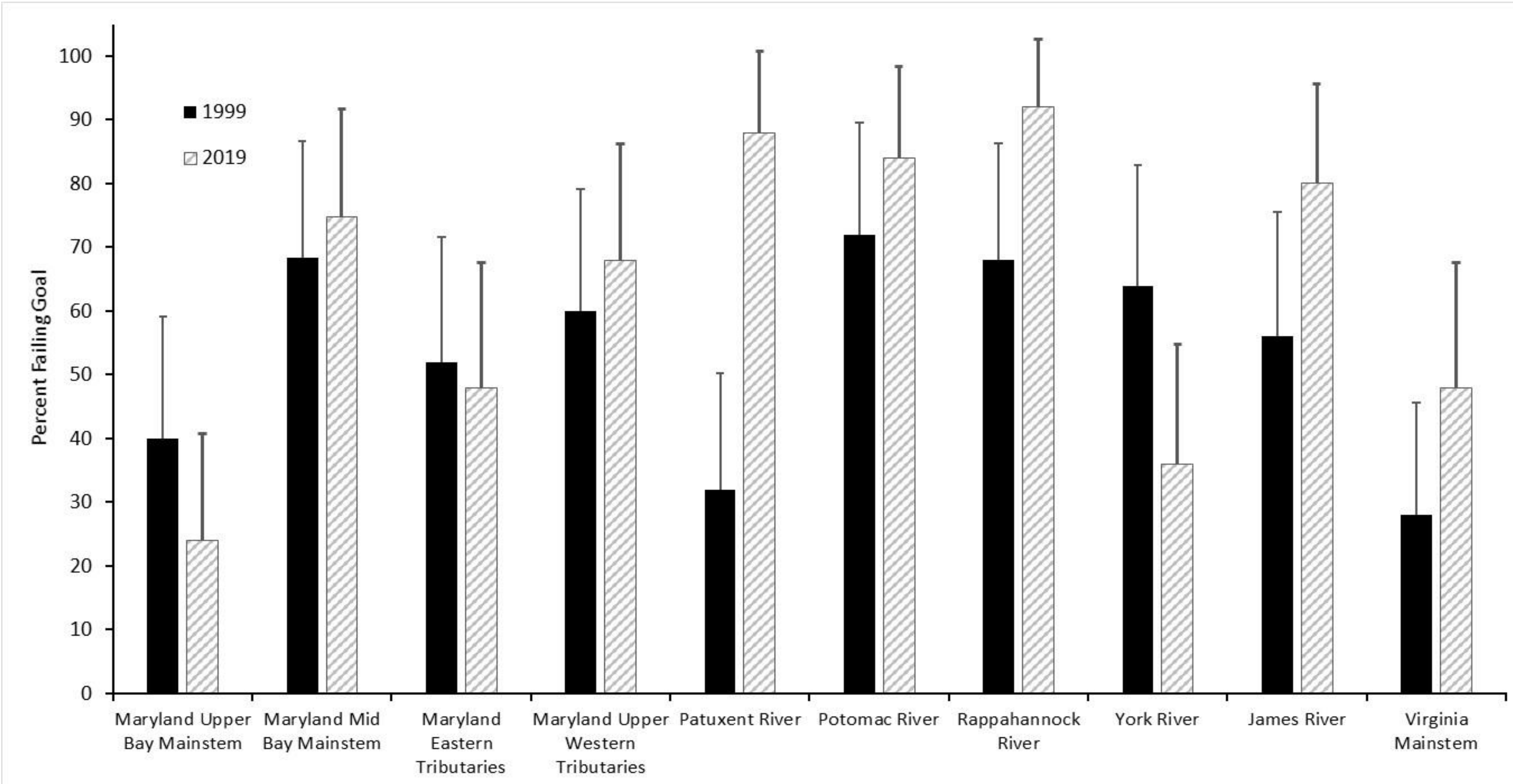


Figure 8. Levels of degradation for the ten benthic strata of the Chesapeake Bay random benthic monitoring program comparing 1999 and 2019 levels of degraded bottom (BIBI < 3.0)

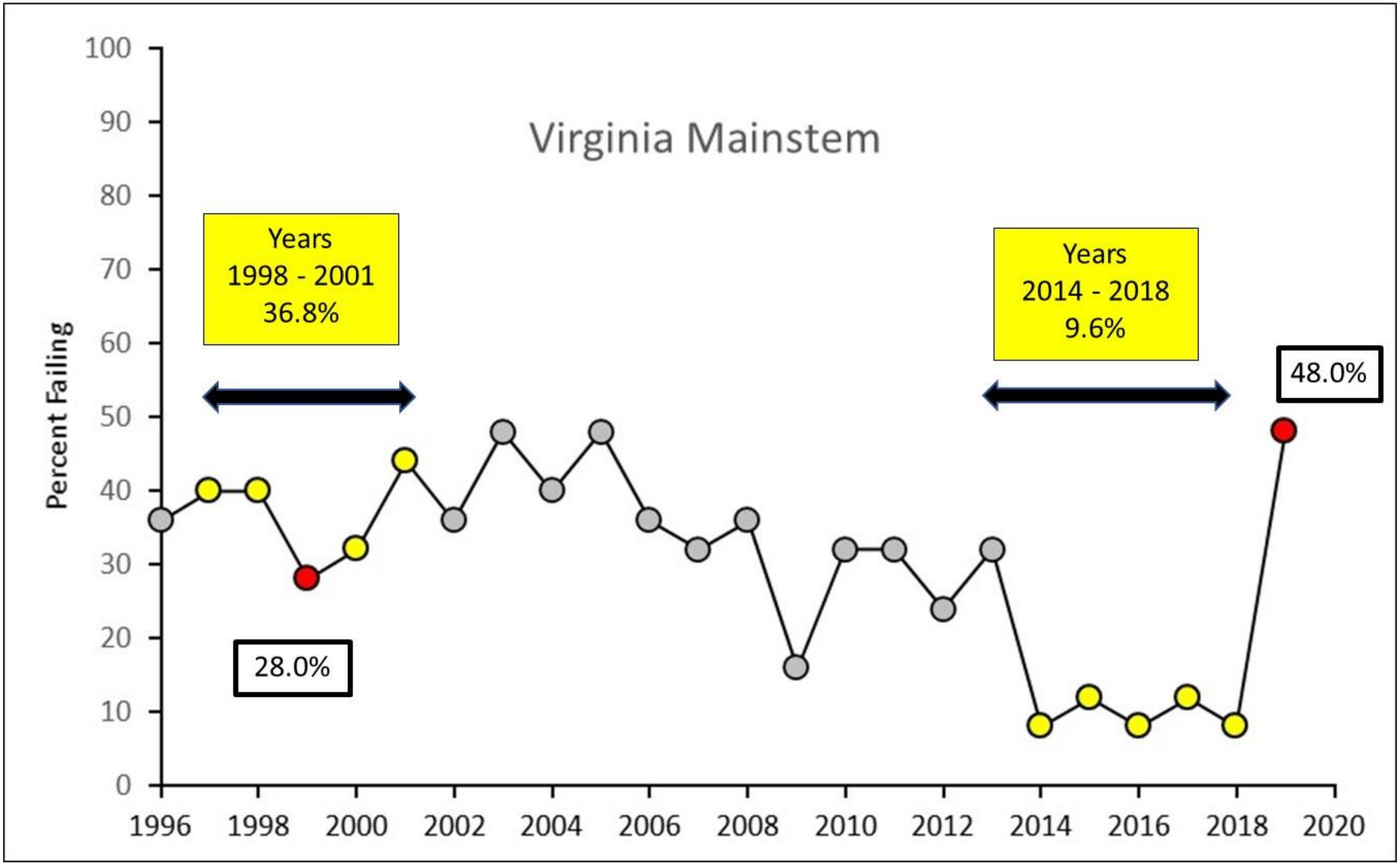


Figure 9. Levels of degradation for the Virginia Mainstem benthic stratum of the Chesapeake Bay random benthic monitoring program comparing 1999 and 2019 levels of degraded bottom (BIBI < 3.0).

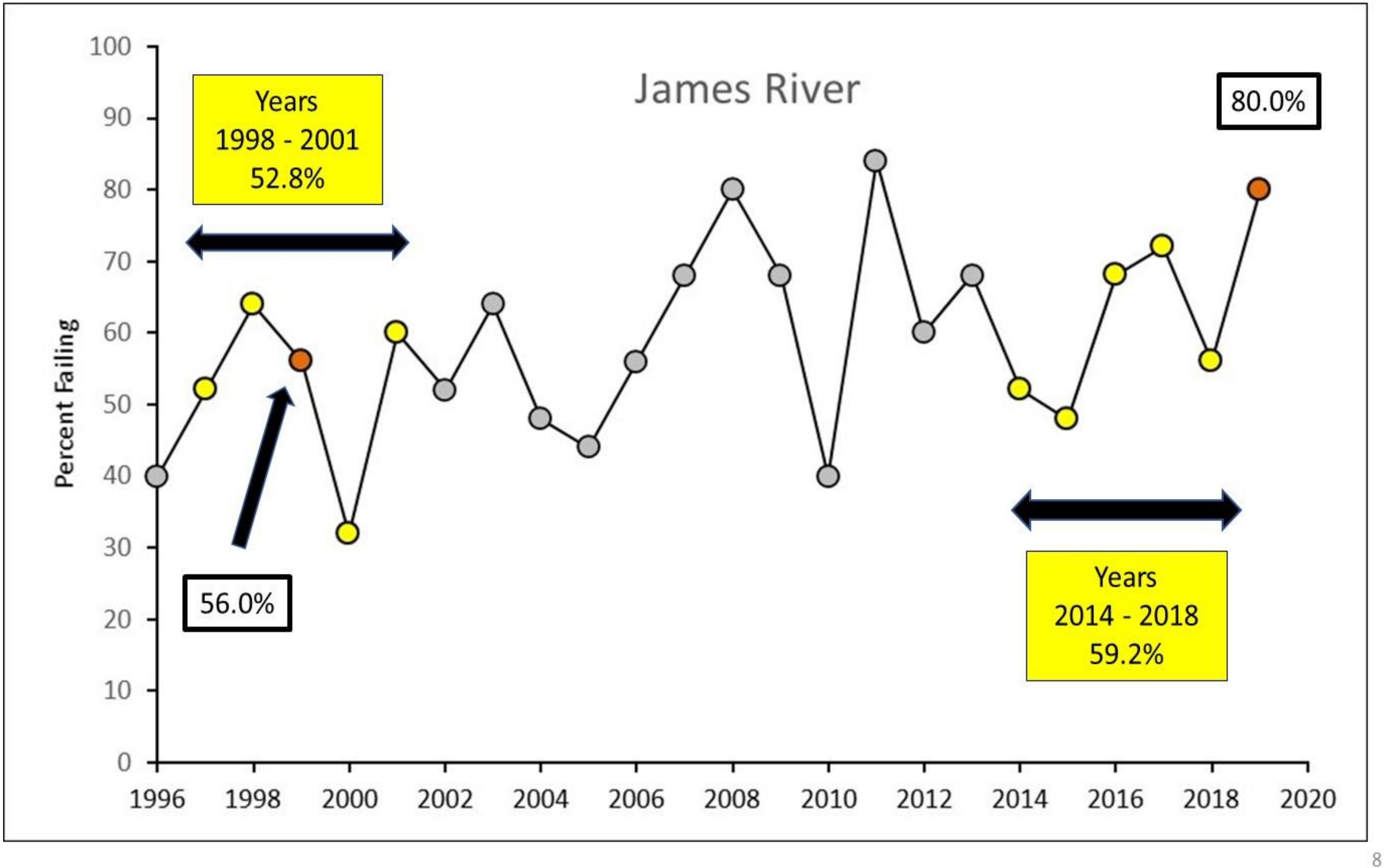


Figure 10. Levels of degradation for the James River benthic stratum of the Chesapeake Bay random benthic monitoring program comparing 1999 and 2019 levels of degraded bottom (BIBI < 3.0).

Tables

Table 1. Mainstem of the Elizabeth River. Physical and chemical parameters by sample for 1999 collections								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
ELR-06Z01	8/13/1999	36.92682	76.3451	3.0	22.2	6.3	83.2	5.8
ELR-06Z02	8/13/1999	36.92065	76.3473	3.0	22.1	6.5	69.2	5.1
ELR-06Z03	8/13/1999	36.91908	76.3404	14.0	23.0	6.0	93.4	7.5
ELR-06Z04	8/13/1999	36.91853	76.3524	3.0	22.8	6.5	63.1	4.0
ELR-06Z05	8/13/1999	36.91765	76.3537	1.0	22.7	6.2	0.8	0.9
ELR-06Z06	8/13/1999	36.91682	76.3528	2.0	22.7	6.6	12.6	1.6
ELR-06Z07	8/13/1999	36.9168	76.3486	3.0	22.3	6.3	85.2	6.7
ELR-06Z08	8/13/1999	36.91407	76.3512	3.0	22.7	6.5	75.5	5.8
ELR-06Z09	8/13/1999	36.91177	76.3302	14.0	22.8	5.8	83.4	7.6
ELR-06Z10	8/13/1999	36.91151	76.3516	3.0	22.7	6.9	69.0	5.2
ELR-06Z11	8/13/1999	36.91056	76.3354	3.0	22.4	7.2	3.4	1.0
ELR-06Z12	8/13/1999	36.91011	76.3366	3.0	22.6	6.6	18.2	1.4
ELR-06Z13	8/13/1999	36.90904	76.3305	1.0	22.5	7.1	1.0	0.5
ELR-06Z14	8/13/1999	36.89668	76.3364	17.0	23.0	5.8	47.1	4.5
ELR-06Z15	8/13/1999	36.88142	76.3497	3.0	22.3	7.0	5.5	0.9
ELR-06Z16	8/13/1999	36.87533	76.3505	1.0	22.4	10.4	2.6	0.4
ELR-06Z17	8/13/1999	36.87293	76.3329	13.0	22.8	5.6	76.5	6.3
ELR-06Z18	8/13/1999	36.87147	76.3316	14.0	22.8	5.3	78.7	7.3
ELR-06Z19	8/13/1999	36.86927	76.3258	3.0	22.0	5.7	12.4	5.9
ELR-06Z20	8/13/1999	36.86645	76.3243	13.0	22.5	5.4	92.7	7.9
ELR-06Z21	8/13/1999	36.85454	76.3101	9.0	22.2	4.5	87.3	7.7
ELR-06Z22	8/13/1999	36.85056	76.3031	10.0	22.1	4.7	95.1	8.0
ELR-06Z23	8/13/1999	36.85042	76.3063	3.0	22.1	5.8	46.9	5.8
ELR-06Z24	8/13/1999	36.8476	76.2945	3.0	21.8	5.0	21.0	4.6
ELR-06Z25	8/13/1999	36.84647	76.3202	1.0	21.3	9.6	90.2	7.8
			Mean	5.8	22.4	6.4	52.6	4.8

Table 2. Mainstem of the Elizabeth River. Physical and chemical parameters by sample for 2019 collections								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
ELI-26Z01	9/9/2019	36.92766	-76.3424	4.4	21.7	6.0	68.3	12.3
ELI-26Z02	9/9/2019	36.92484	-76.3352	5.5	21.8	5.6	27.4	2.0
ELI-26Z03	9/9/2019	36.92348	-76.3354	4.9	21.9	5.5	24.4	2.4
ELI-26Z04	9/9/2019	36.92227	-76.3313	3.5	21.8	5.6	16.8	1.1
ELI-26Z05	9/9/2019	36.91414	-76.3503	3.5	21.6	5.6	69.9	14.3
ELI-26Z06	9/9/2019	36.91001	-76.334	3.5	21.6	5.6	16.0	1.3
ELI-26Z07	9/9/2019	36.90928	-76.3383	17.5	26.4	3.7	78.7	10.2
ELI-26Z08	9/9/2019	36.90762	-76.3338	4.9	21.7	5.8	23.1	1.9
ELI-26Z10	9/9/2019	36.90092	-76.3353	6.3	21.6	5.1	19.2	2.7
ELI-26Z11	9/16/2019	36.89944	-76.3381	16.5	21.9	4.7	79.5	11.0
ELI-26Z12	9/16/2019	36.89906	-76.3368	18.0	21.9	5.0	81.9	5.4
ELI-26Z13	9/16/2019	36.8971	-76.3431	7.9	21.6	5.0	46.6	3.8
ELI-26Z14	9/9/2019	36.89835	-76.3299	4.8	21.6	5.9	23.5	2.5
ELI-26Z15	9/16/2019	36.88923	-76.3386	5.9	21.7	4.7	19.9	1.0
ELI-26Z16	9/16/2019	36.88246	-76.3428	2.9	21.4	4.5	21.6	0.7
ELI-26Z17	9/23/2019	36.87796	-76.3339	17.5	24.1	5.0	76.4	7.6
ELI-26Z19	9/16/2019	36.87091	-76.3464	16.5	21.5	4.3	70.9	7.0
ELI-26Z20	9/16/2019	36.87047	-76.3327	15.0	21.6	4.6	92.5	11.2
ELI-26Z21	9/16/2019	36.87185	-76.3252	1.8	21.3	4.9	12.2	0.6
ELI-26Z22	9/16/2019	36.84279	-76.3222	0.7	19.3	10.5	85.5	11.5
ELI-26Z23	9/16/2019	36.84859	-76.3075	1.5	20.9	5.2	14.6	0.5
ELI-26Z24	9/16/2019	36.8498	-76.3031	12.4	21.6	4.1	71.3	10.4
ELI-26Z25	9/20/2019	36.84558	-76.303	3.0	21.0	4.5	92.3	4.6
ELI-26Z27	9/16/2019	36.87163	-76.3446	1.7	21.4	5.5	14.5	0.2
ELI-26Z28	9/16/2019	36.85552	-76.311	14.8	21.6	4.1	62.8	9.2
			Mean	7.8	21.8	5.2	48.4	5.4

Table 3. Mainstem of Elizabeth River. Summary of benthic community parameters by sample of the 1999 collections.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
ELR-06Z01	2.7	4,432	1.114	2.806	20.5	66.2	46.9	32.7	32.8
ELR-06Z02	3.0	1,977	0.591	3.236	21.8	58.6	26.9	38.5	36.8
ELR-06Z03	1.7	3,250	0.818	2.051	28.7	29.4	47.2	8.3	3.5
ELR-06Z04	2.3	3,909	0.909	2.809	26.7	54.1	27.5	37.5	15.7
ELR-06Z05	3.7	5,114	1.614	3.178	6.2	68.0	5.6	54.9	23.6
ELR-06Z06	3.0	7,182	1.500	2.092	16.5	77.5	25.8	56.1	12.7
ELR-06Z07	2.0	1,477	1.114	2.898	46.2	33.8	46.9	18.4	13.8
ELR-06Z08	2.0	1,409	0.432	2.652	22.6	67.7	42.1	36.8	14.5
ELR-06Z09	2.7	2,432	1.182	2.637	9.3	21.5	7.7	19.2	15.9
ELR-06Z10	2.3	2,750	0.591	2.647	24.8	56.2	53.8	23.1	18.2
ELR-06Z11	4.3	4,886	3.477	3.576	3.7	42.3	2.6	75.2	23.7
ELR-06Z12	3.3	12,636	2.114	3.195	0.4	37.2	2.2	36.6	42.4
ELR-06Z13	3.3	1,818	77.750	3.048	3.8	80.0	0.1	99.8	20.0
ELR-06Z14	3.7	2,409	14.614	2.649	5.7	34.0	0.2	96.9	11.3
ELR-06Z15	3.3	3,136	1.455	3.107	4.3	42.0	20.3	10.9	26.1
ELR-06Z16	2.0	2,273	1.000	2.692	46.0	19.0	20.5	47.7	31.0
ELR-06Z17	3.0	955	19.682	3.650	14.3	35.7	0.2	98.8	14.3
ELR-06Z18	3.3	3,023	2.545	2.643	12.0	27.8	4.5	71.4	6.8
ELR-06Z19	4.0	4,455	2.023	4.003	18.4	26.0	10.1	25.8	16.3
ELR-06Z20	2.7	5,659	1.659	2.454	10.8	27.3	13.7	47.9	8.8
ELR-06Z21	2.0	1,955	0.409	2.584	26.7	38.4	27.8	27.8	12.8
ELR-06Z22	1.7	4,568	1.409	2.354	17.4	17.4	21.0	4.8	3.0
ELR-06Z23	2.3	1,659	0.477	2.122	65.8	24.7	23.8	61.9	5.5
ELR-06Z24	3.3	4,727	0.614	2.813	25.5	55.8	33.3	18.5	9.1
ELR-06Z25	2.0	3,000	1.205	1.975	55.3	11.4	7.5	17.0	6.1
Mean	2.8	3,644	5.612	2.795	21.3	42.1	20.7	42.7	17.0
St Error	0.1	485	3.138	0.101	3.4	3.9	3.4	5.6	2.1

Table 4. Mainstem of Elizabeth River. Summary of benthic community parameters by sample of the 2019 collections.									
Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
ELI-26Z01	2.7	5,352	3.198	2.651	22.9	70.3	47.5	44.7	16.9
ELI-26Z02	4.0	4,536	2.903	3.143	6.0	75.5	3.9	78.9	14.5
ELI-26Z03	4.0	5,942	1.270	3.335	1.1	58.4	3.6	44.6	29.8
ELI-26Z04	3.3	6,305	4.241	2.852	0.0	78.1	0.0	70.1	21.2
ELI-26Z05	2.0	3,357	1.406	2.449	28.4	58.1	48.4	21.0	16.2
ELI-26Z06	4.0	5,421	2.064	3.307	0.8	60.7	1.1	75.8	29.7
ELI-26Z07	3.0	1,724	1.814	2.185	42.1	50.0	10.0	83.8	9.2
ELI-26Z08	4.7	5,806	5.284	3.692	9.4	70.3	3.4	89.3	21.9
ELI-26Z10	4.0	5,375	42.548	3.907	2.5	46.8	0.1	95.9	29.1
ELI-26Z11	2.0	4,355	2.291	2.319	45.8	41.1	53.5	37.6	18.8
ELI-26Z12	3.3	1,315	1.520	2.809	39.7	31.0	3.0	31.3	27.6
ELI-26Z13	1.3	1,452	0.363	1.401	78.1	15.6	68.8	18.8	4.7
ELI-26Z14	3.3	3,379	1.520	3.207	20.8	57.0	19.4	61.2	23.5
ELI-26Z15	3.3	2,903	1.134	2.590	3.9	89.8	8.0	82.0	12.5
ELI-26Z16	3.7	4,672	0.658	2.215	0.5	92.7	3.4	75.9	29.6
ELI-26Z17	1.3	1,157	0.340	1.019	90.2	5.9	73.3	13.3	7.8
ELI-26Z19	2.7	2,994	1.179	2.591	43.2	31.8	30.8	50.0	22.7
ELI-26Z20	2.0	2,268	0.953	2.139	64.0	14.0	64.3	4.8	23.0
ELI-26Z21	2.7	2,540	0.907	2.810	2.7	80.4	7.5	55.0	60.7
ELI-26Z22	1.0	953	0.068	0.437	92.9	0.0	33.3	0.0	0.0
ELI-26Z23	3.3	2,200	0.635	2.562	3.1	85.6	3.6	78.6	17.5
ELI-26Z24	2.0	5,126	1.792	2.796	47.3	26.5	60.8	16.5	8.4
ELI-26Z25	2.3	1,066	0.431	2.435	36.2	25.5	36.8	15.8	42.6
ELI-26Z27	2.0	1,497	0.476	3.478	13.6	56.1	19.0	42.9	24.2
ELI-26Z28	1.7	5,783	1.474	2.061	47.8	37.3	61.5	9.2	6.3
Mean	2.8	3,499	3.219	2.576	29.7	50.3	26.6	47.9	20.7
St Error	0.2	357	1.624	0.156	5.7	5.2	5.0	5.9	2.5

Table 5. Infaunal community composition in the Mainstem stratum of the Elizabeth River watershed in 1999. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, G – gastropod, H- hemichordate, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Mediomastus ambiseta (P)	1,022	0.0282
Paraprionospio pinnata (P)	432	0.1200
Hemichordata spp. (H)	406	0.1291
Neanthes succinea (P)	241	0.0491
Glycinde solitaria (P)	164	0.0236
Tubificoides spp. Group I (O)	151	0.0173
Streblospio benedicti (P)	129	0.0118
Loimia medusa (P)	119	0.1509
Acteocina canaliculate (G)	96	0.0127
Tubificoides wasselli (O)	73	0.0045
Nemertina spp. (N)	68	0.0355
Heteromastus filiformis (P)	68	0.0245
Polydora cornuta (P)	68	0.0045
Phoronis spp. (Ph)	64	0.0245
Tharyx sp. A (P)	59	0.0109
Leitoscoloplos spp. (P)	48	0.0600
Polycirrus eximius (P)	39	0.0073
Scoloplos rubra (P)	37	0.0455
Listriella barnardi (A)	36	0.0118
Spiochaetopterus costarum (P)	35	0.0309

Table 6. Infaunal community composition in the Mainstem stratum of the Elizabeth River watershed in 2019. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, D- decapod, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Mediomastus ambiseta (P)	863	0.0345
Paraprionospio pinnata (P)	652	0.2645
Spiochaetopterus costarum (P)	487	0.2718
Loimia medusa (P)	245	0.3873
Neanthes succinea (P)	150	0.0345
Acteocina canaliculate (G)	133	0.0227
Glycinde solitaria (P)	98	0.0173
Phoronis spp. (Ph)	80	0.0355
Leitoscoloplos spp. (P)	63	0.0564
Podarkeopsis levifuscina (P)	59	0.0136
Sigambra tentaculate (P)	51	0.0155
Tubificoides spp. Group I (O)	48	0.0091
Nemertina spp. (N)	47	0.0482
Streblospio benedicti (P)	45	0.0055
Grandidierella spp. (A)	43	0.0064
Hermundura americana (P)	35	0.0209
Glycera spp. (P)	32	0.0064
Monticellina dorsobrancialis (P)	31	0.0082
Ogyrides alphaerostris (D)	27	0.0255
Clymenella torquata (P)	26	0.1300

Table 7. Southern Branch of the Elizabeth River. Physical and chemical parameters by sample for 1999 samples.								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
ELR-06S01	8/20/1999	36.8259	-76.29282	12.0	23.7	1.9	80.5	8.6
ELR-06S02	8/20/1999	36.8173	-76.29392	13.0	23.2	1.6	89.3	8.7
ELR-06S03	8/20/1999	36.8144	-76.2927	12.0	23.2	1.9	89.2	8.5
ELR-06S04	8/20/1999	36.8118	-76.29274	14.0	23.0	1.8	83.2	8.2
ELR-06S06	8/20/1999	36.8011	-76.29407	10.0	21.7	1.9	39.7	4.8
ELR-06S07	8/20/1999	36.7904	-76.3032	3.0	19.0	3.5	68.9	7.6
ELR-06S08	8/20/1999	36.7876	-76.30305	11.0	21.1	1.7	97.4	9.0
ELR-06S09	8/20/1999	36.7794	-76.29441	3.0	20.0	1.9	60.0	12.9
ELR-06S10	8/20/1999	36.7756	-76.29613	8.0	21.3	1.4	28.7	3.6
ELR-06S11	8/20/1999	36.7616	-76.30747	1.0	19.5	3.3	20.2	2.6
ELR-06S13	8/20/1999	36.7575	-76.30307	3.0	19.5	2.9	57.0	8.4
ELR-06S14	8/20/1999	36.7574	-76.31172	1.0	18.5	3.5	22.5	5.0
ELR-06S15	8/20/1999	36.7514	-76.29249	1.0	18.5	3.3	33.8	7.5
ELR-06S16	8/20/1999	36.7473	-76.29291	2.0	18.0	1.3	57.4	8.7
ELR-06S17	8/20/1999	36.7471	-76.29755	1.0	17.5	3.5	4.6	1.0
ELR-06S18	8/20/1999	36.7456	-76.29764	2.0	18.0	2.9	33.9	5.7
ELR-06S19	8/27/1999	36.7453	-76.29773	3.0	17.8	1.5	12.4	2.5
ELR-06S20	8/27/1999	36.7448	-76.29523	1.0	17.3	2.6	4.6	6.4
ELR-06S21	8/27/1999	36.7378	-76.29579	7.0	20.5	1.1	42.7	1.1
ELR-06S22	8/27/1999	36.7323	-76.29379	1.0	17.0	2.1	64.6	8.8
ELR-06S24	8/27/1999	36.7285	-76.28648	1.0	14.0	3.4	28.8	7.2
ELR-06S25	8/27/1999	36.727	-76.31297	1.0	6.5	1.9	90.6	15.1
ELR-06S26	8/27/1999	36.7483	-76.29609	5.0	20.5	1.1	28.3	3.8
ELR-06S27	8/27/1999	36.7325	-76.26877	1.0	14.5	3.9	21.8	3.7
ELR-06S28	8/27/1999	36.7818	-76.30377	1.0	19.0	3.0	4.6	1.3
			Mean	4.7	18.9	2.4	46.6	6.4

Table 8. Southern Branch of the Elizabeth River. Physical and chemical parameters by sample for 2019 collections								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
SBE-26S01	8/27/2019	36.8311	-76.2946	15.9	28.4	2.9	39.2	3.8
SBE-26S02	8/20/2019	36.83047	-76.2937	14.3	25.2	3.1	59.3	6.2
SBE-26S03	8/20/2019	36.82356	-76.2908	13.7	25.2	3.0	86.3	9.4
SBE-26S04	8/7/2019	36.81775	-76.2911	16.2	20.9	3.3	75.9	10.1
SBE-26S05	8/7/2019	36.81187	-76.2896	11.3	20.8	3.4	30.4	5.4
SBE-26S07	8/7/2019	36.80693	-76.2887	3.5	20.8	3.4	42.9	4.9
SBE-26S08	8/7/2019	36.79036	-76.304	4.2	20.4	3.6	67.0	10.9
SBE-26S09	8/7/2019	36.78477	-76.3046	10.6	20.4	3.4	79.2	12.6
SBE-26S10	8/7/2019	36.78282	-76.2901	0.7	15.0	4.6	28.4	6.3
SBE-26S11	8/7/2019	36.76715	-76.2994	3.1	18.7	3.9	8.4	1.3
SBE-26S12	8/7/2019	36.75959	-76.2972	11.0	19.8	3.2	80.6	14.1
SBE-26S13	8/6/2019	36.75749	-76.3045	5.5	19.3	4.1	69.9	16.9
SBE-26S16	8/6/2019	36.74948	-76.2955	2.5	19.2	3.8	15.9	1.7
SBE-26S17	8/6/2019	36.74625	-76.2966	5.5	19.6	3.7	15.6	1.6
SBE-26S18	8/6/2019	36.74624	-76.2973	4.9	19.4	3.7	12.1	1.2
SBE-26S19	8/6/2019	36.73718	-76.3057	1.9	18.2	5.4	64.0	19.3
SBE-26S20	8/6/2019	36.73206	-76.2929	1.2	17.4	4.0	55.7	14.1
SBE-26S21	8/6/2019	36.73217	-76.2798	2.1	16.9	4.3	14.3	1.0
SBE-26S22	8/6/2019	36.73047	-76.2771	5.3	17.3	4.0	21.8	3.1
SBE-26S23	8/6/2019	36.72974	-76.2754	1.9	15.8	5.0	13.7	1.0
SBE-26S24	8/6/2019	36.72409	-76.2592	1.1	12.8	3.2	74.3	16.7
SBE-26S25	8/6/2019	36.72452	-76.2567	0.5	10.8	5.6	26.1	7.6
SBE-26S27	8/7/2019	36.78508	-76.3033	12.7	20.6	3.4	64.7	7.2
SBE-26S28	8/28/2019	36.79893	-76.2985	1.5	21.4	4.2	93.8	11.6
SBE-26S29	8/28/2019	36.78131	-76.3057	2.0	19.4	4.6	36.3	6.8
			Mean	6.1	19.3	3.9	47.0	7.8

Table 9. Southern Branch of Elizabeth River. Summary of benthic community parameters by sample of the 1999 collections.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
ELR-06S01	2.3	4,909	3.955	2.432	55.6	19.9	70.7	12.6	3.7
ELR-06S02	2.0	1,841	0.977	1.901	71.6	6.2	53.5	20.9	8.6
ELR-06S03	2.0	2,045	0.614	1.052	88.9	2.2	77.8	7.4	5.6
ELR-06S04	2.0	2,568	0.955	0.871	84.1	0.9	85.7	2.4	4.4
ELR-06S06	2.0	3,977	3.409	1.093	88.6	4.6	38.0	36.7	5.1
ELR-06S07	1.7	1,205	0.682	2.374	50.9	20.8	63.3	10.0	18.9
ELR-06S08	1.7	1,568	0.432	1.597	81.2	2.9	57.9	10.5	7.2
ELR-06S09	1.0	455	0.432	2.359	45.0	40.0	73.7	10.5	15.0
ELR-06S10	4.0	3,705	4.841	3.411	20.2	31.9	2.8	76.5	19.6
ELR-06S11	2.3	68	0.023	0.000	0.0	0.0	0.0	0.0	0.0
ELR-06S13	1.3	13,568	0.500	0.239	97.5	1.8	77.3	13.6	1.8
ELR-06S14	1.3	5,909	0.432	0.908	85.8	11.2	26.3	42.1	9.6
ELR-06S15	1.3	6,523	0.500	1.764	69.3	24.0	36.4	45.5	19.5
ELR-06S16	1.0	10,341	0.295	0.086	99.1	0.4	76.9	15.4	0.2
ELR-06S17	2.7	1,955	0.364	2.626	47.7	33.7	12.5	43.8	27.9
ELR-06S18	2.7	1,727	0.386	2.724	1.3	25.0	5.9	17.6	81.6
ELR-06S19	2.7	705	0.250	2.628	19.4	48.4	18.2	18.2	64.5
ELR-06S20	2.0	7,591	1.523	2.085	23.1	11.4	3.0	28.4	13.5
ELR-06S21	1.3	6,568	0.159	0.060	99.3	0.7	85.7	14.3	0.0
ELR-06S22	2.7	1,682	0.318	1.691	67.6	24.3	7.1	50.0	13.5
ELR-06S24	1.7	5,568	1.000	2.564	35.5	6.9	9.1	18.2	19.2
ELR-06S25	2.2	22,614	1.545	0.539	4.3	0.0	4.4	0.0	1.8
ELR-06S26	1.7	909	0.159	2.384	57.5	32.5	42.9	28.6	30.0
ELR-06S27	1.7	4,477	0.477	1.644	69.0	23.4	47.6	42.9	13.7
ELR-06S28	2.7	4,159	1.318	2.566	44.3	12.6	19.0	36.2	19.1
Mean	2.0	4,665	1.022	1.664	56.3	15.4	39.8	24.1	16.2
St Error	0.1	990	0.247	0.196	6.3	2.9	6.1	3.7	3.9

Table 10. Southern Branch of Elizabeth River. Summary of benthic community parameters by sample for the 2019 collections.									
Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
SBE-26S01	2.7	8,913	0.975	1.874	7.1	80.7	14.0	62.8	5.9
SBE-26S02	2.0	5,602	0.794	2.276	13.8	68.8	22.9	40.0	7.7
SBE-26S03	3.3	2,495	0.658	2.461	2.7	67.3	3.4	34.5	17.3
SBE-26S04	2.0	4,150	0.907	1.655	6.6	73.2	17.5	25.0	5.5
SBE-26S05	3.3	4,241	0.907	3.680	11.8	32.6	17.5	15.0	35.3
SBE-26S07	2.7	2,336	0.748	1.844	15.5	11.7	27.3	12.1	75.7
SBE-26S08	2.0	3,039	0.612	2.222	7.5	50.7	22.2	11.1	26.9
SBE-26S09	1.7	1,565	0.249	1.804	7.2	66.7	36.4	18.2	11.6
SBE-26S10	3.7	2,495	1.225	2.275	12.7	50.9	13.0	9.3	40.0
SBE-26S11	3.0	3,901	0.567	1.750	7.0	73.8	40.0	20.0	16.9
SBE-26S12	1.3	930	0.249	1.630	9.8	51.2	36.4	18.2	39.0
SBE-26S13	2.0	726	0.204	1.782	6.3	25.0	22.2	33.3	65.6
SBE-26S16	1.7	1,134	0.249	1.813	0.0	14.0	0.0	27.3	62.0
SBE-26S17	3.0	5,239	0.386	1.348	1.7	79.2	11.8	23.5	17.7
SBE-26S18	3.3	1,588	0.249	1.580	0.0	67.1	0.0	36.4	34.3
SBE-26S19	3.0	2,041	0.476	2.062	10.0	8.9	4.8	19.0	58.9
SBE-26S20	2.7	1,315	0.295	2.289	12.1	5.2	15.4	7.7	36.2
SBE-26S21	3.3	2,177	0.340	1.605	5.2	19.8	6.7	6.7	59.4
SBE-26S22	2.3	8,891	0.318	0.740	7.7	88.0	14.3	50.0	4.8
SBE-26S23	2.3	612	0.181	1.576	11.1	44.4	12.5	12.5	40.7
SBE-26S24	1.3	3,311	0.181	1.022	74.7	20.5	37.5	25.0	4.1
SBE-26S25	2.6	1,860	0.522	2.920	32.9	24.4	13.0	39.1	46.3
SBE-26S27	3.3	1,134	0.771	2.838	8.0	56.0	8.8	64.7	32.0
SBE-26S28	1.7	6,940	0.454	0.691	11.4	87.3	40.0	50.0	0.7
SBE-26S29	2.3	5,988	1.179	1.950	2.7	22.0	9.6	5.8	29.2
Mean	2.5	3,305	0.548	1.908	11.4	47.6	17.9	26.7	30.9
St Error	0.1	474	0.062	0.129	2.9	5.3	2.4	3.3	4.3

Table 11. Infaunal community composition in the Southern Branch stratum of the Elizabeth River watershed in 1999. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Streblospio benedicti (P)	2,086	0.0545
Paraprionospio pinnata (P)	527	0.1682
Tubificoides spp. Group I (O)	229	0.0073
Glycinde solitaria (P)	154	0.0336
Mediomastus ambiseta (P)	124	0.0145
Hemichordata spp. (H)	96	0.0545
Tubificoides heterochaetus	80	0.0018
Heteromastus filiformis (P)	64	0.0636
Cyathura polita (I)	61	0.0309
Neanthes succinea (P)	57	0.0245
Laeonereis culveri (P)	51	0.0391
Podarkeopsis levifuscina (P)	37	0.0136
Loimia medusa (P)	33	0.1755
Leitoscoloplos spp. (P)	29	0.1300
Hobsonia florida (P)	24	0.0027
Parahesione luteola (P)	20	0.0073
Tagelus plebeius (B)	16	0.0164
Spiochaetopterus costarum (P)	15	0.0082
Capitella capitata (P)	13	0.0027
Eteone heteropoda	12	0.0064

Table 12. Infaunal community composition in the Southern Branch stratum of the Elizabeth River watershed in 2019. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Mediomastus ambiseta (P)	1,766	0.0573
Hermundura americana (P)	472	0.1091
Streblospio benedicti (P)	225	0.0164
Leptocheirus plumulosus (A)	207	0.0327
Tubificoides spp. Group I (O)	100	0.0091
Paraprionospio pinnata (P)	69	0.0182
Leitoscoloplos spp. (P)	59	0.0473
Spiochaetopterus costarum (P)	50	0.0218
Glycinde solitaria (P)	44	0.0118
Neanthes succinea (P)	34	0.0164
Rictaxis punctostriatus (G)	26	0.0073
Cyathura polita (I)	26	0.0118
Leucon americanus (C)	25	0.0091
Grandidierella spp. (A)	23	0.0064
Loimia medusa (P)	22	0.0136
Parahesione luteola (P)	22	0.0082
Sigambra tentaculate (P)	15	0.0055
Nemertina spp. (N)	12	0.0073
Polydora cornuta (P)	11	0.0036
Eteone heteropoda (P)	10	0.0064

Table 13. Lafayette River of the Elizabeth River. Physical and chemical parameters by sample for 1999 samples.								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
ELR-06L01	7/30/1999	36.8863	-76.32125	1.0	22.4	9.2	2.2	0.5
ELR-06L02	7/30/1999	36.8963	-76.31939	2.0	22.9	7.2	10.2	1.6
ELR-06L03	7/30/1999	36.9123	-76.31868	1.0	22.7	8.3	95.7	5.8
ELR-06L04	7/30/1999	36.8984	-76.31832	1.0	22.5	8.5	7.2	1.3
ELR-06L05	7/30/1999	36.9084	-76.31798	1.0	22.8	8.7	6.7	1.2
ELR-06L06	7/30/1999	36.9071	-76.31618	3.0	23.2	7.1	35.5	4.5
ELR-06L07	7/30/1999	36.9048	-76.31511	1.0	22.6	10.6	5.9	0.8
ELR-06L08	7/23/1999	36.9093	-76.31255	1.0	22.5	9.3	2.4	0.4
ELR-06L09	7/23/1999	36.9079	-76.31052	1.0	22.6	10.2	3.4	0.7
ELR-06L10	7/23/1999	36.9059	-76.3088	3.0	22.6	6.1	81.6	6.7
ELR-06L11	7/23/1999	36.9036	-76.30821	1.0	21.7	7.3	72.6	6.0
ELR-06L12	7/23/1999	36.9095	-76.3041	1.0	21.8	7.1	96.0	7.3
ELR-06L13	7/23/1999	36.9047	-76.30393	1.0	21.6	6.8	58.0	7.8
ELR-06L14	7/23/1999	36.9041	-76.30238	1.0	22.2	8.8	11.2	1.3
ELR-06L15	7/23/1999	36.9058	-76.30154	3.0	22.8	5.2	96.6	8.7
ELR-06L16	7/23/1999	36.9033	-76.29637	1.0	20.9	6.8	87.4	7.6
ELR-06L17	7/23/1999	36.8919	-76.29408	1.0	20.5	6.6	90.9	8.2
ELR-06L18	7/23/1999	36.891	-76.2865	3.0	21.1	3.4	99.0	9.1
ELR-06L19	7/23/1999	36.8916	-76.275	1.0	19.3	5.8	97.2	9.3
ELR-06L20	7/23/1999	36.8932	-76.27491	1.0	18.6	7.4	19.0	3.1
ELR-06L21	7/23/1999	36.8761	-76.27489	1.0	17.1	11.8	96.7	11.2
ELR-06L22	7/23/1999	36.8948	-76.2747	1.0	18.6	6.1	93.2	9.1
ELR-06L23	7/23/1999	36.893	-76.27279	1.0	19.6	6.6	85.6	8.5
ELR-06L24	7/23/1999	36.9034	-76.26842	1.0	17.5	4.7	92.5	12.2
ELR-06L25	7/23/1999	36.9027	-76.26334	1.0	17.0	3.5	95.5	12.6
			Mean	1.4	21.1	7.3	57.7	5.8

Table 14. Lafayette River of the Elizabeth River. Physical and chemical parameters by sample for 2019 collections								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
LAF-26L01	9/9/2019	36.88614	-76.3179	0.6	21.5	8.6	13.2	0.4
LAF-26L02	9/13/2019	36.90264	-76.3142	1.0	21.4	6.1	10.0	0.4
LAF-26L03	9/13/2019	36.90772	-76.3156	3.9	21.4	5.4	51.8	8.9
LAF-26L05	9/13/2019	36.90586	-76.3077	4.0	21.3	5.6	53.5	1.0
LAF-26L06	9/13/2019	36.90291	-76.3076	2.1	21.4	5.7	69.4	12.7
LAF-26L07	9/13/2019	36.90446	-76.3062	2.5	21.3	5.3	60.5	9.7
LAF-26L08	9/13/2019	36.90687	-76.3035	3.8	21.4	5.4	52.5	9.6
LAF-26L09	9/13/2019	36.90877	-76.303	2.0	21.7	4.4	70.6	6.7
LAF-26L11	9/13/2019	36.90595	-76.3007	4.9	21.7	5.3	87.8	10.3
LAF-26L12	9/13/2019	36.90636	-76.298	3.0	21.7	5.1	46.8	5.1
LAF-26L13	9/13/2019	36.90489	-76.2932	2.0	21.6	4.8	22.9	2.0
LAF-26L14	9/13/2019	36.9062	-76.2848	0.9	20.3	5.0	94.8	14.7
LAF-26L15	9/13/2019	36.90759	-76.2864	1.9	20.7	5.3	81.0	7.3
LAF-26L16	9/4/2019	36.90037	-76.2899	4.0	21.9	5.7	77.2	6.1
LAF-26L17	9/4/2019	36.89794	-76.293	3.2	21.9	5.2	79.3	7.1
LAF-26L18	9/4/2019	36.89134	-76.2947	2.2	21.7	4.9	74.1	7.0
LAF-26L19	9/13/2019	36.88917	-76.2987	0.5	17.8	6.0	77.3	16.1
LAF-26L20	9/4/2019	36.89408	-76.2845	1.5	21.4	6.5	79.6	6.3
LAF-26L21	9/4/2019	36.88733	-76.2787	2.3	21.5	4.8	79.3	7.1
LAF-26L22	9/4/2019	36.88889	-76.2776	2.1	21.4	5.3	81.4	8.4
LAF-26L23	9/4/2019	36.89242	-76.2722	1.3	20.8	4.0	96.6	7.5
LAF-26L24	9/4/2019	36.89558	-76.2675	1.0	20.5	3.5	86.8	9.4
LAF-26L25	9/4/2019	36.8947	-76.2653	0.5	19.8	2.4	38.3	7.6
LAF-26L26	9/9/2019	36.88818	-76.3203	1.7	21.6	6.5	15.2	0.6
LAF-26L27	9/13/2019	36.9053	-76.2906	0.5	19.1	6.9	84.9	10.3
			Mean	2.1	21.1	5.3	63.4	7.3

Table 15. Lafayette River of the Elizabeth River. Summary of benthic community parameters by sample for 1999 collections.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
ELR-06L01	2.3	1,773	0.386	2.377	56.4	28.2	23.5	35.3	6.4
ELR-06L02	4.0	5,386	21.273	3.110	8.4	67.1	0.5	97.3	11.0
ELR-06L03	1.7	841	0.523	3.103	54.1	10.8	65.2	8.7	10.8
ELR-06L04	4.7	3,000	1.909	3.742	3.0	69.7	4.8	75.0	16.7
ELR-06L05	4.0	4,045	2.273	3.125	11.8	52.8	10.0	30.0	14.6
ELR-06L06	3.7	3,682	1.023	3.066	18.5	40.1	11.1	35.6	8.6
ELR-06L07	3.3	3,682	1.091	3.081	20.4	39.5	8.3	56.3	21.0
ELR-06L08	3.3	4,659	0.773	2.995	18.5	39.0	14.7	29.4	16.1
ELR-06L09	2.7	2,250	0.636	3.037	24.2	27.3	21.4	21.4	7.1
ELR-06L10	2.3	2,205	1.000	2.558	50.5	27.8	34.1	6.8	9.3
ELR-06L11	2.3	2,636	1.045	2.578	44.0	35.3	69.6	15.2	8.6
ELR-06L12	2.3	1,568	0.614	2.548	47.8	34.8	63.0	18.5	24.6
ELR-06L13	2.0	2,000	0.409	2.872	25.0	37.5	33.3	16.7	9.1
ELR-06L14	2.7	5,727	1.000	2.644	14.3	67.5	25.0	34.1	6.7
ELR-06L15	1.7	2,955	0.409	1.766	54.6	30.8	61.1	16.7	0.8
ELR-06L16	2.3	4,227	1.795	2.417	41.4	31.7	27.8	48.1	5.9
ELR-06L17	2.3	1,727	0.341	2.087	60.5	22.4	13.3	53.3	9.2
ELR-06L18	1.7	5,705	0.523	1.652	39.4	4.0	21.7	13.0	2.8
ELR-06L19	1.7	6,977	0.477	1.717	43.0	2.6	14.3	14.3	2.0
ELR-06L20	3.0	6,341	1.295	2.679	30.5	1.8	3.5	3.5	21.9
ELR-06L21	1.7	9,409	0.523	1.747	37.9	1.2	17.4	13.0	0.7
ELR-06L22	2.7	5,977	0.705	1.913	22.4	3.8	3.2	38.7	3.0
ELR-06L23	2.3	6,477	1.045	1.891	31.2	3.2	6.5	45.7	2.8
ELR-06L24	2.7	4,023	1.159	2.194	31.6	2.8	3.9	19.6	4.0
ELR-06L25	2.0	6,159	0.591	2.076	15.1	1.1	7.7	7.7	8.5
Mean	2.6	4,137	1.713	2.519	32.2	27.3	22.6	30.2	9.3
St Error	0.2	422	0.821	0.113	3.3	4.4	4.2	4.5	1.3

Table 16. Lafayette River of Elizabeth River. Summary of benthic community parameters by sample for 2019 collections.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
LAF-26L01	2.0	1,043	0.522	3.104	19.6	43.5	26.1	43.5	26.1
LAF-26L02	3.0	2,812	0.748	2.850	6.5	77.4	18.2	48.5	23.4
LAF-26L03	2.3	1,905	0.590	2.099	41.7	52.4	42.3	38.5	8.3
LAF-26L05	1.3	8,187	0.816	1.968	15.8	64.3	27.8	22.2	6.1
LAF-26L06	1.7	11,635	0.885	0.808	7.0	90.3	33.3	43.6	2.9
LAF-26L07	1.7	3,402	0.680	2.011	22.7	67.3	40.0	16.7	10.0
LAF-26L08	1.7	4,468	1.066	1.611	25.4	67.5	38.3	17.0	8.1
LAF-26L09	2.0	6,282	1.157	1.312	15.2	79.8	19.6	27.5	5.4
LAF-26L11	1.7	4,196	1.179	1.303	22.7	74.6	59.6	17.3	3.2
LAF-26L12	1.7	11,794	0.975	1.683	25.4	67.1	16.3	27.9	5.6
LAF-26L13	2.0	907	0.703	2.863	35.0	42.5	61.3	9.7	37.5
LAF-26L14	1.0	408	0.068	1.436	55.6	0.0	33.3	0.0	0.0
LAF-26L15	2.7	7,779	0.930	0.857	18.4	81.3	19.5	73.2	1.5
LAF-26L16	1.3	3,493	0.386	1.412	20.8	76.0	47.1	23.5	7.8
LAF-26L17	2.0	2,359	0.703	1.173	12.5	79.8	54.8	9.7	7.7
LAF-26L18	2.0	9,775	1.293	0.752	14.2	84.9	21.1	70.2	1.6
LAF-26L19	1.3	1,202	0.068	0.000	100.0	0.0	100.0	0.0	0.0
LAF-26L20	2.3	6,600	0.386	0.912	22.0	76.6	11.8	64.7	1.7
LAF-26L21	2.3	9,480	0.907	0.959	26.3	73.0	15.0	60.0	1.2
LAF-26L22	2.3	7,734	1.111	0.960	22.3	76.8	34.7	61.2	1.2
LAF-26L23	2.7	8,482	1.270	0.727	16.8	82.4	3.6	66.1	0.8
LAF-26L24	2.3	10,410	1.678	1.002	28.8	69.5	13.5	85.1	0.0
LAF-26L25	2.0	3,583	0.113	0.527	89.2	10.8	60.0	40.0	0.6
LAF-26L26	4.0	3,810	1.361	2.974	5.4	85.1	10.0	66.7	25.6
LAF-26L27	2.3	9,888	1.066	0.848	20.4	78.7	17.0	68.1	1.1
Mean	2.1	5,665	0.826	1.446	27.6	64.1	33.0	40.0	7.5
St Error	0.1	710	0.082	0.161	4.5	5.0	4.3	4.9	1.9

Table 17. Infaunal community composition in the Lafayette River stratum of the Elizabeth River watershed in 1999. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Streblospio benedicti (P)	1,105	0.0291
Mediomastus ambiseta (P)	684	0.0273
Leptocheirus plumulosus (A)	633	0.0718
Tubificoides spp. Group I (O)	508	0.0191
Tubificoides heterochaetus (O)	172	0.0118
Heteromastus filiformis (P)	129	0.0609
Tharyx sp. A (P)	107	0.0218
Neanthes succinea (P)	76	0.0573
Spiochaetopterus costarum (P)	65	0.0445
Cyathura polita (I)	56	0.0300
Glycinde solitaria (P)	49	0.0173
Nemertea spp. (N)	47	0.0118
Leitoscoloplos spp. (P)	45	0.0527
Phoronis spp. (Ph)	44	0.7873
Paraprionospio pinnata (P)	44	0.0836
Polycirrus eximius (P)	35	0.0091
Tubificoides wasselli (O)	31	0.0055
Polydora cornuta (P)	30	0.0073
Listriella clymenellae (A)	28	0.0036
Clymenella torquata (P)	25	0.1100

Table 18. Infaunal community composition in the Lafayette River stratum of the Elizabeth River watershed in 2019. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Mediomastus ambiseta (P)	3,933	0.3027
Streblospio benedicti (P)	998	0.0409
Paraprionospio pinnata (P)	214	0.0582
Glycinde solitaria (P)	90	0.0182
Spiochaetopterus costarum (P)	84	0.0400
Tubificoides spp. Group I (O)	55	0.0073
Hermundura americana (P)	54	0.1027
Leitoscoloplos spp. (P)	32	0.1200
Acteocina canaliculata	21	0.0064
Neanthes succinea (P)	19	0.0255
Nemertina spp. (N)	19	0.0155
Podarkeopsis levifuscina (P)	15	0.0064
Scolelepis texana (P)	15	0.0027
Polydora cornuta (P)	14	0.0036
Grandidierella spp. (A)	12	0.0045
Phoronis spp. (Ph)	11	0.0055
Spiophanes bombyx (P)	9	0.0009
Ogyrides alphaerostris (D)	8	0.0082
Loimia medusa (P)	7	0.0082
Cyathura polita (I)	6	0.0055

Table 19. Western Branch of the Elizabeth River. Physical and chemical parameters by sample for 1999 samples.								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
ELR-06W01	8/13/1999	36.8547	-76.33735	1.0	23.0	5.2	0.9	0.4
ELR-06W02	8/13/1999	36.8553	-76.33798	1.0	23.1	5.7	2.3	0.4
ELR-06W03	8/13/1999	36.8593	-76.3451	2.0	23.3	5.3	92.9	8.1
ELR-06W04	8/13/1999	36.8576	-76.34835	4.0	23.4	5.7	54.3	7.9
ELR-06W05	8/13/1999	36.8537	-76.35101	3.0	23.4	5.3	68.7	4.5
ELR-06W06	8/13/1999	36.8485	-76.35132	1.0	23.3	6.7	8.2	0.8
ELR-06W07	8/13/1999	36.8513	-76.35204	3.0	23.4	5.6	77.3	5.2
ELR-06W08	8/13/1999	36.8484	-76.35391	1.0	23.5	6.3	89.3	5.6
ELR-06W09	8/13/1999	36.8498	-76.35596	2.0	23.4	6.6	92.0	6.2
ELR-06W10	8/13/1999	36.8478	-76.35613	1.0	23.2	7.6	89.2	5.6
ELR-06W11	8/13/1999	36.8459	-76.35688	1.0	23.2	6.5	91.3	5.7
ELR-06W12	8/13/1999	36.8379	-76.36003	1.0	22.3	8.2	67.1	5.2
ELR-06W13	8/13/1999	36.8407	-76.36086	1.0	22.6	8.8	77.6	5.2
ELR-06W14	8/13/1999	36.8418	-76.36231	7.0	23.1	6.0	90.3	6.8
ELR-06W16	8/13/1999	36.8467	-76.36568	1.0	22.4	10.4	95.1	7.0
ELR-06W17	8/13/1999	36.8366	-76.36989	1.0	22.1	7.8	96.5	7.5
ELR-06W18	8/13/1999	36.8385	-76.37025	1.0	21.9	8.6	97.6	7.3
ELR-06W19	8/13/1999	36.8354	-76.37328	1.0	22.1	5.8	81.7	5.3
ELR-06W22	8/13/1999	36.8381	-76.37984	1.0	21.5	7.3	99.1	6.1
ELR-06W23	8/13/1999	36.8369	-76.38552	2.0	21.2	6.7	88.8	6.9
ELR-06W24	8/13/1999	36.8295	-76.39283	1.0	20.7	7.3	89.6	6.7
ELR-06W25	8/13/1999	36.8302	-76.39341	1.0	20.6	6.4	88.8	6.7
ELR-06W26	8/13/1999	36.8393	-76.37335	3.0	21.8	7.1	94.1	6.9
ELR-06W27	8/13/1999	36.8569	-76.35552	1.0	23.1	7.0	10.9	0.9
ELR-06W28	8/13/1999	36.831	-76.39186	1.0	20.5	6.5	92.7	7.2
			Mean	1.7	22.5	6.8	73.5	5.4

Table 20. Western Branch of the Elizabeth River. Physical and chemical parameters by sample for 2019 collections								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
WBE-26W01	9/19/2019	36.85904	-76.3399	4.5	21.4	5.3	28.5	4.8
WBE-26W02	9/19/2019	36.85808	-76.3393	6.9	21.4	5.5	60.9	5.9
WBE-26W03	9/19/2019	36.85601	-76.3372	1.9	21.2	5.5	9.8	0.3
WBE-26W04	9/19/2019	36.85477	-76.336	1.3	21.2	6.1	15.2	0.4
WBE-26W05	9/19/2019	36.85949	-76.3426	2.3	21.4	5.7	15.2	1.5
WBE-26W07	9/19/2019	36.85546	-76.3494	4.3	21.3	5.1	46.6	6.3
WBE-26W09	9/19/2019	36.85573	-76.3632	1.6	21.0	6.5	68.0	6.6
WBE-26W10	9/19/2019	36.84876	-76.3505	0.9	21.2	5.9	80.9	9.3
WBE-26W11	9/19/2019	36.84842	-76.3521	2.2	21.2	6.1	69.4	5.8
WBE-26W12	9/19/2019	36.84768	-76.3538	2.4	21.2	6.4	74.4	6.1
WBE-26W13	9/19/2019	36.84876	-76.361	1.9	21.0	6.2	33.0	2.4
WBE-26W14	9/17/2019	36.84424	-76.3577	2.1	20.9	5.6	73.2	6.0
WBE-26W15	9/17/2019	36.84106	-76.3622	5.2	21.0	5.9	79.1	8.3
WBE-26W16	9/17/2019	36.842	-76.3649	1.3	20.9	5.8	11.5	0.7
WBE-26W18	9/17/2019	36.83715	-76.3681	2.8	20.8	5.5	88.5	9.6
WBE-26W19	9/17/2019	36.83456	-76.3739	2.0	20.4	5.5	79.7	6.0
WBE-26W20	9/17/2019	36.83755	-76.3787	3.7	20.5	5.4	70.8	6.4
WBE-26W21	9/17/2019	36.83859	-76.3816	5.9	20.6	5.3	83.2	9.6
WBE-26W22	9/17/2019	36.84064	-76.3859	2.1	20.4	5.6	83.2	7.7
WBE-26W23	9/17/2019	36.84482	-76.389	1.5	19.7	6.4	81.4	8.1
WBE-26W24	9/17/2019	36.82883	-76.3927	1.7	19.8	6.1	71.1	7.9
WBE-26W25	9/17/2019	36.82595	-76.3979	1.7	19.6	6.7	56.1	6.9
WBE-26W27	9/17/2019	36.8261	-76.3955	1.4	19.6	6.5	79.2	8.9
WBE-26W28	9/19/2019	36.83287	-76.3886	4.0	20.2	6.9	79.3	7.8
WBE-26W29	9/19/2019	36.84918	-76.3585	5.9	21.2	6.0	39.9	3.8
			Mean	2.9	20.8	5.9	59.1	5.9

Table 21. Western Branch of the Elizabeth River. Summary of benthic community parameters by sample for 1999 collections.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
ELR-06W01	3.0	2,023	0.545	2.878	16.9	28.1	8.3	33.3	14.6
ELR-06W02	2.7	2,614	0.682	3.225	28.7	48.7	16.7	36.7	13.9
ELR-06W03	2.3	1,932	0.545	2.619	57.6	23.5	20.8	20.8	20.0
ELR-06W04	2.0	3,205	0.705	2.518	51.8	29.1	51.6	16.1	9.2
ELR-06W05	2.3	5,864	1.523	3.329	23.6	19.0	23.9	3.0	19.8
ELR-06W06	3.7	4,477	1.045	2.930	30.5	21.3	4.3	10.9	12.7
ELR-06W07	1.7	3,591	0.500	1.938	52.5	43.7	63.6	18.2	2.5
ELR-06W08	2.0	3,114	0.318	1.873	38.0	48.2	7.1	50.0	3.6
ELR-06W09	2.3	2,341	0.614	1.722	37.9	61.2	63.0	33.3	5.8
ELR-06W10	1.7	2,886	0.318	2.113	33.1	45.7	35.7	21.4	3.9
ELR-06W11	1.3	3,159	0.477	2.128	41.7	38.8	61.9	28.6	4.3
ELR-06W12	2.0	2,523	0.773	2.243	55.9	18.9	32.4	11.8	9.9
ELR-06W13	2.3	4,045	1.000	2.356	55.6	31.5	15.9	50.0	14.6
ELR-06W14	1.7	2,955	0.386	1.990	43.1	11.5	29.4	17.6	4.6
ELR-06W16	2.7	1,773	0.864	2.771	32.1	30.8	13.2	18.4	15.4
ELR-06W17	1.7	2,432	0.455	2.386	57.0	18.7	65.0	20.0	18.7
ELR-06W18	2.0	1,864	0.455	2.214	56.1	24.4	25.0	55.0	9.8
ELR-06W19	2.0	2,409	0.477	2.642	42.5	32.1	23.8	19.0	17.0
ELR-06W22	2.3	3,114	0.750	2.431	45.3	32.1	21.2	36.4	12.4
ELR-06W23	2.3	2,432	0.591	2.418	39.3	12.1	34.6	15.4	6.5
ELR-06W24	2.3	3,250	0.682	2.777	37.8	9.8	6.7	20.0	11.9
ELR-06W25	2.3	4,000	0.750	2.292	44.9	7.4	9.1	51.5	6.8
ELR-06W26	3.0	1,977	0.523	2.513	49.4	19.5	17.4	47.8	12.6
ELR-06W27	3.3	4,659	1.114	2.448	21.5	29.8	12.2	22.4	6.8
ELR-06W28	2.3	3,500	0.545	2.226	47.4	13.0	16.7	50.0	8.4
Mean	2.3	3,045	0.665	2.439	41.6	28.0	27.2	28.3	10.6
St Error	0.1	199	0.055	0.080	2.3	2.8	3.9	3.0	1.1

Table 22. Western Branch of Elizabeth River. Summary of benthic community parameters by sample for 2019 collections									
Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
WBE-26W01	3.0	2,563	1.746	1.823	2.7	68.1	1.3	68.8	31.0
WBE-26W02	1.3	1,043	0.340	1.559	63.0	26.1	53.3	6.7	8.7
WBE-26W03	2.7	1,656	0.476	2.681	5.5	68.5	14.3	52.4	56.2
WBE-26W04	1.7	771	0.408	2.381	23.5	11.8	11.1	22.2	47.1
WBE-26W05	3.0	8,800	1.338	1.604	16.2	76.0	6.8	32.2	5.9
WBE-26W07	1.7	4,445	0.930	1.432	20.9	72.4	51.2	12.2	5.6
WBE-26W09	1.0	862	0.363	1.616	57.9	36.8	81.3	6.3	5.3
WBE-26W10	1.7	3,901	0.272	0.512	3.5	0.0	8.3	0.0	0.0
WBE-26W11	1.7	7,439	1.066	1.136	12.8	78.7	29.8	23.4	8.8
WBE-26W12	2.3	5,421	0.590	1.141	13.0	79.9	19.2	38.5	8.8
WBE-26W13	3.3	3,946	0.794	1.468	9.8	79.3	11.4	45.7	12.1
WBE-26W14	2.0	4,604	0.726	1.168	9.9	79.3	15.6	28.1	10.8
WBE-26W15	2.3	3,924	0.635	0.993	10.4	80.9	14.3	32.1	8.7
WBE-26W16	2.3	998	0.204	2.217	29.5	61.4	11.1	44.4	20.5
WBE-26W18	1.7	3,334	0.998	1.352	14.3	74.1	59.1	13.6	12.2
WBE-26W19	2.0	7,348	0.726	0.756	8.6	87.3	25.0	50.0	4.0
WBE-26W20	2.0	6,441	0.748	0.996	21.1	75.4	30.3	36.4	3.5
WBE-26W21	2.3	11,068	1.769	0.870	18.4	79.5	15.4	79.5	1.8
WBE-26W22	2.0	5,715	0.703	0.737	15.1	84.1	45.2	51.6	0.8
WBE-26W23	2.0	4,400	0.680	0.905	18.0	78.9	36.7	40.0	3.1
WBE-26W24	2.0	5,239	0.975	0.897	14.7	81.0	37.2	46.5	4.3
WBE-26W25	2.3	2,359	0.227	0.912	19.2	77.9	10.0	40.0	2.9
WBE-26W27	3.0	5,919	0.930	0.680	12.6	85.4	4.9	68.3	1.9
WBE-26W28	2.3	6,827	0.658	1.101	32.6	64.1	10.3	41.4	3.3
WBE-26W29	3.3	5,489	95.143	2.166	13.6	68.2	0.1	98.3	12.0
Mean	2.2	4,580	4.538	1.324	18.7	67.0	24.1	39.1	11.2
St Error	0.1	511	3.700	0.112	2.8	4.5	4.0	4.6	2.7

Table 23. Infaunal community composition in the Western Branch stratum of the Elizabeth River watershed in 1999. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Streblospio benedicti (P)	1,081	0.0327
Mediomastus ambiseta (P)	632	0.0327
Tubificoides heterochaetus (O)	240	0.0155
Heteromastus filiformis (P)	127	0.0636
Tubificoides spp. Group I (O)	125	0.0164
Tharyx sp. A (P)	123	0.0282
Paraprionospio pinnata (P)	103	0.0500
Leptocheirus plumulosus (A)	85	0.0155
Cyathura polita (I)	82	0.0491
Glycinde solitaria (P)	75	0.0264
Nemertina spp. (N)	54	0.0255
Neanthes succinea (P)	44	0.0473
Demonax microphthalmos (P)	43	0.0182
Leitoscoloplos spp. (P)	35	0.0727
Hemichordata spp. (H)	32	0.0064
Polydora cornuta (P)	29	0.0027
Podarkeopsis levifuscina (P)	27	0.0155
Spiochaetopterus costarum (P)	20	0.0145
Eteone heteropoda (P)	14	0.0100
Macoma mitchelli (B)	9	0.0418

Table 24. Infaunal community composition in the Western Branch stratum of the Elizabeth River watershed in 2019. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, D – decapoda, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Mediomastus ambiseta (P)	3,218	0.2236
Streblospio benedicti (P)	611	0.0318
Hermundura americana (P)	235	0.1873
Spiochaetopterus costarum (P)	100	0.0718
Paraprionospio pinnata (P)	91	0.0273
Leitoscoloplos spp. (P)	31	0.1155
Glycinde solitaria (P)	25	0.0091
Acteocina canaliculata (G)	23	0.0009
Capitomastus aciculatus (P)	14	0.0036
Haminoea solitaria (G)	13	0.0018
Neanthes succinea (P)	11	0.0055
Phoronis spp. (Ph)	11	0.0082
Grandidierella spp. (A)	9	0.0018
Demonax microphthalmos (P)	7	0.0009
Ogyrides alphaerostris (D)	5	0.0045
Podarkeopsis levifuscina (P)	5	0.0036
Tubificoides wasselli (O)	5	0.0009
Tubificoides spp. Group I	4	0.0018
Alpheus heterochaelis (D)	3	0.0164
Nassarius vibex (G)	3	0.0455

Table 25. Eastern Branch of the Elizabeth River. Physical and chemical parameters by sample for 1999 samples.

Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
EBE-26E01	8/26/2019	36.8414	-76.28742	9.3	23.6	3.1	80.0	8.7
EBE-26E02	8/26/2019	36.8391	-76.28351	1.7	20.7	5.3	17.8	3.3
EBE-26E03	8/26/2019	36.839	-76.27941	2.9	21.2	4.5	27.5	3.4
EBE-26E04	8/26/2019	36.8384	-76.27738	10.3	23.5	2.8	83.4	8.8
EBE-26E07	8/26/2019	36.8414	-76.26958	11.9	24.2	1.2	72.3	10.4
EBE-26E08	8/27/2019	36.8377	-76.26773	3.0	21.3	4.2	94.8	8.1
EBE-26E09	8/27/2019	36.8417	-76.26669	6.7	21.0	4.5	68.7	10.7
EBE-26E10	8/26/2019	36.8382	-76.26034	2.4	19.9	4.8	96.6	8.6
EBE-26E11	9/3/2019	36.8236	-76.23582	2.7	20.7	4.2	34.7	6.6
EBE-26E12	9/3/2019	36.8183	-76.2425	1.5	19.3	5.5	54.4	22.8
EBE-26E13	9/3/2019	36.8151	-76.24264	1.0	19.0	6.8	23.6	0.6
EBE-26E15	8/27/2019	36.8394	-76.2334	1.9	19.2	6.5	91.5	10.6
EBE-26E16	8/27/2019	36.8388	-76.22799	3.2	20.4	3.5	57.6	6.6
EBE-26E17	9/3/2019	36.8407	-76.22635	2.1	20.5	3.8	74.8	11.8
EBE-26E18	9/3/2019	36.8432	-76.21811	1.1	19.4	6.8	81.4	16.8
EBE-26E19	9/3/2019	36.8458	-76.22457	1.5	20.3	4.4	80.2	15.5
EBE-26E20	8/28/2019	36.8364	-76.21822	0.7	18.9	5.7	55.7	8.6
EBE-26E21	8/28/2019	36.8333	-76.21783	1.8	15.8	5.2	61.2	9.9
EBE-26E22	8/28/2019	36.8317	-76.21356	1.9	16.2	5.3	83.6	10.8
EBE-26E23	8/28/2019	36.832	-76.21031	1.2	15.5	4.6	58.0	11.4
EBE-26E24	8/28/2019	36.828	-76.20111	2.1	14.9	4.4	14.5	1.4
EBE-26E25	8/28/2019	36.8266	-76.18702	3.9	11.9	2.9	91.2	9.1
EBE-26E26	8/27/2019	36.8407	-76.28343	8.5	23.3	3.9	78.3	8.5
EBE-26E27	8/27/2019	36.8384	-76.24813	5.4	21.1	3.7	81.2	8.3
EBE-26E28	9/3/2019	36.8243	-76.23647	1.0	20.6	4.0	60.2	13.2
			Mean	3.6	19.7	4.5	64.9	9.4

Table 26. Eastern Branch of the Elizabeth River. Physical and chemical parameters by sample for 2019 collections								
Station	Date	Latitude	Longitude	Depth (m)	Salinity (ppt)	Dissolved Oxygen (ppm)	Silt-clay Content (%)	Volatile Solids (%)
ELR-06E01	8/27/1999	36.84224	-76.2925	9.0	21.5	2.4	92.7	7.9
ELR-06E02	8/27/1999	36.84274	-76.2869	4.0	20.5	2.9	27.1	6.0
ELR-06E03	8/27/1999	36.84187	-76.2833	6.0	21.0	2.4	45.8	6.0
ELR-06E04	8/27/1999	36.84133	-76.2753	4.0	19.7	2.5	4.6	3.8
ELR-06E05	8/27/1999	36.84066	-76.27	5.0	19.7	1.9	45.2	4.7
ELR-06E06	8/27/1999	36.83809	-76.2697	1.0	19.2	4.4	76.8	7.4
ELR-06E08	8/23/1999	36.83677	-76.2622	2.0	18.0	4.5	96.6	8.1
ELR-06E09	8/23/1999	36.8402	-76.2577	3.0	19.0	2.7	82.3	9.0
ELR-06E10	8/23/1999	36.8403	-76.2573	2.0	17.2	6.4	57.1	6.3
ELR-06E11	8/23/1999	36.83902	-76.2449	2.0	16.8	7.5	88.3	7.7
ELR-06E12	8/23/1999	36.83415	-76.242	2.0	17.8	2.5	82.5	8.2
ELR-06E15	8/23/1999	36.83034	-76.2385	1.0	14.5	10.8	75.6	8.1
ELR-06E16	8/23/1999	36.8387	-76.2376	3.0	16.5	4.3	97.1	10.5
ELR-06E19	8/23/1999	36.84341	-76.2265	1.0	15.5	8.1	94.1	12.9
ELR-06E20	8/23/1999	36.84406	-76.226	1.0	14.5	7.0	91.4	14.7
ELR-06E21	8/23/1999	36.83695	-76.2232	3.0	16.8	3.1	93.0	9.1
ELR-06E22	8/23/1999	36.8383	-76.221	1.0	16.8	3.9	95.6	9.9
ELR-06E23	8/23/1999	36.83266	-76.2191	2.0	16.5	3.6	96.6	10.5
ELR-06E24	8/23/1999	36.83483	-76.219	2.0	16.5	3.0	85.7	8.3
ELR-06E25	8/23/1999	36.83103	-76.2136	2.0	16.2	4.0	86.9	8.0
ELR-06E26	8/23/1999	36.84079	-76.2278	1.0	15.0	10.1	95.1	10.7
ELR-06E27	8/23/1999	36.84304	-76.2211	1.0	15.2	7.5	98.4	13.9
ELR-06E28	8/23/1999	36.83733	-76.2226	3.0	16.8	3.6	83.9	7.9
ELR-06E29	8/27/1999	36.84035	-76.2887	7.0	21.0	2.6	33.3	4.2
ELR-06E30	27-Aug-99	36.83854	-76.2559	6.0	20.0	2.4	49.4	4.6
			Mean	3.0	17.7	4.6	75.0	8.3

Table 27. Eastern Branch of the Elizabeth River. Summary of benthic community parameters by sample for 1999 collections.									
Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
ELR-06E01	3.0	1,523	1.023	2.667	23.9	10.4	4.4	28.9	9.0
ELR-06E02	4.0	4,295	3.477	3.390	10.6	55.0	5.2	48.4	18.0
ELR-06E03	2.0	4,318	1.273	3.250	48.9	14.7	50.0	12.5	14.7
ELR-06E04	3.3	2,705	1.841	3.726	5.0	17.6	8.6	11.1	32.8
ELR-06E05	2.0	682	1.386	3.240	20.0	6.7	8.2	1.6	16.7
ELR-06E06	2.0	1,091	0.886	3.255	43.8	20.8	25.6	5.1	22.9
ELR-06E08	2.0	3,886	1.045	1.690	63.2	7.6	41.3	43.5	8.8
ELR-06E09	1.7	4,364	0.773	2.375	64.6	13.0	64.7	8.8	6.3
ELR-06E10	3.7	4,364	2.159	3.225	41.7	5.7	25.3	45.3	15.1
ELR-06E11	2.7	3,705	1.318	2.272	63.2	9.2	39.7	41.4	12.3
ELR-06E12	1.7	3,273	1.114	1.245	89.6	1.4	63.3	4.1	4.9
ELR-06E15	3.0	2,386	1.091	2.170	65.7	10.5	33.3	50.0	14.3
ELR-06E16	1.7	3,864	0.591	0.787	94.1	0.6	73.1	3.8	3.5
ELR-06E19	1.7	4,432	0.909	1.683	68.7	0.0	62.5	0.0	6.7
ELR-06E20	1.3	5,250	1.432	1.969	62.3	0.4	52.4	1.6	6.1
ELR-06E21	2.3	2,864	0.545	1.759	56.3	4.8	8.3	41.7	6.3
ELR-06E22	2.3	2,182	1.682	2.296	57.3	6.3	31.1	8.1	9.4
ELR-06E23	2.7	3,727	0.955	2.058	50.0	3.7	7.1	31.0	7.3
ELR-06E24	1.7	6,682	1.068	1.322	74.5	0.7	29.8	2.1	5.8
ELR-06E25	2.0	4,886	0.591	1.850	63.3	2.8	15.4	3.8	9.3
ELR-06E26	2.3	4,045	0.909	2.010	58.4	1.1	45.0	2.5	10.1
ELR-06E27	2.7	2,273	0.841	2.200	62.0	8.0	32.4	24.3	13.0
ELR-06E28	2.0	3,045	0.705	1.886	61.9	3.0	45.2	9.7	11.9
ELR-06E29	2.3	1,114	8.000	2.098	73.5	12.2	2.6	96.3	12.2
ELR-06E30	2.7	2,477	0.682	3.327	56.9	26.6	53.3	20.0	15.6
Mean	2.3	3,337	1.452	2.310	55.2	9.7	33.1	21.8	11.7
St Error	0.1	286	0.300	0.153	4.3	2.3	4.3	4.7	1.3

Table 28. Eastern Branch of Elizabeth River. Summary of benthic community parameters by sample for 2019 collections									
Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
EBE-26E01	2.3	4,445	0.839	2.417	25.5	67.9	35.1	40.5	9.7
EBE-26E02	2.7	9,616	1.225	1.826	17.0	72.2	42.6	20.4	4.2
EBE-26E03	2.7	1,383	0.680	2.811	11.5	55.7	13.3	66.7	31.1
EBE-26E04	1.7	1,066	0.499	2.453	38.3	53.2	68.2	13.6	12.8
EBE-26E07	1.7	1,724	0.159	0.696	92.1	5.3	57.1	14.3	2.6
EBE-26E08	1.7	658	0.408	1.401	17.2	6.9	33.3	11.1	79.3
EBE-26E09	2.0	7,122	0.816	1.305	34.4	63.1	52.8	36.1	1.6
EBE-26E10	1.7	5,625	0.522	1.150	15.7	78.2	26.1	21.7	6.0
EBE-26E11	2.0	7,212	1.406	1.246	74.5	18.9	27.4	6.5	4.4
EBE-26E12	1.3	1,043	0.204	1.186	69.6	0.0	22.2	0.0	17.4
EBE-26E13	1.3	2,699	0.839	1.738	57.1	0.0	18.9	0.0	65.5
EBE-26E15	1.7	3,720	0.930	1.732	25.0	58.5	34.1	17.1	4.3
EBE-26E16	2.0	4,808	0.885	1.181	34.0	65.6	56.4	41.0	1.4
EBE-26E17	2.7	5,625	1.429	0.923	16.9	82.7	9.5	88.9	1.2
EBE-26E18	1.0	953	0.181	1.754	35.7	0.0	25.0	0.0	4.8
EBE-26E19	2.3	5,443	0.408	0.933	31.3	68.3	11.1	72.2	0.0
EBE-26E20	1.7	3,946	0.703	1.366	46.0	52.9	51.6	22.6	1.1
EBE-26E21	2.3	8,460	9.253	0.981	27.3	71.6	2.0	5.4	0.8
EBE-26E22	1.7	7,779	1.066	1.046	31.5	67.9	46.8	51.1	0.0
EBE-26E23	1.7	5,851	0.862	1.156	42.2	55.8	52.6	31.6	0.0
EBE-26E24	1.7	3,243	0.159	1.582	44.1	22.4	28.6	28.6	0.0
EBE-26E25	1.8	11,431	0.885	0.543	8.9	0.2	7.7	2.6	0.8
EBE-26E26	1.7	3,561	0.658	2.278	24.8	61.8	41.4	24.1	14.0
EBE-26E27	1.7	1,429	0.386	2.289	30.2	60.3	23.5	47.1	9.5
EBE-26E28	1.0	680	0.318	2.239	43.3	6.7	21.4	7.1	16.7
Mean	1.8	4,381	1.029	1.529	35.8	43.8	32.4	26.8	11.6
St Error	0.1	592	0.343	0.118	4.0	5.8	3.5	4.7	3.9

Table 29. Infaunal community composition in the Eastern Branch stratum of the Elizabeth River watershed in 1999. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Streblospio benedicti (P)	1,661	0.0527
Leptocheirus plumulosus (A)	289	0.0600
Heteromastus filiformis (P)	228	0.0864
Mediomastus ambiseta (P)	146	0.0091
Paraprionospio pinnata (P)	145	0.0400
Tubificoides heterochaetus (O)	116	0.0127
Leitoscoloplos spp. (P)	95	0.2436
Tubificoides spp. Group I (O)	76	0.0145
Nemertina spp. (N)	65	0.0409
Cyathura polita (I)	65	0.0655
Parahesione luteola (P)	63	0.0145
Podarkeopsis levifuscina (P)	39	0.0164
Neanthes succinea (P)	35	0.0136
Eteone heteropoda (P)	28	0.0127
Hemichordata spp. (H)	27	0.0218
Glycinde solitaria (P)	26	0.0091
Leucon americanus (C)	26	0.0073
Loimia medusa (P)	26	0.0845
Macoma mitchelli (B)	24	0.0691

Table 30. Infaunal community composition in the Eastern Branch stratum of the Elizabeth River watershed in 2019. Shown are the top twenty density dominants and their biomass. Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H- hemichordate, I – isopod, In – insecta, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance per m^2	Biomass per m^2
Mediomastus ambiseta (P)	2,137	0.1382
Streblospio benedicti (P)	1,179	0.0509
Tubificoides spp. Group I (O)	115	0.0136
Leitoscoloplos spp. (P)	97	0.1536
Hermundura americana (P)	95	0.1127
Paraprionospio pinnata (P)	72	0.0091
Spiochaetopterus costarum (P)	55	0.0264
Laeonereis culveri (P)	52	0.0309
Chironomus spp. (In)	28	0.0045
Leptocheirus plumulosus (A)	20	0.0045
Glycinde solitaria (P)	19	0.0091
Phoronis spp. (Ph)	12	0.0073
Capitomastus aciculatus (P)	11	0.0064
Eteone heteropoda (P)	9	0.0082
Grandidierella spp. (A)	8	0.0018
Parahesione luteola (P)	5	0.0036
Haminoea solitaria (G)	5	0.0018
Loimia medusa (P)	5	0.0018
Cyathura polita (I)	5	0.0118
Macoma mitchelli (B)	5	0.0109

Table 31. Summary of BIBI and metrics comparing 1999 and 2019 data by stratum. Abundance in individuals per m^2, biomass in AFDW gC per m^2, Shannon index using base 2, and all other metrics are percentages.

Stratum	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
Mainstem									
1999	2.8	3,644	5.612	2.80	21.3	42.1	20.7	42.7	17.0
2019	2.8	3,499	3.219	2.58	29.7	50.3	26.6	47.9	20.7
Southern Branch									
1999	2.0	4,665	1.022	1.66	56.3	15.4	39.8	24.1	16.2
2019	2.5	3,305	0.548	1.91	11.4	47.6	17.9	26.7	30.9
Lafayette									
1999	2.6	4,137	1.713	2.52	32.2	27.3	22.6	30.2	9.3
2019	2.1	5,665	0.826	1.45	27.6	64.1	33.0	40.0	7.5
Western Branch									
1999	2.3	3,045	0.665	2.44	41.6	28.0	27.2	28.3	10.6
2019	2.2	4,580	0.810*	1.32	18.7	67.0	24.1	39.1	11.2
Eastern Branch									
1999	2.3	3,337	1.452	2.31	55.2	9.7	33.1	21.8	11.7
2019	1.8	4,381	1.029	1.53	35.8	43.8	32.4	26.8	11.6

*- Including a single large bivalve (the hard shell clam *Mercenaria mercenaria*) value was 4.538 g C/m^2

Table 32. Summary of percent area of each stratum with Benthic Index of Biotic Integrity values below 3.0 (Total Percent Degraded) comparing 1999 and 2019 data. Also shown are area estimates with Marginal BIBI values (2.9 – 2.6), Degraded BIBI values (<2.6 – 2.1) and Severely Degraded BIBI values (≤ 2.0). Also shown are the areal estimates for all Virginia Tidal waters for 1999 and 2019.

Elizabeth River	Year	Total Degraded	Marginal	Degraded	Severely Degraded	Degraded plus Severely Degraded
Mainstem of River	1999	52	12	12	28	40
	2019	44	12	4	28	32
Southern Branch	1999	96	20	12	64	76
	2019	64	16	12	36	48
Lafayette River	1999	72	16	28	28	56
	2019	92	4	28	60	88
Western Branch	1999	84	8	36	40	76
	2019	80	4	24	52	76
Eastern Branch	1999	80	16	16	48	64
	2019	100	4	12	84	96
Virginia Tidal Waters	1999	36	12	10	14	24
	2019	50	22	11	17	28

Table 33. Infaunal community composition for lower James River polyhaline stations during 1999 and their average abundance (# of individuals/m^2) and biomass (g C AFDW/m^2). Taxon code: A – amphipod, B – bivalve, C – cumacean, Ce – cephalochordate, G – gastropod, H- hemichordate, I – isopod, In – insecta, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance (#/m^2)	Biomass (AFDW/m^2)
Mediomastus ambiseta (P)	783	0.0354
Streblospio benedicti (P)	737	0.0202
Tubificoides heterochaetus (O)	310	0.0051
Glycinde solitaria (P)	255	0.0480
Neanthes succinea (P)	207	0.2652
Paraprionospio pinnata (P)	179	0.0657
Hemichordata (H)	152	0.0657
Tubificoides spp Group I (O)	129	0.0101
Heteromastus filiformis (P)	119	0.0657
Nemertea (N)	58	0.0152
Leitoscoloplos spp. (P)	50	0.0505
Loimia medusa (P)	38	0.0783
Pectinaria gouldii (P)	28	0.0101
Branchiostoma virginiae (Ce)	25	0.0152
Tharyx sp. A Doner (P)	25	0.0076
Macoma balthica (B)	23	0.0884
Polycirrus eximius (P)	18	0.0076
Listriella clymenellae (A)	15	0.0051
Scolelepis texana (P)	15	0.0025
Acteocina canaliculata	13	0.0101
Clymenella torquata (P)	13	0.0429

Table 34. Infaunal community composition for lower James River polyhaline stations during during 2019 and their average abundance (# of individuals/m^2) and biomass (g C AFDW/ m^2). Taxon code: A – amphipod, B – bivalve, C – cumacean, G – gastropod, H-hemichordate, I – isopod, In – insecta, N – nemertine, O – oligochaete, P – polychaeta, Ph – phoronid.

Name	Abundance (#/m^2)	Biomass (AFDW/m^2)
Mediomastus ambiseta (P)	1,823	0.0726
Spiochaetopterus costarum (P)	370	0.0771
Paraprionospio pinnata (P)	172	0.1610
Hermundura americana (P)	127	0.0885
Acteocina canaliculata	116	0.0227
Leitoscoloplos spp. (P)	93	0.1225
Streblospio benedicti (P)	79	0.0159
Tubificoides spp. Group I (O)	73	0.0113
Glycinde solitaria (P)	70	0.0227
Nemertea (N)	68	0.0204
Phoronis spp. (Ph)	50	0.0204
Leucon americanus (C)	36	0.0113
Sigambra tentaculate (P)	32	0.0204
Neanthes succinea (P)	25	0.0295
Ampelisca vadorum (A)	14	0.0045
Grandidierella spp. (A)	11	0.0023
Pectinaria gouldii (P)	11	0.0068
Mulinia lateralis (B)	9	0.0159
Podarkeopsis levifuscina (P)	9	0.0091

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 theses 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 strata were the Mainstem of the river, the Lafayette River, the Eastern Branch, Western Branch and Southern Branch. In future years the entire Elizabeth River watershed will be sampled as a single stratum.

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 5^{th} percentile and the 50^{th} percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5^{th} percentile are scored as a 1. Samples with values between the 5^{th} and 50^{th} metrics are scored as 3 and values greater than the 50^{th} percentile are scored as 5. For abundance and biomass, values below the 5^{th} and above the 95^{th} percentile are scored as 1, values between the 5^{th} and 25^{th} and the 75^{th} and 95^{th} percentiles are scored as 3 and values between the 25^{th} and 75^{th} percentiles are scored as 5.

Appendix B.

Elizabeth River Watershed.
Maps of Benthic Community Condition.

1999

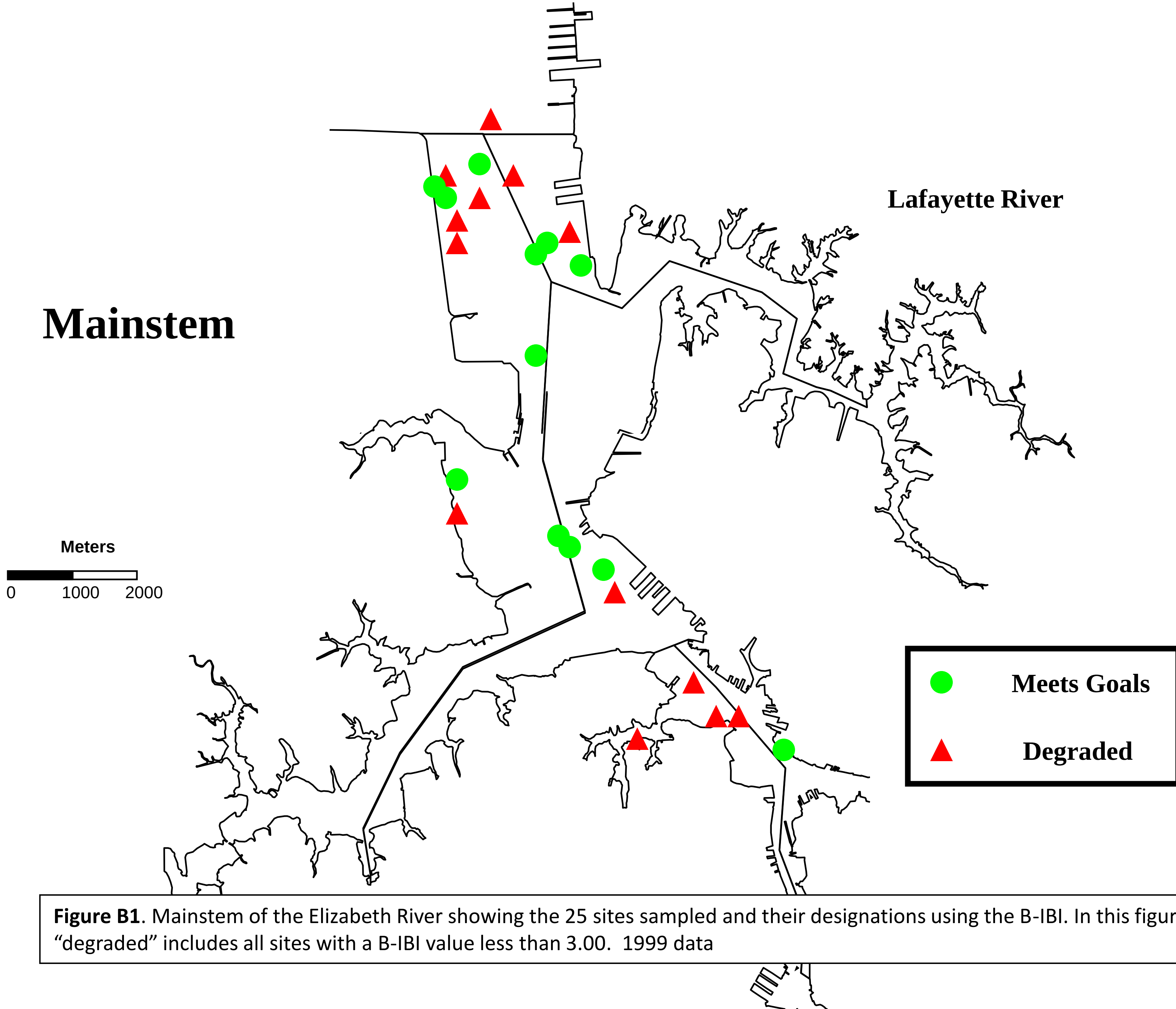


Figure B1. Mainstem of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 1999 data

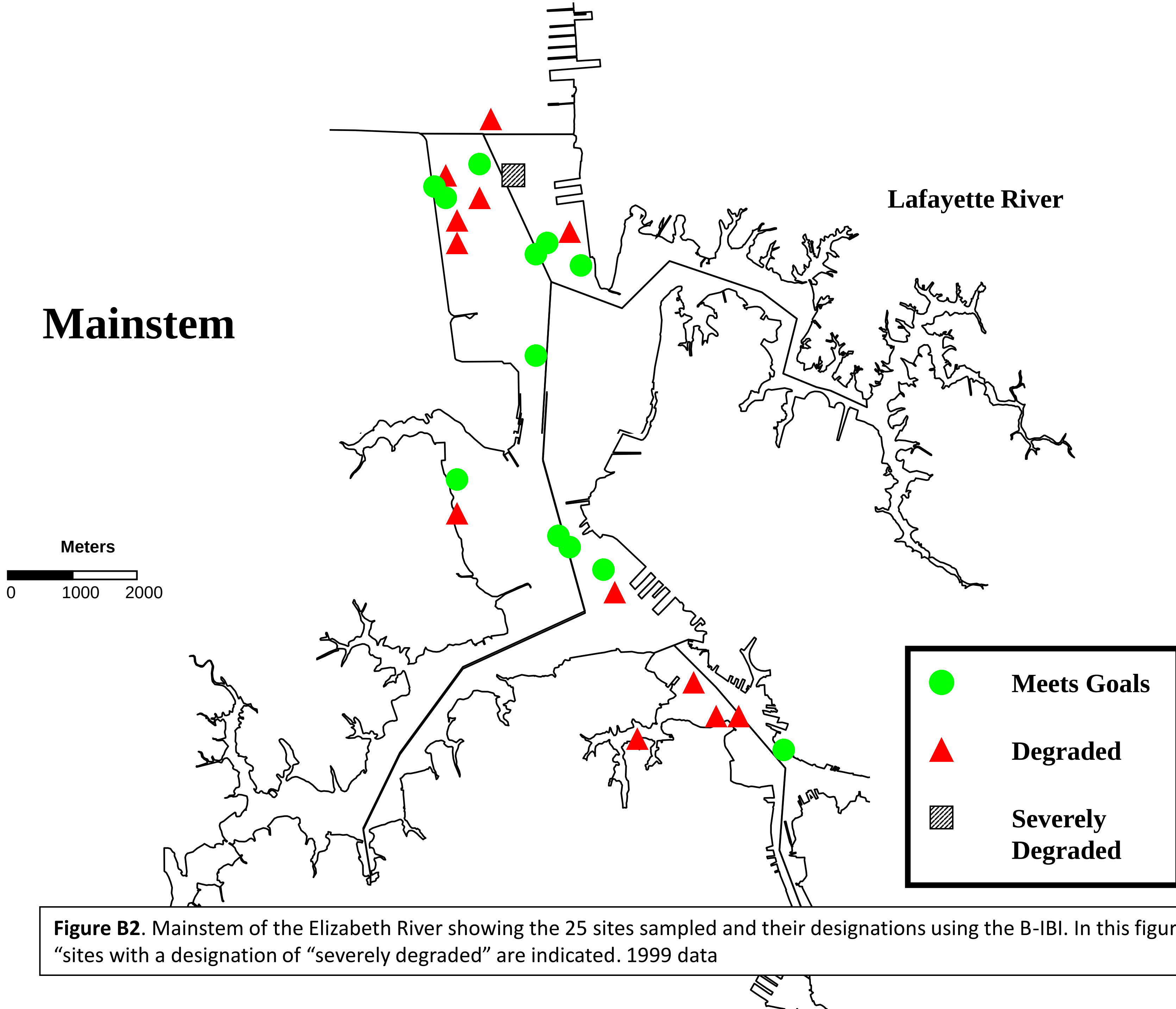


Figure B2. Mainstem of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 1999 data

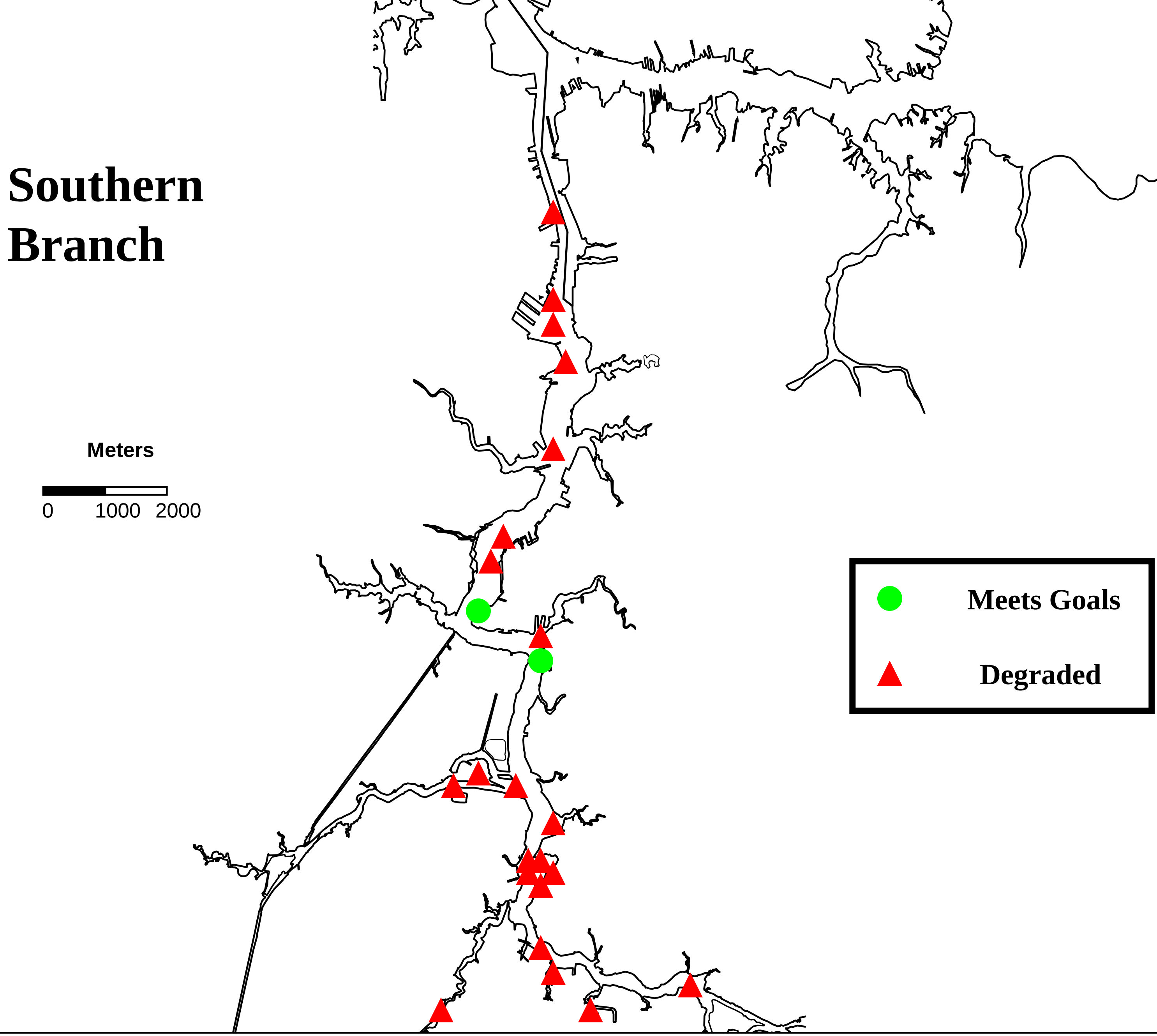


Figure B3. Southern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 1999 data

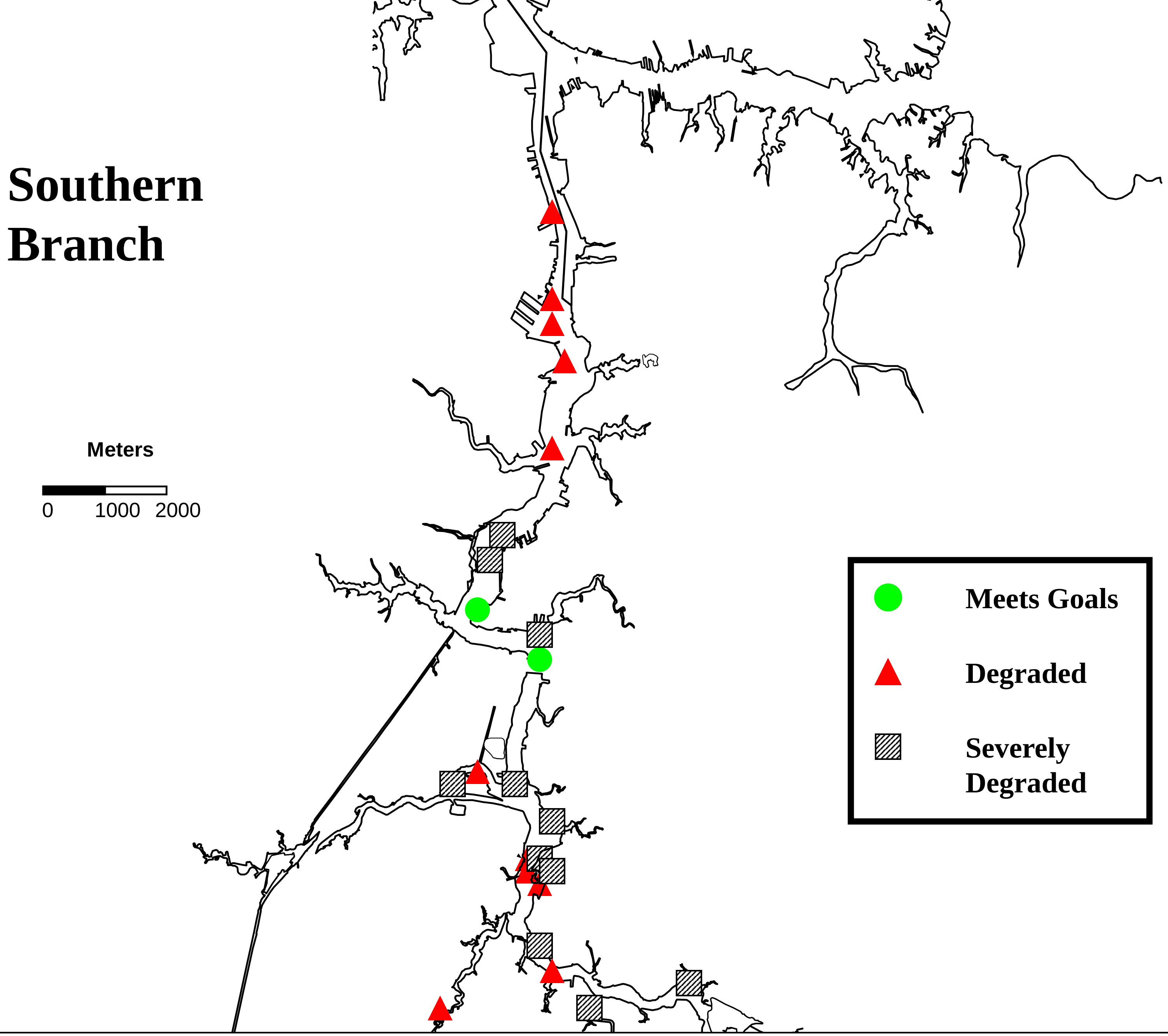


Figure B4. Southern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 1999 data

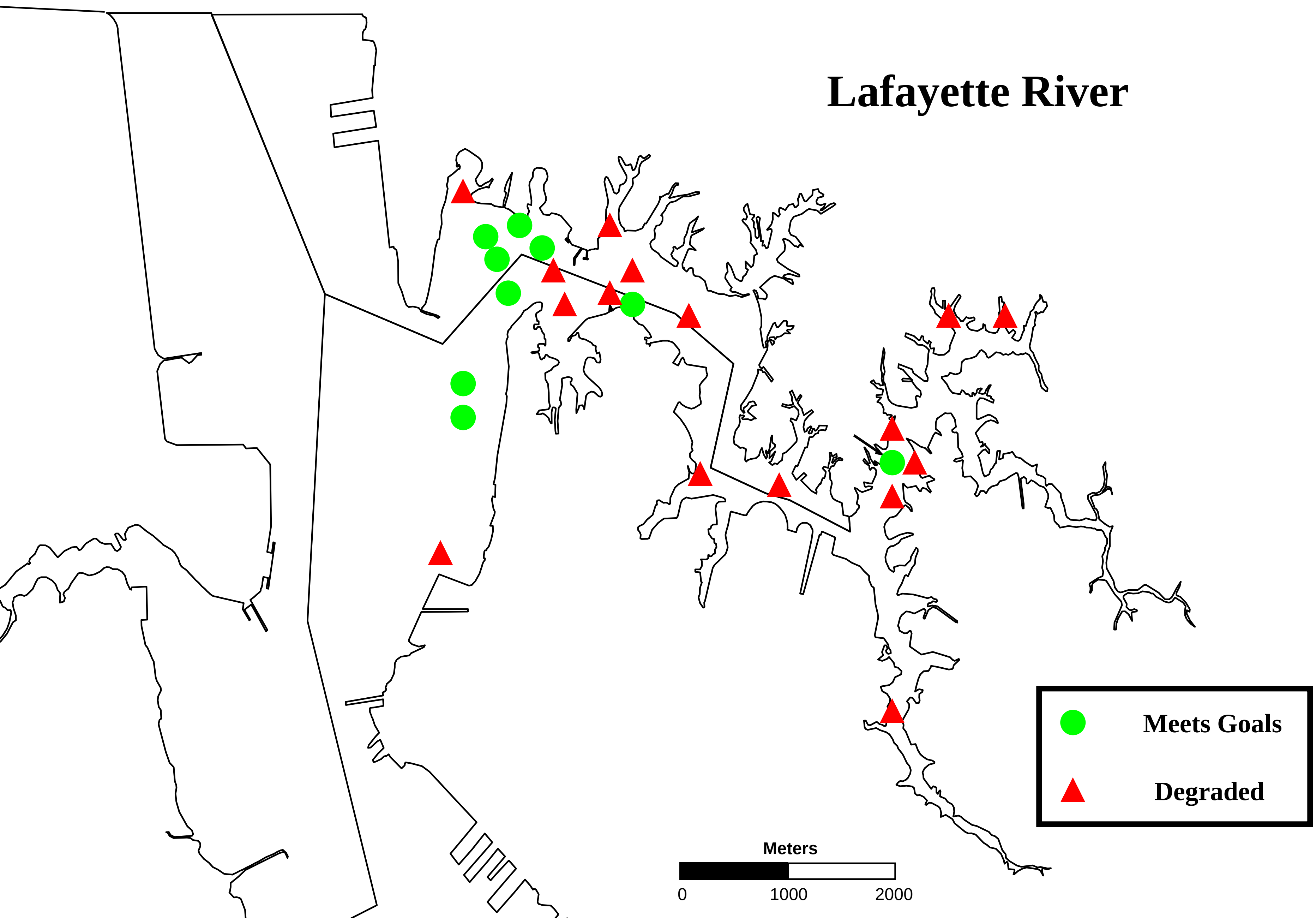


Figure B5. Lafayette River of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 1999 data

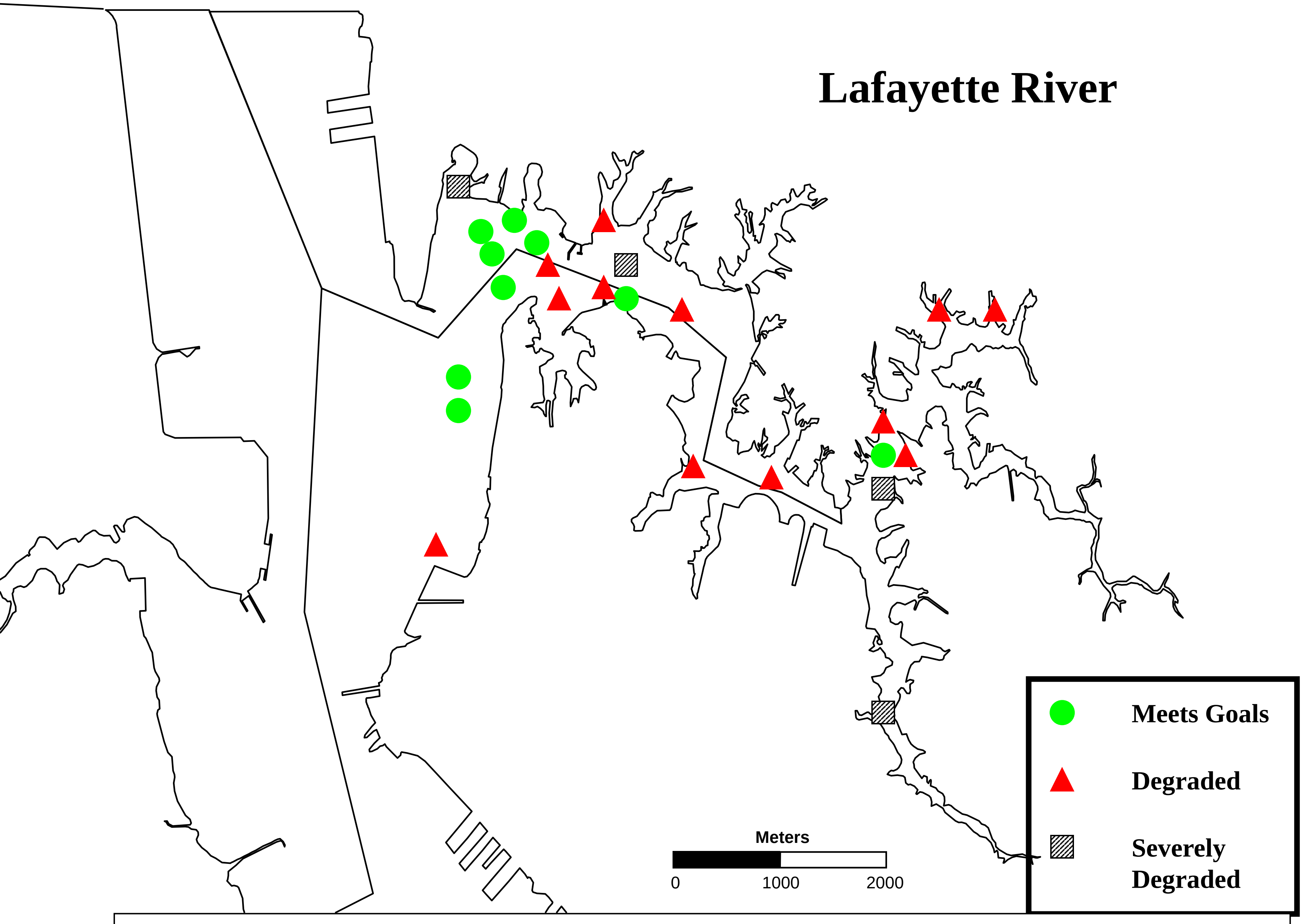


Figure B6. Lafayette River of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 1999 data

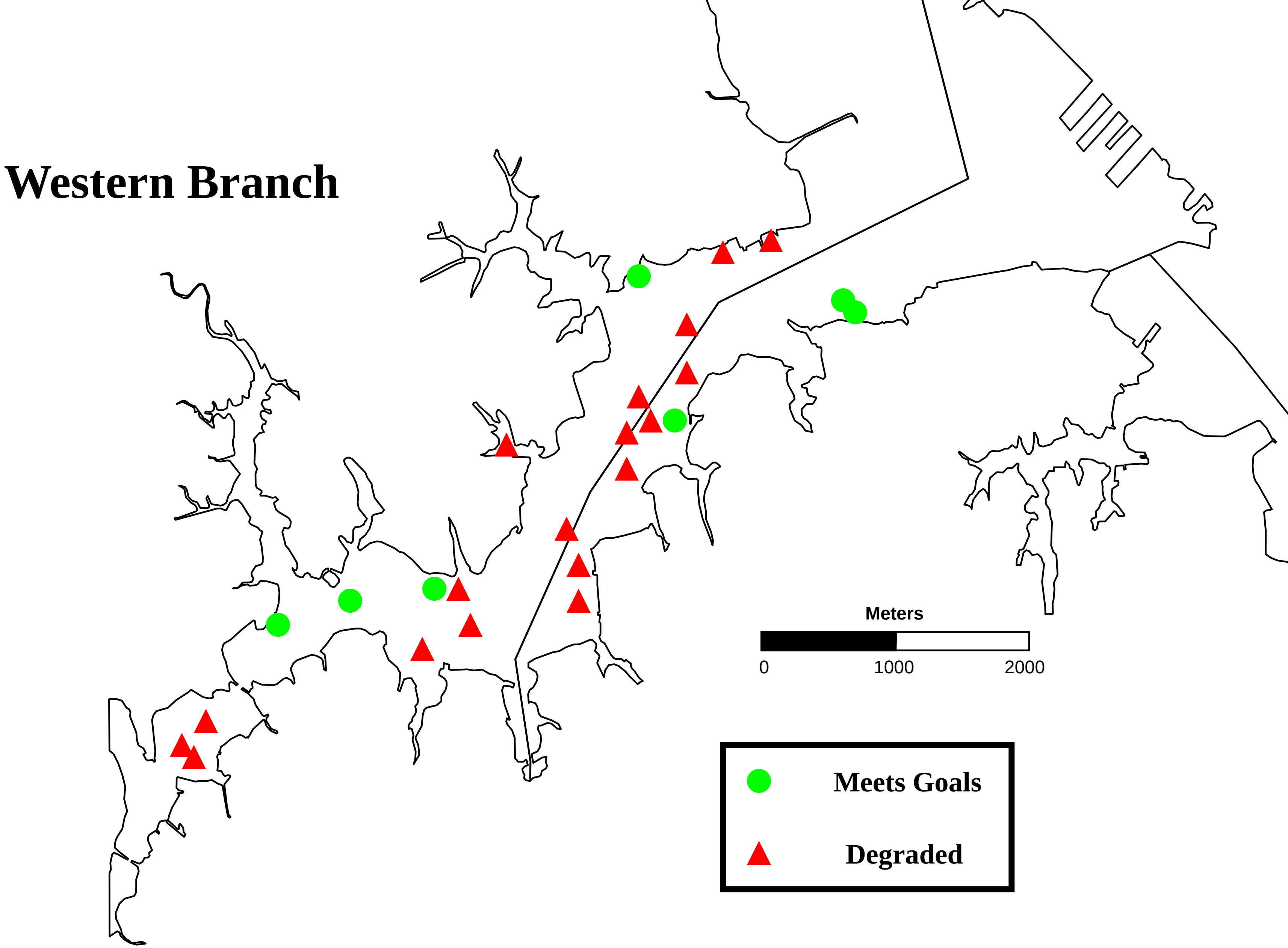
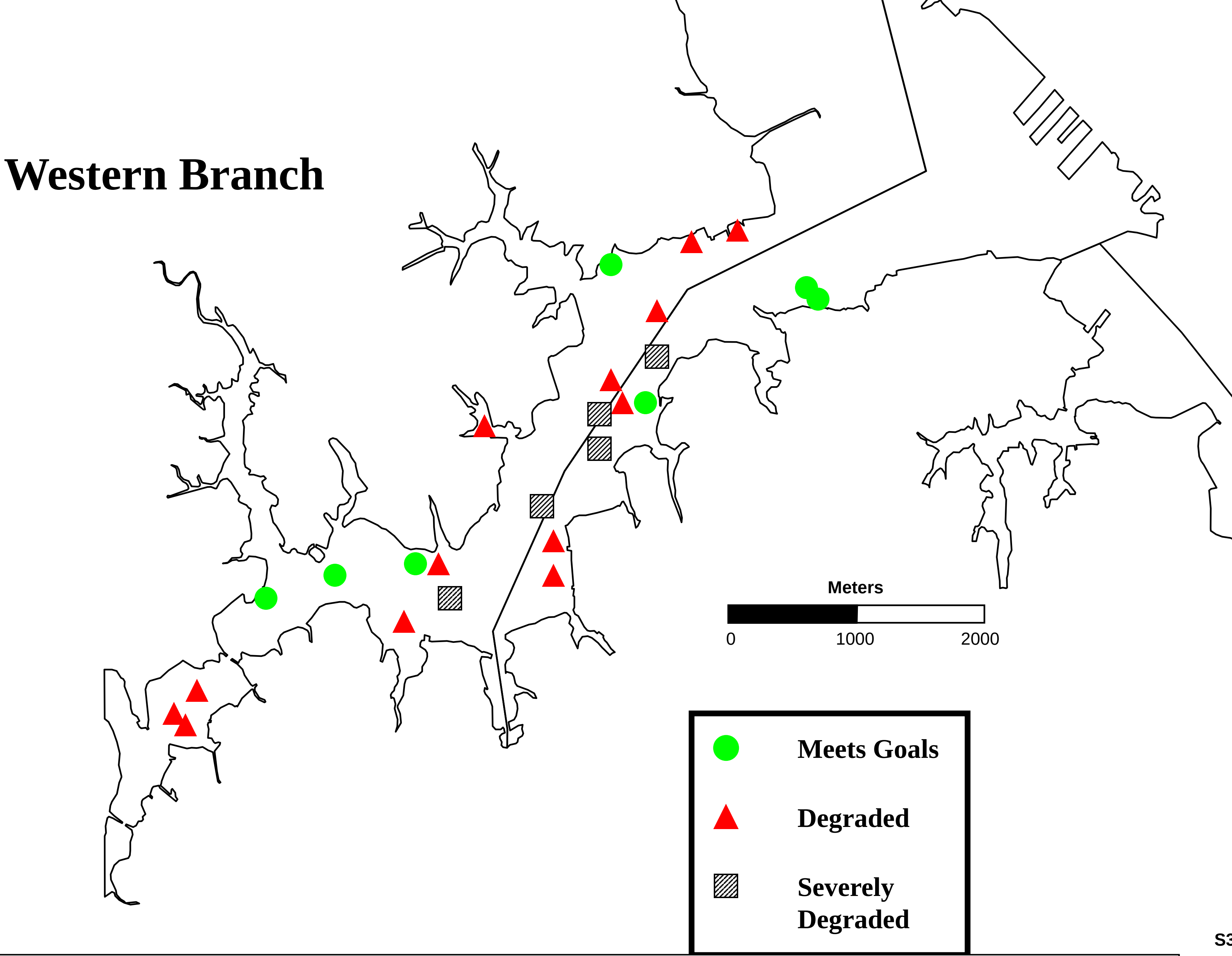


Figure B7. Western Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure “degraded” includes all sites with a B-IBI value less than 3.00. 1999 data



S3

Figure B8. Western Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 1999 data

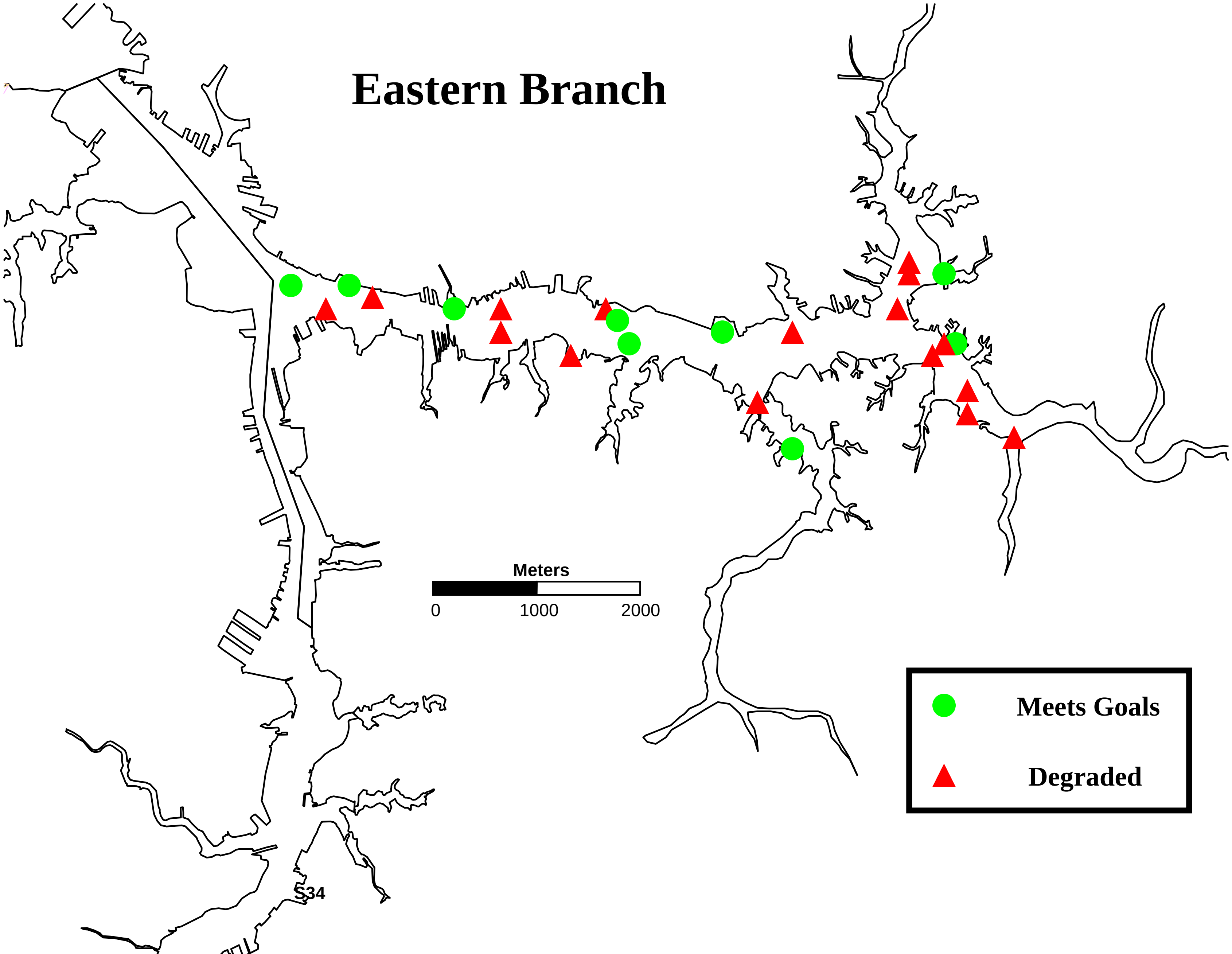


Figure B9. Eastern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 1999 data

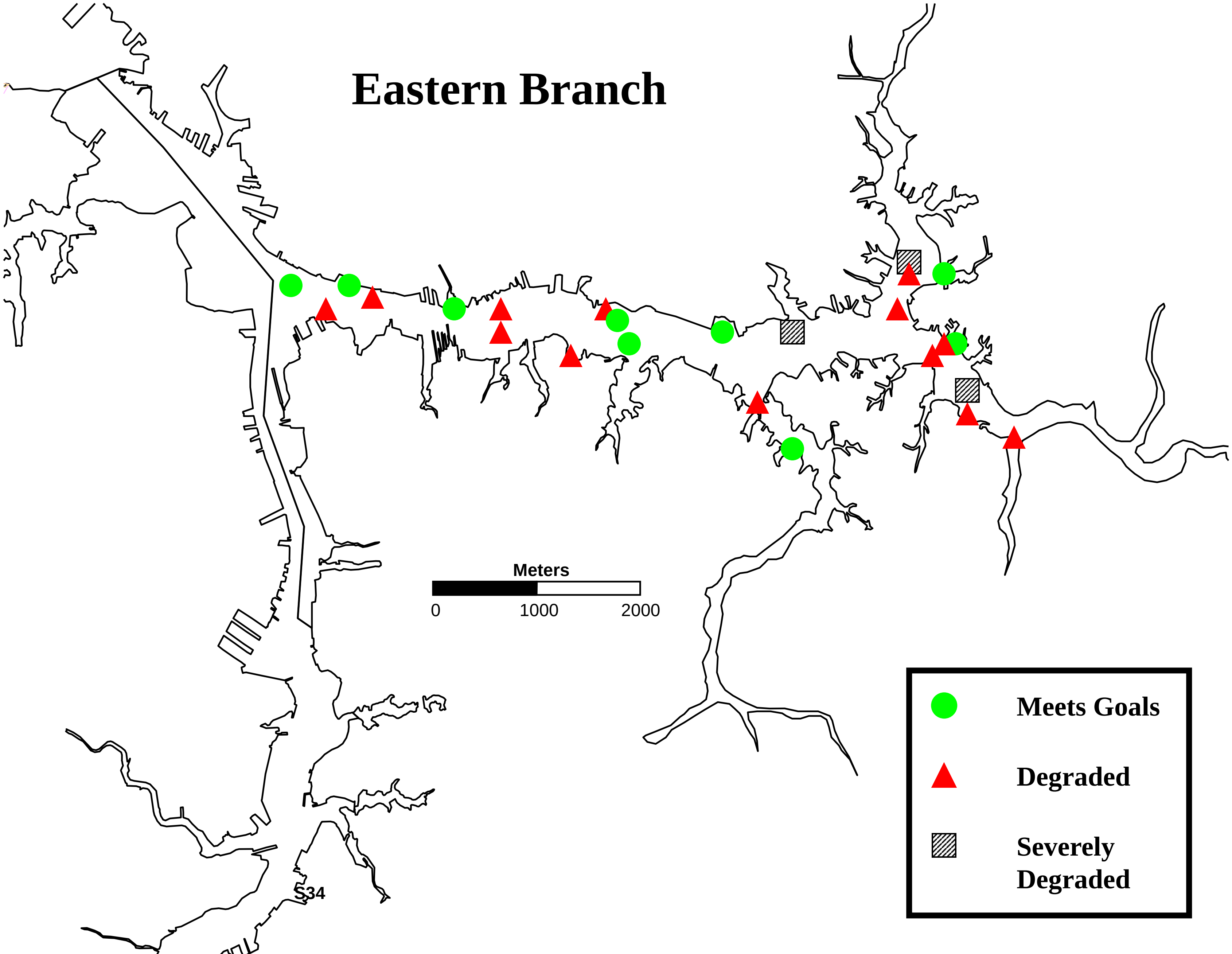


Figure B10. Eastern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 1999 data

Appendix C.

Elizabeth River Watershed.
Maps of Benthic Community Condition.

2019

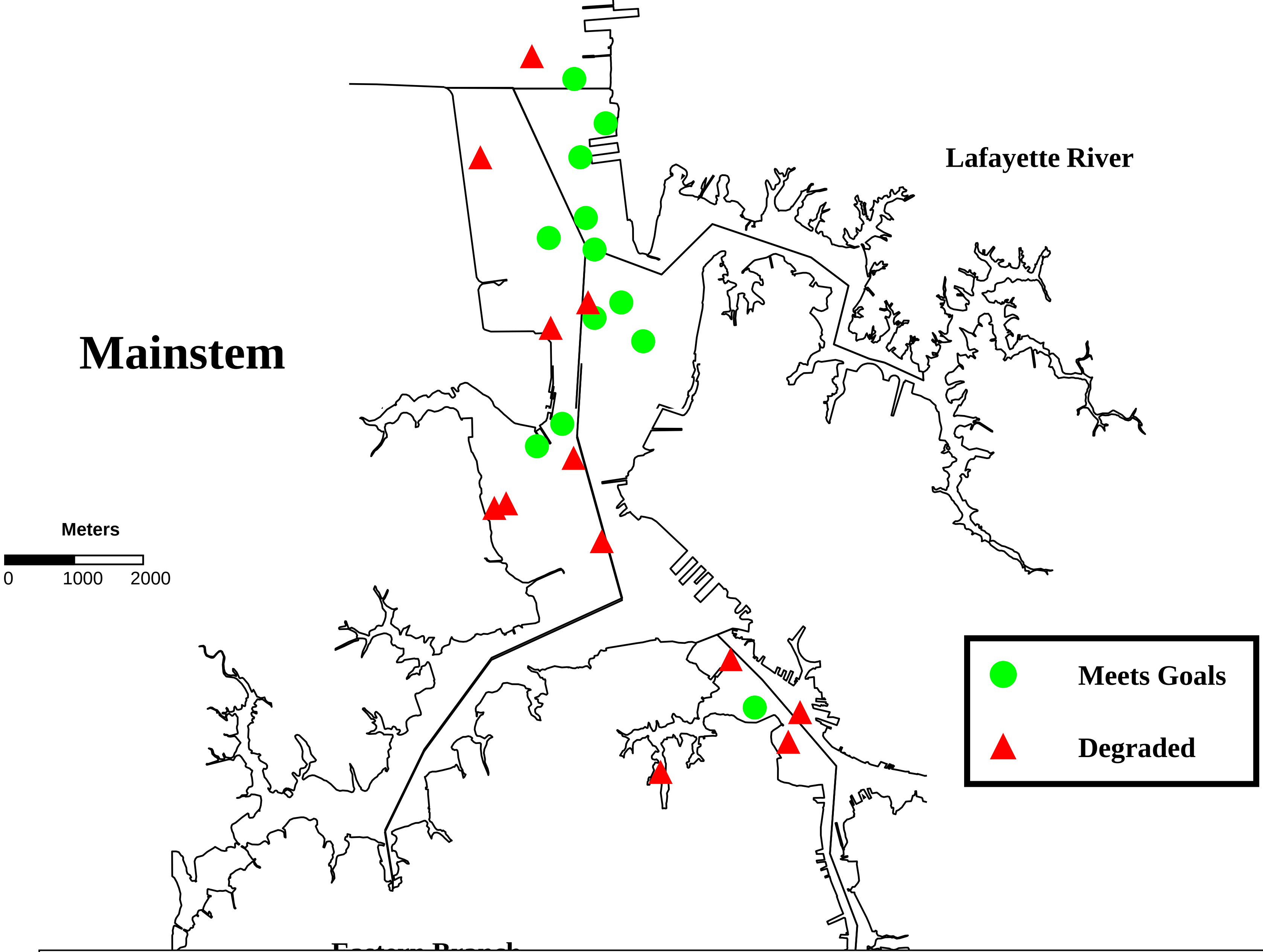


Figure C1. Mainstem of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 2019 data

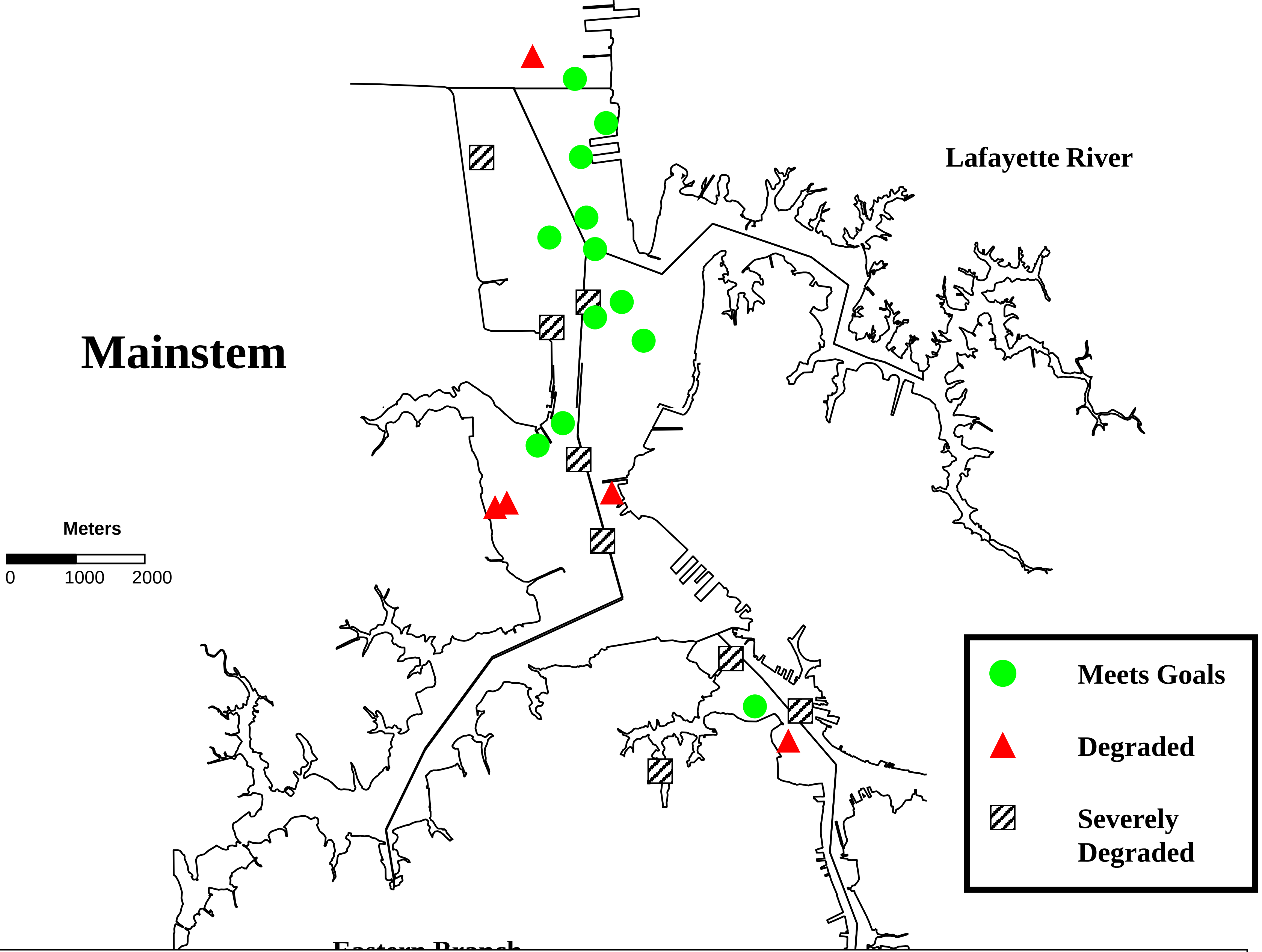


Figure C2. Mainstem of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 2019 data

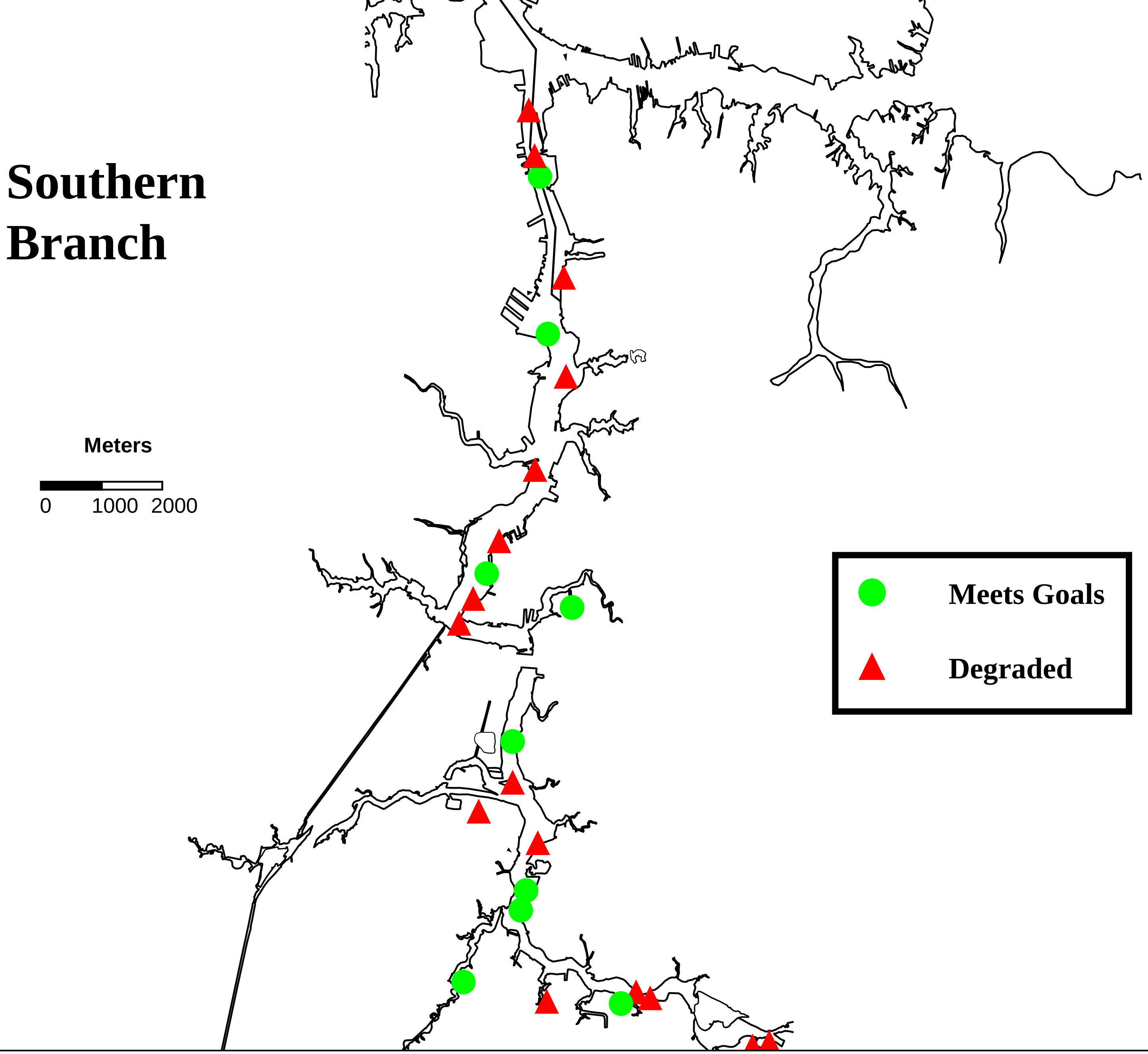


Figure C3. Southern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 2019 data

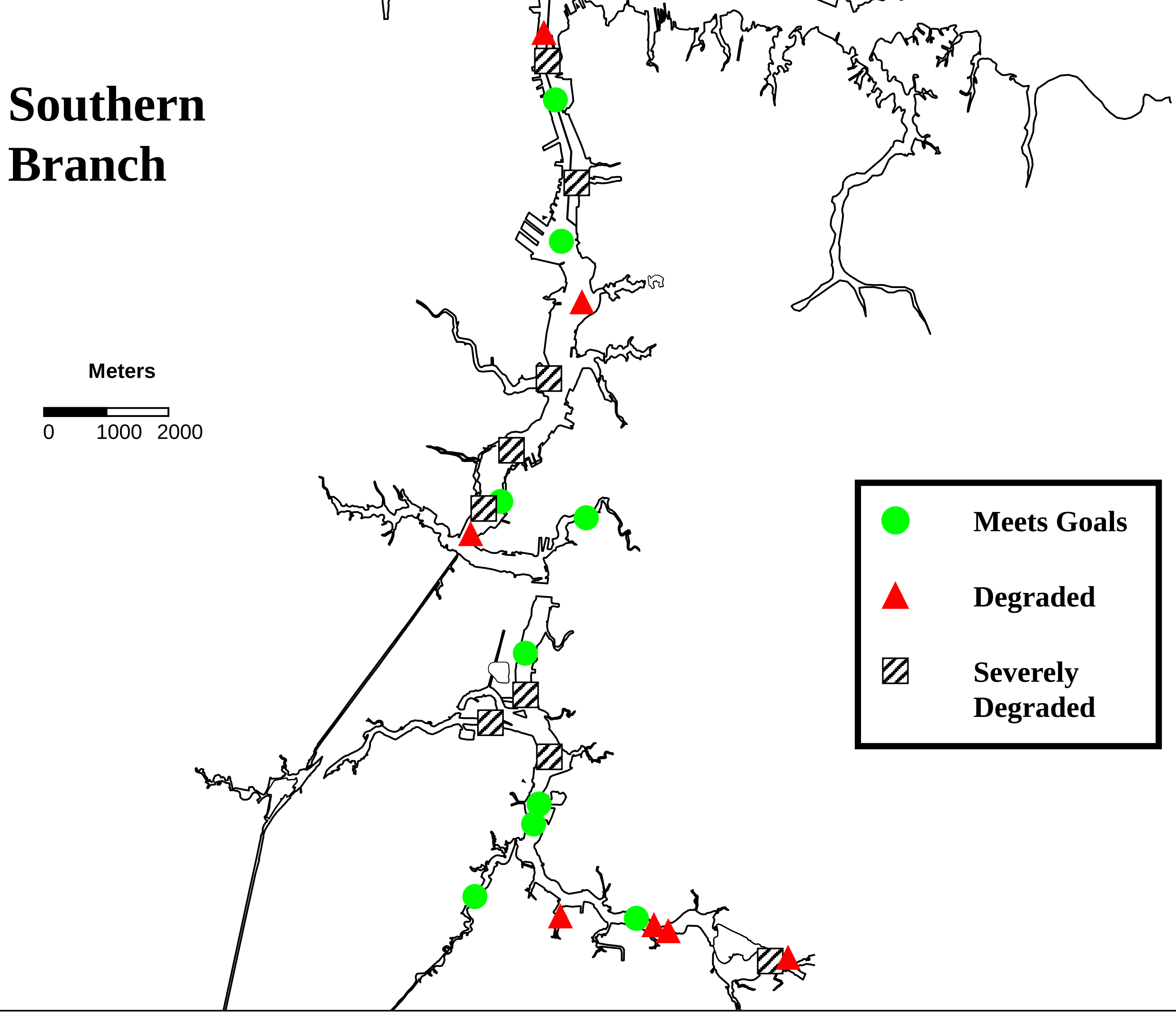


Figure C4. Southern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 2019 data

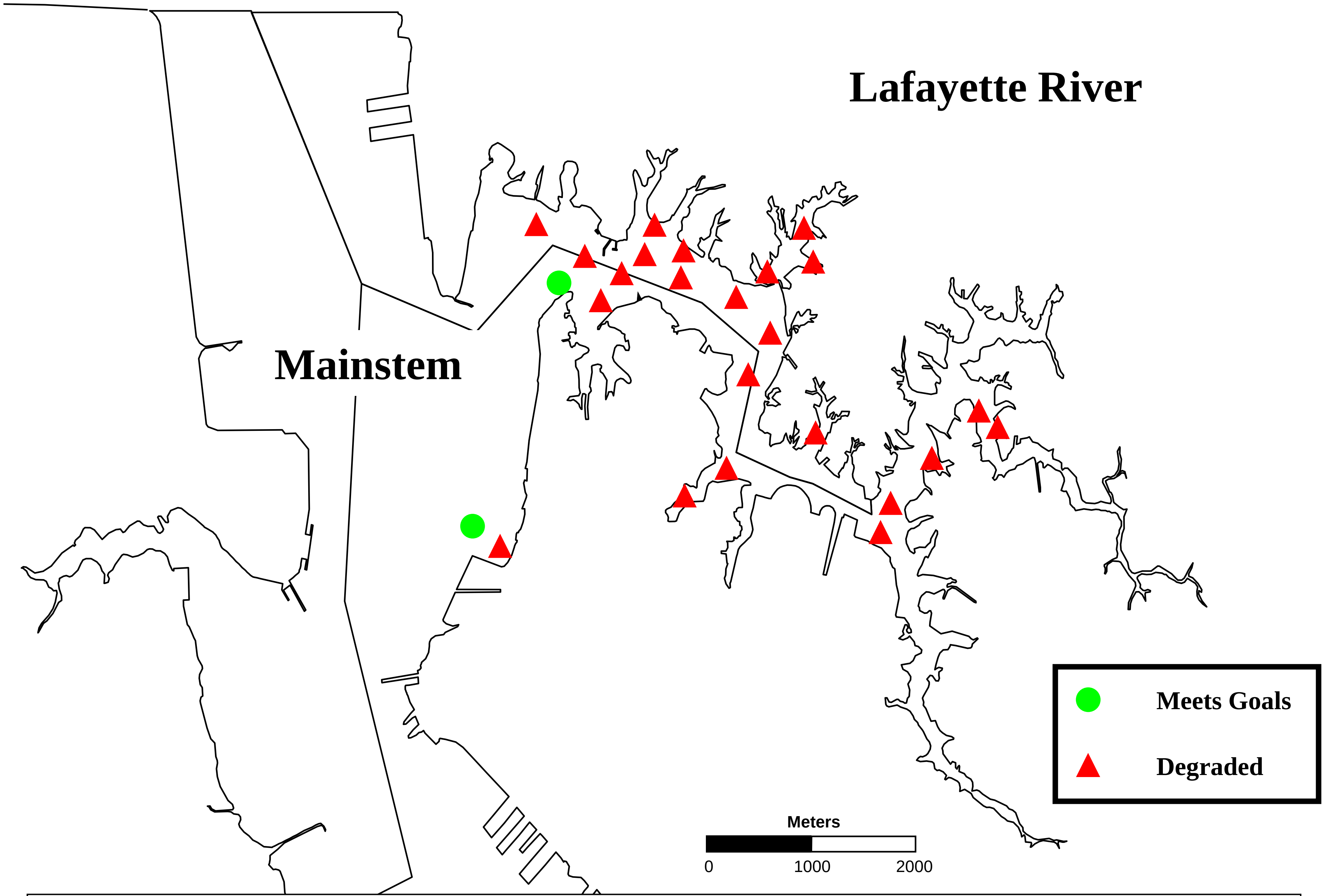


Figure C5. Lafayette River of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 2019 data

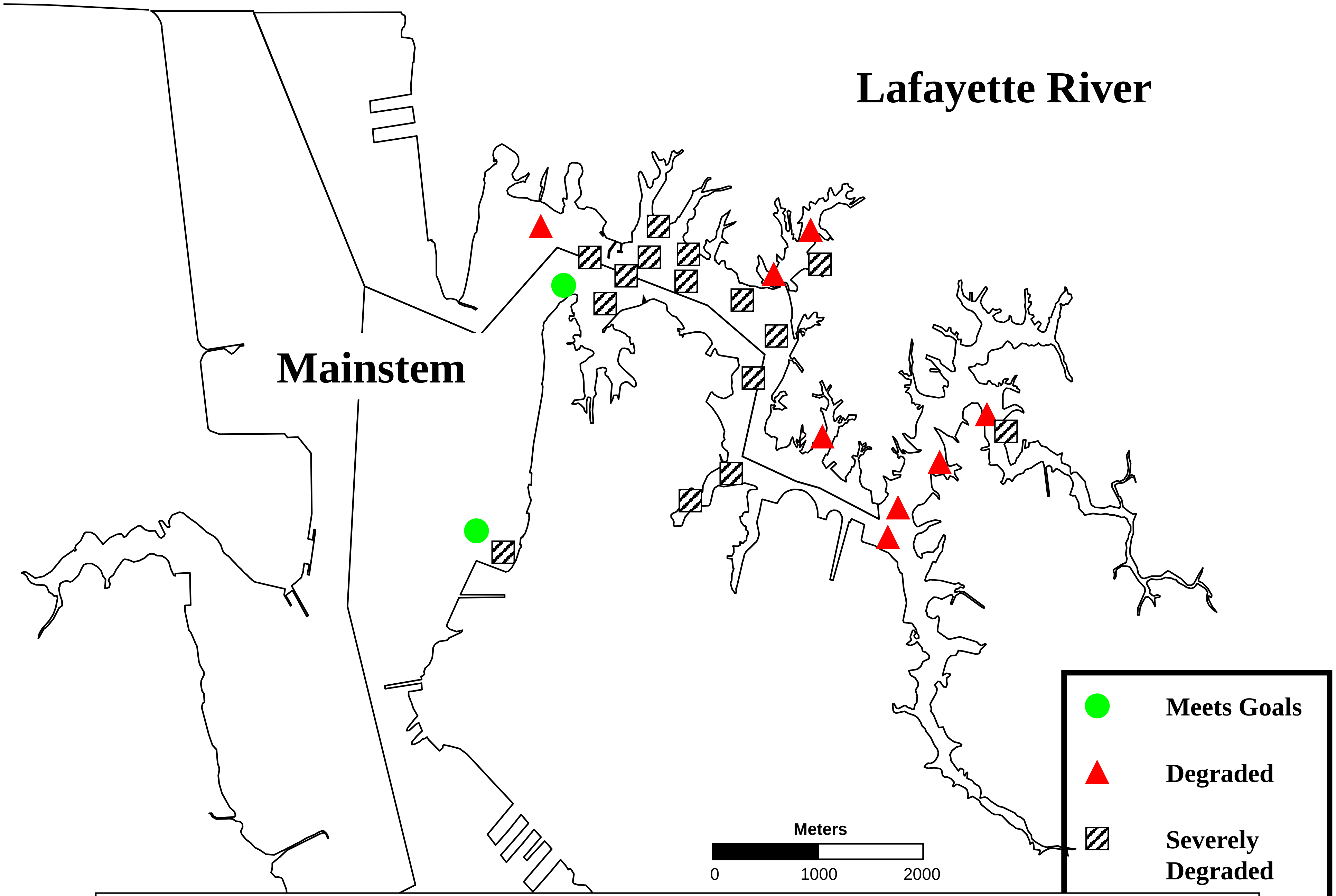


Figure C6. Lafayette River of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure “sites with a designation of “severely degraded” are indicated. 2019 data

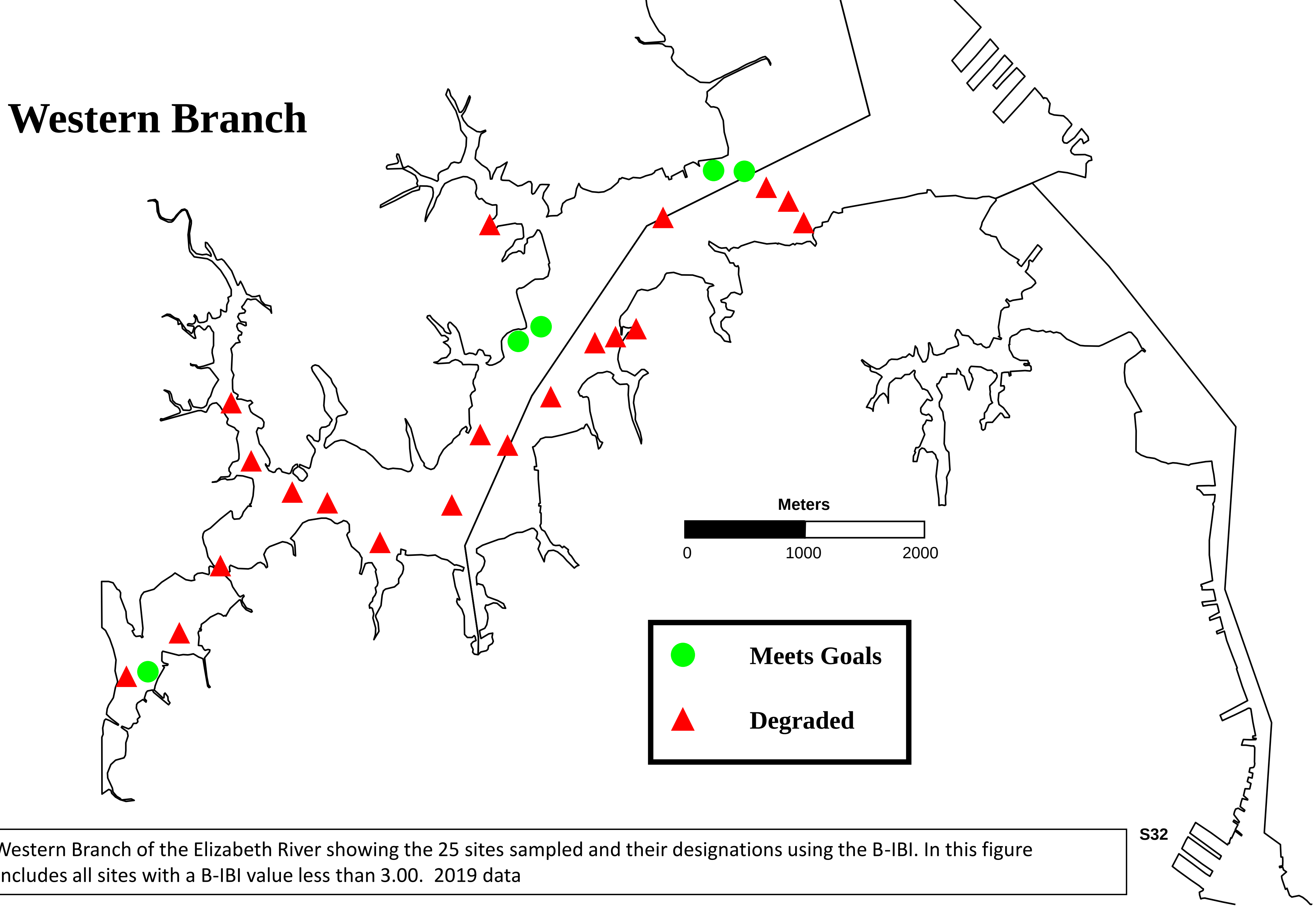


Figure C7. Western Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 2019 data

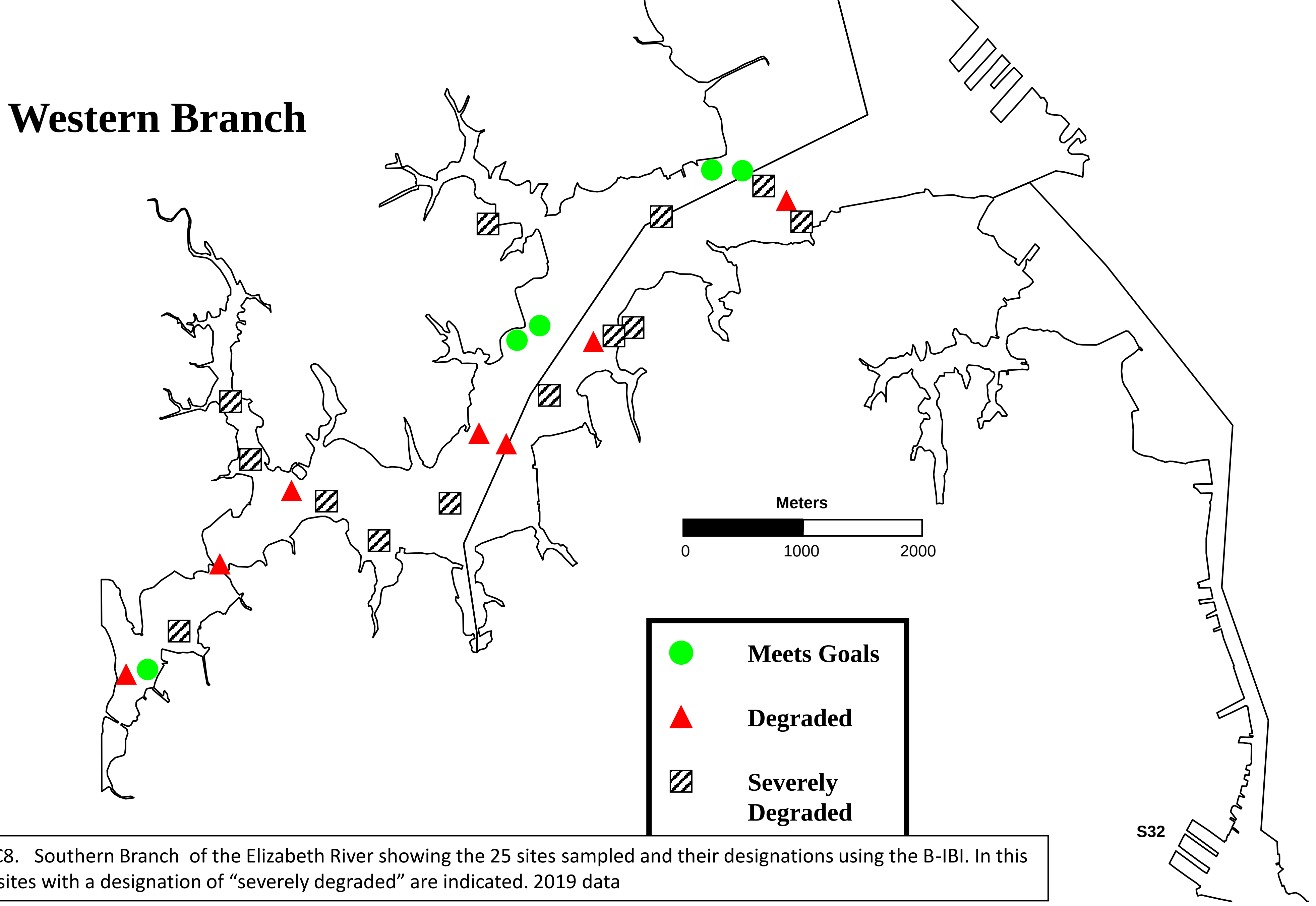


Figure C8. Southern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "sites with a designation of "severely degraded" are indicated. 2019 data

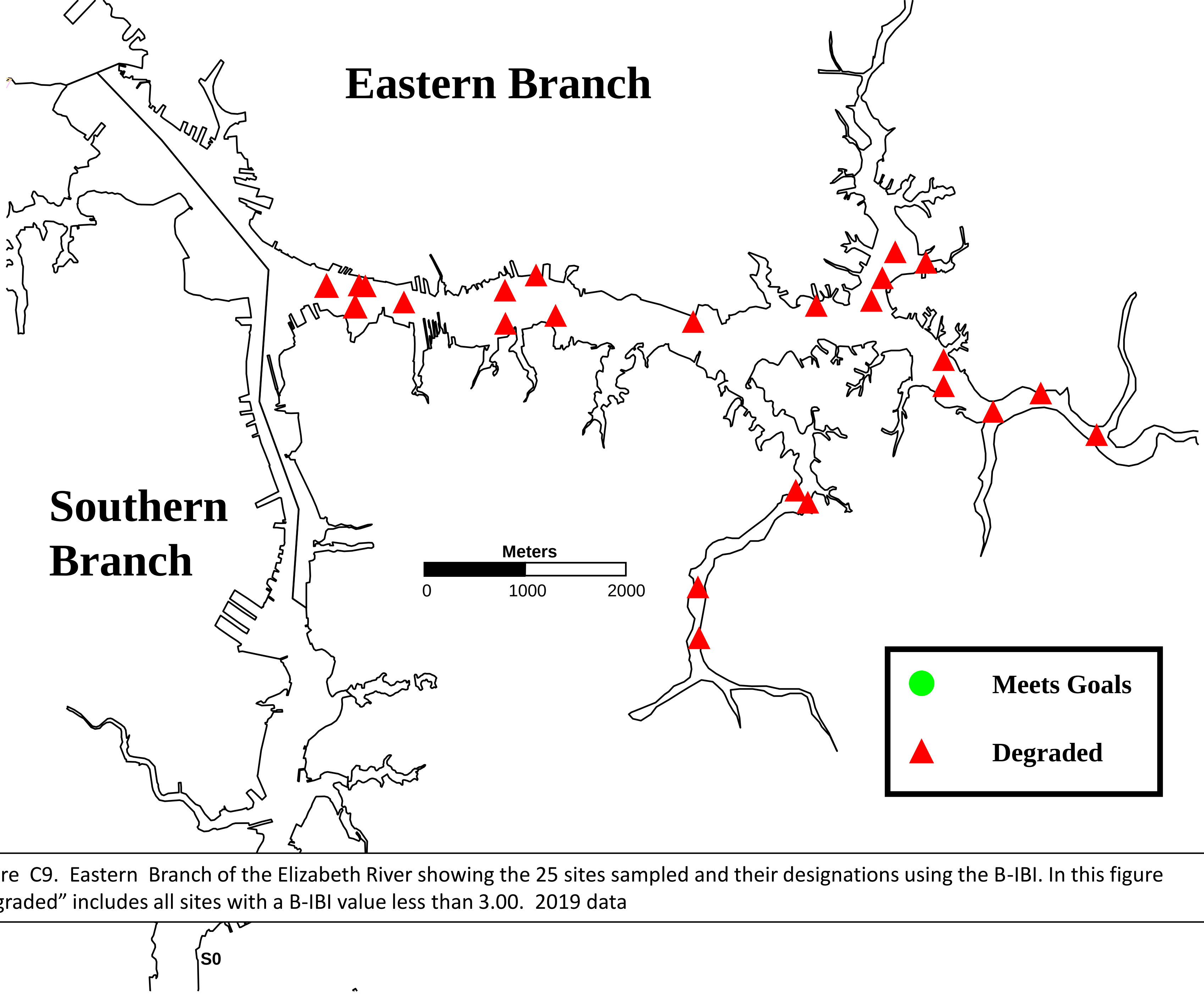


Figure C9. Eastern Branch of the Elizabeth River showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00. 2019 data

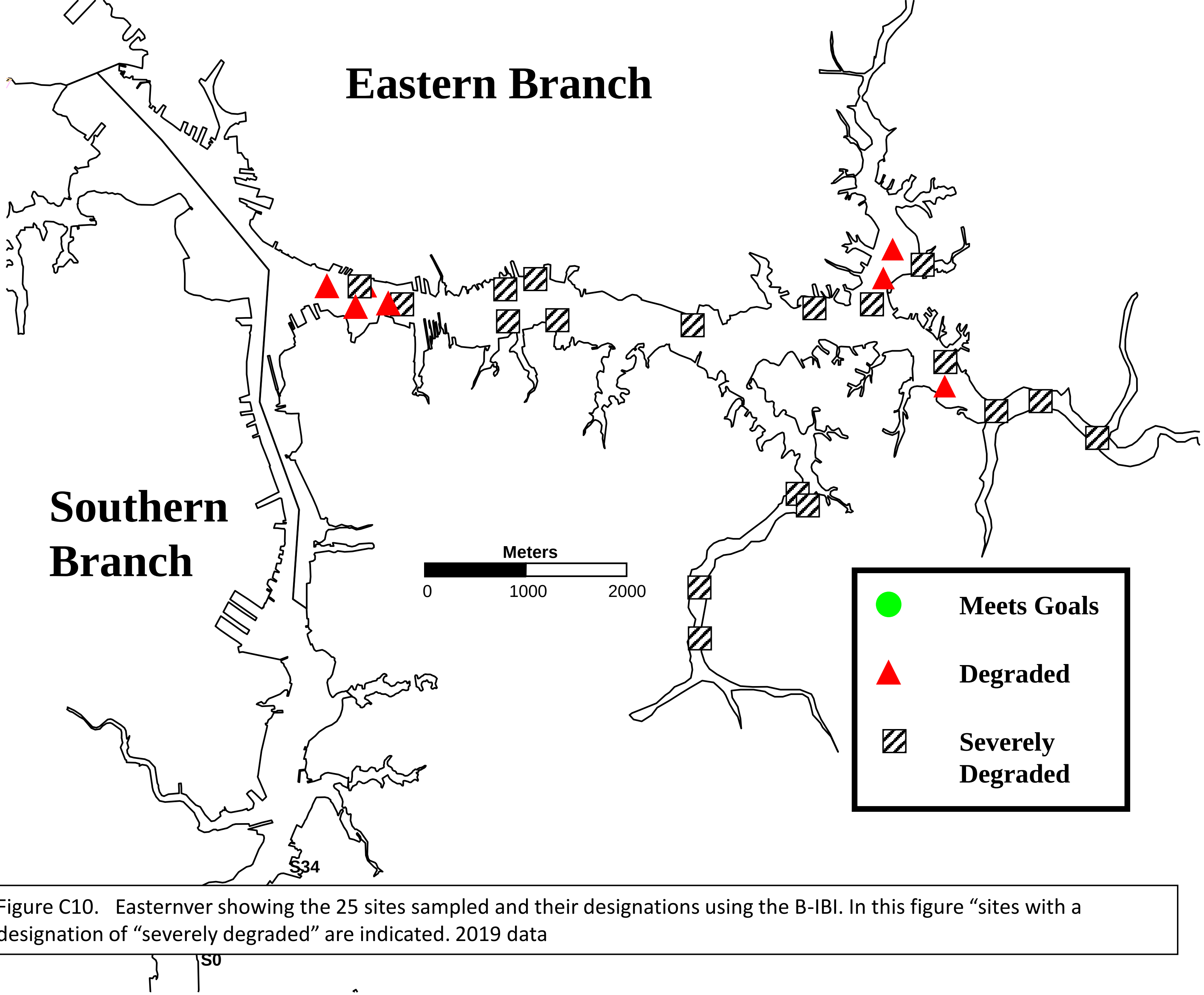


Figure C10. Easternver showing the 25 sites sampled and their designations using the B-IBI. In this figure “sites with a designation of “severely degraded” are indicated. 2019 data