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BENTHIC BIOLOGICAL MONITORING PROGRAM OF THE ELIZABETH RIVER WATERSHED (2003)

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Erratum (January 2005): In this edition Appendix B- Summary of water quality status and trends for the Elizabeth River has been updated. Several nutrient trends previously reported as having improving trends had non-significant patterns. The appropriate figures and tables of the appendix were corrected.

Table of Contents

EXECUTIVE SUMMARY 1

INTRODUCTION 3

RATIONALE 3

METHODS 4
- Strata Sampled 4
- Probability-Based Sampling 4
- Probability-Based Estimation of Degradation 4
- Fixed-Point Station sampling 5
- Laboratory Analysis 5
- Benthic Index of Biotic Integrity 6
  - B-IBI and Benthic Community Status Designations 6
  - Further Information concerning the B-IBI 6
- Fixed-Point Stations in the Elizabeth River from the Chesapeake Bay Program 7
- Water Quality of the Elizabeth River 8

RESULTS 8
- Benthic Community Condition using Probability-Based Sampling 8
  - Environmental Parameters 8
  - Benthic Community Condition 8
- Benthic Community Trends using Fixed -Point Stations 9
  - Environmental Parameters 9
  - Benthic Community 9
  - Summary Patterns in the B-IBI and Selected Metrics 9
    - Mainstem 9
    - Southern Branch 10
    - Western and Eastern Branches 11
    - Lafayette River 12
- Benthic Community Trends in the James River of the Chesapeake Bay Program 12
- Water Quality of the Elizabeth River 12

Discussion 13
- Watershed Level Condition of Benthic Communities 13
- Long-term Trends of Benthic Communities 14
- Water Quality of the Elizabeth River 14

REFERENCES 15

Glossary of selected terms 18

Figures 19

Tables 30

Appendix A: Metrics and thresholds for calculating the Benthic Index Biotic Integrity A-40

Appendix B: Summary of water quality status and trends for the Elizabeth River B-44

Appendix C: Summary of benthic community status and trends for the Elizabeth River stations (SBE2 and SBE5) of the Benthic Monitoring Program of the Chesapeake Bay Program C-51

Appendix D: Plots of fixed -point station B-IBI and metric values from 1999-2003 for the 14 stations of the Elizabeth River Benthic Monitoring Program. D-62

EXECUTIVE SUMMARY

Macrobenthic communities of the Elizabeth River watershed have been quantitatively sampled since summer 1999. This report presents the data from the fifth year of sampling in 2003. The three objectives of the Benthic Biological Monitoring Program of the Elizabeth River watershed are: (1) To characterize the health of the tidal waters of the Elizabeth River watershed as indicated by the structure of the benthic communities. (2) To conduct trend analyses on long-term data at 14 fixed-point stations to relate temporal trends in the benthic communities to changes in water and/or sediment quality. Trend analyses will be updated annually as new data are available. (3) To produce an historical data base that will allow annual evaluations of biotic impacts by comparing trends in status within probability-based strata and trends at fixed-point stations to changes in water and/or sediment quality.

The health of the benthic communities of the Elizabeth River watershed is characterized by combining the Benthic Index of Biotic Integrity (B-IBI) developed for the Chesapeake Bay and probability-based sampling. A probability-based sampling design allows calculation of confidence intervals around estimates of condition of the benthic communities and allows estimates of the areal extent of degradation of the benthic communities. The 2003 areal estimate of degraded benthic bottom was the highest level recorded since the beginning of this program in 1999. Based upon probability-based sampling the estimate of benthic bottom not meeting the benthic restoration goals was 64 ± 10.1 % in 1999, 72 ± 17.6% in 2000, 52 ± 19.6% in 2001, 72 ± 17.6 % in 2002, and 80 ± 15.7 % in 2003. Average B-IBI values for the Elizabeth River watershed were 2.7, 2.6 , 2.7, 2.4 and 2.3 respectively for the years 1999-2003. For the first time since the program began the pollution sensitive bivalve *Macoma balthica* was listed as a density dominant as the sixth mot abundant species at 115 individuals per m^{-2}. There appeared to be successful recruitment of this species particularly in the Western Branch, Eastern Branch and Lafayette River.

Trend analyses were conducted for the first time using the data from the 14 fixed point stations for the period 1999-2003. The present trend analyses have limited statistical power due to the number of years of the program. No stations showed a trend in the B-IBI at $p<0.05$. However, at this probability level there were mixed improving and degrading trends in five individual B-IBI metrics. At $p<0.10$ level there was a single improving trend in the B-IBI at Station LFA1 in the Lafayette River and 23 trends in individual metrics. Of these 23 metric trends, five were degrading trends and 18 were improving trends. Of the five degrading trends, three were due to trends in community abundance to excessive levels. Improving trends were seen in community biomass at both stations in the Western Branch, Station EBB1 in the Eastern Branch and Station SBC1 in the Southern Branch. The remaining improving trends were in community composition (balance between pollution sensitive and pollution indicative species) and included Station ELD1 in the Mainstem, three stations in the Southern Branch (SBB1, SBC1, SBD2), both stations in the Western Branch (WBB1, WBB5) and the single station in the Eastern Branch (EBB1). Using the approach of the Chesapeake Bay Program, the status of each of the 14 fixed-point stations was characterized using the median value of the B-IBI for the last three years (2001-2003). Only one station, ELD1 in the Mainstem, had a B-IBI value over 3.0

and was considered to have met the Benthic Restoration Goals of the B-IBI. A second station in the Mainstem, ELD1, had a marginal value. All other fixed-point stations had a degraded or severely degraded category.

In general for the Elizabeth River watershed, species diversity and biomass remain below reference condition levels while abundance was often above reference condition levels and considered excessive. Community composition was unbalanced with levels of pollution indicative species above, and levels of pollution sensitive species, below reference conditions.

The water quality of the Elizabeth River can be generally characterized as follows: (1) nutrients have a poor status indicating high concentration levels, (2) there were widespread improvements in long-term trends in surface total nitrogen levels (STN) and inorganic nitrogen levels (SDIN), and (3) widespread improvements in long-term trends in surface total phosphorus levels (STP). Nutrient levels of the Elizabeth River exceed those of the lower section of the James River (Table 9). Nitrogen levels are highest in the Southern Branch with smaller differences between the branches of the river for phosphorus levels. The nutrient level in the Elizabeth River are more comparable to levels in the upper reaches of the James River in oligohaline and tidal freshwater regions (Dauer et al. 2003a,b). Chlorophyll levels, indicative of algal blooms when high, are good in both the Eastern Branch and Southern Branch in spite of high nutrient levels and good water clarity (Appendix B, Fig. B3). Chlorophyll levels are poor in the Western Branch but there is an improving long-term trend. Bottom dissolved oxygen are fair to good in all branches with improving trends in all branches except the Mainstem.

INTRODUCTION

A long-term monitoring program of the macrobenthic communities of the Elizabeth River watershed was initiated in summer 1999. The three objectives of the Benthic Biological Monitoring Program of the Elizabeth River watershed are: (1) To characterize the health of the tidal waters of the Elizabeth River watershed as indicated by the structure of the benthic communities. This characterization is based upon application of benthic restoration goals and the Benthic Index of Biotic Integrity (B-IBI) developed for the Chesapeake Bay to the Elizabeth River Watershed (Ranasinghe et al. 1994; Weisberg et al. 1997; Alden et al. 2002). In each year 25 samples are randomly allocated in a probability-based sampling design. A probability-based sampling design allows calculation of confidence intervals around estimates of condition of the benthic communities. (2) To conduct trend analyses on long-term data at 14 fixed-point stations to relate temporal trends in the benthic communities to changes in water and/or sediment quality. Trend analyses will be updated annually as new data are available. (3) To produce an historical data base that will allow annual evaluations of biotic impacts by comparing trends in status within probability-based strata and trends at fixed-point stations to changes in water and/or sediment quality.

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). This study updates the benthic community characterization of the Elizabeth River watershed base upon data collected in 2003 and presents the first long term trend analyses based upon the 14 fixed-point stations.

RATIONALE

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; Dauer 1993; Tapp et al. 1993; Wilson and Jeffrey 1994). Many characteristics of benthic assemblages make them useful indicators (Bilyard 1987), 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). Recently 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).

METHODS

A glossary of selected terms used in this report is found on page 18.

Strata Sampled

In the summer of 1999, 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 (Fig. 1). In addition two small creeks of the Southern Branch of the river were also sampled as part of a sediment contaminant remediation effort - Scuffletown Creek and Jones-Gilligan Creek. Beginning in 2000 and in subsequent years the Elizabeth River was sampled as a single stratum of 25 random samples. In 2001 Paradise Creek was sampled as a separate stratum.

Probability-based Sampling

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 probability-based stratum, 25 random locations were sampled using a 0.04 m^2 Young grab. 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 an B-IBI value of less than 3.0. The process produces a binomial distribution: the percentage of the stratum attaining goals versus the percentage not attaining the goals. With a binomial distribution the 95% confidence interval for these percentages can be calculated as:

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

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

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

Fixed-Point Station Sampling

Fourteen fixed point stations were established for long-term trend analysis (Fig. 2). All field collection procedures were the same as for probability based sampling except that three replicate Young grab sample were collected for macrobenthic community analysis.

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 °C and ashing at 550 °C for four hours. Biomass was expressed as the difference between the dry and ashed weight.

Particle-size analysis was conducted using the techniques of Folk (1974). Each sediment sample is first separated into a sand fraction (> 63 µm) and a silt-clay fraction (< 63 µm). The sand fraction was dry sieved and the silt-clay fraction quantified by pipette analysis. For random stations, only the percent sand and percent silt-clay fraction were estimated. For the fixed-point stations particle-size distribution parameters were determined by the graphic and moment measures methods of Folk (1974). 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.

Benthic Index of Biotic Integrity

B-IBI and Benthic Community Status Designations

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

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

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 (Ranasinghe et al. 1994; Dauer et al. 1998a, 1998b; Ranasinghe et al. 1998; Dauer et al. 2002a,b; Llansó et al 2004).

Further Information concerning the B-IBI

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

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

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

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

In tables presenting B-IBI results salinity classes are coded as follows: 1- tidal freshwater, 2 - oligohaline, 3- low mesohaline, 4 - high mesohaline and 5 - polyhaline. The two sediment classes are as follows: 1 - silt clay content < 40% and 2 - silt clay content $ 40%. All abundance values are individuals per m^{-2}, biomass values are AFDW g per m^{-2}, and pollution indicative, pollution sensitive and cavnivore/omnivore metrics are percent of abundance or biomass as indicated in tables.

Fixed-Point Stations in the Elizabeth River from the Chesapeake Bay Program

Data concerning benthic community status and trends for James River, including the Elizabeth River, are collected by the Virginia Benthic Monitoring Program as part of the Chesapeake Bay Restoration Program. These data have been updated recently to include all data through 2003 and are presented here to summarize patterns for the five James River stations and two Elizabeth River stations that are part of that program. Details of collection and laboratory methodology can be found in Dauer et al. 2003a,b which can be downloaded in pdf format from the Old Dominion University Chesapeake Bay Program website <www.chesapeakebay.odu.edu>

under "Reports." The James River Report includes the Elizabeth River, the Chickahominy River and the Appomattox River.

Water Quality of the Elizabeth River

Data concerning water quality status and trends for the Elizabeth River are collected by the Virginia Water Quality Monitoring Program as part of the Chesapeake Bay Restoration Program. These data have been updated recently to include all data through 2003 and are presented here to summarize water quality of the Elizabeth River. Details of collection and laboratory methodology can be found in Dauer et al. 2003a,b which can be downloaded in pdf format from the Old Dominion University Chesapeake Bay Program website <www.chesapeakebay.odu.edu> under "Reports." The James River Report includes the Elizabeth River, the Chickahominy River and the Appomattox River. Also available at this website are appendices that include (1) tables of status for all parameters measured at all stations sampled by each program, (2) tables of all parameters and metrics for which there was a significant trend, and (3) scatter plots of all parameters over time. There are five appendices: water quality, phytoplankton, primary productivity, zooplankton and benthos.

RESULTS

Benthic Community Condition using Probability-Based Sampling

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 1. Water depths varied from less than 1m to over 15 m reflecting shoal and channel depths. In contrast to most previous summer collections when most salinity values were in the polyhaline range during the summer of 2003 values were mostly in the high mesohaline range to low polyhaline range. All bottom dissolved oxygen measurements were above 2.0 ppm. Marobenthic communities are generally not altered by low dissolved oxygen unless values fall below at least 2.0 ppm (Diaz and Rosenberg 1995). As in previous collection years silt-clay content varied widely from less than 1% to greater than 95% and total volatile solids values were also less than 3%.

Benthic Community Condition

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 2. The average B-IBI values for the 25 random sites was 2.3. The distribution of the random sites and benthic community condition designations are shown in Figure 3. For the 2003 data 80 ± 15.7 % of the watershed had degraded benthos. Individual metric scores incorporated in the B-IBI are presented in Table 3. The dominant taxa of the random sites are summarized in Table 4. For the first time since the program began the pollution sensitive bivalve *Macoma balthica* was listed as a density dominant as the sixth mot abundant species at 115 individuals per m^{-2}.

The B-IBI value, Shannon's index, abundance, biomass and the proportion of pollution sensitive and pollution indicative species are shown in Figs. 4-9. In these figures the five strata of the Elizabeth River sampled in 1999 are shown. Also shown is the area weighted average for all 125 random samples from the five strata sampled in 1999. The 2000 through 2003 values are based upon the 25 random sampled from each respective year.

Benthic Community Trends using Fixed -Point Stations

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 5.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 6. Figure 7 lists the status of the 14 fixed-point stations. Status is determined by the three year (2001-2003) average B-IBI values at each station. Only one station, ELD1 in the Mainstem, had a B-IBI value over 3.0 and was considered to have met the Benthic Restoration Goals of the B-IBI. A second station in the Mainstem, ELD1, had a marginal value. All other fixed-point stations had a degraded or severely degraded category.

No stations showed a trend in the B-IBI at $p < 0.05$. At this probability level there were mixed improving and degrading trends in five individual B-IBI metrics. At $p < 0.10$ level there was a single improving trend in the B-IBI at Station LFA1 in the Lafayette River and 23 trends in individual metrics. Of these 23 metric trends, five were degrading trends and 18 were improving trends. Of the five degrading trends, three were due to trends in community abundance to excessive levels. Improving trends were seen in community biomass at both stations in the Western Branch, Station EBB1 in the Eastern Branch and Station SBC1 in the Southern Branch. The remaining improving trends were in community composition (balance between pollution sensitive and pollution indicative species) and included Station ELD1 in the Mainstem, three stations in the Southern Branch (SBB1, SBC1,SBD2), both stations in the Western Branch (WBB1, WBB5) and the single station in the Eastern Branch (EBB1).

Summary Patterns in the B-IBI and Selected Metrics

Mainstem

’ **Benthic Index of Biotic Integrity:** From 1999-2003, the B-IBI values for stations ELC1 and ELD1 were generally close to 3.0 but both stations had lower B-IBI values in 2003. Station ELF1 was consistently below 3.0.

’ **Species Diversity:** The mouth stations (ELC1 and ELD1) generally had higher diversity values with the index typically above 2.6 - 2.7, while Station ELF1 generally had lower values. All three stations showed a decrease in species diversity to their lowest values in

2003. These species diversity patterns were consistent with the general pattern for the B-IBI.

- **Abundance:** For 1999 - 2002 the mouth stations (ELC1 and ELD1) generally had community abundance values between 2,000 - 3,000 individuals m^{-2} with highest values in 2003 around 6,000 individuals m^{-2}. Station ELF1 showed a more erratic pattern with peak values in 2000 and 2003 exceeding 5,000 individuals m^{-2}. In general the Mainstem stations had the lowest abundances compared to the other branches of the river; however, for most high salinity habitat types an abundance in excess of 5,000-8,000 individuals m^{-2} is considered excessive and results in a low score for this metric.

- **Biomass:** No patterns were obvious in biomass values. In all branches of the river most biomass values were around 1.0 g AFDW m^{-2} with some stations reaching their highest value in the last year or two. All values were generally considered to be at insufficient levels relative to the Benthic Restoration Goals.

- **Community Composition:** For the period 1999 - 2002 the mouth stations (ELC1 and ELD1) had a percent composition of Pollution Indicative Species that was less than 30% (ELC1) or 20% (ELD1) while Station ELF1 showed no value below 30%. All three stations showed an increase to their highest values in 2003 with values exceeding 70% at stations ELD1 and ELF1. As would be expected, the relative abundance of Pollution Sensitive Species was inversely related to the patterns for Pollution Indicative Species. This pattern is due to the large increase in the pollution indicative spionid polychaete *Streblospio benedicti* over these years. When averaging these three stations as a group *S. benedicti* abundance was generally below 2,000 individuals m^{-2} from 1999 to 2002 and in 2003 was over 10,000 individuals m^{-2} .

Southern Branch

- **Benthic Index of Biotic Integrity:** The B-IBI values for all stations were consistently below 3.0 except for years 2001 and 2003 at Station SBD4.

- **Species Diversity:** Species Diversity values in the Southern Branch were more consistent with the upper Mainstem Station ELF1 and were generally lower than the two Mainstem Stations near the mouth of the Elizabeth River. Lowest species diversity values generally occurred in the last two (2002 - 2003) or three years (2001 - 2003).

- **Abundance:** Community abundance values were much higher than in the Mainstem Stations and typically exceeded 10,000 individuals m^{-2}. Such an abundance is considered to be excessive relative to the Benthic Restoration Goals. The lower stations, SBA1 and SBB1, reached their highest values in the last two years, 2002 and 2003; the middle station SBC1 peaked in 2001 but retained high values in the last two years; and the two upper stations, SBD2 and SBD4, reached their highest values in the last year, 2003.

- **Biomass:** No patterns were obvious in biomass values with most values less than 1.5 AFDW g m^{-2}. In all branches of the river most biomass values were around 1.0 g AFDW m^{-2} with some stations reaching their highest value in the last year or two. All values were generally considered to be at insufficient levels relative to the Benthic Restoration Goals.

- **Community Composition:** After 1999 the level of Pollution Indicative Species declined and was mostly below 30%. This was in contrast to the three Mainstem stations where in 2003 there was an increase to their highest values with values exceeding 70% at stations ELD1 and ELF1. There was a general increase in Pollution Sensitive Species after 1999 due primarily to increased abundances of the pollution sensitive polychaete *Mediomastus ambiseta*.

Western and Eastern Branches

- **Benthic Index of Biotic Integrity:** The B-IBI values for the Western Branch were generally below 3.0 and slightly higher at the upper station WBB5. The Eastern Branch station was near 3.0 the in 1999-2000 and like the Western Branch stations there were declines in the B-IBI in 2001 and 2002.

- **Species Diversity:** Species Diversity values declined from 2000 through 2003 in both branches.

- **Abundance:** Community abundance values were higher than in the Mainstem Stations and typically exceeded 7,000 to 10,000 individuals m^{-2} particularly in the later years of 2000 through 2003. In these years each stations was dominated by the pollution sensitive polychaete *Mediomastus ambiseta*.

- **Biomass:** Biomass values increased in all stations in 2003 due to a high settlement of the bivalve *Macoma balthica*. The biomass of *M. balthica* increased from 2002 to 2003 at each station - from 0.0 to 0.9 g m^{-2} at WBB1, from 0.1 to 2.9 g m^{-2} at WBB5 and from 0.2 to 2.9 g m^{-2} at EBB1. Densities of *M. balthica* increased from 2002 to 2003 at each station - from 0 to 258 individuals m^{-2} at WBB1, from 17 to 367 individuals m^{-2} at WBB5 and from 34 to 1,092 individuals m^{-2} at EBB1. Consistent with other metrics the upper Western Branch station had higher values than the lower Western Branch station. In all branches of the river most biomass values were around 1.0 g AFDW m^{-2} with some stations reaching their highest value in the last year or two. All values were generally considered to be at insufficient levels relative to the Benthic Restoration Goals.

- **Community Composition:** In general in both branches Pollution Indicative Species declined while Pollution Sensitive Species composition a pattern due to increased abundances of the pollution sensitive polychaete *Mediomastus ambiseta* and the pollution sensitive bivalve *Macoma balthica*.

Lafayette River

- **Benthic Index of Biotic Integrity:** The B-IBI values for the Lafayette River were consistently below 3.0 except for the 2003 value at the upper station LFB1. There was a slight increase in B-IBI value over time and the trend at Station LFA1 was marginally significant (p = 0.086, Table 8) but the improvement was negligible.

- **Species Diversity:** Species Diversity values were higher at the lower station and declined in the later years in the upper station.

- **Abundance:** Community abundance levels were more comparable to the Mainstem and lower then the Southern Branch, Western Branch and Eastern Branch values. Abundance values were variable at the lower station and generally increased at the upper station. Values at both stations were in the range of 3,000 to 5,000 individuals m^{-2}, a range often resulting in the maximum B-IBI metric score of 5.

- **Biomass:** Biomass values increased at both stations to their highest levels in 2003. In all branches of the river most biomass values were around 1.0 g AFDW m^{-2} with some stations reaching their highest value in the last year or two. All values were generally considered to be at insufficient levels relative to the Benthic Restoration Goals.

- **Community Composition:** Pollution Indicative Species increased slightly in the lower stations and were erratic at the upper stations. In contrast, Pollution Sensitive Species pattern was erratic in the lower station and increased greatly in the upper station.

Benthic Community Trends in the James River of the Chesapeake Bay Program

There are two stations in the Southern Branch of the Elizabeth River that are sampled as part of the larger Chesapeake Bay Program (SBE2 and SBE5, see Appendix C, Fig. C1). The status of both stations is poor but there are many improving trends in the benthic community and the B-IBI values at Station SBE5 shows a significant overall improving trend (Appendix C, Fig. C2, C4).

Water Quality of the Elizabeth River

Nutrient levels in all branches of the Elizabeth River are characterized by the Chesapeake Bay Program criteria as having a poor status; however, there are several improving trends (Appendix B, Fig. B2 and Tables B1, B3). Surface and bottom nitrogen (STN and BTN) showed improving trends in almost all branches. Surface dissolved inorganic nitrogen improved in all branches except the Western Branch. Total phosphorus improved in all branches with dissolved inorganic phosphorus improving only in the Southern Branch. Chlorophyl levels (SCHLA) had a good status in the Southern Branch, fair in the Eastern Branch, poor status in the Mainstem, and poor status and a degrading trend in the Western Branch (Appendix B, Fig. B3). Indicators of water clarity, total suspended solids (STSS , BTSS) and secchi depth (SECCHI) generally showing improving trends an all branches. Finally, bottom dissolved oxygen showed improving trends in all branches except the Mainstem with a Fair to Good status (Appendix B, Fig. B3, Table B3).

Discussion

Watershed Level Condition of Benthic Communities

Probability-based sampling allows an annual characterization of the overall condition of the benthic communities of the Elizabeth River watershed. In 1999 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 (Dauer 2000). The 1999 intensive sampling serves as a benchmark for all future analyses. The five strata were characterized in terms of benthic community condition into three categories: (1) the best condition in the Mainstem of the river, (2) the worst condition in the Southern Branch, and (3) intermediate condition in the Eastern Branch, Western Branch and Lafayette River. The Mainstem of the river had the highest average B-IBI value of 2.9, the Southern Branch the lowest value of 2.0 and the other branches had values between 2.5 and 2.7 with an overall average of 2.5. In 1999 each of the five strata were sampled at 25 random locations for a total of 125 random samples. In succeeding years the entire Elizabeth River watershed has been sampled as a single stratum of 25 random samples.

In 2003 the average watershed-level value for the B-IBI was the lowest recorded since 1999 and the area of benthic not meeting the Chesapeake Bay Benthic Restoration Goals was the highest recorded since 1999. Average B-IBI values for the Elizabeth River watershed were 2.3 (2003), 2.4 (2002), 2.7 (2001), 2.6 (2000), 2.7 (1999) (see Dauer and Rodi 1999; Dauer 2000, 2001, 2002, 2003). Based upon probability-based sampling the estimate of benthic bottom not meeting the benthic restoration goals was 80 ± 15.7 % in 2003, 76 ± 16.7 % in 2002, 52 ± 19.6% in 2001, 72 ± 17.6% in 2000, and 64 ± 10.1 % in 1999.

Compared to the Chesapeake Bay Benthic Restoration Goals the macrobenthic communities of the Elizabeth River can be characterized as (1) having lower than expected species diversity and biomass, (2) abundance levels generally higher than reference conditions and (3) species composition with levels of pollution indicative species higher than reference conditions and levels of pollution sensitive species lower than reference conditions (Table 2; Figs. 4-9). However, there are some positive indications with the increase in the proportion of pollution sensitive species (Fig. 9).

Long-term trends of Benthic Communities

Long-trend analyses in values of the B-IBI were conducted for the first time using the data from 14 fixed point stations for the period 1999-2003. In addition, examinations of the trends of the metrics of the index provide insight into observed patterns The present trend analyses have limited statistical power due to the number of years of the program. No stations showed a trend in the B-IBI at $p<0.05$. At this probability level there were mixed improving and degrading trends in five individual B-IBI metrics. At $p<0.10$ level there was a single improving trend in the B-IBI at Station LFA1 in the Lafayette River and 23 trends in individual metrics. Of these 23 metric trends, five were degrading trends and 18 were improving trends. Of the five degrading trends, three were due to trends in community abundance to excessive levels. Improving trends were seen in community biomass at both stations in the Western Branch, Station EBB1 in the Eastern Branch and Station SBC1 in the Southern Branch. The remaining improving trends were in community composition (balance between pollution sensitive and pollution indicative species) and included Station ELD1 in the Mainstem, three stations in the Southern Branch (SBB1, SBC1,SBD2), both stations in the Western Branch (WBB1, WBB5) and the single station in the Eastern Branch (EBB1).

Water Quality of the Elizabeth River

The water quality of the Elizabeth River can be generally characterized as (1) nutrients have a poor status indicating high concentration levels, (2) widespread improvements in long-term trends in surface total nitrogen levels (STN) and inorganic nitrogen levels (SDIN), and (3) widespread improvements in long-term trends in surface total phosphorus levels (STP). Nutrient levels of the Elizabeth River exceed those of the lower section of the James River (Table 9). Nitrogen levels are highest in the Southern Branch with smaller differences between the branches of the river for phosphorus levels. Nutrient levels in the Elizabeth River are more comparable to levels in the upper reaches of the James River in oligohaline and tidal freshwater regions (Dauer et al. 2003a,b). Chlorophyll levels, indicative of algal blooms when high, are fair and good the Eastern Branch and Southern Branch, respectively, in spite of high nutrient levels and good water clarity (Appendix B, Fig. B3). Chlorophyll levels are poor in the Western Branch but there is an improving long-term trend. Bottom dissolved oxygen levels are fair to good in all branches with improving trends in all branches except the Mainstem.

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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 the1999 study the primary strata were the Mainstem of the river, the Lafayette River, the Eastern Branch, Western Branch and Southern Branch. In succeeding years the entire Elizabeth River watershed was 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 5th percentile and the 50th percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5th percentile are scored as a 1. Samples with values between the 5th and 50th metrics are scored as 3 and values greater than the 50th percentile are scored as 5. For abundance and biomass, values below the 5th and above the 95th percentile are scored as 1, values between the 5th and 25th and the 75th and 95th percentiles are scored as 3 and values between the 25th and 75th percentiles are scored as 5.

Figures

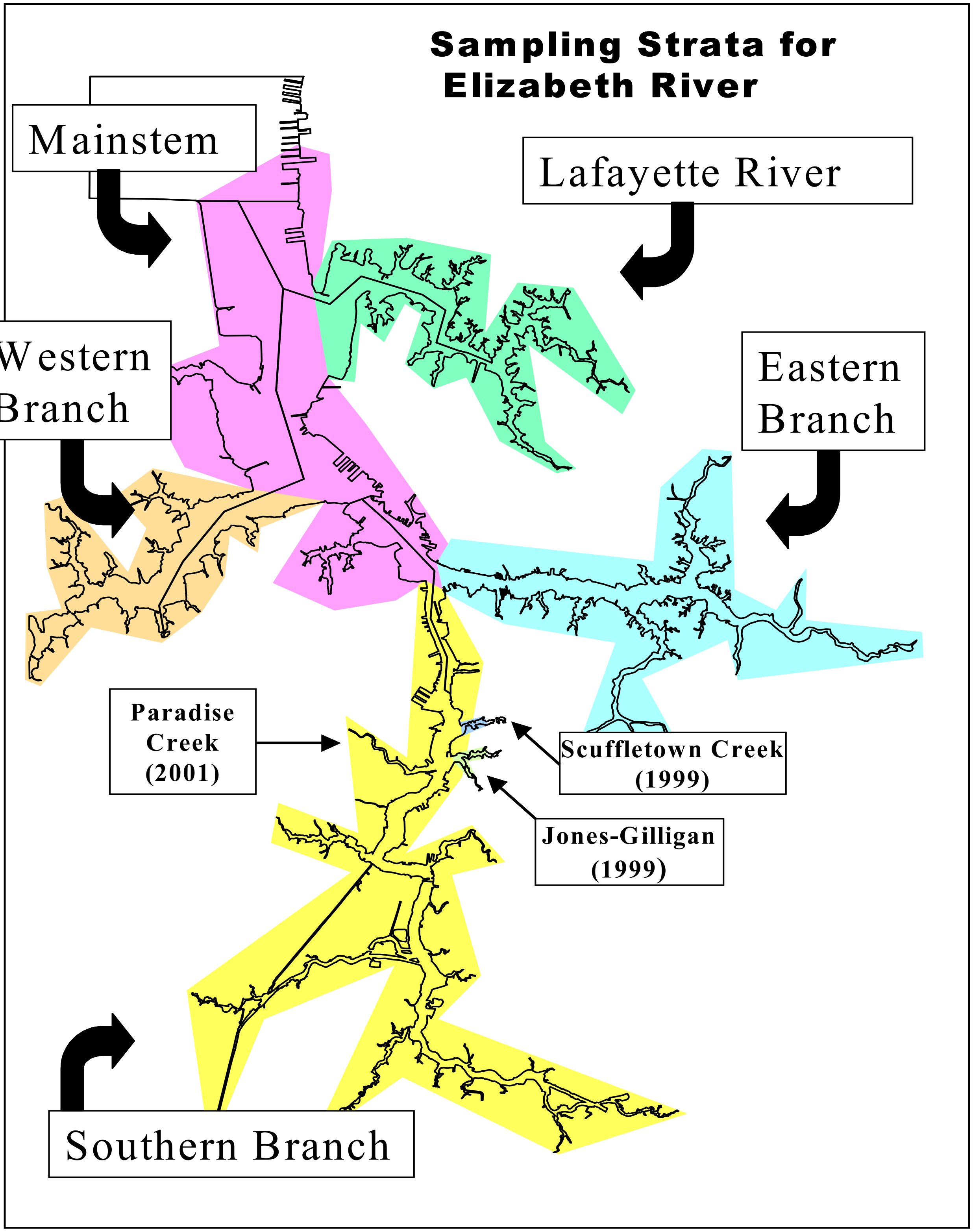


Figure 1. Elizabeth River watershed showing the five major segments sampled in 1999. Insert shows Scuffletown Creek and the Jones-Gilligan Creek strata also sampled in 1999 and Paradise Creek stratum sampled in 2001.

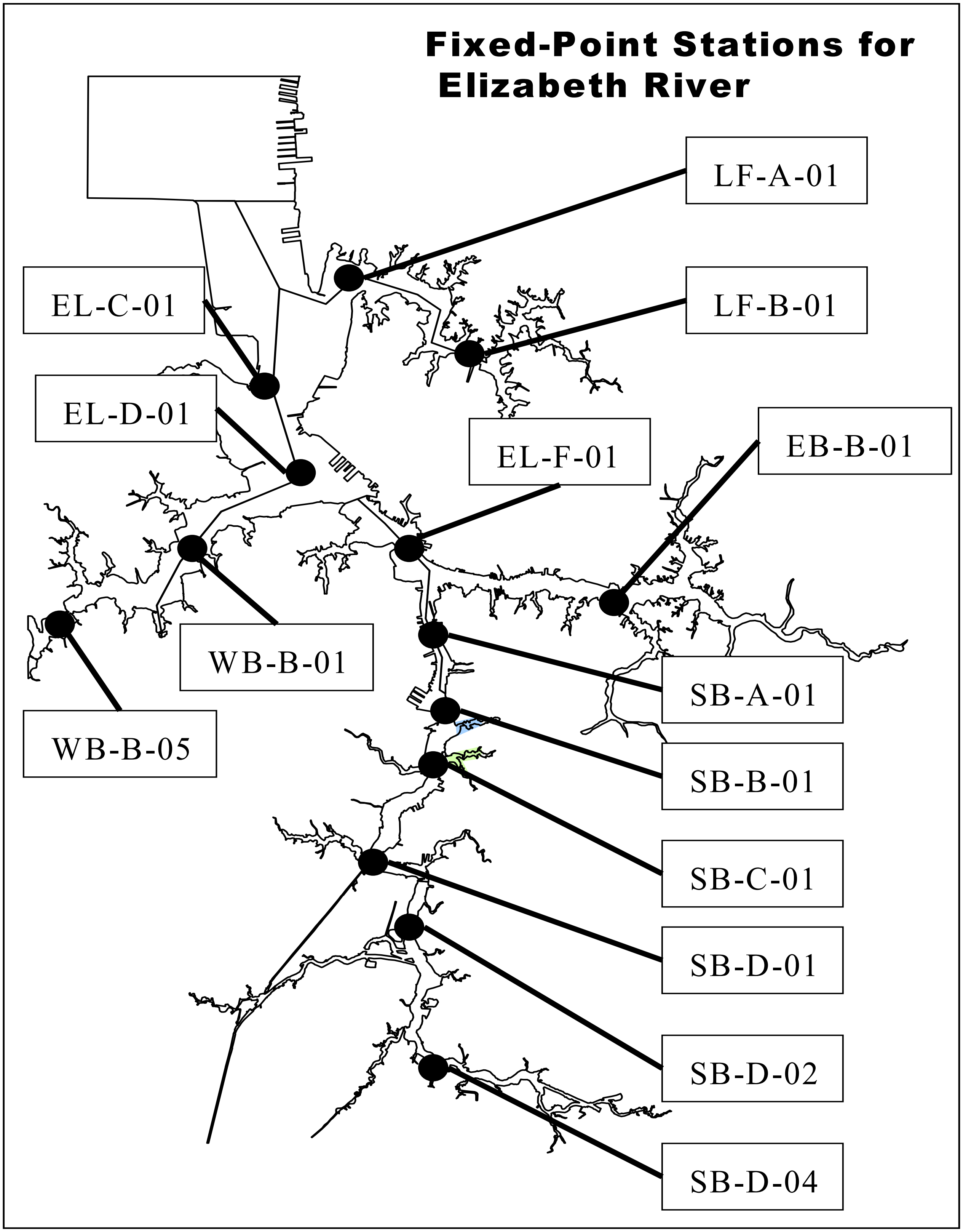


Figure 2. Elizabeth River watershed showing the 14 fixed-point stations for long-term trend analyses.

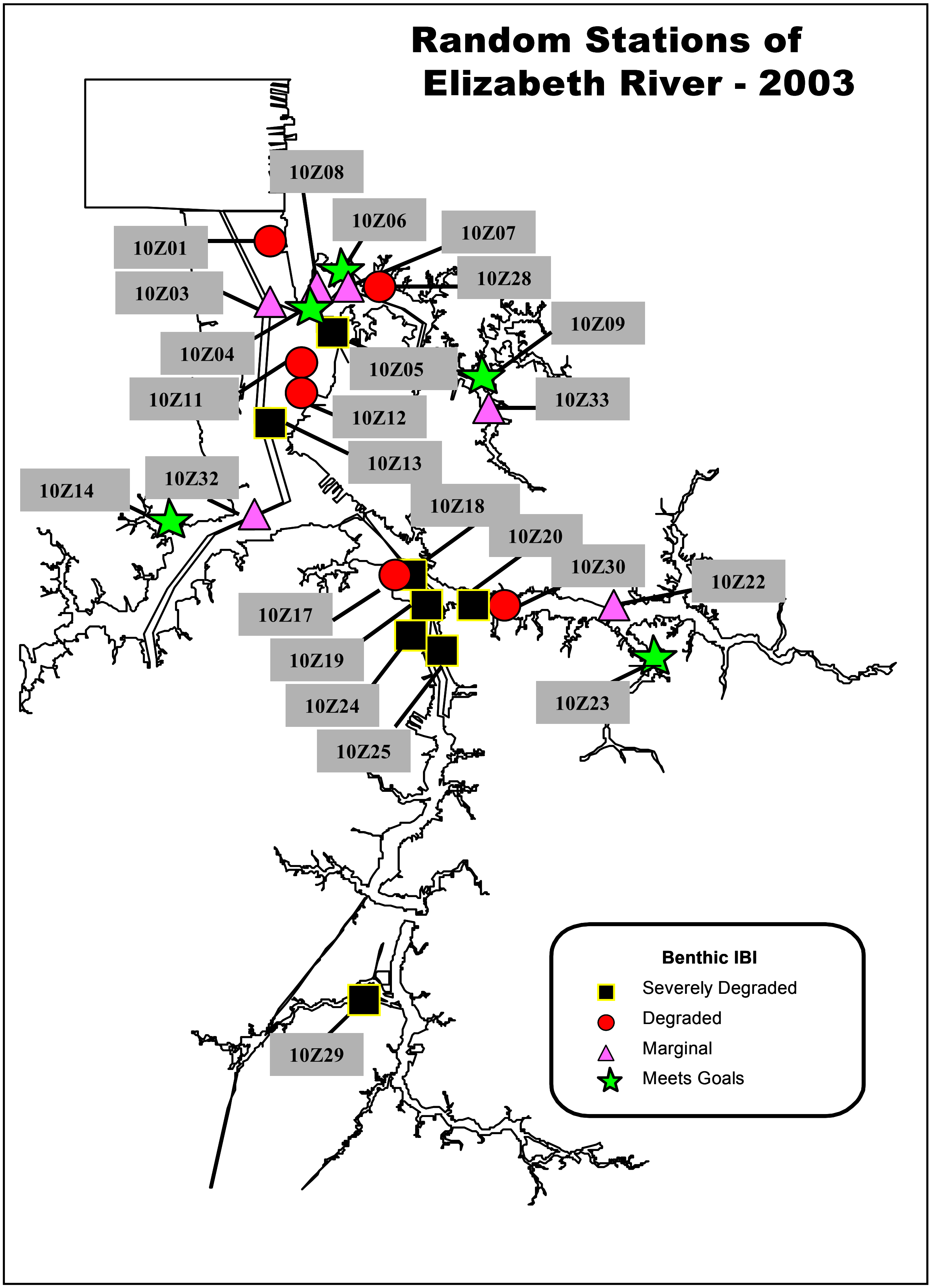


Figure 3. Map showing the 25 random locations sampled in 2003 and indicating station location and condition of the benthic communities using the mean B-IBI value for 2000-2003.

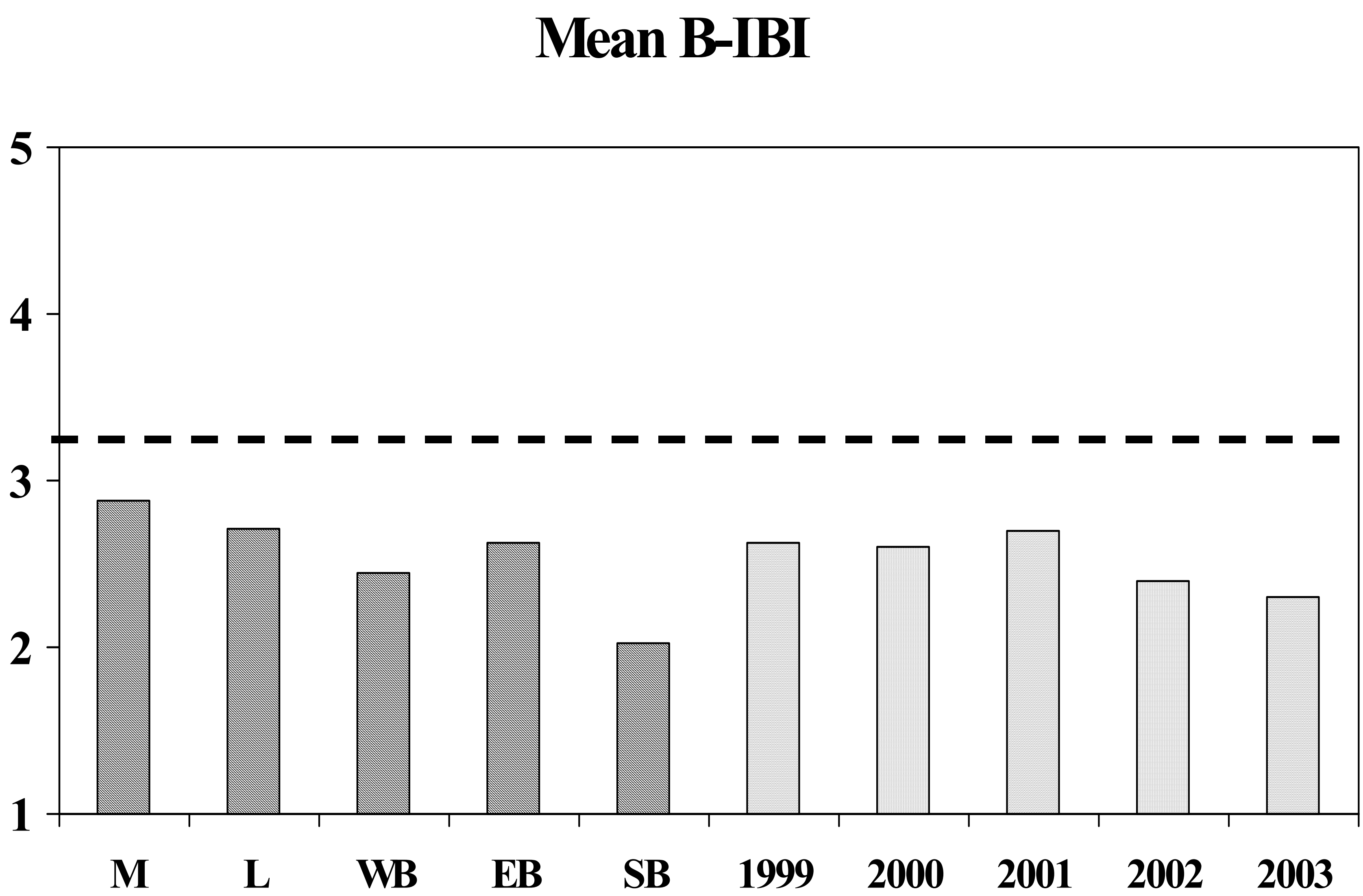


Figure 4. Average B-IBI values. Dashed line indicates a B-IBI value of 3.0, the goal for benthic restoration. Shown are the five strata from the 1999 sampling (crosshatched bars) compared with the area weighted value for 1999 and the values for 2000 through 2003 based upon a single stratum for the entire watershed (stippled bars). Abbreviations: M - Mainstem of Elizabeth River, L - Lafayette River, WB - Western Branch, EB - Eastern Branch, SB - Southern Branch.

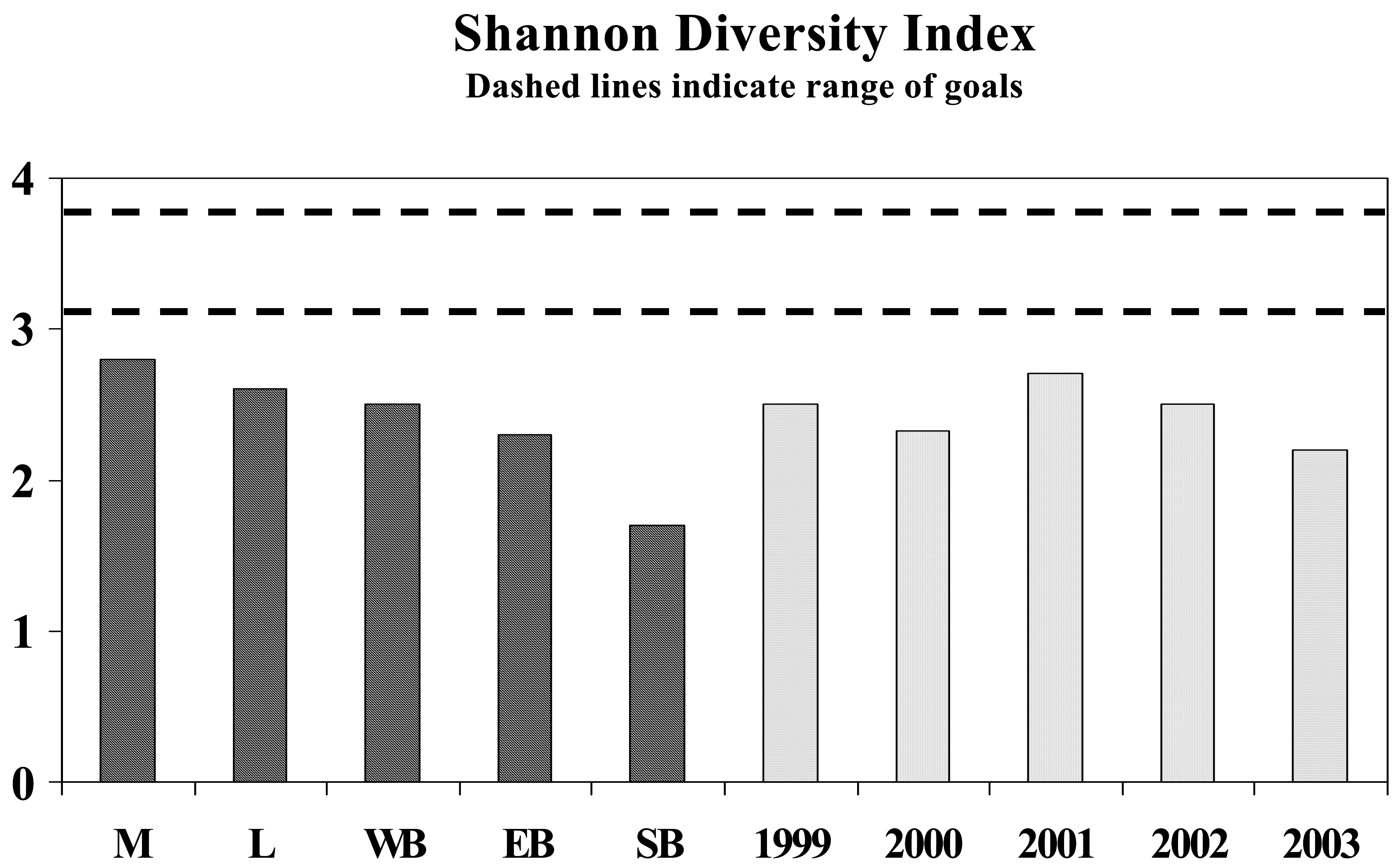


Figure 5 . Shannon Diversity Index. Shown are the five strata from the 1999 sampling, the 1999 area weighted average for the entire watershed and the 2000 through 2003 results. See Figure 4 for abbreviations. Dashed lines indicate range of values from benthic restoration goals.

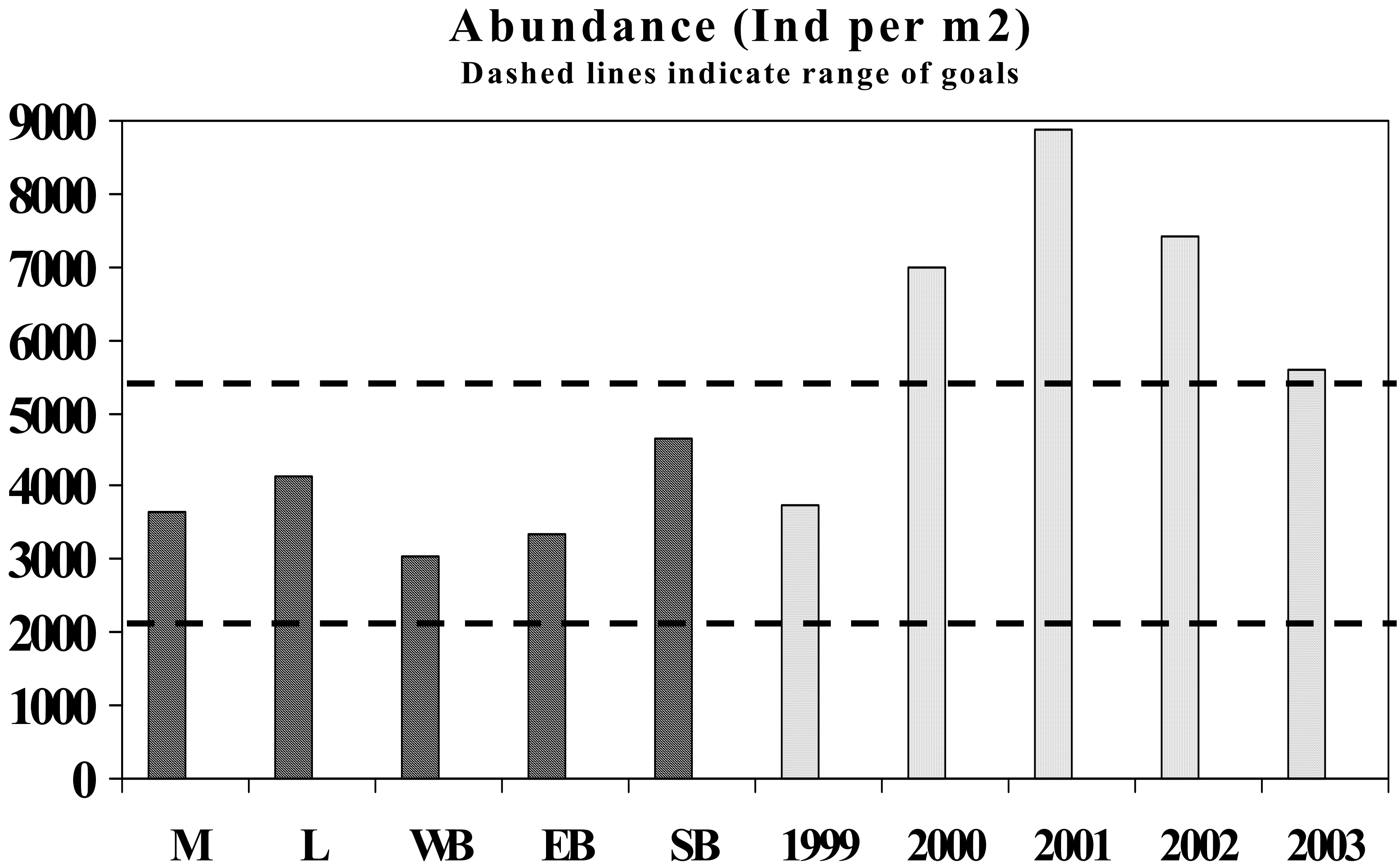


Figure 6. Average abundance of individuals per m^2. Shown are the five strata from the 1999 sampling, the 1999 area weighted average for the entire watershed and the 2000 through 2003 results. See Figure 4 for abbreviations. Dashed lines indicate range of values from benthic restoration goals.

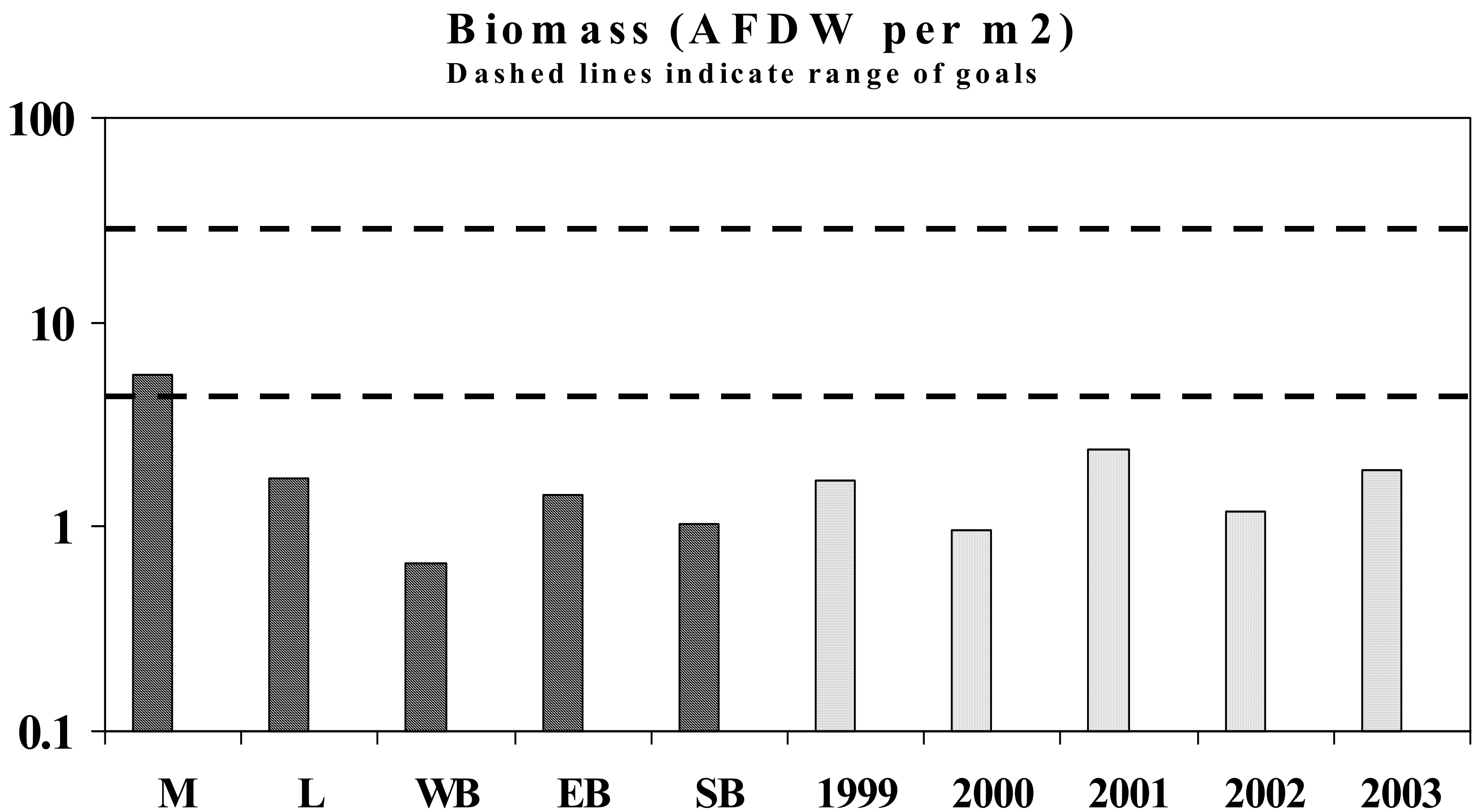


Figure 7. Average ash-free dry weight biomass in g per m^2. Shown are the five strata from the 1999 sampling, the 1999 area weighted average for the entire watershed and the 2000 through 2003 results. See Figure 4 for abbreviations. Dashed lines indicate range of values from benthic restoration goals.

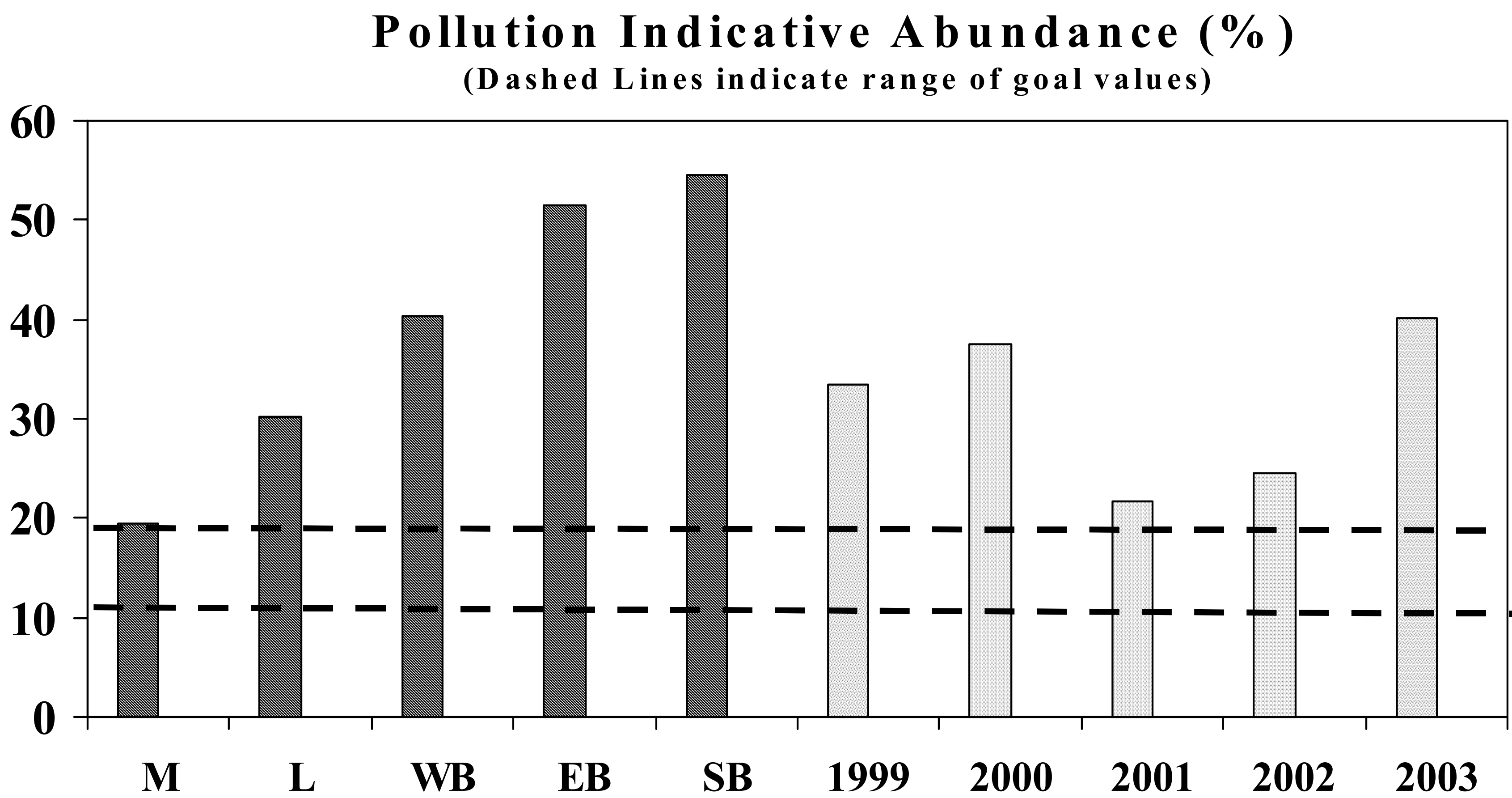


Figure 8. Average percentage of pollution indicative species abundance. Shown are the five strata from the 1999 sampling, the 1999 area weighted average for the entire watershed and the 2000 through 2003 results. See Figure 4 for abbreviations. Dashed lines indicate range of values from benthic restoration goals.

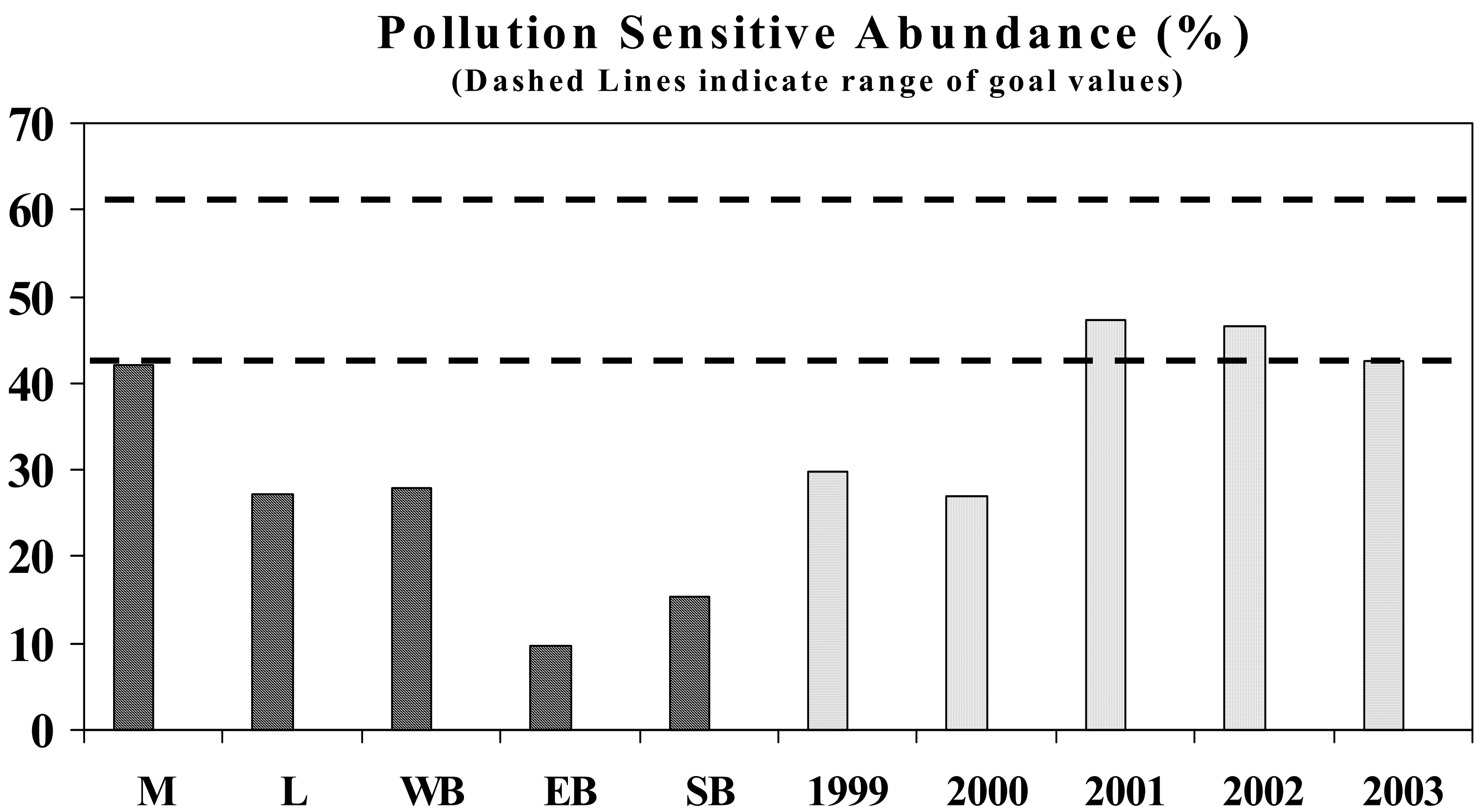


Figure 9. Average percentage of pollution sensitive species abundance. Shown are the five strata from the 1999 sampling, the 1999 area weighted average for the entire watershed and the 2000 through 2003 results. See Figure 4 for abbreviations. Dashed lines indicate range of values from benthic restoration goals.

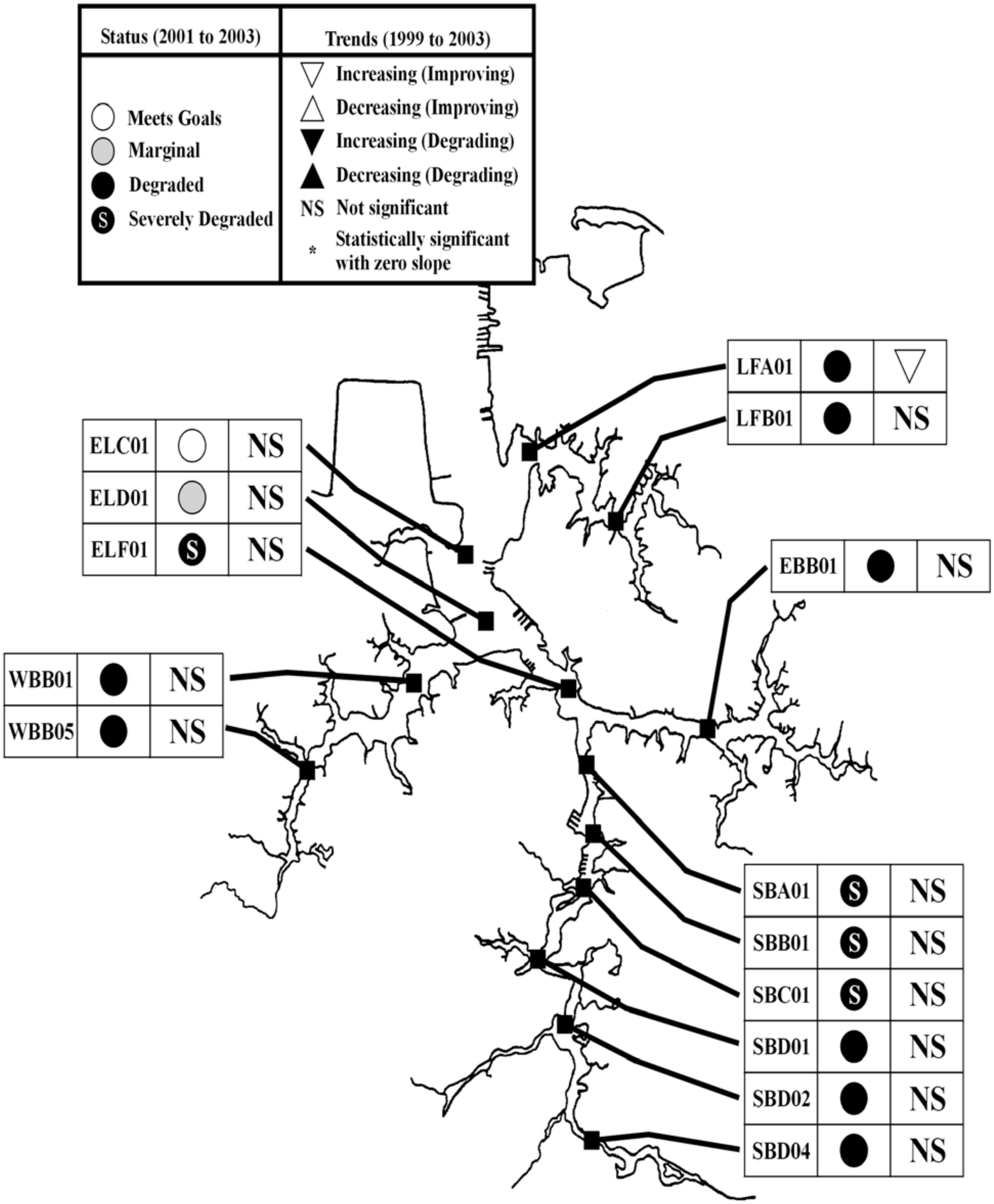


Figure 10. Fixed-point stations showing the benthic community status of each station. Status is based upon the average value of the B-IBI for the three year period 2001-2003. Values less than 2 were classified as **severely degraded**; values from 2.0 to 2.6 as **degraded**; values greater than 2.6 but less than 3.0 as **marginal**; and values of 3.0 or more as **meeting the goal.** Long-term trends in the B-IBI for the period of 1999 through 2003. The single trend shown was significant at p <=0.10.

Tables

Table1. Random Stations of the Elizabeth River sampled in 2003. Summary of physical-chemical parameters.

Station	Date Collected	Latitude	Longitude	Water depth (m)	Temperature (°C)	Salinity (ppt)	Dissolved oxygen (ppm)	Silt_clay content (%)	Volatile organics (%)
10Z01	7/16/03	36.9192	-76.3327	10.0	25.0	19.1	4.3	45.9	1.6
10Z03	7/16/03	36.9040	-76.3319	4.5	27.0	17.8	5.9	10.3	0.8
10Z04	7/16/03	36.9026	-76.3233	1.0	26.9	17.6	7.1	0.6	0.3
10Z05	9/16/03	36.9013	-76.3193	2.5	26.6	17.7	6.4	1.6	0.2
10Z06	7/16/03	36.9064	-76.3189	3.0	26.3	17.8	6.2	51.6	1.7
10Z07	7/16/03	36.9074	-76.3177	4.0	26.1	17.8	6.1	61.9	1.5
10Z08	7/16/03	36.9111	-76.3198	2.0	26.1	17.9	5.7	44.9	1.2
10Z09	7/16/03	36.8883	-76.2792	6.5	26.8	15.2	3.6	92.4	1.9
10Z11	7/16/03	36.8971	-76.3302	5.0	26.6	17.9	6.0	19.1	1.1
10Z12	7/16/03	36.8879	-76.3230	2.5	27.0	17.7	6.9	3.0	0.3
10Z13	7/17/03	36.8793	-76.3380	10.0	26.3	18.1	5.2	47.8	1.8
10Z14	7/23/03	36.8592	-76.3644	0.3	27.9	15.3	4.8	90.9	1.9
10Z17	7/17/03	36.8469	-76.3030	2.5	27.1	17.3	3.5	36.3	1.9
10Z18	7/17/03	36.8449	-76.3019	3.0	27.0	17.5	4.0	29.7	1.6
10Z19	7/17/03	36.8414	-76.2940	14.0	25.6	18.7	3.8	95.8	2.0
10Z20	7/17/03	36.8412	-76.2853	10.5	26.1	18.2	3.3	84.5	2.5
10Z22	7/17/03	36.8354	-76.2410	3.0	26.8	15.9	3.0	56.6	2.3
10Z23	7/17/03	36.8281	-76.2344	2.5	27.5	13.1	3.0	87.2	2.7
10Z24	7/15/03	36.8348	-76.2953	14.0	25.3	19.6	3.0	88.9	2.1
10Z25	7/15/03	36.8274	-76.2933	15.5	25.1	20.0	2.8	66.6	1.8
10Z28	7/16/03	36.9060	-76.3083	4.5	25.8	18.0	5.5	63.0	1.8
10Z29	7/15/03	36.7554	-76.3101	4.0	30.9	14.1	3.3	1.4	0.4
10Z30	7/17/03	36.8402	-76.2784	10.5	26.2	18.0	3.3	51.2	2.3
10Z32	7/17/03	36.8590	-76.3420	4.5	27.0	17.7	5.5	61.6	1.9
10Z33	8/28/03	36.8829	-76.2750	1.1	31.5	16.7	13.6	96.6	2.2

Table 2. Random Stations of the Elizabeth River sampled in 2003. Summary of benthic community parameters. Abundance reported as ind./m^2, Biomass reported as AFDW g/m^2, all other abundance and biomass metrics are percentages.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance	Deep Deposit Feeder Abundance
10Z01	2.0	1,701	0.953	2.39	73.3	10.7	71.4	9.5	9.3	24.0
10Z03	2.7	4,763	3.039	2.90	54.8	36.7	30.6	53.7	9.0	43.3
10Z04	3.0	2,109	3.334	2.61	20.4	4.3	50.3	4.1	6.5	71.0
10Z05	1.7	6,260	1.497	1.96	75.4	11.6	27.3	33.3	8.3	15.9
10Z06	2.7	2,948	1.610	2.58	49.2	32.3	25.4	50.7	7.7	40.8
10Z07	2.7	2,359	1.633	2.89	41.3	39.4	30.6	48.6	5.8	49.0
10Z08	3.3	3,924	3.697	2.36	23.1	68.8	20.9	69.9	5.8	62.4
10Z09	3.3	2,994	2.041	2.01	12.9	59.1	10.0	76.7	4.5	75.0
10Z11	2.3	3,334	0.567	3.05	44.9	10.2	24.0	16.0	29.3	16.3
10Z12	2.0	4,082	1.202	2.25	67.2	18.9	28.3	37.7	4.4	26.1
10Z13	1.7	6,486	1.497	1.91	70.6	17.8	84.8	7.6	2.4	26.6
10Z14	3.0	4,899	1.293	1.55	7.4	87.0	7.0	84.2	12.5	74.1
10Z17	2.0	8,278	2.177	2.02	26.3	68.5	14.6	70.8	2.7	71.5
10Z18	1.7	8,346	0.930	1.73	34.8	62.8	58.5	26.8	2.2	70.7
10Z19	1.3	8,550	2.517	2.17	40.6	21.5	73.9	10.8	1.1	62.1
10Z20	1.7	8,800	1.814	1.55	19.3	67.0	48.8	47.5	0.5	83.2
10Z22	2.7	9,775	2.427	1.47	19.5	76.8	11.2	83.2	1.2	77.5
10Z23	3.0	14,810	5.693	1.31	8.7	87.0	3.6	87.6	6.3	80.7
10Z24	1.7	2,109	0.408	2.33	44.1	31.2	77.8	5.6	0.0	59.1
10Z25	1.7	10,478	2.586	2.58	45.0	27.3	66.7	23.7	0.4	54.8
10Z28	2.3	2,223	0.658	2.16	58.2	34.7	41.4	48.3	8.2	32.7
10Z29	1.7	7,348	0.522	1.60	30.9	65.4	21.7	60.9	1.5	60.5
10Z30	2.3	5,670	2.381	2.75	61.6	22.8	23.8	58.1	6.8	32.4
10Z32	2.7	2,517	0.953	2.09	49.6	40.5	21.4	47.6	5.4	45.0
10Z33	2.7	5,262	1.656	1.50	24.1	70.7	2.7	89.0	3.0	68.5
Mean	2.3	5,601	1.880	2.15	40.1	42.9	35.1	46.1	5.8	52.9
S E	0.6	3,294	1.190	0.50	20.6	25.9	24.7	27.7	5.9	21.2

Table 3. Random Stations of the Elizabeth River sampled in 2003. Summary of benthic community parameters scores of the BIBI.

Station	BIBI	Salinity Class	Sediment Class	Shannon Index	Abundance	Biomass	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance	Deep Deposit Feeder Abundance
10Z01	2.0	5	2	1	5	3	.	.	1	1	1	.
10Z03	2.7	4	1	3	3	5	1	3	.	.	1	.
10Z04	3.0	4	1	3	5	5	3	1	.	.	1	.
10Z05	1.7	4	1	1	1	3	1	3	.	.	1	.
10Z06	2.7	4	2	3	3	3	.	.	3	3	1	.
10Z07	2.7	4	2	3	5	3	.	.	1	3	1	.
10Z08	3.3	4	2	3	3	5	.	.	3	5	1	.
10Z09	3.3	4	2	3	3	5	.	.	3	5	1	.
10Z11	2.3	4	1	3	3	1	1	3	.	.	3	.
10Z12	2.0	4	1	1	3	3	1	3	.	.	1	.
10Z13	1.7	5	2	1	3	3	.	.	1	1	1	.
10Z14	3.0	4	2	1	3	3	.	.	3	5	3	.
10Z17	2.0	4	1	1	1	3	1	5	.	.	1	.
10Z18	1.7	4	1	1	1	1	1	5	.	.	1	.
10Z19	1.3	5	2	1	1	3	.	.	1	1	1	.
10Z20	1.7	5	2	1	1	3	.	.	1	3	1	.
10Z22	2.7	4	2	1	1	5	.	.	3	5	1	.
10Z23	3.0	4	2	1	1	5	.	.	5	5	1	.
10Z24	1.7	5	2	1	5	1	.	.	1	1	1	.
10Z25	1.7	5	2	3	1	3		.	1	1	1	.
10Z28	2.3	5	2	1	5	3		.	1	3	1	.
10Z29	1.7	4	1	1	1	1	1	5	.	.	1	.
10Z30	2.3	5	2	3	3	3	.	.	1	3	1	.
10Z32	2.7	4	2	3	3	3	.	.	3	3	1	.
10Z33	2.7	4	2	1	1	3	.	.	5	5	1	.

Table 4. Random Stations of the Elizabeth River sampled in 2003. Dominant taxa by abundance. Abundance is average for the 25 random samples expressed as individuals per m^2. Taxon code: A = amphipod, An=Anemone B = bivalve, G = gastropod, I = isopod, O = oligochaete, P = polychaete, R = rhynchocoel.

	Taxon	Abundance per m^2
1	Mediomastus ambiseta (P)	2,496
2	Streblospio benedicti (P)	1,570
3	Tubificoides spp. Group I (O)	344
4	Leitoscoloplos spp. (P)	254
5	Paraprionospio pinnata (P)	157
6	Macoma balthica (B)	115
7	Nemertea spp. (N)	76
8	Heteromastus filiformis (P)	58
9	Cyathura polita (I)	53
10	Leucon americanus (C)	53
11	Eteone heteropoda (P)	42
12	Paranais littoralis (O)	42
13	Clymenella torquata (P)	35
14	Polydora cornuta (P)	27
15	Leptocheirus plumulosus (A)	25

Table 5. Fixed Stations of the Elizabeth River sampled in 2003.						Summary of physical-chemical parameters.			
Station	Date collected	Latitude	Longitude	Water depth (m)	Temperature (^oC)	Salinity (ppt)	Dissolved oxygen (ppm)	Silt_clay content (%)	Volatile organics (%)
EBB1	7/17/03	36.8378	-76.2422	1.5	15.1	27.1	3.0	80.7	6.6
ELC1	7/17/03	36.8796	-76.3476	3.0	17.7	27.3	6.7	28.0	1.5
ELD1	7/17/03	36.8614	-76.3357	2.0	17.7	27.0	5.9	3.0	0.3
ELF1	7/17/03	36.8489	-76.2972	12.0	18.9	25.4	3.7	84.2	5.7
LFA1	7/16/03	36.9092	-76.3138	3.0	17.8	26.0	5.8	68.8	3.0
LFB1	7/16/03	36.8896	-76.2830	3.3	15.5	26.6	2.6	88.6	7.0
SBA1	7/15/03	36.8257	-76.2914	13.5	19.4	25.4	2.9	93.7	6.9
SBB1	7/15/03	36.8117	-76.2886	2.0	17.0	28.2	3.9	55.5	5.0
SBC1	7/15/03	36.7994	-76.2944	12.0	19.6	25.7	2.7	93.7	7.9
SBD1	7/15/03	36.7796	-76.3106	11.2	18.1	26.5	2.7	89.6	7.5
SBD2	7/15/03	36.7668	-76.2970	2.0	15.3	29.2	2.9	75.9	9.5
SBD4	7/15/03	36.7402	-76.2990	1.5	13.0	28.0	3.5	5.1	0.7
WBB1	7/23/03	36.8462	-76.3576	1.5	17.3	26.7	5.8	85.8	5.1
WBB5	7/23/03	36.8293	-76.3932	1.0	14.6	27.5	3.7	83.6	5.8

Table 6. Fixed Point Stations of the Elizabeth River sampled in 2003. Summary of benthic community parameters. All values are station means (n=3). Abundance reported as ind/m^2, biomass reported as grams/m^2, all other abundance and biomass metrics are percentages.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance	Deep Deposit Feeder Abundance
EBB1	2.7	13,260	4.476	1.54	11.9	85.1	6.6	85.8	6.5	76.0
ELC1	2.1	6,358	1.716	2.33	43.2	48.7	34.1	53.8	3.2	55.4
ELD1	1.7	5,307	6.849	1.88	73.6	15.1	32.5	50.8	1.7	18.4
ELF1	1.8	5,587	1.376	1.66	74.4	12.1	63.8	26.7	1.0	23.8
LFA1	2.3	4,082	1.716	2.34	42.7	48.5	48.1	39.6	5.8	55.6
LFB1	3.1	4,702	3.009	1.66	11.9	73.4	6.6	87.9	1.3	79.1
SBA1	1.4	10,796	2.374	1.98	25.1	51.8	52.2	30.6	0.6	75.3
SBB1	2.0	9,238	0.885	1.59	24.2	68.9	24.6	29.7	3.0	85.2
SBC1	2.7	7,371	9.306	1.73	15.8	81.7	20.7	78.4	0.6	69.8
SBD1	2.1	3,258	0.779	2.32	35.6	22.1	34.9	35.6	3.6	26.4
SBD2	2.3	17,191	1.051	1.34	30.4	63.1	14.1	70.4	1.5	62.3
SBD4	2.1	9,261	1.157	1.93	23.1	71.3	7.8	80.1	1.9	46.7
WBB1	2.8	5,163	1.935	1.97	28.2	66.8	18.8	63.5	4.7	63.5
WBB5	3.0	7,401	3.886	1.73	2.1	42.6	3.1	77.1	7.8	32.9
Mean	2.3	7,784	2.894	1.86	31.6	53.7	26.3	57.9	3.1	55.0
SE	0.1	1,037	0.669	0.08	5.7	6.4	5.0	6.0	0.6	5.9

Table 7. Status in benthic community condition based on the Benthic IBI at the Elizabeth River Project monitoring stations for the period of 2001 through 2003.

Station	Mean IBI	Status
Mainstem		
ELC1	3.2	Meets Goals
ELD1	2.8	Marginal
ELF1	1.9	Severely degraded
Southern Branch		
SBA1	2.0	Severely Degraded
SBB1	2.0	Severely Degraded
SBC1	2.0	Severely Degraded
SBD1	2.1	Degraded
SBD2	2.2	Degraded
SBD4	2.6	Degraded
Western Branch		
WBB1	2.2	Degraded
WBB5	2.6	Degraded
Eastern Branch		
EBB1	2.4	Degraded
Lafayette River		
LFA1	2.1	Degraded
LFB1	2.3	Degraded

Table 8. Long-term trends in the B-IBI and associated metrics for the Elizabeth River Program monitoring stations for the period of 1999 through 2003. A. Trends shown were significant at p = 0.028. B. Trends shown were significant with p = 0.086. Baseline value is mean value for 1999-2001. Current value is projection to 2003 from the trend slope.

A. Trends with p = 0.028						
Station	Water Body	Variable	Baseline	Current	% Change	
ELF1	Mainstem	Pollution Indicative Species Biomass	37.9	71.3	88.0	Degrading
SBA1	Southern Branch	Pollution Indicative Species Biomass	18.7	58.0	209.7	Improving
EBB1	Eastern Branch	Total Community Abundance	3,557	15,743	342.6	Degrading
LFB1	Lafayette River	Pollution Sensitive Species Abundance	6.4	86.7	1,263.2	Improving
LFB1	Lafayette River	Pollution Sensitive Species Biomass	22.2	93.0	318.9	Improving
B. Trends with p = 0.086						
Station	Water Body	Variable	Baseline	Current	% Change	
ELD1	Mainstem	Pollution Sensitive Species Abundance	68.1	18.7	-72.5	Degrading
ELD1	Mainstem	Pollution Sensitive Species Biomass	32.3	53.6	65.8	Improving
SBA1	Southern Branch	Total Community Abundance	3,863	13,613	252.4	Degrading
SBB1	Southern Branch	Pollution Sensitive Species Abundance	31.8	88.2	177.8	Improving
SBC1	Southern Branch	Total Community Biomass	1.0	6.5	552.4	Improving
SBC1	Southern Branch	Pollution Sensitive Species Abundance	39.9	97.3	144.0	Improving
SBD2	Southern Branch	Total Community Abundance	3,103	20,384	556.8	Degrading
SBD2	Southern Branch	Pollution Sensitive Species Biomass	26.1	80.4	207.5	Improving
WBB1	Western Branch	Total Community Biomass	0.8	1.5	95.7	Improving
WBB1	Western Branch	Pollution Sensitive Species Abundance	52.1	77.8	49.4	Improving
WBB1	Western Branch	Pollution Indicative Species Abundance	37.1	16.8	-54.7	Improving
WBB1	Western Branch	Pollution Sensitive Species Biomass	13.6	59.9	340.1	Improving
WBB1	Western Branch	Pollution Indicative Species Biomass	35.9	7.4	-79.4	Improving
WBB5	Western Branch	Total Community Biomass	1.0	2.0	99.9	Improving
WBB5	Western Branch	Pollution Indicative Species Abundance	27.3	-7.8	-128.5	Improving
WBB5	Western Branch	Pollution Sensitive Species Biomass	37.2	80.5	116.5	Improving
EBB1	Eastern Branch	Total Community Biomass	1.1	4.4	298.9	Improving
EBB1	Eastern Branch	Pollution Sensitive Species Abundance	16.1	103.8	545.9	Improving
LFA1	Lafayette River	Benthic IBI	1.9	2.3	20.1	Improving

Table 9. Comparison of nutrient concentrations in the Elizabeth River compare to the lower polyhaline section of the James River (JMSPH see Appendix B, Fig. B1). All values are in mg/l and are the median values for the last three years fo collection. Data for JMSPH from Dauer et al. 2003.					
Parameter	James River (JMSPH)	Elizabeth River Mainstem	Western Branch	Eastern Branch	Southern Branch
STN	0.41	0.66	0.70	0.83	1.03
SDIN	0.05	0.21	0.25	0.38	0.54
STP	0.01	0.06	0.06	0.05	0.06
SDIP	0.01	0.04	0.05	0.04	0.04

Appendix A: Metrics and thresholds for calculating the Benthic Index Biotic Integrity

Table A1. Thresholds used to score each metric of the Chesapeake Bay B-IBI. Updated for the tidal freshwater and oligohaline habitats, and corrected from Weisberg et al. (1997) for the high mesohaline mud and polyhaline sand habitats.

	Scoring Criteria		
	5	**3**	**1**
Tidal Freshwater			
Abundance (#/m^2)	$1050-4000	800-1050 or $4000-5500	<800 or $³5500
Abundance of pollution-indicative taxa (%)	#39	39-87	>87
Abundance of deep-deposit feeders (%)	#70	70-95	>95
Tolerance Score	#8	8-9.35	>9.35
Oligohaline			
Abundance (#/m^2)	$450-3350	180-450 or $3350-4050	<180 or $4050
Abundance of pollution-indicative taxa (%)	#27	27-95	>95
Abundance of pollution-sensitive taxa (%)	$26	0.2-26	<0.2
Abundance of carnivores and omnivores (%)	$35	15-35	<15
Tolerance Score	#6	6-9.05	>9.05
Tanypodini to Chironomidae abundance ratio (%)	#17	17-64	>64
Low Mesohaline			
Shannon-Wiener	$2.5	1.7-2.5	<1.7
Abundance (#/m^2)	$1500-2500	500-1500 or $2500-6000	<500 or $6000
Biomass (g/m^2)	$5-10	1-5 or $10-30	<1 or $30
Abundance of pollution-indicative taxa (%)	#10	10-20	>20
Biomass of pollution-sensitive taxa (%)	$80	40-80	<40
Biomass deeper than 5 cm (%)	$80	10-80	<10

Table A1. Continued.

	Scoring Criteria		
	5	**3**	**1**
High Mesohaline Sand			
Shannon-Wiener	$3.2	2.5-3.2	<2.5
Abundance (#/m^2)	$1500-3000	1000-1500 or $3000-5000	<1000 or $5000
Biomass (g/m^2)	$3-15	1-3 or $15-50	<1 or $50
Abundance of pollution-indicative taxa (%)	#10	10-25	>25
Abundance of pollution-sensitive taxa (%)	$40	10-40	<10
Abundance of carnivores and omnivores (%)	$35	20-35	<20
High Mesohaline Mud			
Shannon-Wiener	3.0	2.0-3.0	<2.0
Abundance (#/m^2)	$1500-2500	1000-1500 or $2500-5000	<1000 or $5000
Biomass (g/m^2)	$2-10	0.5-2 or $10-50	<0.5 or $50
Biomass of pollution-indicative taxa (%)	#5	5-30	>30
Biomass of pollution-sensitive taxa (%)	$60	30-60	<30
Abundance of carnivores and omnivores (%)	$25	10-25	<10
Biomass deeper than 5 cm (%)	$60	10-60	<10
Polyhaline Sand			
Shannon-Wiener	$3.5	2.7-3.5	<2.7
Abundance (#/m^2)	$3000-5000	1500-3000 or $5000-8000	<1500 or $8000
Biomass (g/m^2)	$5-20	1-5 or $20-50	<1 or $50
Biomass of pollution-indicative taxa (%)	#5	5-15	>15
Abundance of pollution-sensitive taxa (%)	$50	25-50	<25
Abundance of deep-deposit feeders (%)	$25	10-25	<10

Table A1. Continued.

	Scoring Criteria		
	5	3	1
Polyhaline Mud			
Shannon-Wiener	$3.3	2.4-3.3	<2.4
Abundance (#/m^2)	$1500-3000	1000-1500 or $3000-8000	<1000 or $8000
Biomass (g/m^2)	$3-10	0.5-3 or $10-30	<0.5 or $30
Biomass of pollution-indicative taxa (%)	#5	5-20	>20
Biomass of pollution-sensitive taxa (%)	$60	30-60	<30
Abundance of carnivores and omnivores	$40	25-40	<25
Number of taxa >5 cm below the sediment-water interface (%)	$40	10-40	<10

Appendix B: Summary of water quality status and trends for the Elizabeth River

Preface:

In this appendix water quality status and trends for the Elizabeth River are summarized. These data are collected by the Virginia Water Quality Monitoring Program as part of the Chesapeake Bay Restoration Program. Details of collection and laboratory methodology can be found in Dauer et al. 2003a,b which can be downloaded in pdf format from the Old Dominion University Chesapeake Bay Program website <www.chesapeakebay.odu.edu> under "Reports." The James River Report includes the Elizabeth River, the Chickahominy River and the Appomattox River. The York River Report includes the tidal Pamunkey River and Mattaponi River. The Rappahannock River Report includes the Corrotoman River. Also available at this website are appendices that include (1) tables of status for all parameters measured at all stations sampled by each program, (2) tables of all parameters and metrics for which there was a significant trend, and (3) scatter plots of all parameters over time. There are five appendices: water quality, phytoplankton, primary productivity, zooplankton and benthos.

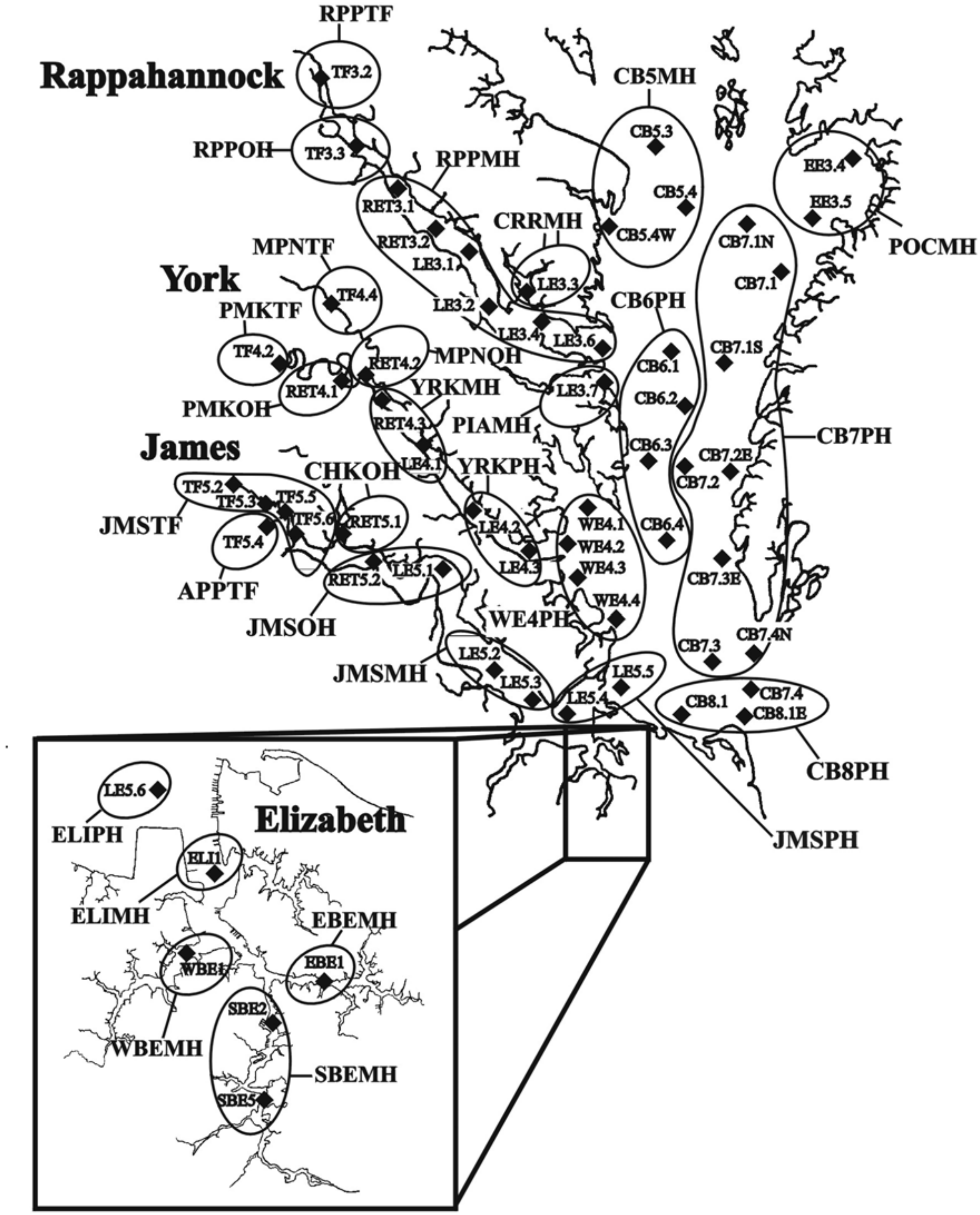
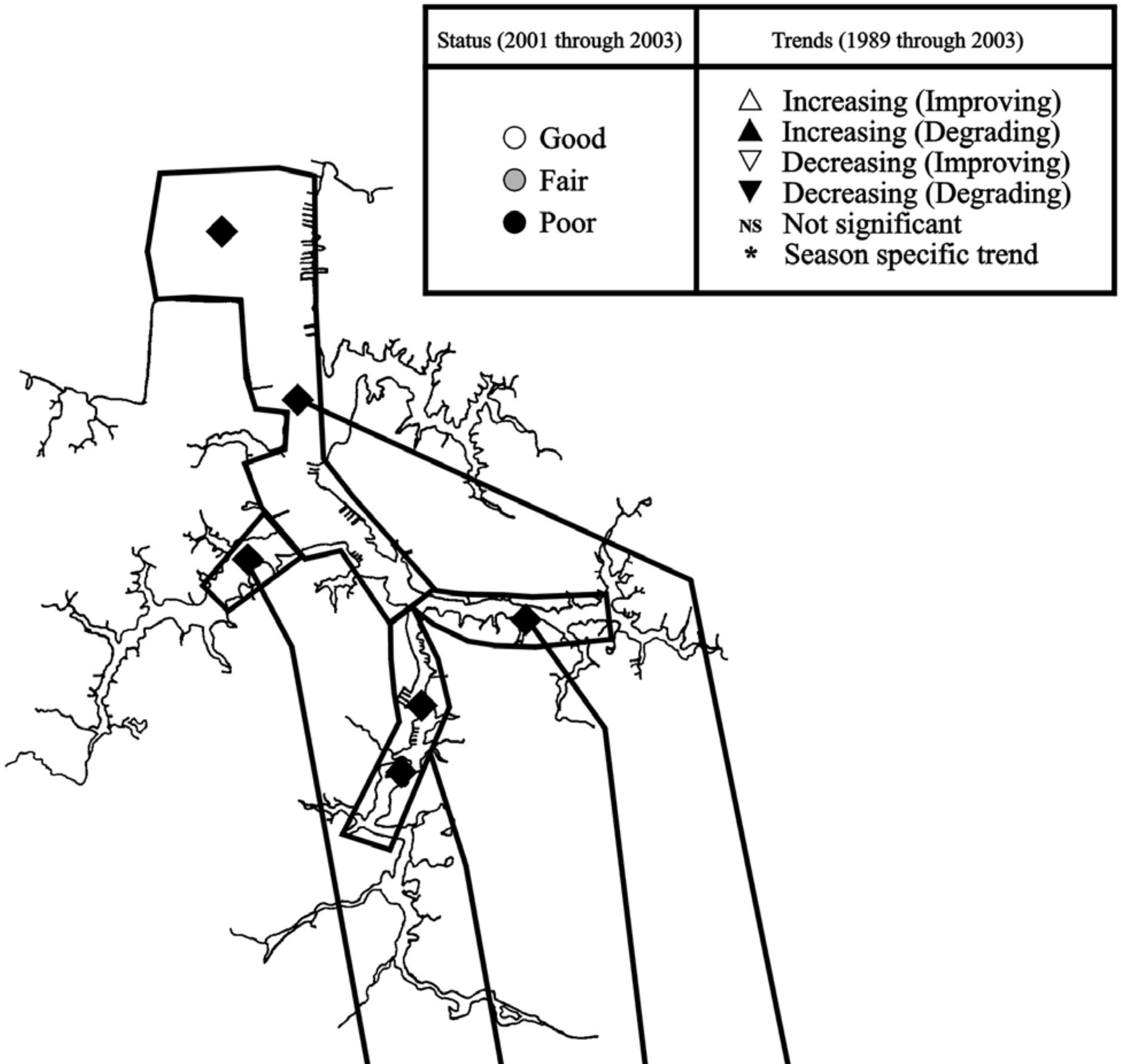
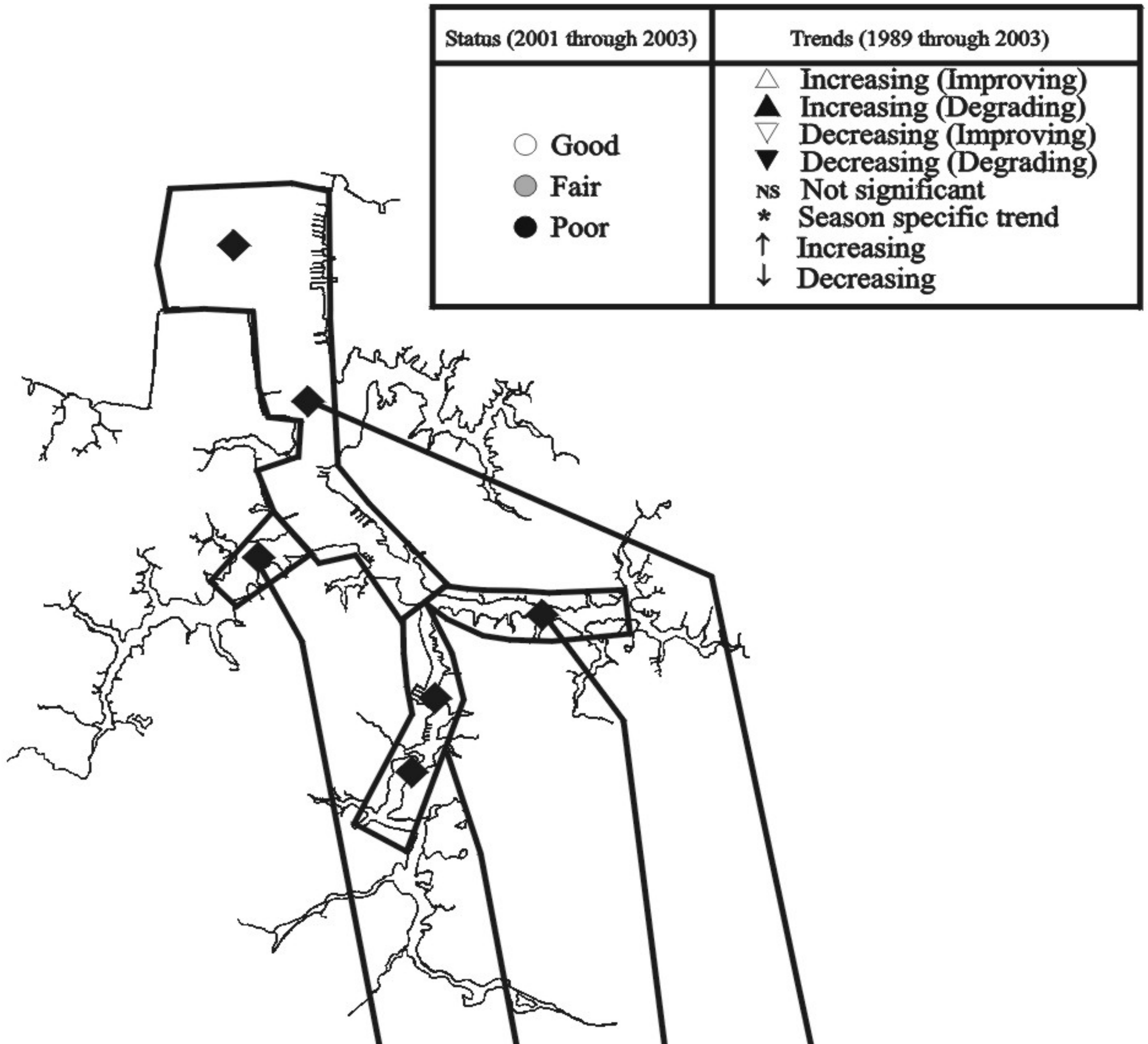


Figure B1. Map showing the locations of the water quality monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem (Dauer et al 2003). Insert shows location of Elizabeth River monitoring stations. Also shown are ellipses that delineate the Chesapeake Bay Program segmentation scheme.



Parameter	Western Branch		Southern Branch		Eastern Branch		Elizabeth River Mainstem	
STN	●	▽	●	▽	●	▽	●	▽
BTN	●	▽	●	NS	●	▽	●	▽
SDIN	●	NS	●	▽	●	▽	●	▽
BDIN	●	NS	●	NS	●	▽	●	▽
STP	●	▽	●	▽	●	▽	●	▲85 ▽95
BTP	●	▽	●	▽	●	▽	●	▲85 ▽95
SDIP	●	NS	●	▽	●	NS	●	▽85
BDIP	●	NS	●	▽	●	NS	●	▽95

Figure B2. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment. Abbreviations: TN - total nitrogen; DIN - dissolved inorganic nitrogen; TP - total phosphorus; DIP - dissolved inorganic phosphorus. The prefixes S and B refer to surface and bottom measurements.



Parameter	Western Branch	Southern Branch	Eastern Branch	Elizabeth River Mainstem
SCHLA	● ▽	○ NS	◍ NS	● NS
STSS	● ▽	◍ ▽	◍ ▽	● ▽
BTSS	● ▽	○ ▽	○ ▽	◍ NS
SECCHI	○ △	○ △	○ NS	○ ▽
BDO	○ △	◍ △	◍ △	○ NS
SWTEMP	NS	↑	NS	NS
BWTEMP	NS	↑	↑	NS
SSALIN	↑	↑	↑	NS
BSALIN	NS	NS	NS	NS

Figure B3. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment. Abbreviations: SCHLA -surface chlorophyll a; TSS- total suspended solids, SECCHI - secchi depth, BDO - bottom dissolved oxygen; WTEMP - water temperature, SALIN - salinity. The prefixes S and B refer to surface and bottom measurements.

Table B-1. Status in water quality environmental indicators in the Elizabeth River. Status designations determined by the Chesapeake Bay Program for the three year period 2001 through 2003. Secchi depth in meters, chlorophyll *a* in : g/l, all others in mg/l. S is surface and B is bottom layer. WBEMH - Western Branch, SBEMH - Southern Branch, EBEMH - Eastern Branch, ELIPH - Elizabeth River Mainstem.

Segment	Season	Parameter	Median	Score	Status
Mainstem					
ELIPH	Annual	STN	0.66	70.13	Poor
ELIPH	Annual	BTN	0.60	74.53	Poor
ELIPH	Annual	SDIN	0.21	77.21	Poor
ELIPH	Annual	BDIN	0.21	86.67	Poor
ELIPH	Annual	STP	0.06	84.71	Poor
ELIPH	Annual	BTP	0.07	79.00	Poor
ELIPH	Annual	SPO4F	0.04	98.64	Poor
ELIPH	Annual	BPO4F	0.04	94.13	Poor
ELIPH	Annual	SCHLA	10.20	62.98	Poor
ELIPH	Annual	STSS	10.41	61.81	Poor
ELIPH	Annual	BTSS	17.74	49.54	Fair
ELIPH	Annual	SECCHI	1.03	13.04	Good
ELIPH	Summer1	BDISOXY	5.39	-	Good
Southern Branch					
SBEMH	Annual	STN	1.03	98.38	Poor
SBEMH	Annual	BTN	0.96	97.29	Poor
SBEMH	Annual	SDIN	0.54	98.97	Poor
SBEMH	Annual	BDIN	0.50	99.82	Poor
SBEMH	Annual	STP	0.06	85.55	Poor
SBEMH	Annual	BTP	0.06	75.81	Poor
SBEMH	Annual	SPO4F	0.04	98.91	Poor
SBEMH	Annual	BPO4F	0.05	99.29	Poor
SBEMH	Annual	SCHLA	4.18	16.56	Good
SBEMH	Annual	STSS	8.60	45.25	Fair
SBEMH	Annual	BTSS	10.03	26.16	Good
SBEMH	Annual	SECCHI	1.13	17.55	Good
SBEMH	Summer1	BDISOXY	4.22	-	Fair
Western Branch					
WBEMH	Annual	STN	0.70	63.12	Poor
WBEMH	Annual	BTN	0.70	75.94	Poor
WBEMH	Annual	SDIN	0.25	72.64	Poor
WBEMH	Annual	BDIN	0.20	79.02	Poor
WBEMH	Annual	STP	0.06	89.16	Poor
WBEMH	Annual	BTP	0.06	69.45	Poor
WBEMH	Annual	SPO4F	0.05	99.68	Poor
WBEMH	Annual	BPO4F	0.05	99.16	Poor
WBEMH	Annual	SCHLA	11.75	66.98	Poor
WBEMH	Annual	STSS	19.00	88.26	Poor
WBEMH	Annual	BTSS	20.68	67.20	Poor
WBEMH	Annual	SECCHI	0.70	6.08	Good
WBEMH	Summer1	BDISOXY	5.83	-	Good
Eastern Branch					
EBEMH	Annual	STN	0.83	88.29	Poor
EBEMH	Annual	BTN	0.73	82.93	Poor
EBEMH	Annual	SDIN	0.38	89.51	Poor
EBEMH	Annual	BDIN	0.31	97.84	Poor
EBEMH	Annual	STP	0.05	80.15	Poor
EBEMH	Annual	BTP	0.05	62.09	Poor
EBEMH	Annual	SPO4F	0.04	98.85	Poor
EBEMH	Annual	BPO4F	0.06	99.62	Poor
EBEMH	Annual	SCHLA	7.16	47.28	Fair
EBEMH	Annual	STSS	8.83	57.32	Fair
EBEMH	Annual	BTSS	12.30	37.43	Good
EBEMH	Annual	SECCHI	1.10	17.55	Good
EBEMH	Summer1	BDISOXY	4.93	-	Fair

Table B-2. Blocked seasonal Kendall Long-term trends in water quality for the segment ELIPH in the Elizabeth River (1985-2003). Parameters are as follows: STN=Surface total nitrogen, BTN=Bottom total nitrogen, SDIN=Surface dissolved inorganic nitrogen, BDIN=Bottom dissolved inorganic nitrogen, STP=Surface total phosphorus, BTP=Bottom total phosphorus, SPO4F=Surface dissolved inorganic phosphorus, BPO4F=Bottom dissolved inorganic phosphorus.

Segment	Parameter	'85-'93 Trend p value	'85-93 Trend slope	'85-'93 Trend Direction	'95-'02 Trend p value	'95-'02 Trend Slope	'95-'02 Trend Direction	Trend Comparison p value	Trend Comparison Significance
ELIPH	STN	0.2685	0.0075	Not sign.	0.0000	-0.0266	Improving	<0.0001	Different
ELIPH	BTN	0.0000	0.0000	Improving - Zero Slope	0.0000	-0.0218	Improving	<0.0001	Different
ELIPH	SDIN	0.0997	0.0077	Not sign.	0.0000	-0.0080	Improving	<0.0001	Different
ELIPH	BDIN	0.1734	0.0080	Not sign.	0.0000	-0.0075	Improving	<0.0001	Different
ELIPH	STP	0.0001	0.0025	Degrading	0.0000	-0.0012	Improving	<0.0001	Different
ELIPH	BTP	0.0057	0.0025	Degrading	0.0001	-0.0011	Improving	<0.0001	Different
ELIPH	SPO4F	0.0145	0.0000	Degrading - Zero slope	0.0373	-0.0003	Improving	0.0070	Different
ELIPH	BPO4F	0.0542	0.0000	Not sign.	0.0134	-0.0003	Improving	0.0030	Different

Table B-3. Significant (p #0.05) water quality trends in the Elizabeth River for the period of 1989 through 2002. Abbreviations: See legends of Figures 2 and 3. The prefixed S and B refer to surface and bottom measurements. Baseline is the median value for the period 1989-1991. Secchi depth in meters, salinity in parts per thousand, temperature in degrees Celsius, chlorophyll *a* in : g/l, all others in mg/l.

Segment	Parameter	Season	Baseline Median	Slope	% Change	P value	Direction
Mainstem							
ELIPH	STSS	ANNUAL	8	-0.2000	-47.5	0.0153	Improving
ELIPH	SSECCHI	ANNUAL	1.1	-0.0088	-15.24	0.0017	Degrading
Southern Branch							
SBEMH	STN	ANNUAL	1.333	-0.0148	-16.66	0.0018	Improving
SBEMH	SDIN	ANNUAL	0.7376	-0.0145	-29.44	0.0001	Improving
SBEMH	STP	ANNUAL	0.0735	-0.0011	-23.21	0.0000	Improving
SBEMH	BTP	ANNUAL	0.0788	-0.0015	-28.57	0.0000	Improving
SBEMH	SPO4F	ANNUAL	0.0478	-0.0006	-18.06	0.0156	Improving
SBEMH	BPO4F	ANNUAL	0.0478	-0.0007	-21.99	0.0122	Improving
SBEMH	STSS	ANNUAL	8.575	-0.2000	-34.99	0.0118	Improving
SBEMH	BTSS	ANNUAL	13.075	-0.4903	-56.24	0.0000	Improving
SBEMH	BDISOXY	SUMMER1	2.65	0.0909	51.46	0.0227	Improving
SBEMH	SWTEMP	ANNUAL	18.2	0.1142	9.41	0.0028	Increasing
SBEMH	BWTEMP	ANNUAL	17.1	0.2100	18.42	0.0000	Increasing
SBEMH	SSALIN	ANNUAL	14.75	0.1691	17.2	0.0163	Increasing
Western Branch							
WBEMH	STN	ANNUAL	0.8	-0.0094	-17.69	0.0006	Improving
WBEMH	BTN	ANNUAL	0.791	-0.0069	-13.12	0.0137	Improving
WBEMH	STP	ANNUAL	0.083	-0.0019	-33.68	0.0000	Improving
WBEMH	BTP	ANNUAL	0.0795	-0.0017	-31.2	0.0000	Improving
WBEMH	SCHLA	ANNUAL	23	-0.3733	-24.34	0.0083	Improving
WBEMH	STSS	ANNUAL	20.6	-0.3233	-23.54	0.0160	Improving
WBEMH	BTSS	ANNUAL	20.5	-0.4380	-32.05	0.0367	Improving
WBEMH	SSECCHI	ANNUAL	0.6	0.0000	0	0.0156	Improving
WBEMH	BDISOXY	SUMMER1	4.4	0.1057	36.04	0.0243	Improving
WBEMH	SSALIN	ANNUAL	15.9	0.1500	14.15	0.0191	Increasing
Eastern Branch							
EBEMH	STN	ANNUAL	1.04	-0.0099	-14.28	0.0177	Improving
EBEMH	BTN	ANNUAL	0.855	-0.0094	-16.45	0.0007	Improving
EBEMH	SDIN	ANNUAL	0.5069	-0.0077	-22.93	0.0290	Improving
EBEMH	BDIN	ANNUAL	0.4902	-0.0100	-30.47	0.0003	Improving
EBEMH	STP	ANNUAL	0.0745	-0.0014	-27.25	0.0000	Improving
EBEMH	BTP	ANNUAL	0.074	-0.0013	-27.31	0.0000	Improving
EBEMH	STSS	ANNUAL	9.95	-0.2040	-30.75	0.0086	Improving
EBEMH	BTSS	ANNUAL	12.15	-0.2650	-32.72	0.0375	Improving
EBEMH	BDISOXY	SUMMER1	3.25	0.076	35.08	0.0420	Improving
EBEMH	BWTEMP	ANNUAL	15.9	0.0921	8.69	0.0125	Increasing
EBEMH	SSALIN	ANNUAL	16.85	0.1150	10.24	0.0257	Increasing

Appendix C: Summary of benthic community status and trends for the Elizabeth River stations (SBE2 and SBE5) of the Benthic Monitoring Program of the Chesapeake Bay Program.

Preface:

In this appendix status and trends in the benthic community for the Elizabeth River are summarized. These data are collected by the Virginia Benthic Monitoring Program as part of the Chesapeake Bay Restoration Program. Details of collection and laboratory methodology can be found in Dauer et al. 2003a,b which can be downloaded in pdf format from the Old Dominion University Chesapeake Bay Program website <www.chesapeakebay.odu.edu> under "Reports." This appendix presents a summary of status and trends for stations SBE2 and SBE5 which are located in the Southern Branch of the river. Shown are scatter plots of the B-IBI and for several benthic metrics for the period 1989 to 2002.

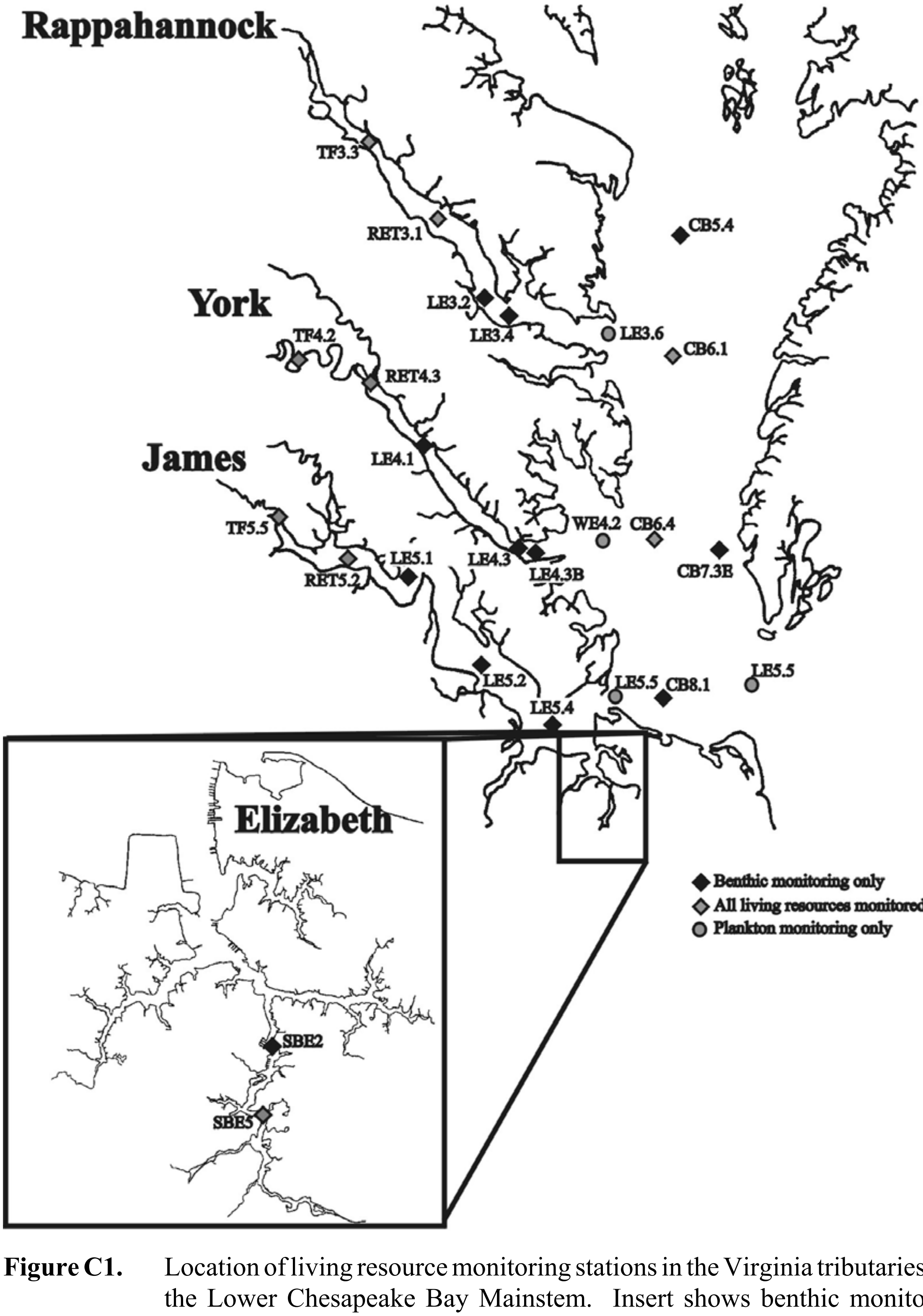
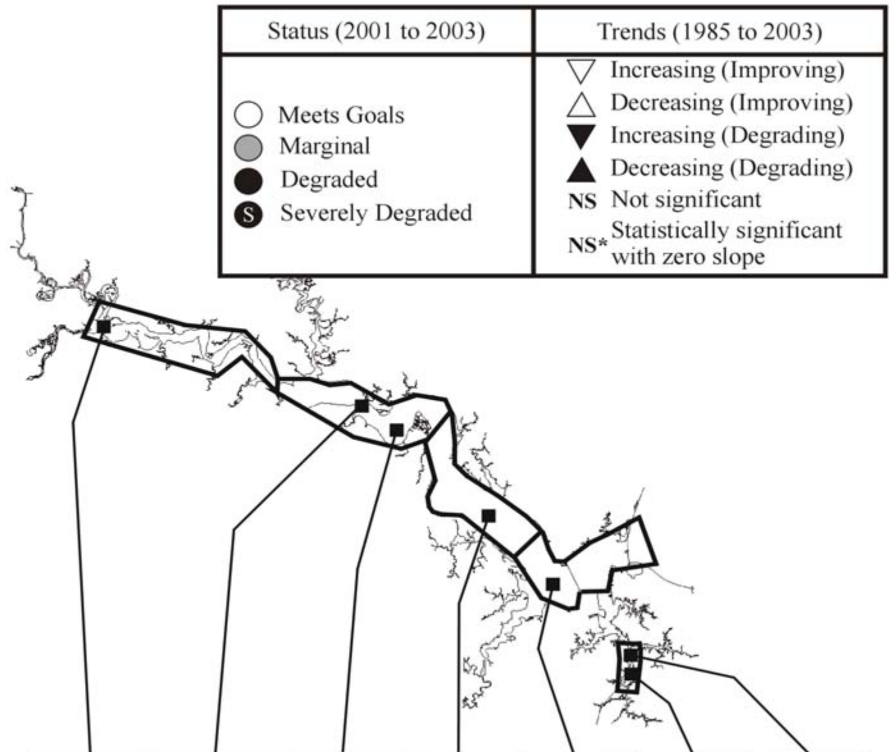
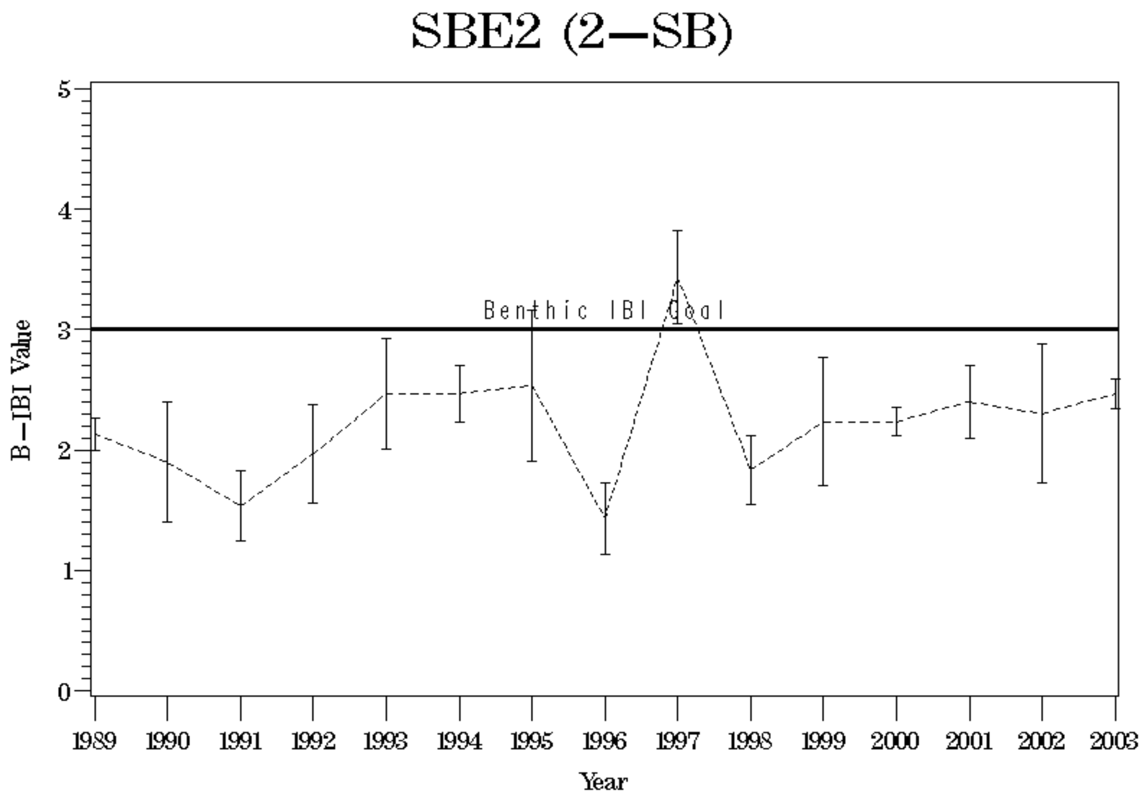


Figure C1. Location of living resource monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem. Insert shows benthic monitoring stations in the Southern Branch (SBE2 and SBE5) established in 1989.



	TF5.5	RET5.2	LE5.1	LE5.2	LE5.4	SBE5	SBE2
Benthic IBI	● △	○ △	○ NS	◍ NS	○ NS	● △	● NS
Total Abundance	NS	△	NS	△	NS	NS	△
Total Biomass	NS	NS	NS	NS	NS	△	△
Pollution Sensitive Species Abundance (%)	△	△	NS	NS	NS	△	△
Pollution Indicative Species Abundance (%)	NS	NS	NS*	NS	▽	▽	▽
Pollution Sensitive Species Biomass (%)	△	△	NS	NS	▼	△	△
Pollution Indicative Species Biomass (%)	NS	NS	NS	NS	NS	▽	NS
Shannon-Weiner Diversity Index	NS	△	NS	NS	NS	△	NS

Figure C2. Summary of trends in benthic community inn the James River watershed. Elizabeth River stations are SBE2 and SBE5 located in the Southern Branch.



FigureC3. Plot of the B-IBI Station SBE2 for 1985 through 2003.

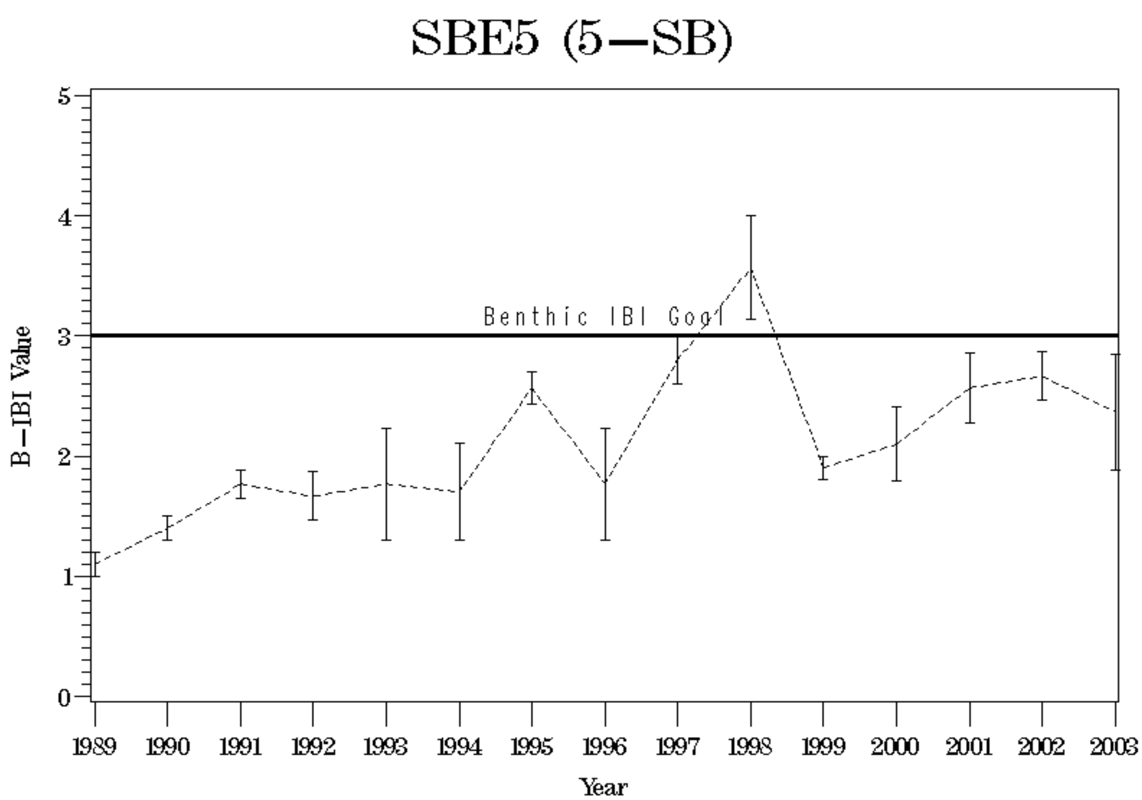


Figure C4. Plot of the B-IBI at Station SBE5 for 1985 through 2003.

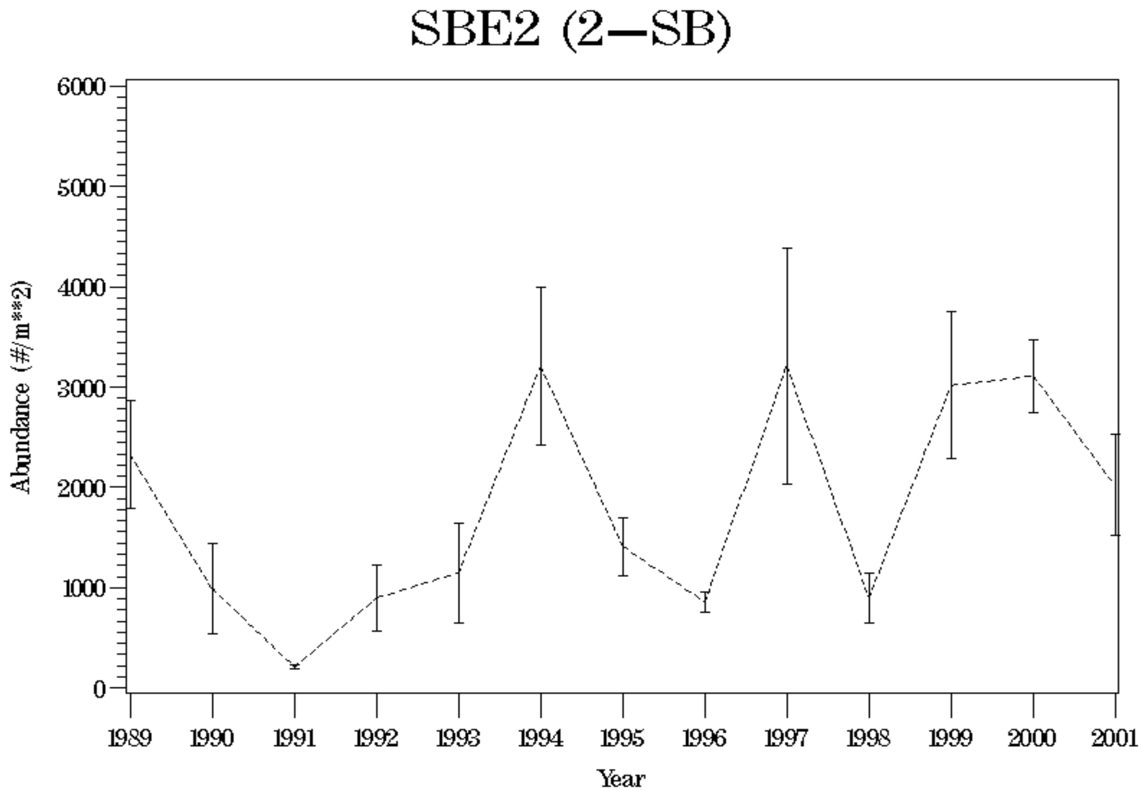


Figure C5 Benthic community abundance at station SBE2 (1985 - 2002).

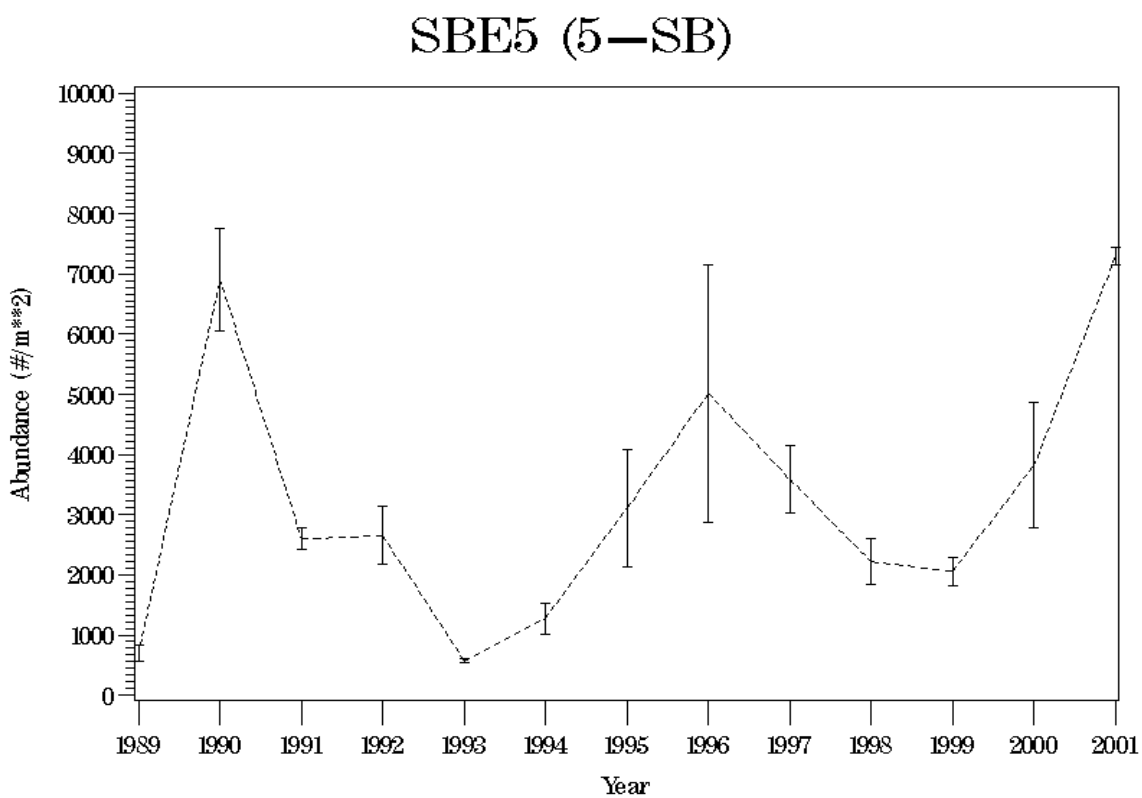


Figure C6 Benthic community abundance at station SBE5 (1985 - 2002).

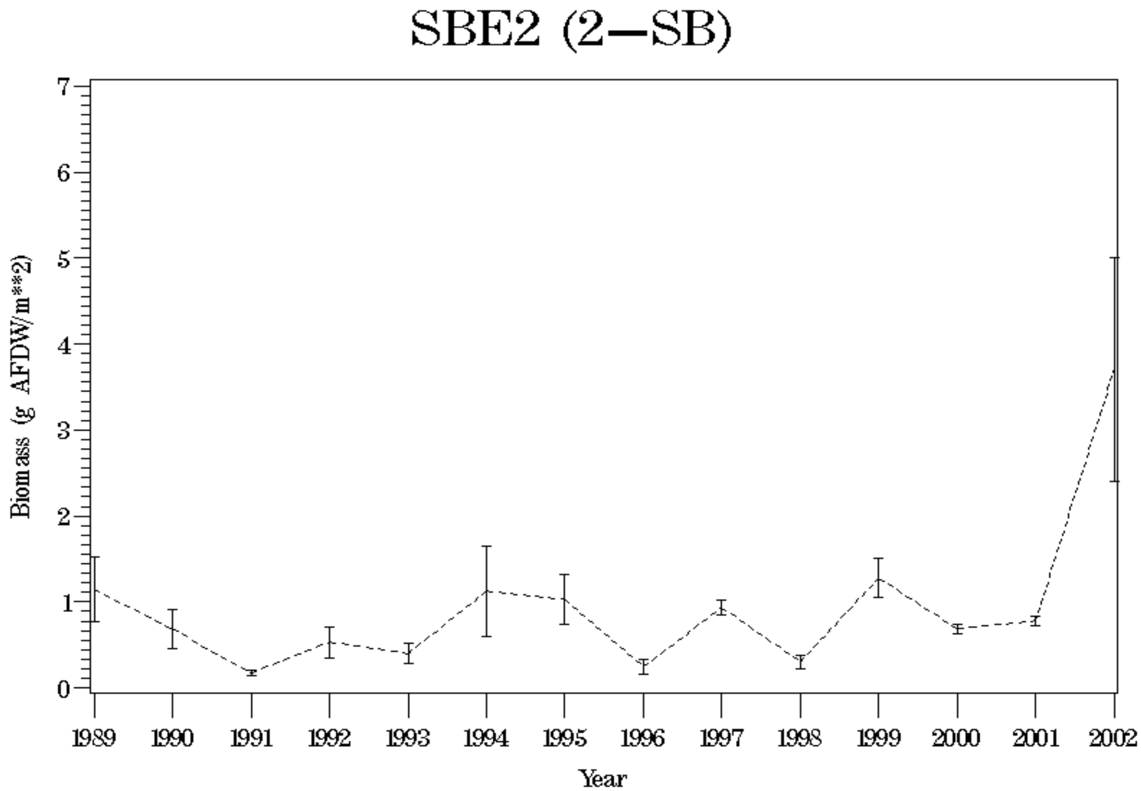


Figure C7. Benthic community biomass at station SBE2 (1985 - 2002).

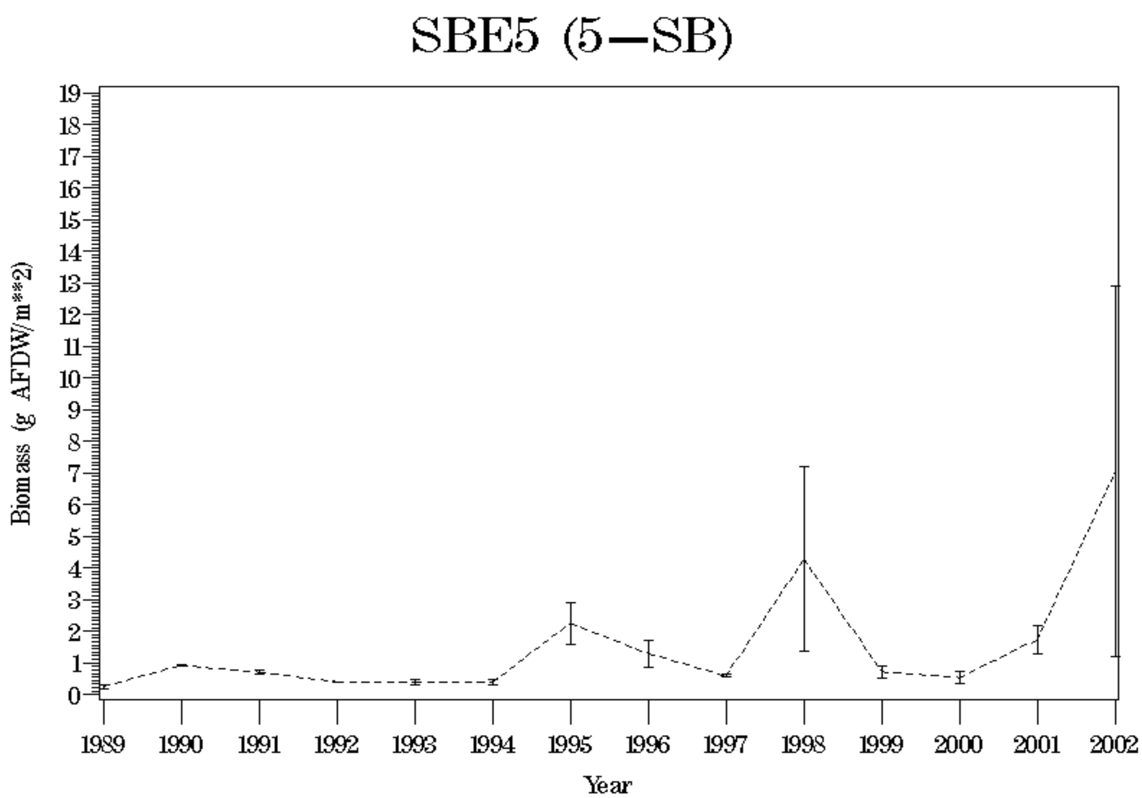


Figure C8. Benthic community biomass at station SBE5 (1985 - 2002).

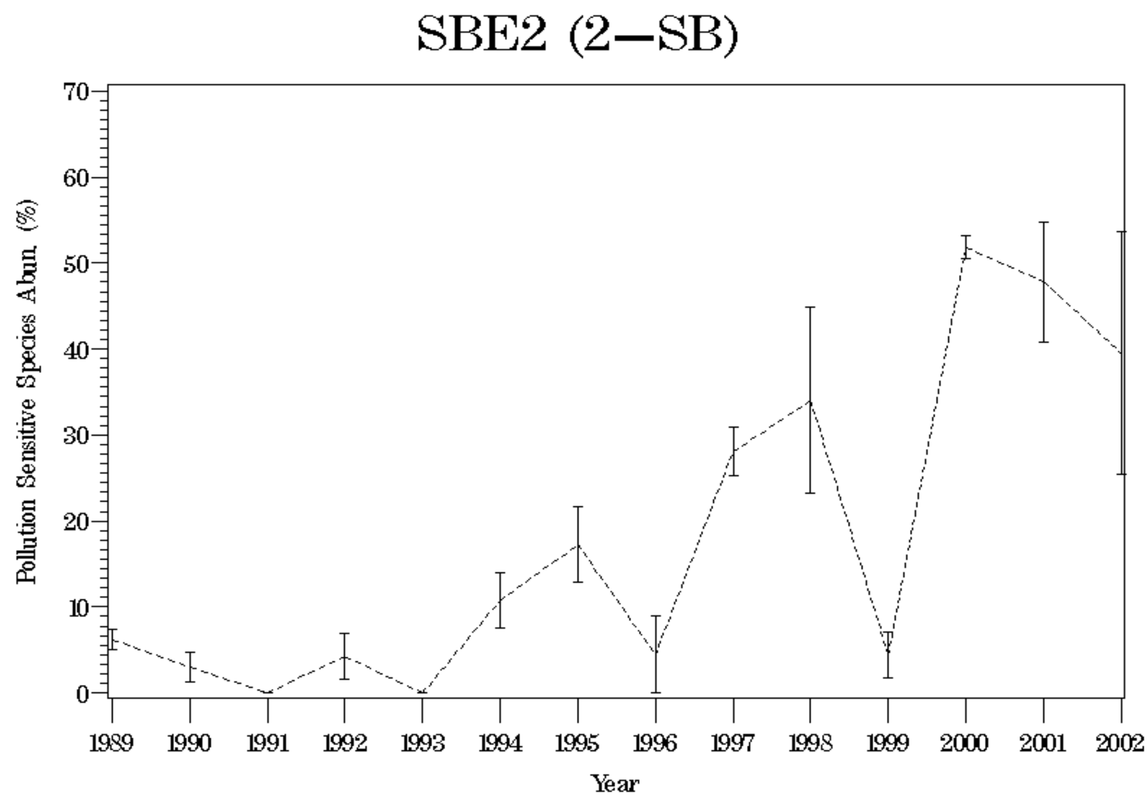


Figure C9. Pollution sensitive species abundance at SBE2 (1989-2002).

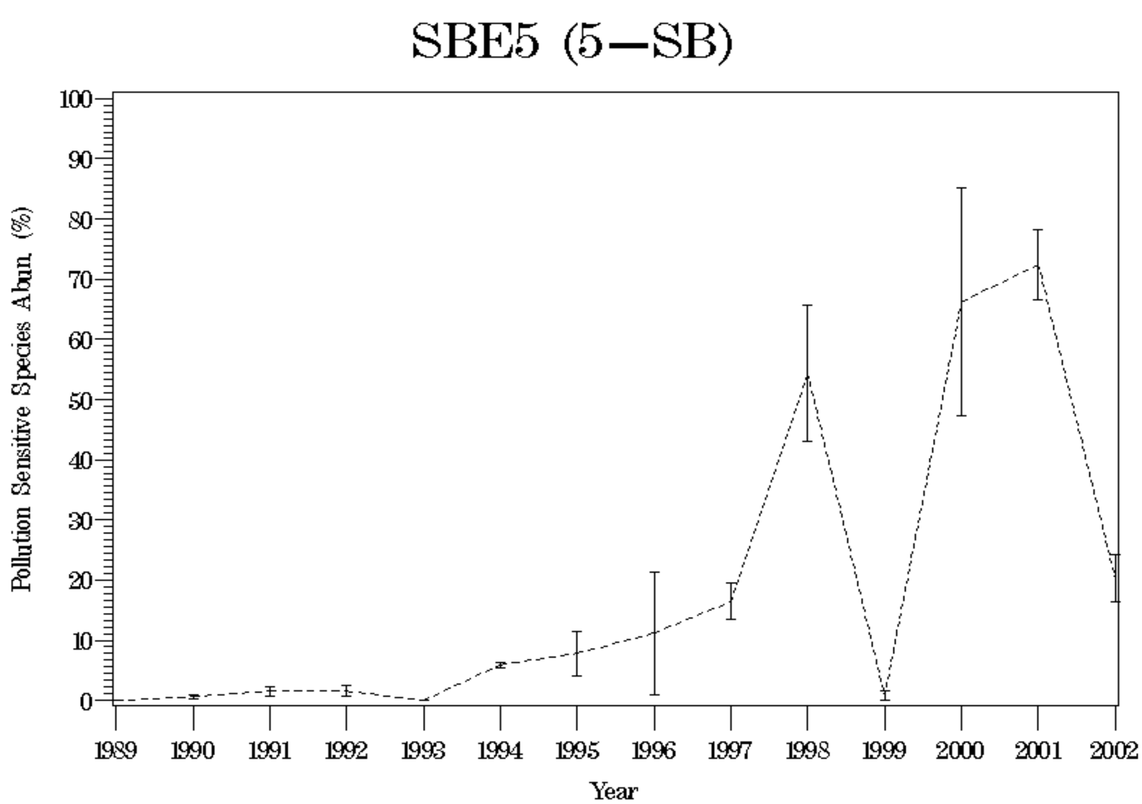


Figure C10. Pollution sensitive species abundance at SBE5 (1989-2002).

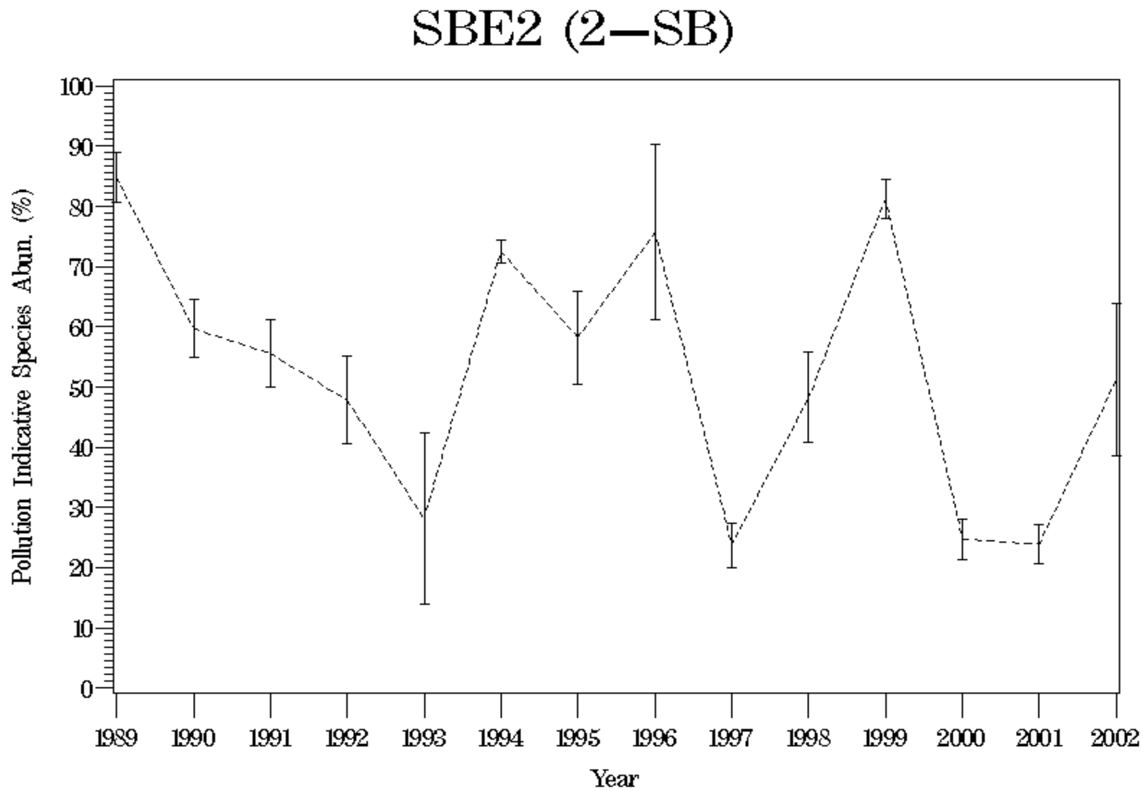


Figure C11. Pollution indicative species abundance at SBE2 (1985 - 2002).

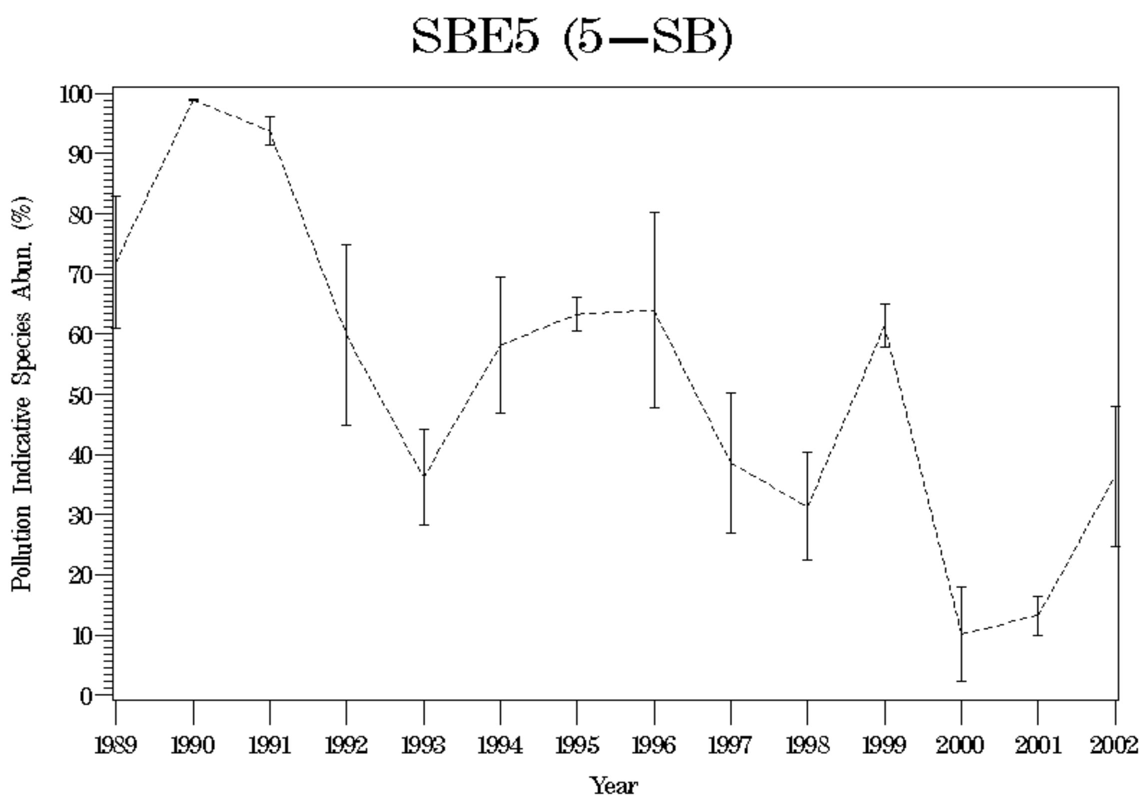


Figure C12. Pollution indicative species abundance at SBE5 (1985 - 2002).

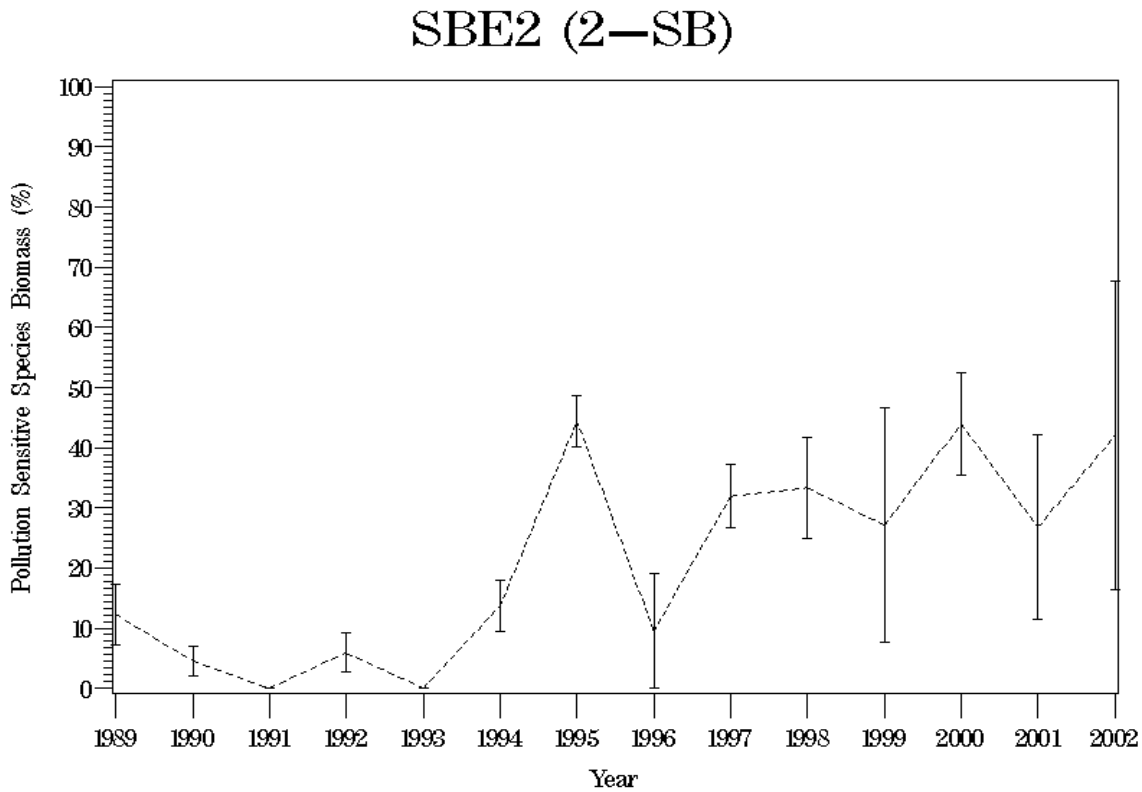


Figure C13. Pollution sensitive species biomass at SBE2 (1985 - 2002).

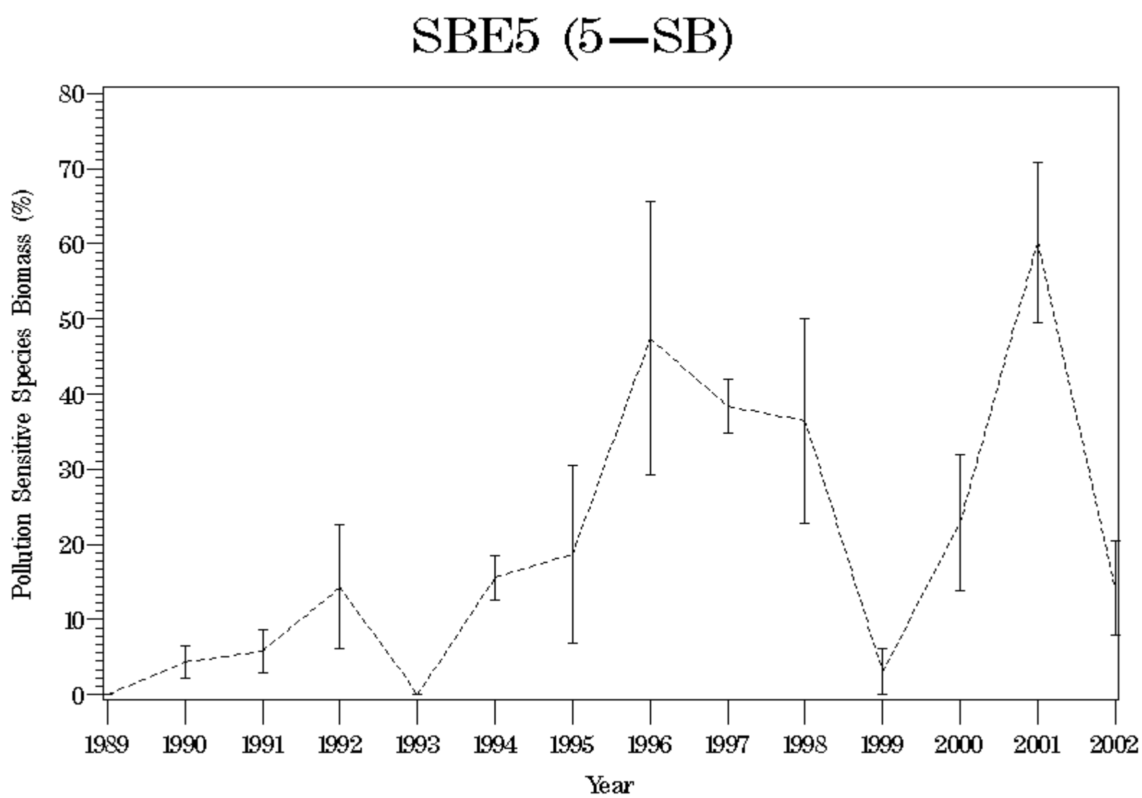


Figure C14. Pollution sensitive species biomass at SBE5 (1985 - 2002).

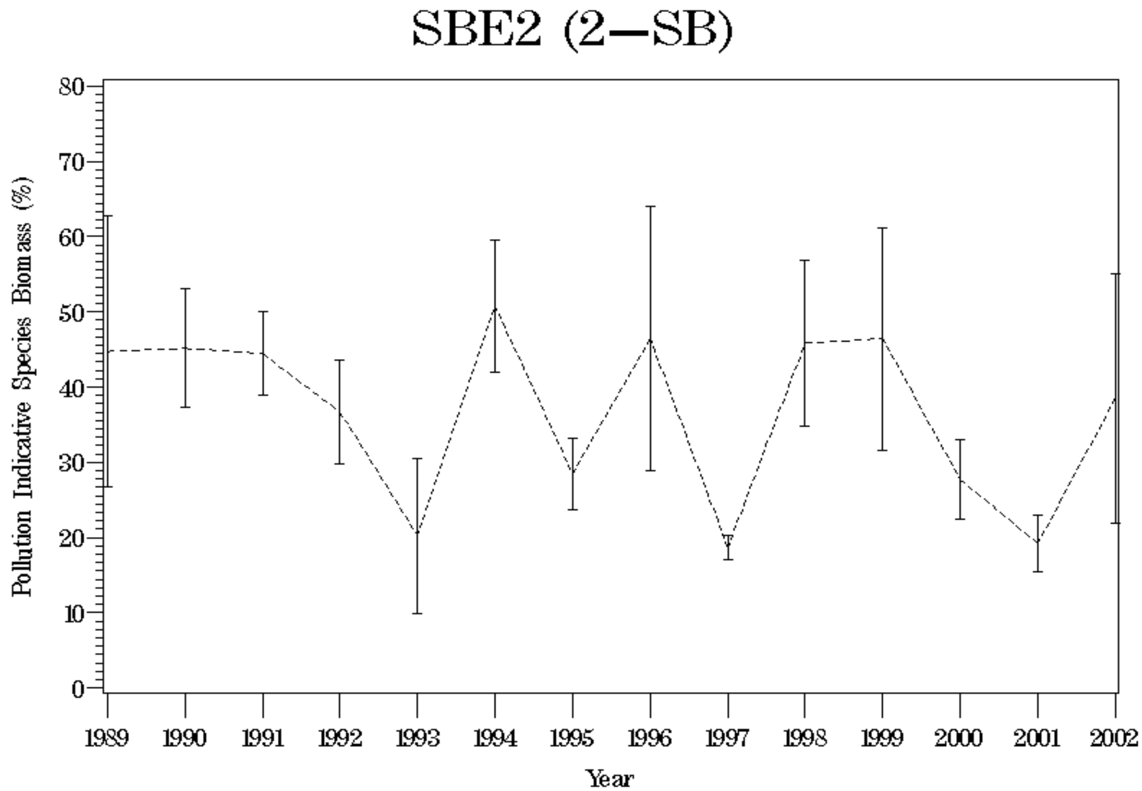


Figure C15. Pollution indicative species biomass at SBE2 (1985 - 2002).

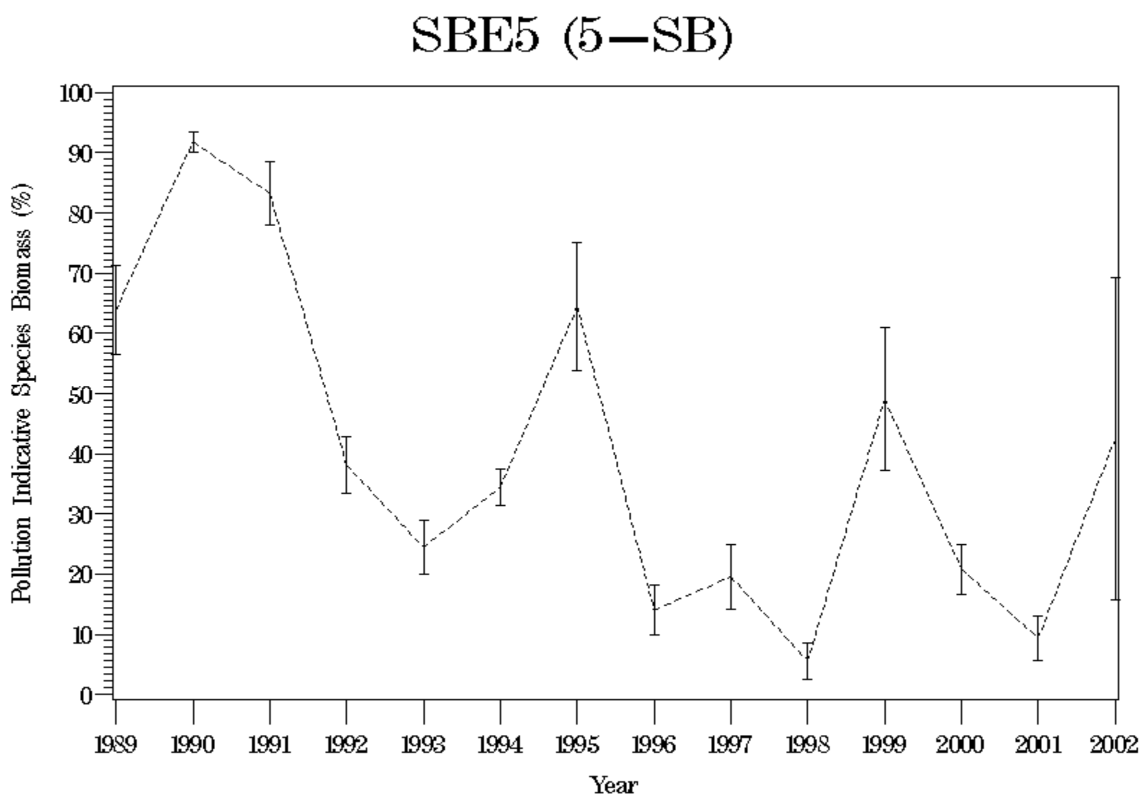


Figure C16. Pollution indicative species biomass at SBE5 (1985 - 2002).

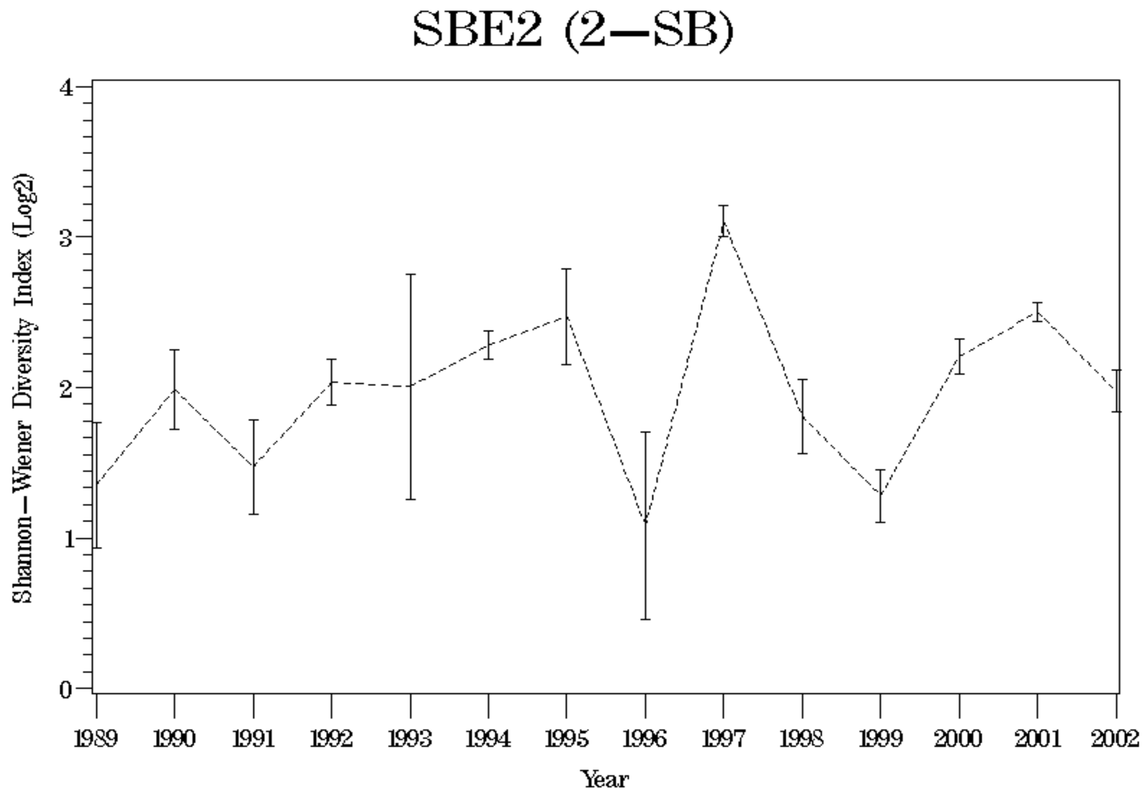


Figure C17. Shannon-Weiner diversity index at SBE2 (1985 - 2002).

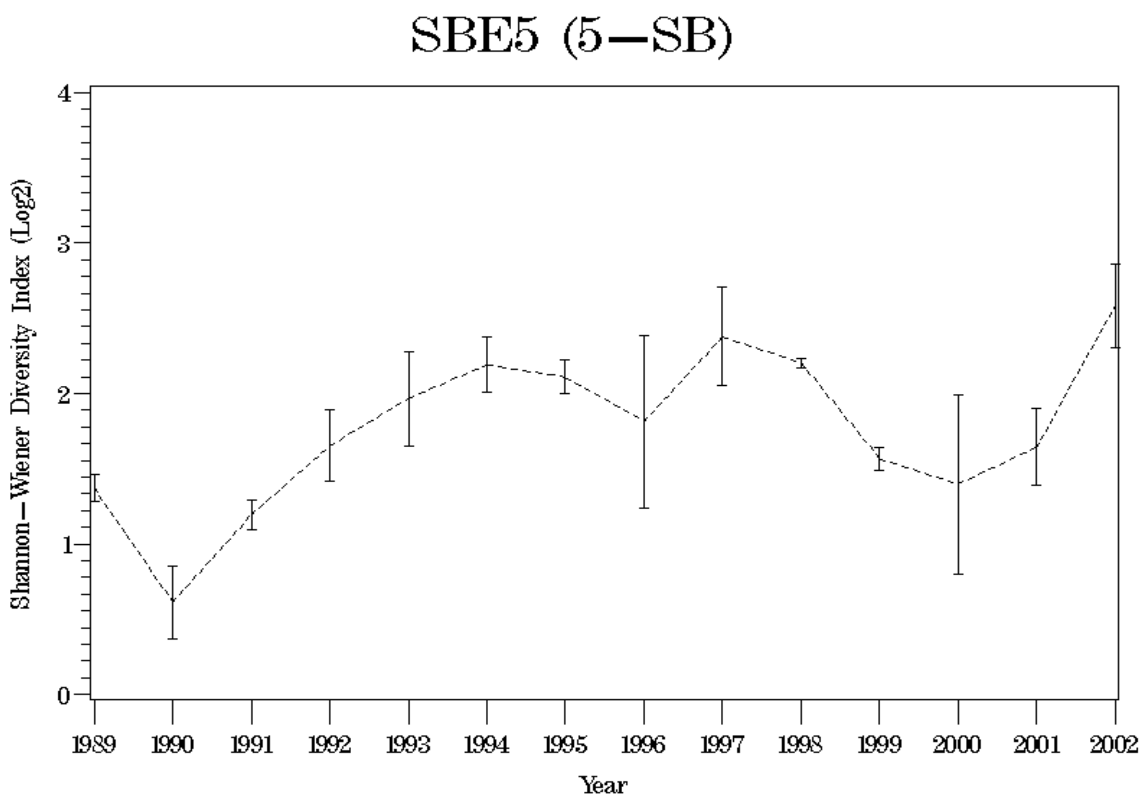


Figure C18. Shannon-Weiner diversity index at SBE5 (1985 - 2002).

Appendix D: Plots of fixed -point station B-IBI and metric values from 1999-2003 for the 14 stations of the Elizabeth River Benthic Monitoring Program.

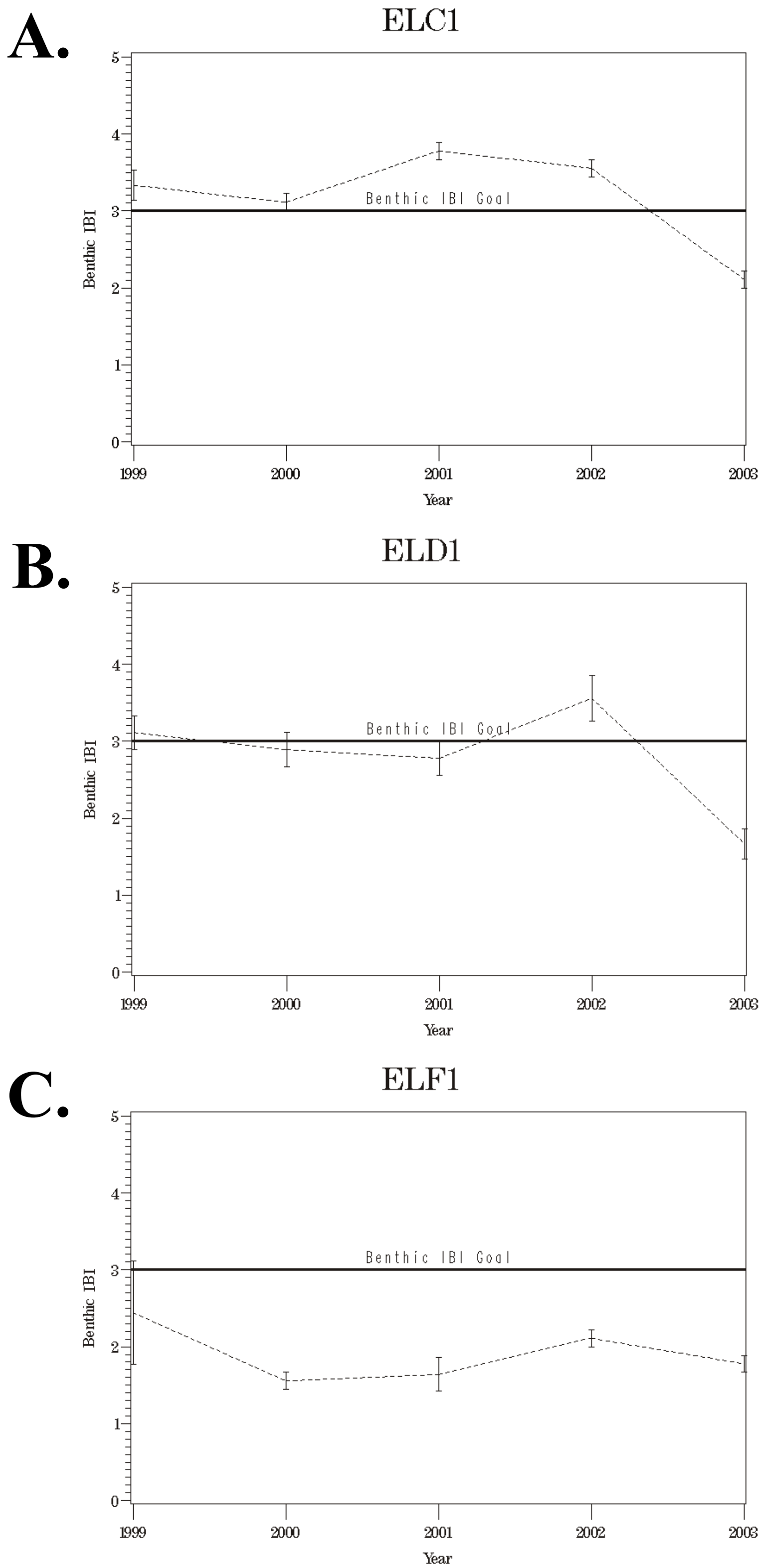


Figure D1. Plots of the Benthic Index of Biotic Integrity for the Mainstem Stations (1999-2003). A. Station ELC1. B. Station ELD1. C. Station ELF1.

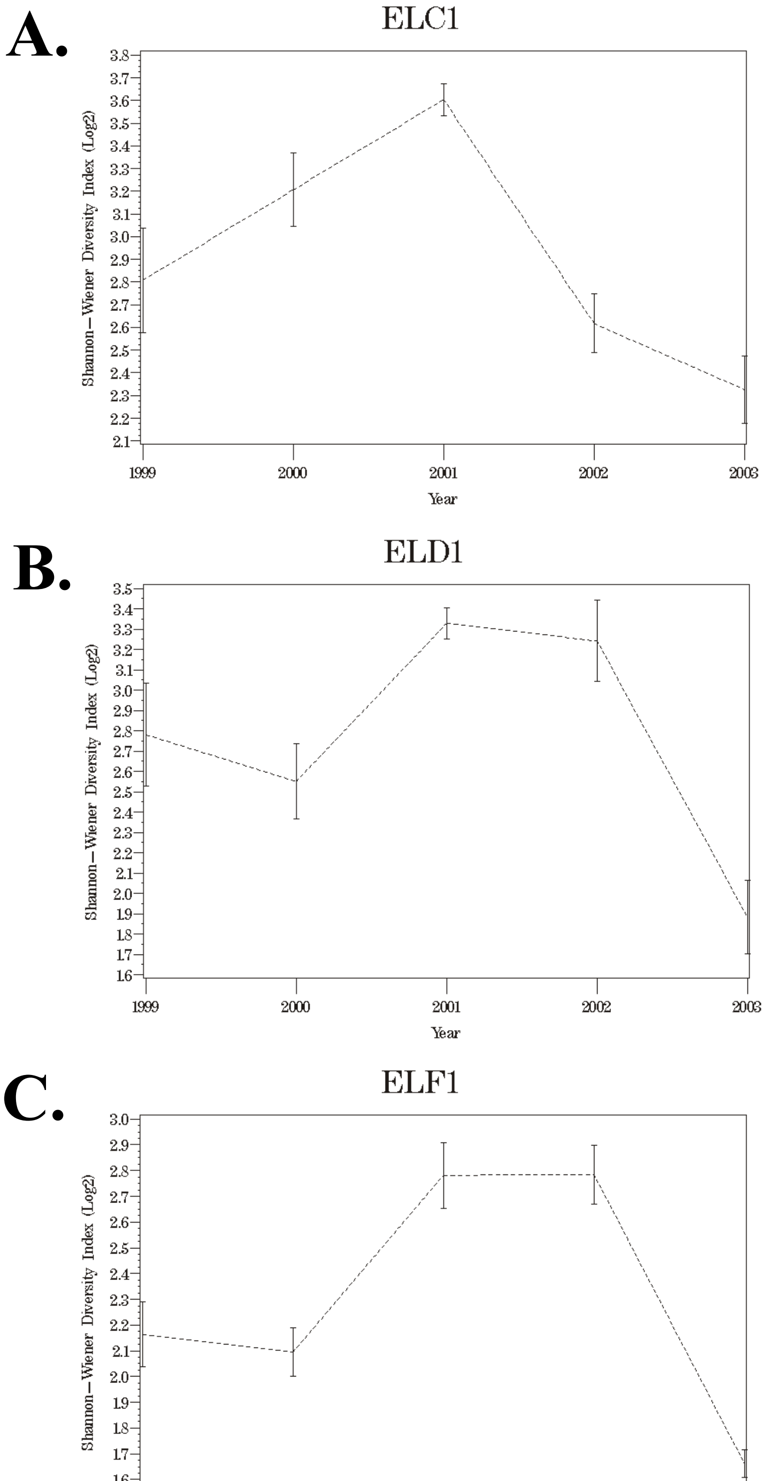


Figure D2. Plots of the Shannon Species Diversity Index for the Mainstem Stations (1999-2003). A. Station ELC1. B. Station ELD1. C. Station ELF1.

A.

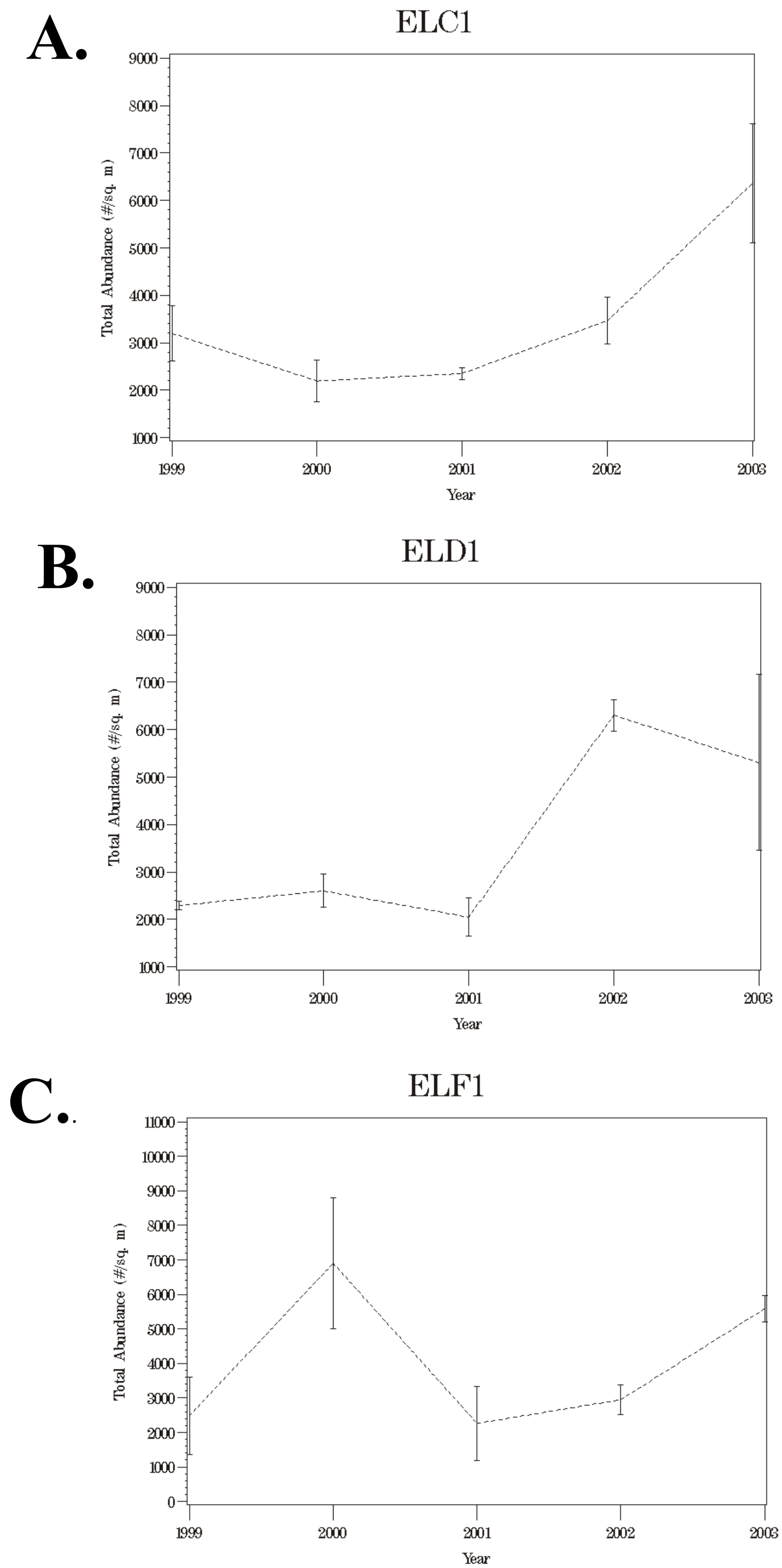


Figure D3. Plots of community abundance for the Mainstem Stations (1999-2003). A. Station ELC1. B. Station ELD1. C. Station ELF1.

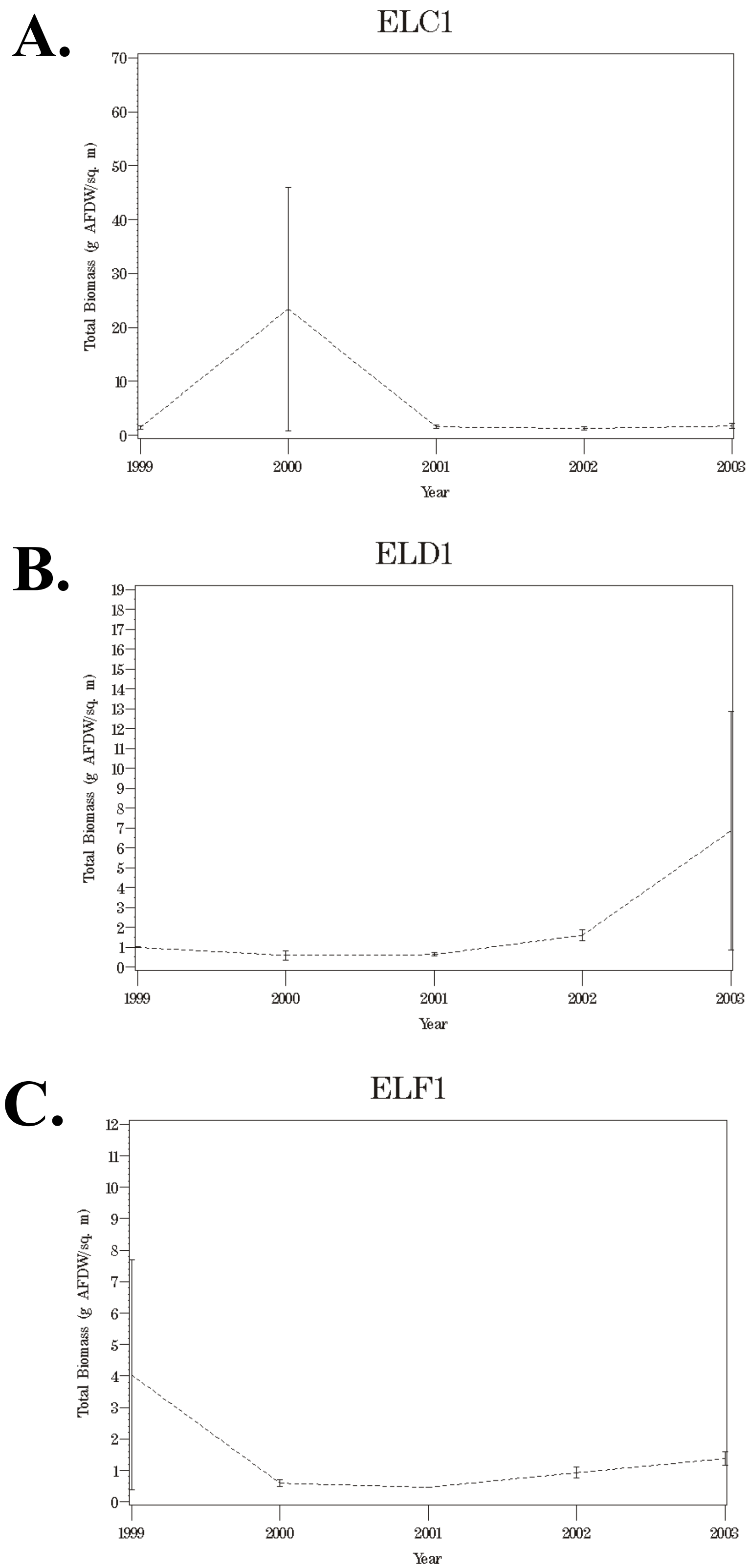


Figure D4. Plots of community biomass for the Mainstem Stations (1999-2003). A. Station ELC1. B. Station ELD1. C. Station ELF1.

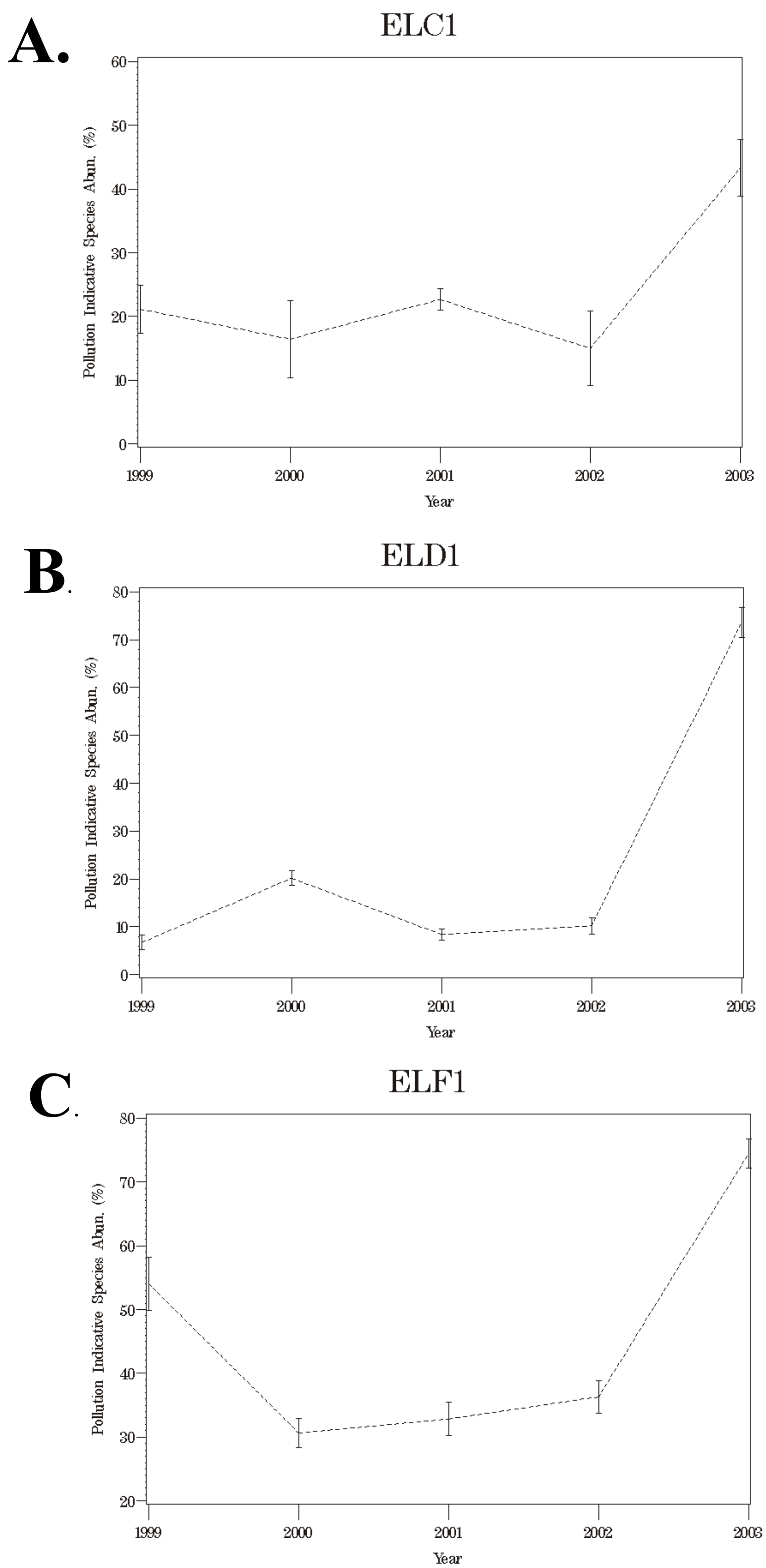


Figure D5. Plots of relative Pollution Indicative Species Abundance for the Mainstem Stations (1999-2003). A. Station ELC1. B. Station ELD1. C. Station ELF1.

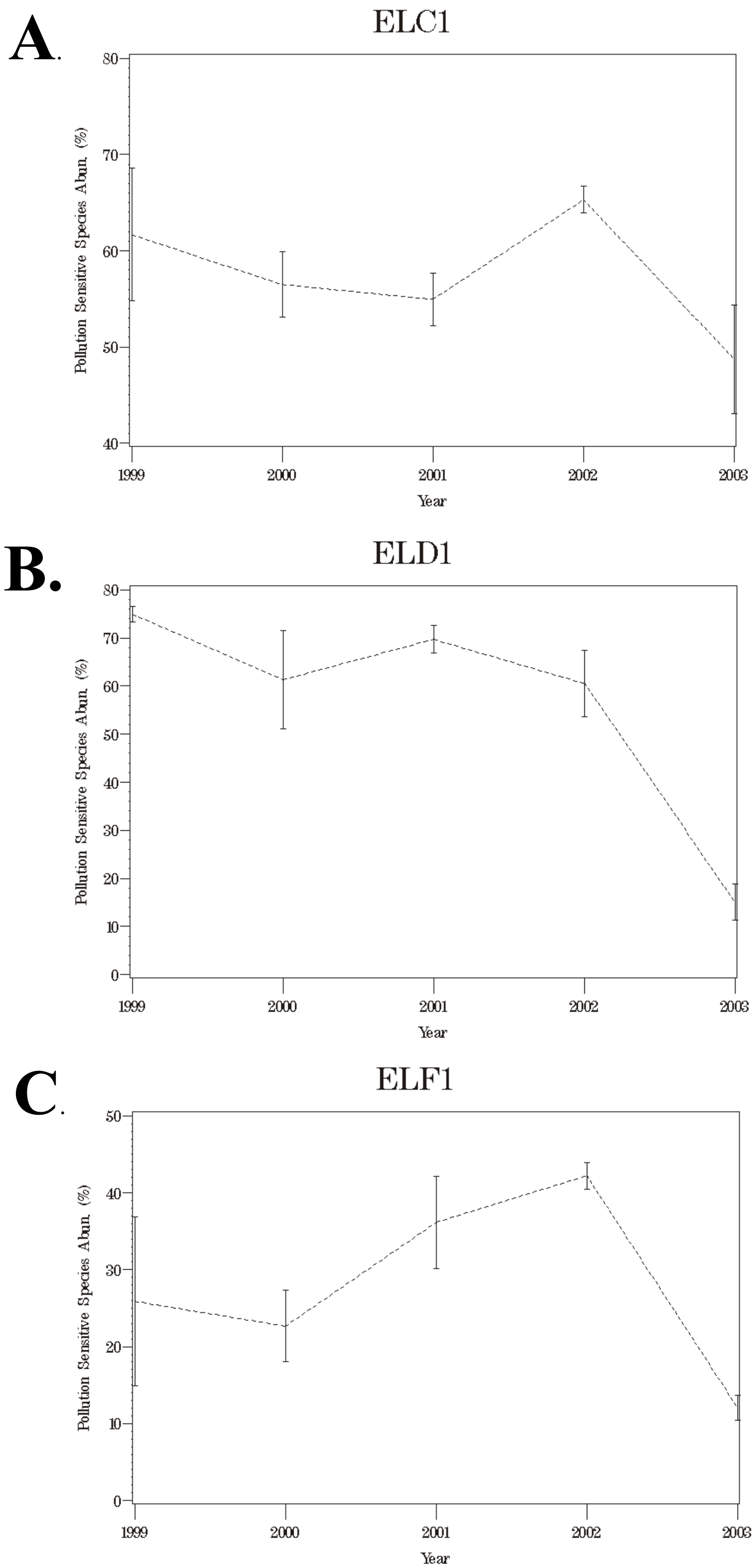


Figure D6. Plots of Pollution Sensitive Species Abundance for the Mainstem Stations (1999-2003). A. Station ELC1. B. Station ELD1. C. Station ELF1.

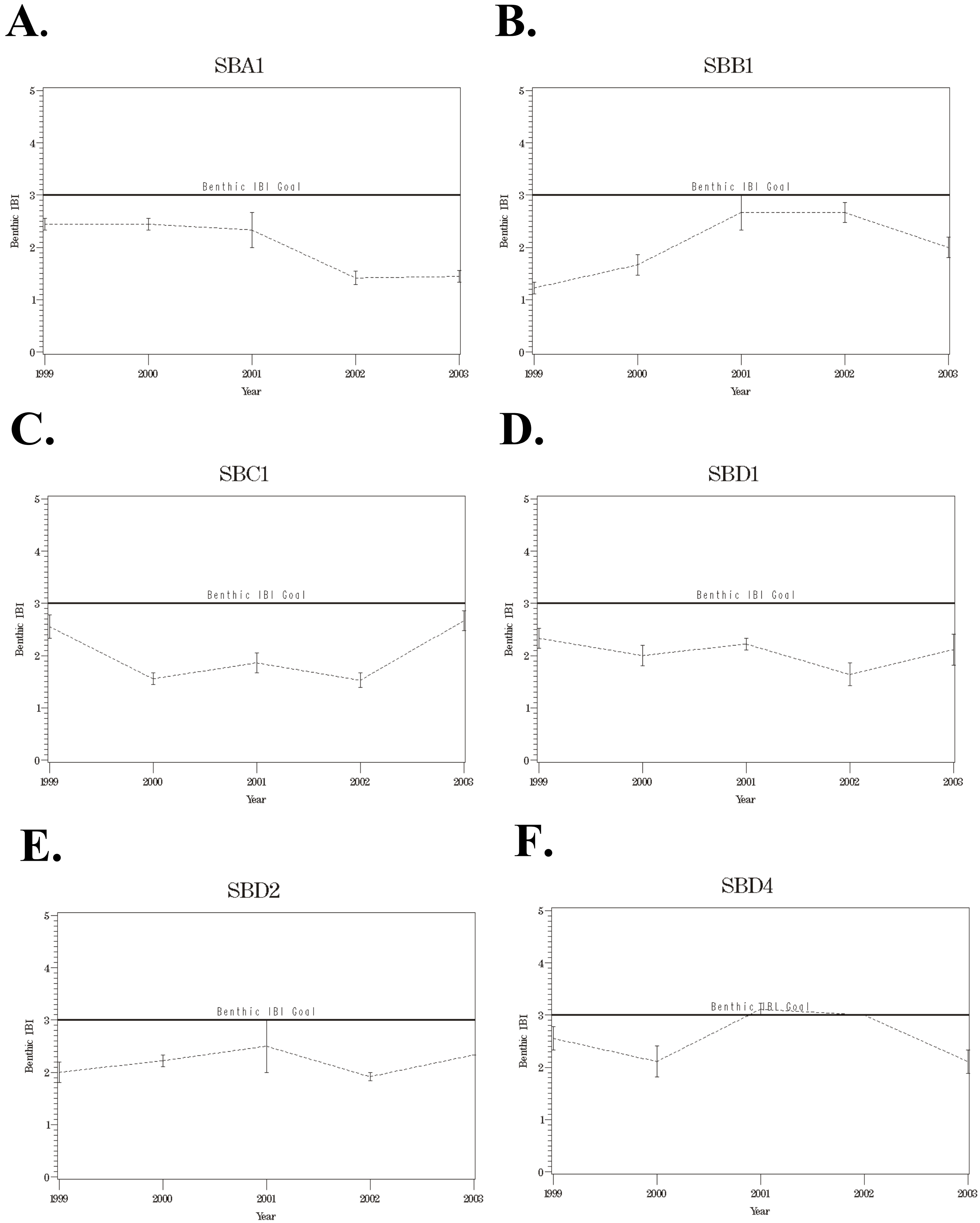


Figure D7. Plots of the Benthic Index of Biotic Integrity for the Southern Branch Stations (1999-2003). A. Station SBA1, B. Station SBB1, C. Station SBC1, D. Stations SBD1, E. Station SBD2, F. Station BD4.

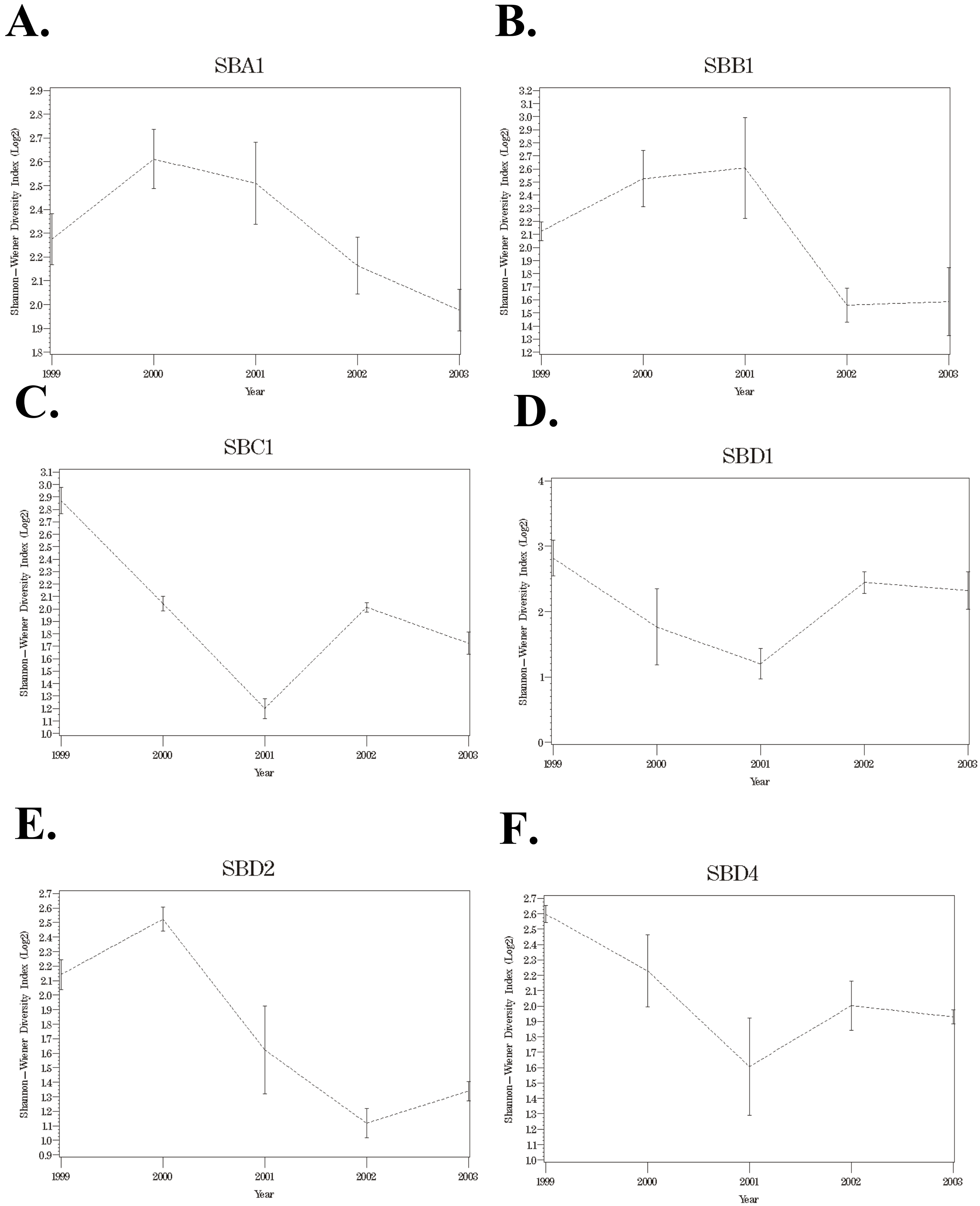


Figure D8. Plots of the Shannon Species Diversity Index for the Southern Branch Stations (1999-2003). A. Station SBA1, B. Station SBB1, C. Station SBC1, D. Stations SBD1, E. Station SBD2, F. Station BD4.

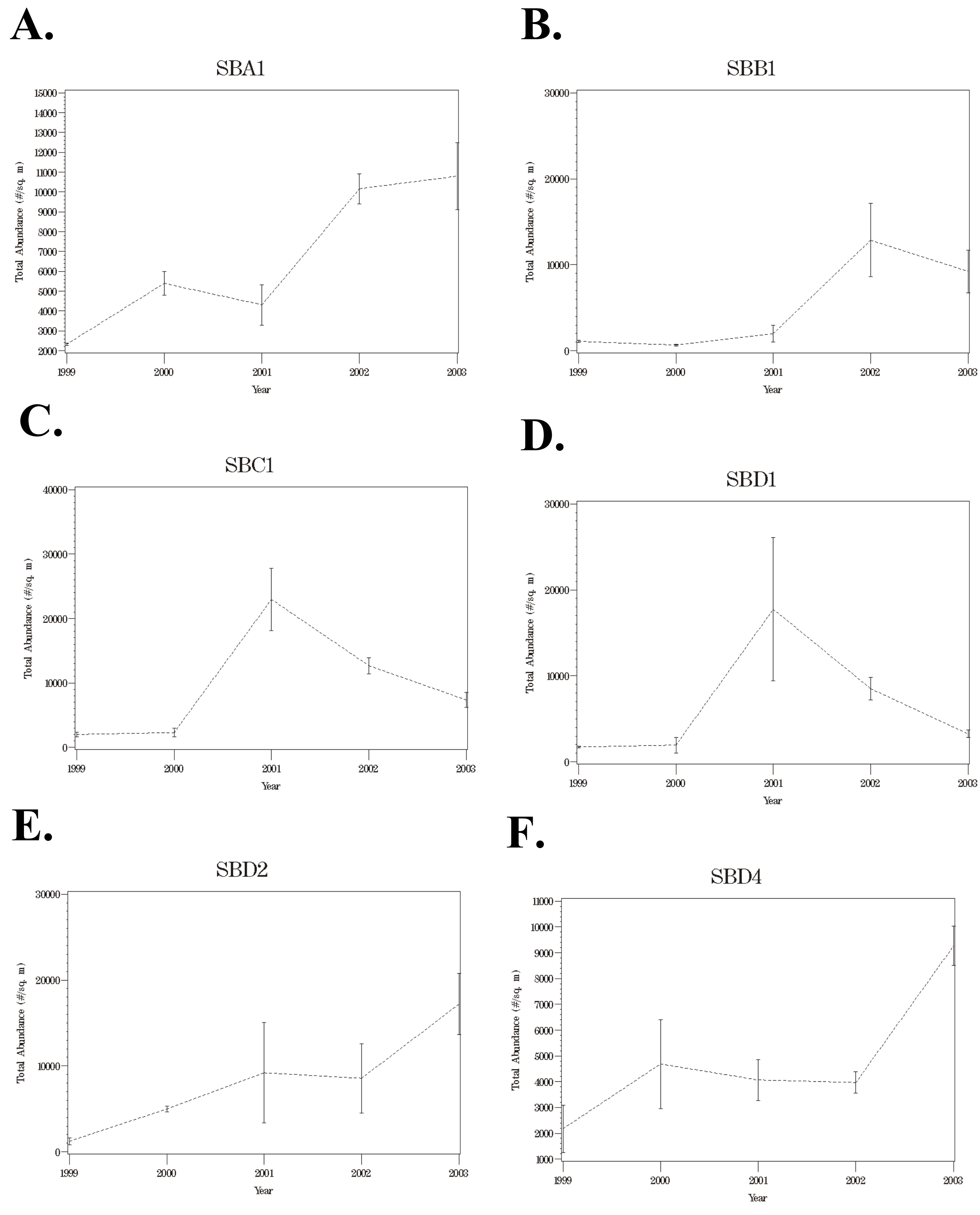


Figure D9. Plots of the Community Abundance for the Southern Branch Stations (1999-2003). A. Station SBA1, B. Station SBB1, C. Station SBC1, D. Stations SBD1, E. Station SBD2, F. Station BD4.

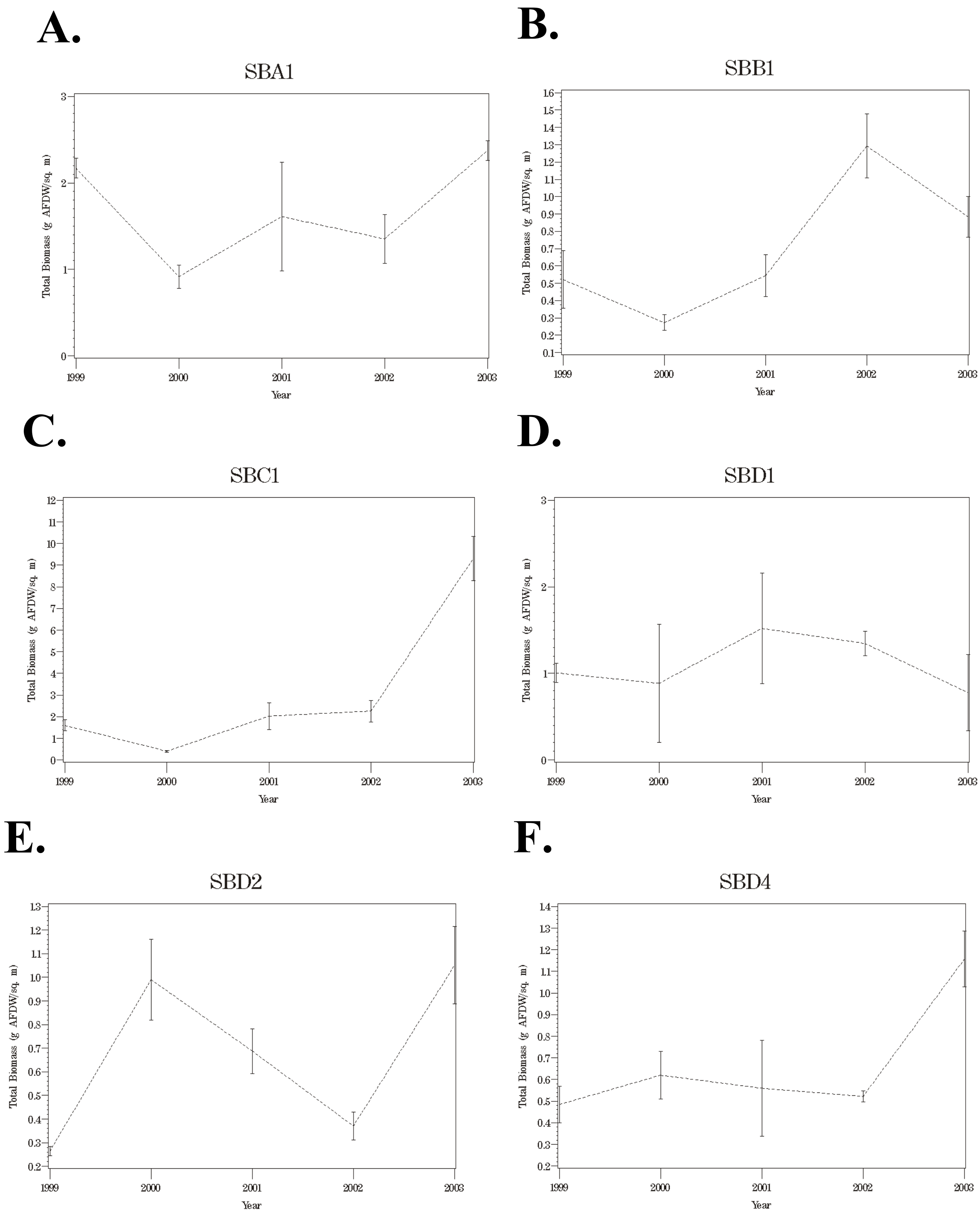


Figure D10. Plots of the Community Biomass for the Southern Branch Stations (1999-2003). A. Station SBA1, B. Station SBB1, C. Station SBC1, D. Station SBD1, E. Station SBD2, F. Station BD4.

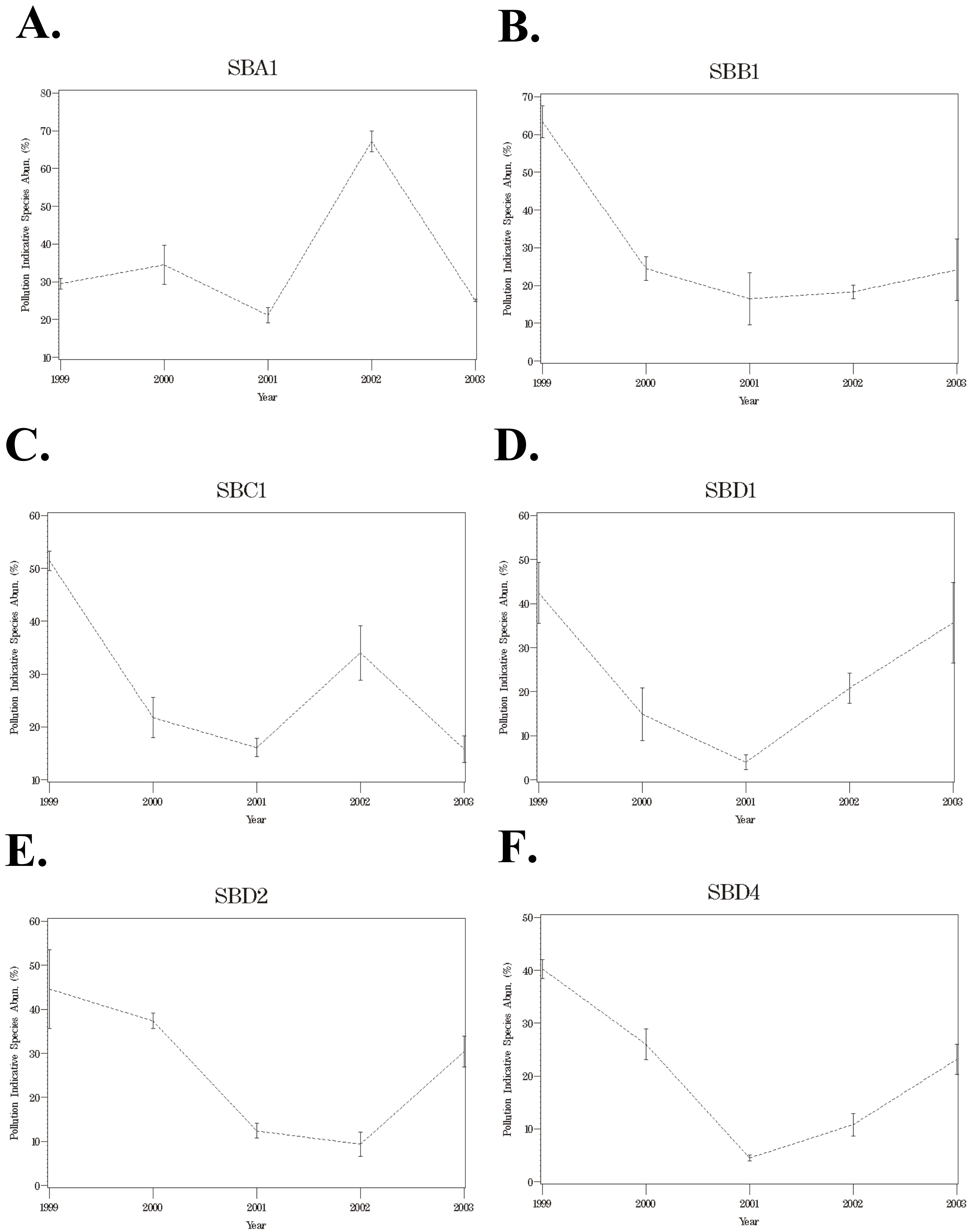


Figure D11. Plots of the relative Pollution Indicative Species Abundance for the Southern Branch Stations (1999-2003). A. Station SBA1, B. Station SBB1, C. Station SBC1, D. Station SBD1, E. Station SBD2, F. Station BD4.

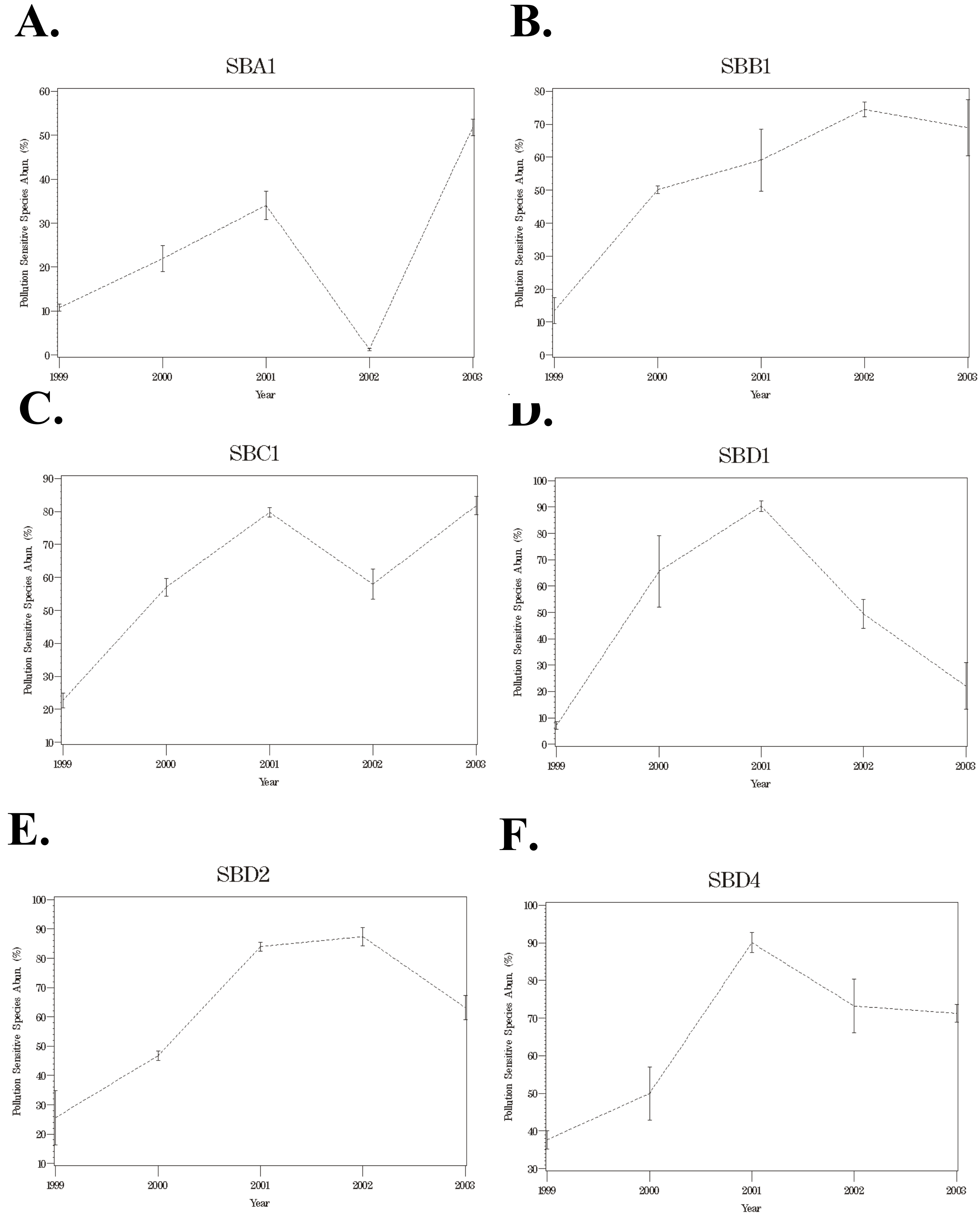


Figure D12. Plots of the relative Pollution Sensitive Species Abundance for the Southern Branch Stations (1999-2003). A. Station SBA1, B. Station SBB1, C. Station SBC1, D. Station SBD2, E. Station BD4.

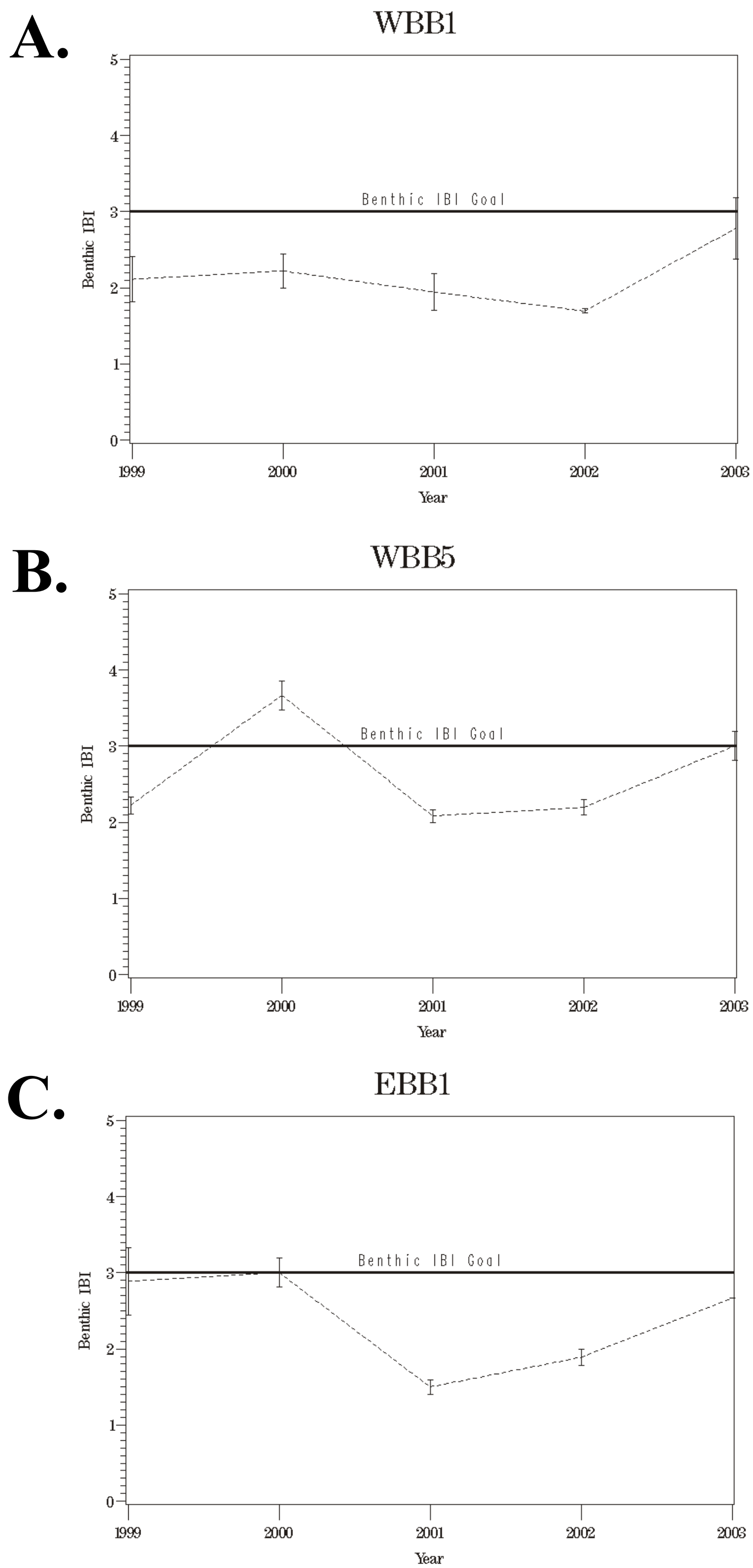


Figure D13. Plots of the Benthic Index of Biotic Integrity for the Western and Eastern Branch Stations (1999-2003). A. Station WBB1. B. Station WBB5. C. Station EBB1.

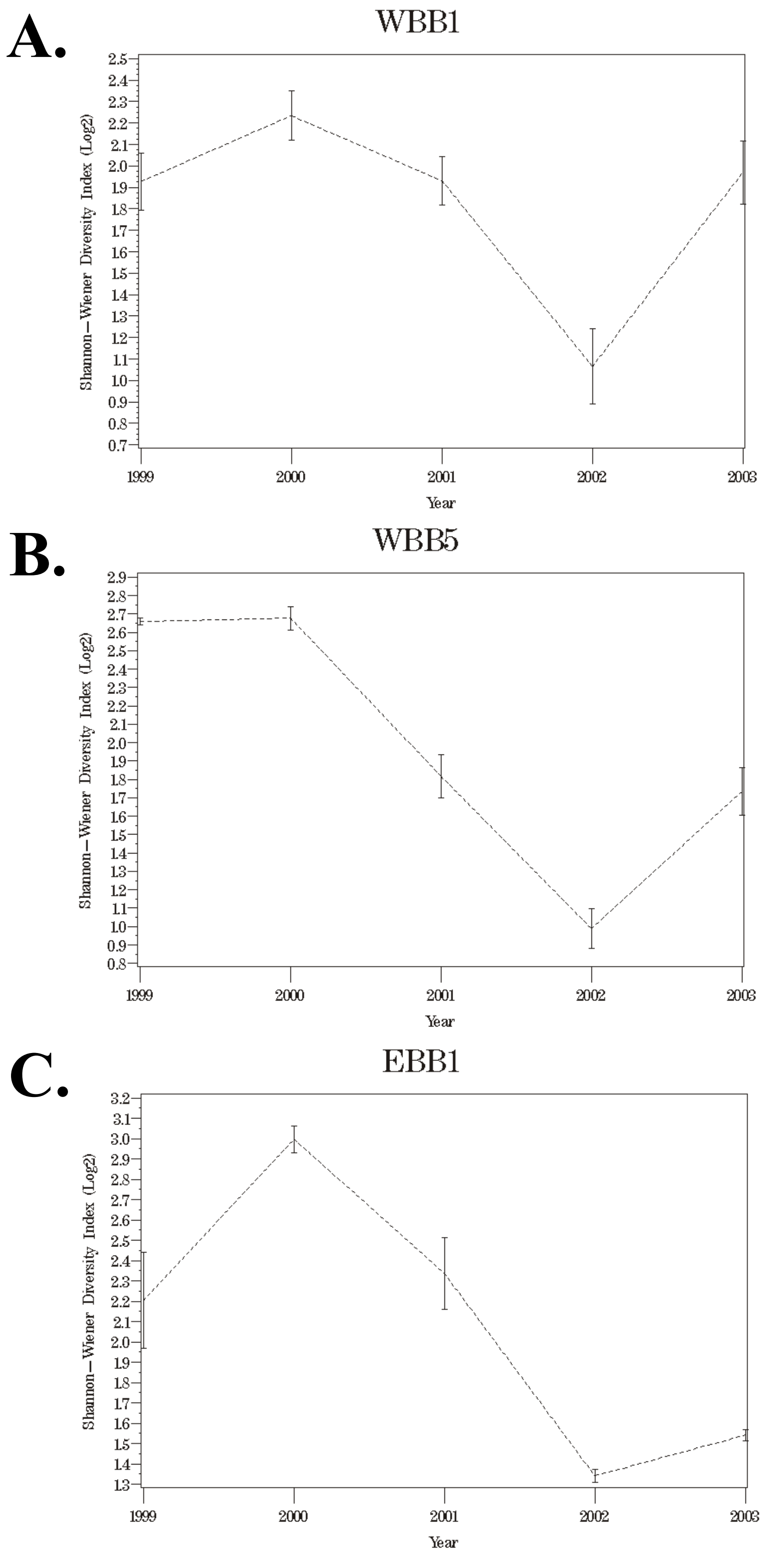


Figure D14. Plots of the Shannon Index for the Western and Eastern Branch Stations (1999-2003). A. Station WBB1. B. Station WBB5. C. Station EBB1.

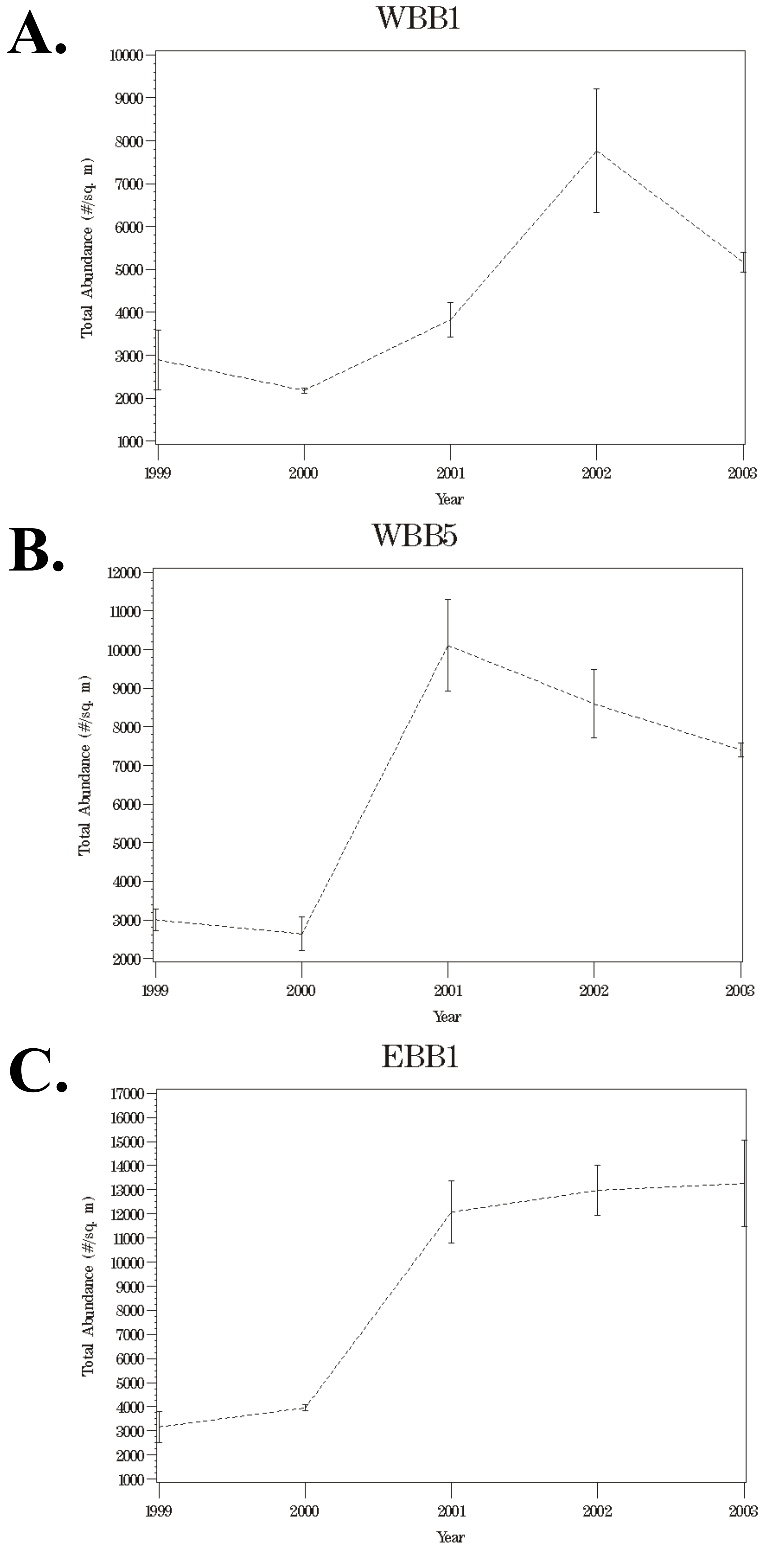


Figure D15. Plots of Community Abundance for the Western and Eastern Branch Stations (1999-2003). A. Station WBB1. B. Station WBB5. C. Station EBB1.

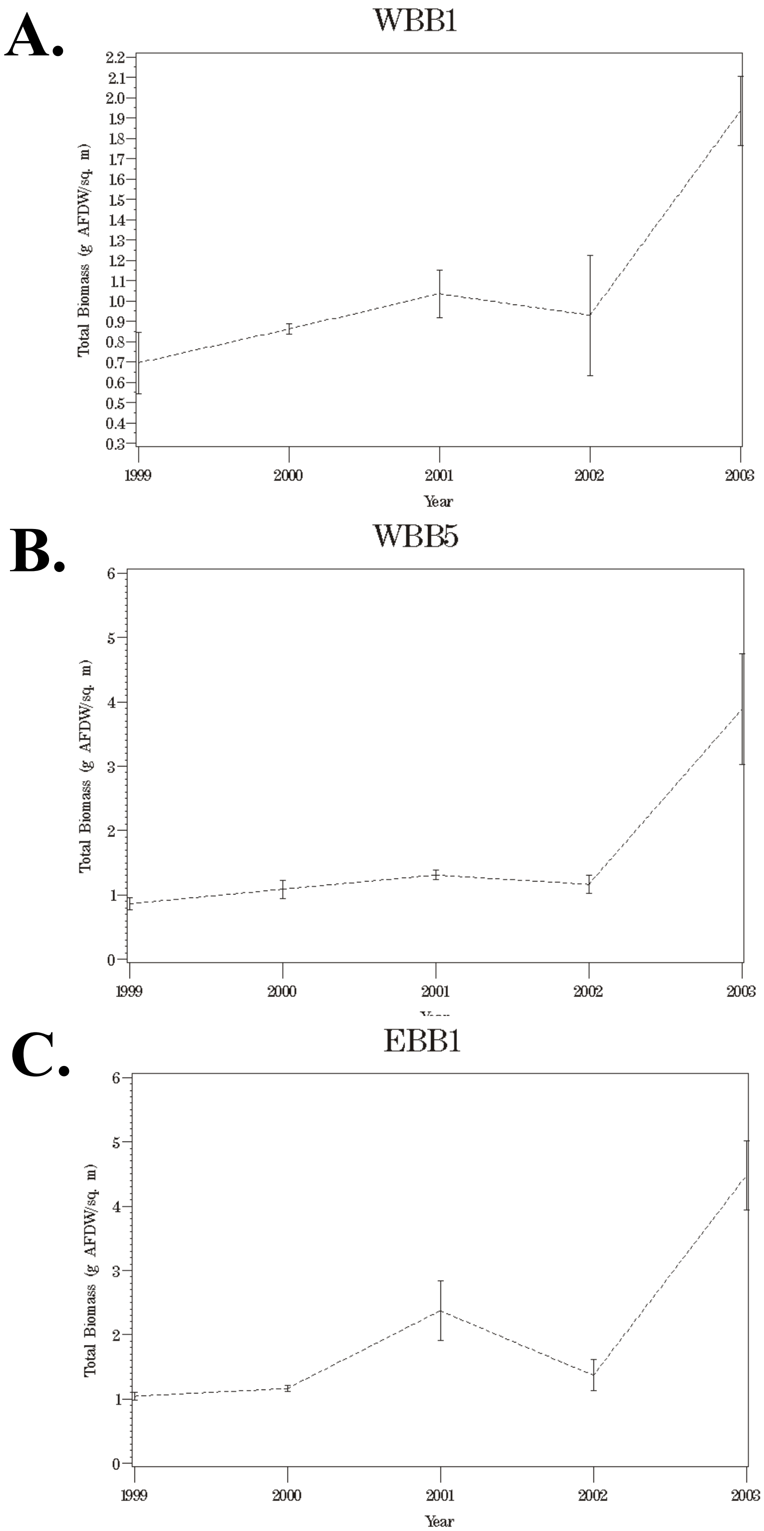


Figure D16. Plots of Community Biomass for the Western and Eastern Branch Stations (1999-2003). A. Station WBB1. B. Station WBB5. C. Station EBB1.

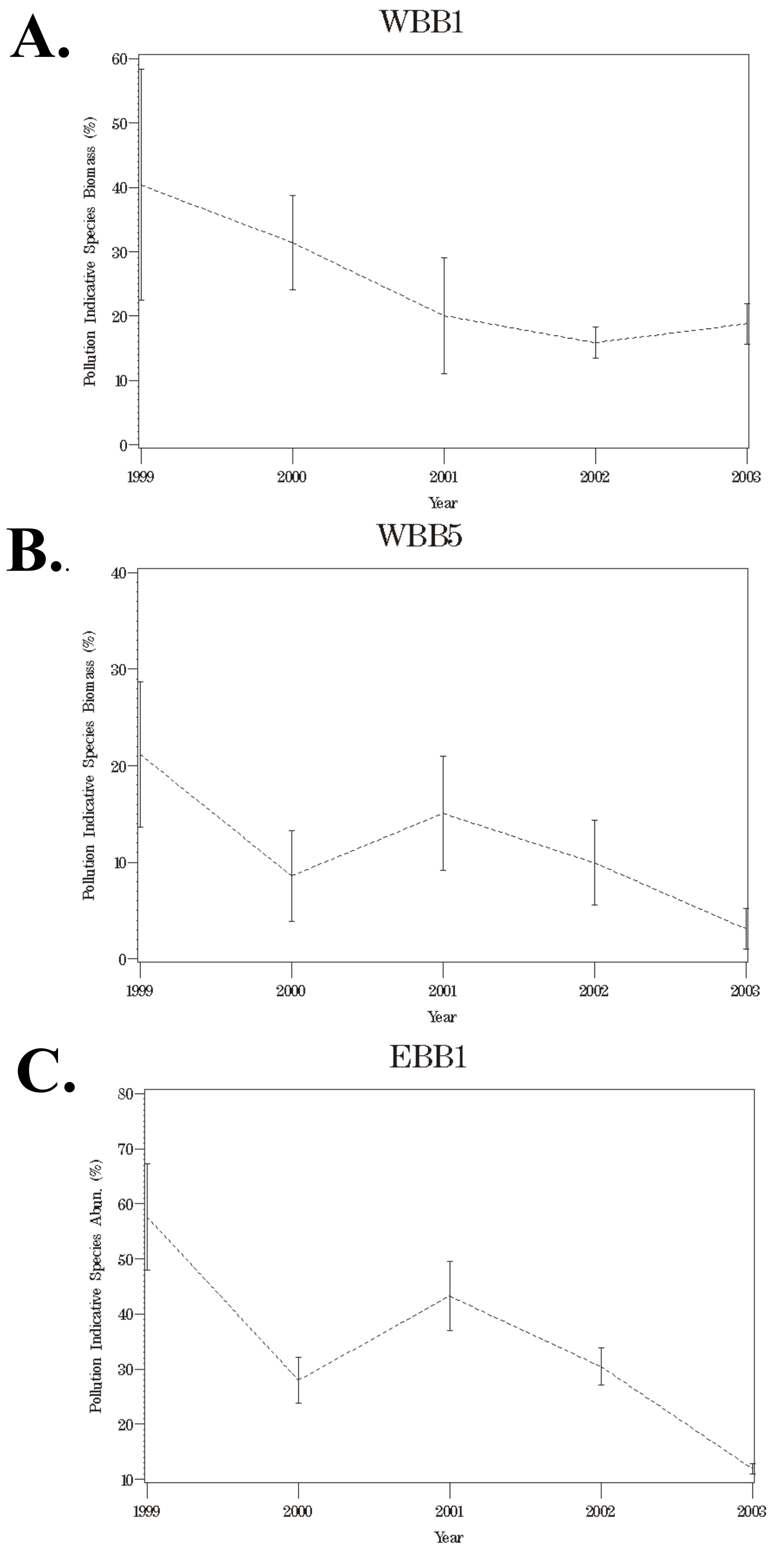


Figure D17. Plots of Pollution Indicative Species Abundances for the Western and Eastern Branch Stations (1999-2003). A. Station WBB1. B. Station WBB5. C. Station EBB1.

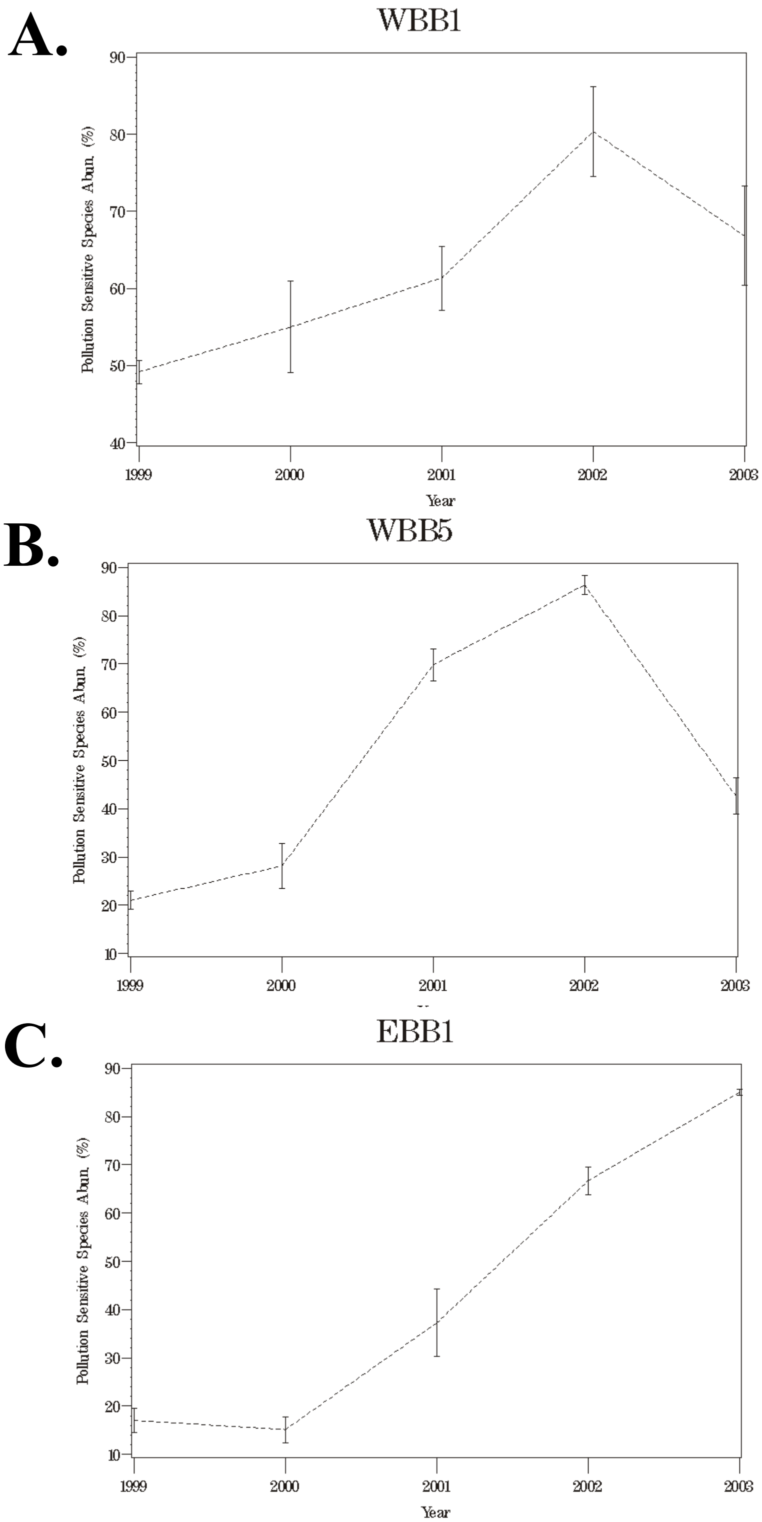
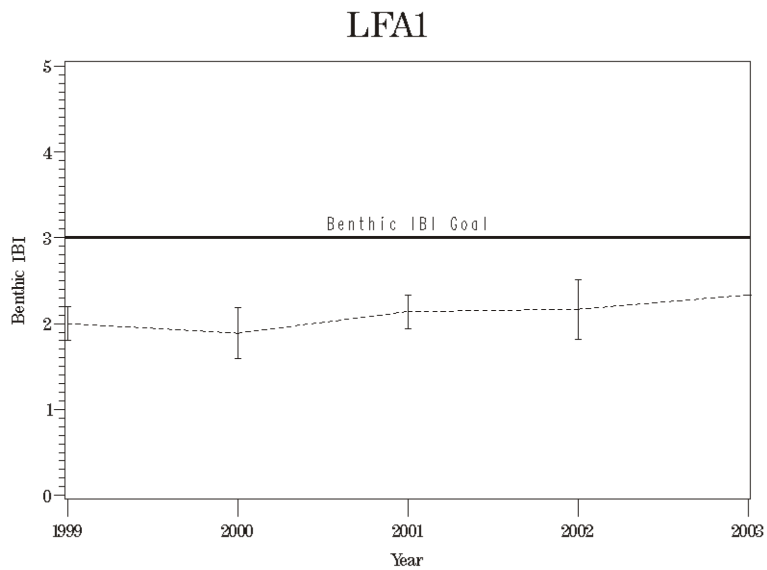


Figure D18. Plots of Pollution Sensitive Species Abundances for the Western and Eastern Branch Stations (1999-2003). A. Station WBB1. B. Station WBB5. C. Station EBB1.

A.



B.

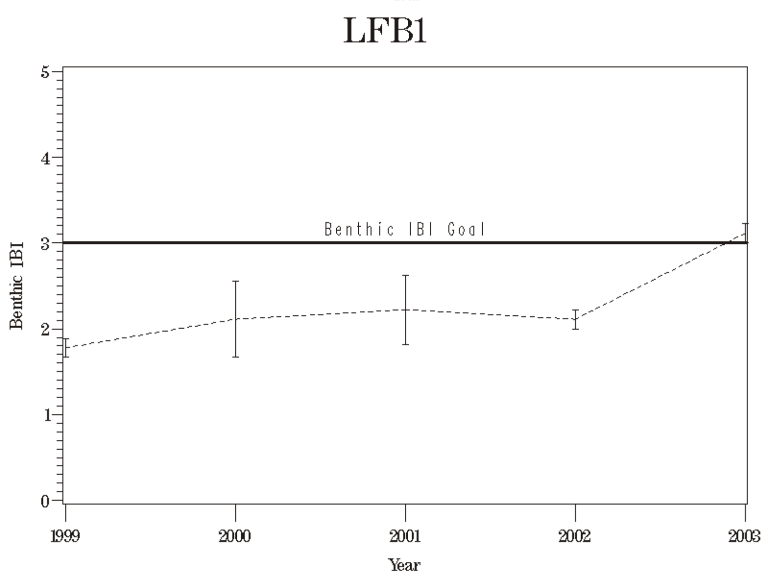


Figure D19. Plots of Benthic Index of Biotic Integrity for the Lafayette River Stations (1999-2003). A. Station LFA1. B. Station LFB1.

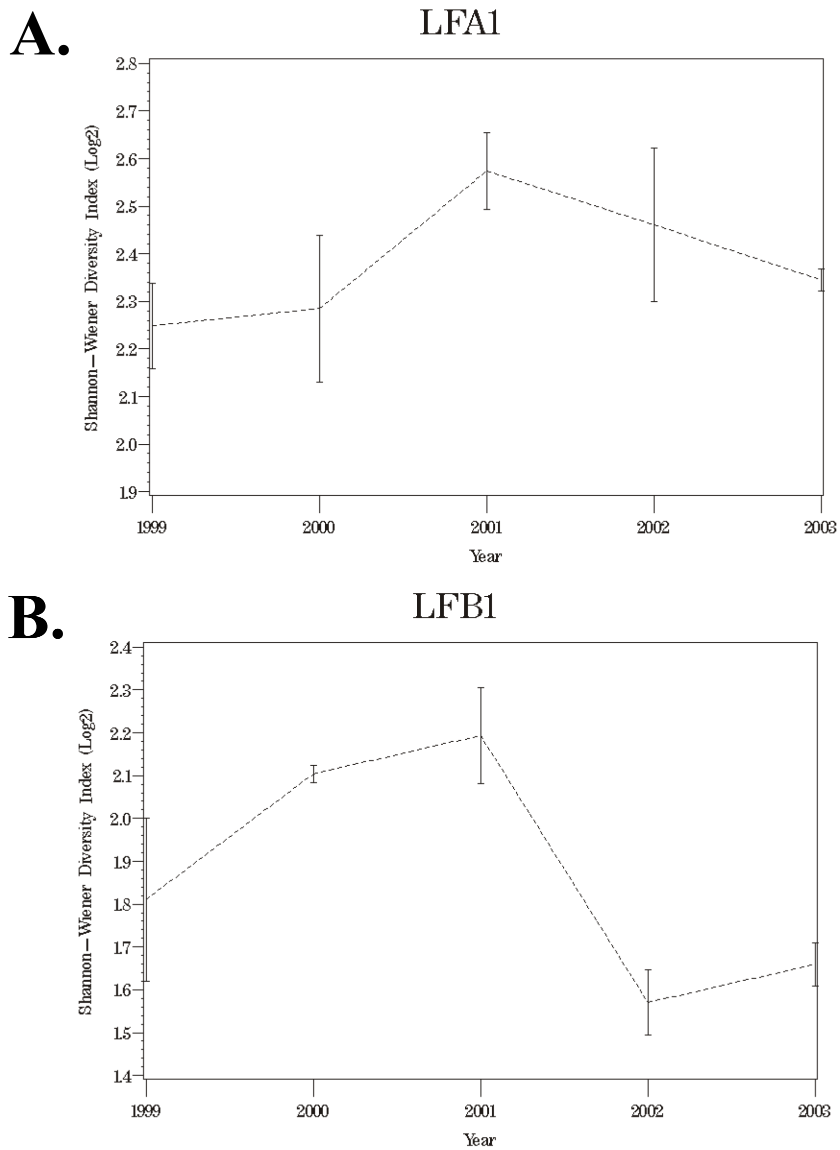


Figure D20. Plots of Shannon Index for the Lafayette River Stations (1999-2003). A. Station LFA1. B. Station LFB1.

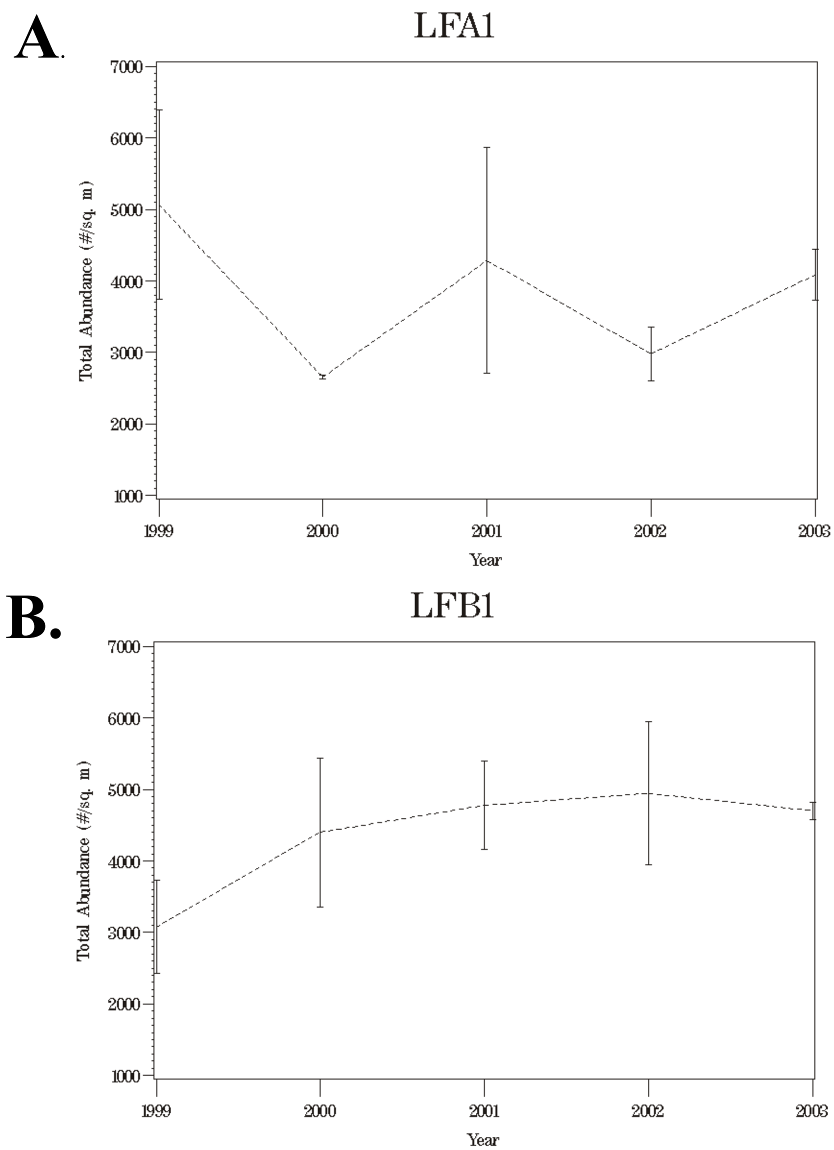
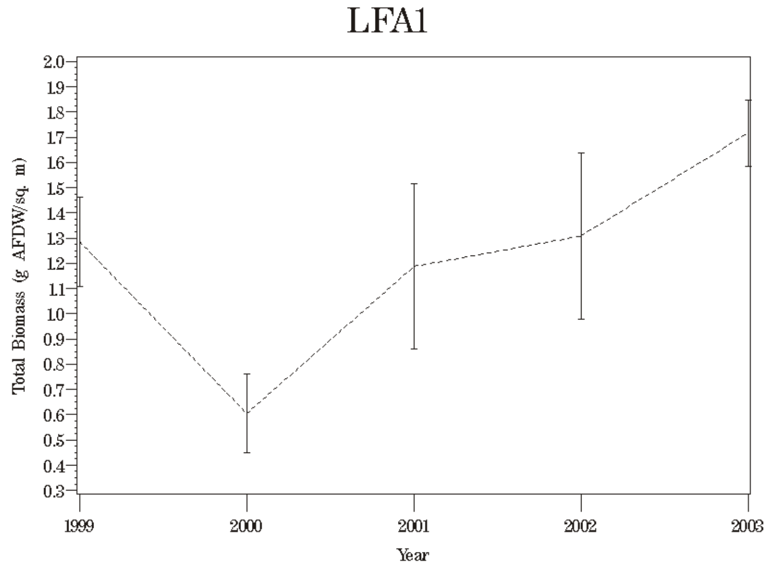


Figure D21. Plots of Community Abundance for the Lafayette River Stations (1999-2003). A. Station LFA1. B. Station LFB1.

A.



B.

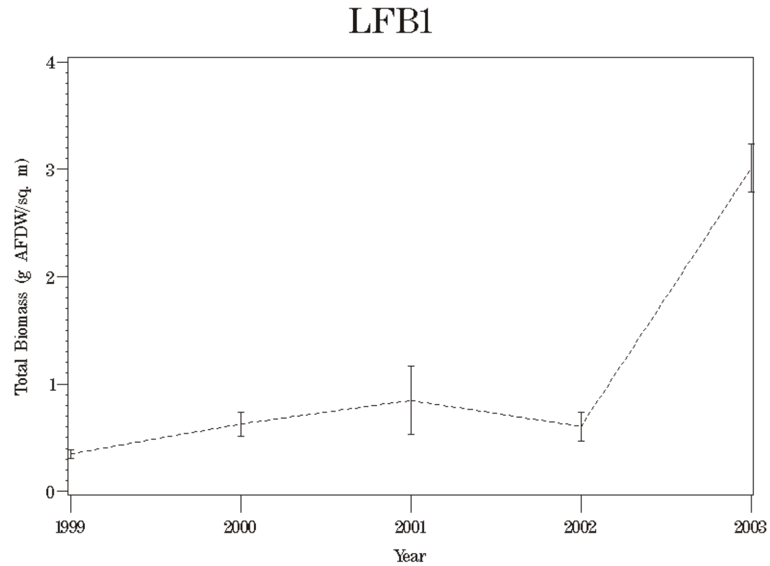
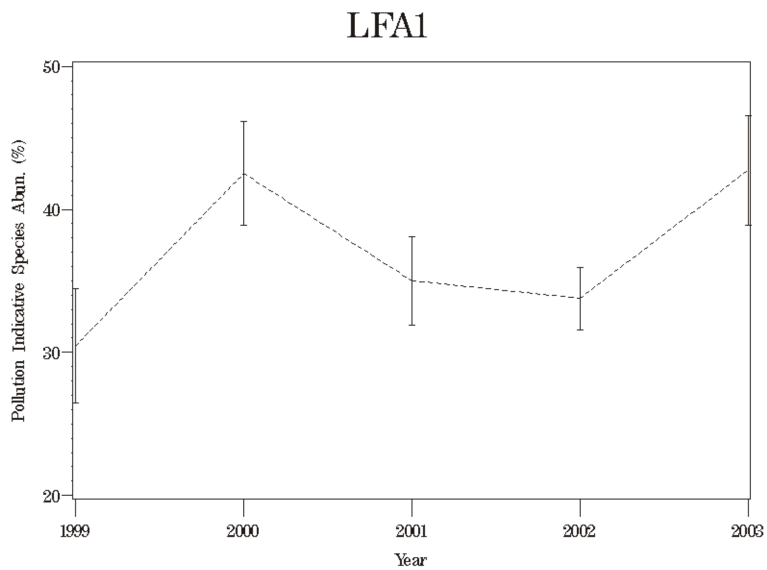


Figure D22. Plots of Community Biomass for the Lafayette River Stations (1999-2003). A. Station LFA1. B. Station LFB1.

A.



B.

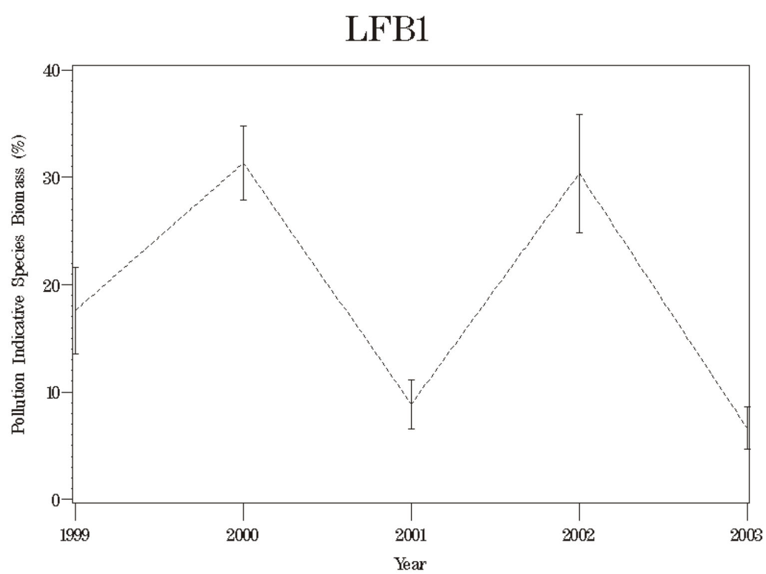
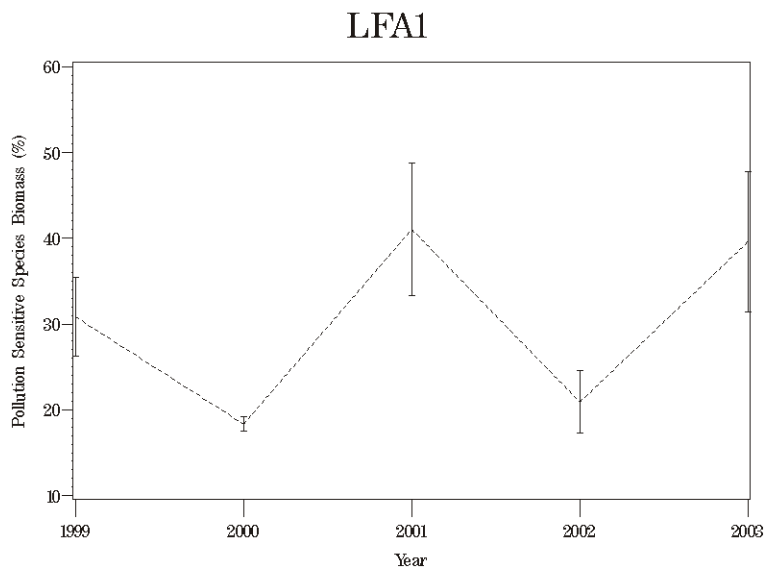


Figure D23. Plots of Pollution Indicative Species Abundance for the Lafayette River Stations (1999-2003). A. Station LFA1. B. Station LFB1.

A.



B.

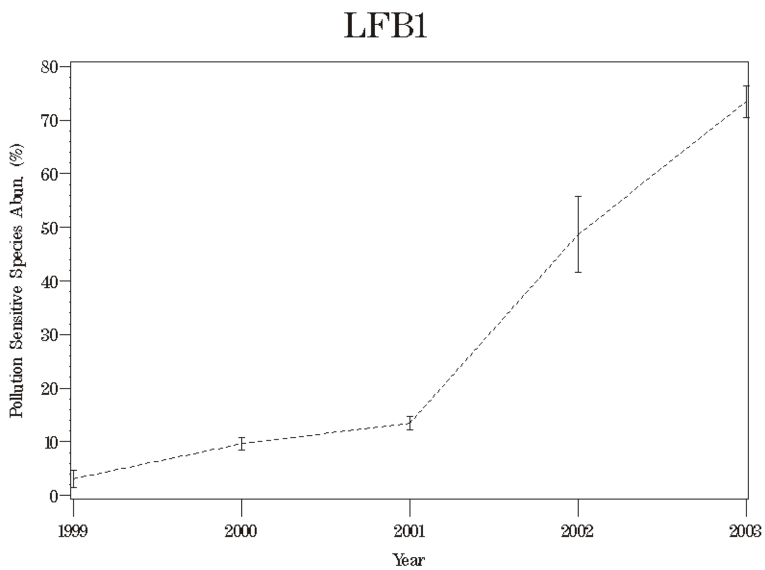


Figure D24. Plots of Pollution Sensitive Species Abundance for the Lafayette River Stations (1999-2003). A. Station LFA1. B. Station LFB1.