Final Report

# Chesapeake Bay Water Quality Monitoring Program

# Long-term Benthic Monitoring and Assessment Component Level 1 Comprehensive Report

## July 1984 – December 2024 (Volume 1)

Prepared for

**Maryland Department of Natural Resources**
**Resource Assessment Service**
**Tidewater Ecosystem Assessments**
**Annapolis, Maryland**

Prepared by

Versar, Inc.
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October 2025

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# CHESAPEAKE BAY WATER QUALITY MONITORING PROGRAM

# LONG-TERM BENTHIC MONITORING AND ASSESSMENT COMPONENT LEVEL I COMPREHENSIVE REPORT

## JULY 1984 - DECEMBER 2024 (VOLUME 1)

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# FOREWORD

This document, Chesapeake Bay Water Quality Monitoring Program: Long-Term Benthic Monitoring and Assessment Component, Level I Comprehensive Report (July 1984-December 2024), was prepared by Versar, Inc., at the request of Mr. Tom Parham of the Maryland Department of Natural Resources under Contract # K00R1600026 between Versar, Inc., and Maryland DNR. The report assesses the status of Chesapeake Bay benthic communities in 2024 and evaluates their responses to changes in water quality.

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# ACKNOWLEDGEMENTS

We are grateful to the State of Maryland’s Environmental Trust Fund which partially funded this work. The benthic studies discussed in this report were conducted from the University of Maryland's (R/V *Rachel Carson*) and Maryland DNR (R/V *Kerhin*) research vessels over the years and we appreciate the efforts of their captains and crew. We thank Nancy Mountford and Tim Morris of Cove Corporation who identified benthos in many of the historical samples and provided current taxonomic and autoecological information. We also thank those at Versar whose efforts helped produce this report: the field crew who collected samples, including Field Coordinator Marc Molé, William Morrissey, and Charles Tonkin; the laboratory staff who processed the samples and provided taxonomic identifications, Suzanne Arcuri, Istvan Turcsanyi, and Michael Winnell; and Allison Brindley for GIS support. Mike Lane at Old Dominion University managed and analyzed the data. Roberto Llansó was Principal Investigator. David Wong was Contract and Program Manager.

We appreciate the efforts of Dr. Daniel M. Dauer, Mike Lane, and Anthony (Bud) Rodi of Old Dominion University who coordinate the activities of the Virginia Benthic Monitoring Program. Lastly, we thank Todd Beser and MMG-US who helped coordinate logistics for the sampling of the Aberdeen Proving Grounds.

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# EXECUTIVE SUMMARY

Benthic macroinvertebrates have been an important component of the State of Maryland's Chesapeake Bay water quality monitoring program since the program's inception in 1984. Benthos integrate temporally variable environmental conditions and the effects of multiple types of environmental stress. They are sensitive indicators of environmental status. Information on the condition of the benthic community provides a direct measure of the effectiveness of management actions. The Long-Term Benthic Monitoring and Assessment Program contributes information to the Chesapeake Bay Health and Restoration Reports, and to the water quality characterization and list of impaired waters under the Clean Water Act. This report is one in a series of Level-One Annual Reports that summarize data up to the current sampling year. In this report, benthic community condition and trends in the Chesapeake Bay are assessed for 2024.

Benthic community degradation in Chesapeake Bay and the Maryland portion of the Chesapeake Bay increased in 2024. The increase, as estimated by the benthic index of biotic integrity, affected all of the sampling strata in Maryland except the Maryland Western Tributaries, and all of the sampling strata in Virginia. The increase was not very large, within the uncertainty of the estimate in both Maryland and Virginia. The change observed between 2023 and 2024 was consistent with larger than average hypoxic volume (bottom waters with dissolved oxygen below 2 mg/L) in Chesapeake Bay in May and early June 2024. Low spring river flow and reduced nutrient runoff in 2023 contrasted with high spring river flow in 2024. Typically, excess nutrient runoff in years of high rainfall changes the balance of biological and chemical processes, and these changes frequently lead to hypoxia and loss of benthic biomass and productivity. In Chesapeake Bay benthic condition varies annually depending on a variety of factors, among which nutrient loading, variability in spring river flow, physical forcing, and the timing of hypoxia play contributing and interacting roles.

**The highlights for 2024 can be summarized as follows:**

<u>Random-site Results</u>

(1) The tidal area with degraded benthos in Chesapeake Bay increased from 46% in 2023 to 54% in 2024.

- There was no statistically significant trend in percent area degraded over the 1996-2024 time period.

(2) In Maryland the tidal area with degraded benthos increased from 60% in 2023 to 65% in 2024.

- There was no statistically significant trend in percent area degraded over the 1995-2024 time period.

- Degradation increased in all of the Maryland strata except the Maryland Western Tributaries.

- The Patuxent River and the Maryland Eastern Tributaries had the largest increase in degradation. The Potomac and the Patuxent rivers were in poorest condition, whereas the Upper Bay Mainstem remained in best condition.

Fixed-site Results

(3) Benthic community condition (B-IBI scores averaged over the last 3 years of monitoring) remained within the same condition category at all of the long-term fixed monitoring sites.

  - Currently, 7 sites meet the benthic community restoration goals and 20 sites fail the goals.

(4) Statistically significant B-IBI trends were detected at 18 of the 27 fixed monitoring sites.

  - 5 sites had improving trends (significantly increasing B-IBI score): Upper Bay mainstem (Station 026), Elk River (Station 029), mesohaline Choptank River (Station 064), Bear Creek (Station 201), and Back River (Station 203).
  - 13 sites had declining trends (significantly decreasing B-IBI score): mid-bay mainstem at Calvert Cliffs (Stations 001 and 006), Baltimore Harbor (Station 022), tidal freshwater Potomac River (Station 036), mesohaline Potomac River at Morgantown (Stations 043 and 047), deep mesohaline Potomac River at St. Clements Island (Station 052), Nanticoke River (Station 062), oligohaline Choptank River (Station 066), Patuxent River at Broomes Island (Station 071), Patuxent River at Holland Cliff (Station 077), Curtis Bay (Station 202), and Severn River (Station 204).
  - Changes in 2024 from 2023 results were limited to the appearance of a declining B-IBI trend in the mid-Bay mainstem (Station 006).

Fixed-site and probability-based sampling sites in 2024 continued to show improvements in benthic condition from excess abundance (eutrophic condition). There was a statistically significant declining trend in the percentage of sites in Maryland tidal waters scoring 1 for excess abundance (above restorative thresholds). This trend may be evidence of favorable conditions in recent years associated with restoration efforts to reduce nutrient pollution. In addition, the response of the benthic communities to high spring river flow in 2024 was attenuated compared to other years with similar high river flow. We propose that better than expected benthic conditions in 2024 were likely related to the ongoing restoration efforts. Even though spring river flow was high in 2024, the amount of nitrogen measured at river input monitoring stations was about the same as the average taken between 1985 and 2023. Thus efforts to keep nutrient pollution from entering the Chesapeake Bay appeared to be working.

Despite improvements in recent years, benthic community degradation in Chesapeake Bay remains large. Biomass-dominant species have declined over the years and low rates of benthic production are observed in areas impacted by hypoxia. This background suggests that the recovery of the benthic communities, on which many fisheries and avian species depend, may be tied to factors in which not only management plays a role, but increasingly important aspects of climate change interact with species populations to provide patterns of benthic community change that mask the restoration efforts. However, inter-annual variability in benthic condition suggests that benthic communities are resilient and respond quickly to improvements in water quality.

In reference to changes in status of the non-indigenous polychaete *Hermundura americana* in Chesapeake Bay, this species is now density-dominant in the mesohaline region of the Potomac River. A Gulf of Mexico species, *H. americana* was first reported in Chesapeake Bay in the Southern Branch of the Elizabeth River in a single benthic sample in 2009. From the Elizabeth River *H. americana* spread into the James River in 2012 and is now found throughout the tidal James River and its tributaries. In 2018, *H. americana* was found in the Maryland portion of the Chesapeake Bay at five locations, three in the Potomac River. By 2024, *H. americana* had colonized a wide range of salinity, depth, and sediment types in the James, Rappahannock, and Potomac rivers, and was recorded in the York River. In 2024, *H. americana* spread to many new locations in Maryland, where it was previously unrecorded. No other warm water, non-indigenous benthic species has recently been found in Chesapeake Bay. However, the widespread intrusion of *H. americana* in Chesapeake Bay and its ability to rapidly colonize a wide range of habitat types is serious cause of concern and should be closely monitored in the future.

The use of probability-based sampling and fixed point monitoring allows us to provide an overall picture of benthic condition in Chesapeake Bay that helps track the success of efforts to clean up the bay. This picture would not have emerged if only water quality were monitored, and points to the value of long-term biological monitoring in the face of natural variability and climate change.

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# 1.0 INTRODUCTION

## 1.1 BACKGROUND

Monitoring is a necessary part of environmental management because it provides the means for assessing the effectiveness of previous management actions and the information necessary to focus future actions (NRC 1990). Towards these ends, the State of Maryland has maintained a water quality monitoring program for Chesapeake Bay since 1984. The goals of the program are to:

- quantify the types and extent of water quality problems (i.e., characterize the “state-of-the-bay”);
- determine the response of key water quality measures to pollution abatement and resource management actions;
- identify processes and mechanisms controlling the bay’s water quality;
- define linkages between water quality and living resources;
- contribute information to the Chesapeake Bay Health and Restoration Reports; and
- contribute information to the Water Quality Characterization Report (305b report) and the List of Impaired Waters (303d list).

The program includes elements to measure water quality, phytoplankton, and benthic macroinvertebrates (i.e., those invertebrates retained on a 0.5-mm mesh sieve). The monitoring program includes assessments of biota because the condition of biological indicators integrates temporally variable environmental conditions and the effects of multiple types of environmental stress. In addition, most environmental regulations and contaminant control measures are designed to protect biological resources; therefore, information about the condition of biological resources provides a direct measure of the effectiveness of management actions.

The Maryland program uses benthic macroinvertebrates as biological indicators because they are reliable and sensitive indicators of habitat quality in aquatic environments. Most benthic organisms have limited mobility and cannot avoid changes in environmental conditions (Gray 1979). Benthos live in bottom sediments, where exposure to contaminants and oxygen stress is most frequent. Benthic assemblages include diverse taxa representing a variety of sizes, modes of reproduction, feeding guilds, life history characteristics, and physiological tolerances to environmental conditions; therefore, they respond to and integrate natural and anthropogenic changes in environmental conditions in a variety of ways (Pearson and Rosenberg 1978; Warwick 1986; Dauer 1993; Wilson and Jeffrey 1994).

Benthic organisms are also important secondary producers, providing key linkages between primary producers and higher trophic levels (Virnstein 1977; Holland et al. 1980, 1989; Baird and Ulanowicz 1989; Diaz and Schaffner 1990). Benthic invertebrates are among the most important components of estuarine ecosystems and may represent the largest standing stock of organic carbon in estuaries (Frithsen 1989). Many benthic organisms, such as clams, are economically important. Others, such as polychaete annelids and small crustaceans, contribute significantly to the diets of economically important bottom feeding juvenile and adult fishes, such as spot and croaker (Homer and Boynton 1978; Homer et al. 1980).

The Chesapeake Bay Program's decision to adopt benthic community restoration goals (Ranasinghe et al. 1994 updated by Weisberg et al. 1997) enhanced use of benthic macroinvertebrates as a monitoring tool. Based largely on data collected as part of Maryland's monitoring effort, these goals describe the characteristics of benthic assemblages expected at sites exposed to little environmental stress. The restoration goals provide a quantitative benchmark against which to measure the health of sampled assemblages and ultimately the Chesapeake Bay. Submerged aquatic vegetation (Dennison et al. 1993) and benthic macroinvertebrates are the only biological communities for which such quantitative goals have been established in Chesapeake Bay.

A variety of anthropogenic stresses affect benthic macroinvertebrate communities in Chesapeake Bay. These include toxic contaminants, organic enrichment, and low dissolved oxygen. While toxic contaminants are generally restricted to urban and industrial areas typically associated with ports, low dissolved oxygen (hypoxia) is the more widespread problem, encompassing an area of about 600 million $m^2$ mainly along the deep mainstem of the bay and at the mouth of the major Chesapeake Bay tributaries (Flemer et al. 1983). Organic enrichment, associated with excess phytoplankton growth and decay, is also a major problem in some regions of the Bay.

A variety of factors contribute to the development and spatial variation of hypoxia in Chesapeake Bay. Freshwater inflow, salinity, temperature, wind stress, and tidal circulation are primary factors in the development of hypoxia (Holland et al. 1987; Tuttle et al. 1987; Boicourt 1992). The development of vertical salinity gradients during the spring freshwater run off leads to water column density stratification. The establishment of a pycnocline, in association with periods of calm and warm weather, restricts water exchange between the surface and the bottom layers of the estuary, where oxygen consumption is large. This process is especially manifested along the Maryland mid-bay and Potomac River deep troughs. Formation or disruption of the pycnocline is probably the most important process determining intensity and extent of hypoxia (Seliger et al. 1985; Boicourt 1992), albeit not the only one. Biological processes contribute significantly to deep water oxygen depletion in Chesapeake Bay (Officer et al. 1984). Benthic metabolic rates increase during spring and early summer, leading to an increase of the rate of oxygen consumption in bottom waters. This depends in part on the amount of organic carbon available for the benthos, which is derived to a large extent from seasonal phytoplankton blooms (Officer et al. 1984). Anthropogenic nutrient inputs to the Chesapeake Bay further stimulate phytoplankton growth, which results in increased deposition of organic matter to sediments and a concomitant increase in chemical and biological oxygen demand (Malone 1987). Winter to spring accumulation of phytoplankton biomass has been linked to depletion of bottom water oxygen in the Chesapeake Bay (Malone et al. 1988; Boynton and Kemp 2000).

The effects of hypoxia on benthic organisms vary as a function of the severity, spatial extent, and duration of low dissolved oxygen events. Oxygen concentrations down to about 2 mg $L^{-1}$ do not appear to significantly affect benthic organisms, although incipient community effects have been measured at 3 mg $L^{-1}$ (Diaz and Rosenberg 1995; Ritter and Montagna 1999). Hypoxia brings about structural and organizational changes in the community, and may lead to hypoxia resistant communities. With an increase in the frequency of hypoxic events, benthic populations become dominated by fewer and short-lived species, and their overall productivity is decreased (Diaz and Rosenberg 1995). Major reductions in species numbers and abundance in Chesapeake Bay have been attributed to hypoxia (Dauer et al. 1992, Llansó 1992). These reductions become larger both spatially and temporally as the severity and duration of hypoxic events increase. As hypoxia becomes persistent, mass mortality of benthic organisms often occurs with almost complete elimination of the macrofauna.

Hypoxia has also major impacts on the survival and behavior of a variety of benthic organisms and their predators (Diaz and Rosenberg 1995). Many infaunal species respond to low oxygen by migrating toward the sediment surface, thus potentially increasing their availability to demersal predators. On the other hand, reduction or elimination of the benthos following severe hypoxic and anoxic (absence of oxygen) events results in a reduction of food for demersal fish species and crabs. Therefore, the structural changes and species replacements that occur in communities affected by hypoxia may alter the food supply of important ecological and economical fish species in Chesapeake Bay. Given that dissolved oxygen stress and nutrient run-off are critical factors in the health of the biological resources of the Chesapeake Bay region, monitoring that evaluates benthic condition and tracks changes over time helps Chesapeake Bay managers assess the effectiveness of nutrient reduction efforts and the status of the biological resources of one of the largest and most productive estuaries in the nation.

## 1.2 OBJECTIVES OF THIS REPORT

This report is part of a series of Level I Comprehensive reports produced annually by the Long-Term Benthic Monitoring and Assessment Component (LTB) of the Maryland Chesapeake Bay Water Quality Monitoring Program. Level I reports summarize data from the latest sampling year and provide a limited examination of how conditions in the latest year differ from conditions in previous years of the study, as well as how data from this year contribute to describing trends in the Bay's condition.

The report reflects the maturity of the current program focus and design. Approaches introduced when the new program design was implemented in 1995 continue to be extended, developed, and better defined. The level of detail in which changes are examined at the fixed stations sampled for trend analysis continues to increase. For example, we report on how species contribute to changes in condition and discuss trends in relation to changes in water quality. The Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI) is applied to each sampling site, from tidal freshwater to polyhaline zones, and thus provides a uniform measure of ecological condition across the estuarine gradient. In describing baywide benthic community condition, estimates of degraded condition are presented for all subregions of the Bay, and community measures that contribute to restoration goal failure are used to diagnose the causes of failure.

The continued presentation of estimates of Bay area meeting the Chesapeake Bay Program benthic community restoration goals, rather than Maryland estimates only, reflects improved coordination and unification of objectives among the Maryland and Virginia benthic monitoring programs. The sampling design and methods in both states are compatible and complementary.

In addition to the improvements in technical content, we have enhanced electronic production and transmittal of data. Data and program information are available to the research community and the general public through the Chesapeake Bay Benthic Monitoring Program Home Page at https://baybenthos.versar.com. The 2024 data, as well as the data from previous years, can be downloaded from this website. The Benthic Monitoring Program Home Page represents the culmination of collaborative efforts between Versar, Maryland DNR, and the Chesapeake Information Management System (CIMS). The activities that Versar undertakes as a partner of CIMS were recorded in a Memorandum of Agreement signed October 28, 1999.

## 1.3 ORGANIZATION OF REPORT

This report has two volumes. Volume 1 is organized into five major sections and five appendices. Section 1 is this introduction. Section 2 presents the field, laboratory, and data analysis methods used to collect, process, and evaluate the LTB samples. Section 3 presents the results of analyses conducted for 2024, and consists of two assessments: an assessment of trends in benthic community condition at the fixed sites sampled annually by LTB in the Maryland Chesapeake Bay, and an assessment of the area of the Bay that meets the Chesapeake Bay Benthic Community Restoration Goals. Section 4 discusses the results and evaluates status and trends relative to changes in water quality. Section 5 is the literature cited in the report. Appendix A amplifies information presented in Table 3-2 and Table 3-3 by providing rates of change for the 1985-2024 fixed site trend analysis. Appendix B includes additional fixed-site trend analysis results using a Generalized Additive Model. Appendices C and D present the B-IBI values for the 2024 fixed and random sampling components, respectively. Appendix E presents newly collected data on benthic chlorophyll-*a* and phaeophytin. Finally, Volume 2 consists of the benthic, sedimentary, and hydrographic data appendices.

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# 2.0 METHODS

## 2.1 SAMPLING DESIGN

The LTB sampling program contains two primary elements: a fixed site monitoring effort directed at identifying trends in benthic condition and a probability-based sampling effort intended to estimate the area of the Maryland Chesapeake Bay with benthic communities meeting the Chesapeake Bay Program's benthic community restoration goals (Ranasinghe et al. 1994, updated by Weisberg et al. 1997; Alden et al. 2002). The sampling design for each of these elements is described below.

### 2.1.1 Fixed Site Sampling

The fixed site element of the program involves sampling at 27 sites, 23 of which have been sampled since the program's inception in 1984, 2 since 1989, and 2 since 1995 (Figure 2-1). Sites are defined by geography (within 1 km from a fixed location), and by specific depth and substrate criteria (Table 2-1).

The 2024 fixed site sampling continues trend measurements, which began with the program's initiation in 1984. In the first five years of the program, from July 1984 to June 1989, 70 fixed stations were sampled 8 to 10 times per year. On each visit, three benthic samples were collected at each site and processed. Locations of the 70 fixed sites are shown in Figure 2-2.

In the second five years of the program, from July 1989 to June 1994, fixed site sampling was continued at 29 sites and a stratified random sampling element was added. Samples were collected at random from approximately 25 km$^2$ small areas surrounding these sites (Figure 2-3) to assess the representativeness of the fixed locations. Sites 006, 047, 062, and 077, which are part of the current design, were not sampled during this five-year period. Stratum boundaries were delineated on the basis of environmental factors that are important in controlling benthic community distributions: salinity regime, sediment type, and bottom depth (Holland et al. 1989). In addition, four new areas were established in regions of the Bay targeted for management actions to abate pollution: the Patuxent River, Choptank River, and two areas in Baltimore Harbor. Each area was sampled four to six times each year.

From July 1994 through 2008, three replicate samples were collected in spring and summer at most of the current suite of 27 sites (Stations 203 and 204 were added in 1995, Table 2-1, Figure 2-1). This sampling regime was selected as being most cost effective after analysis of the first 10 years of data jointly with the Virginia Benthic Monitoring Program (Alden et al. 1997). Starting in 2009, spring sampling was eliminated due to budgetary constraints.

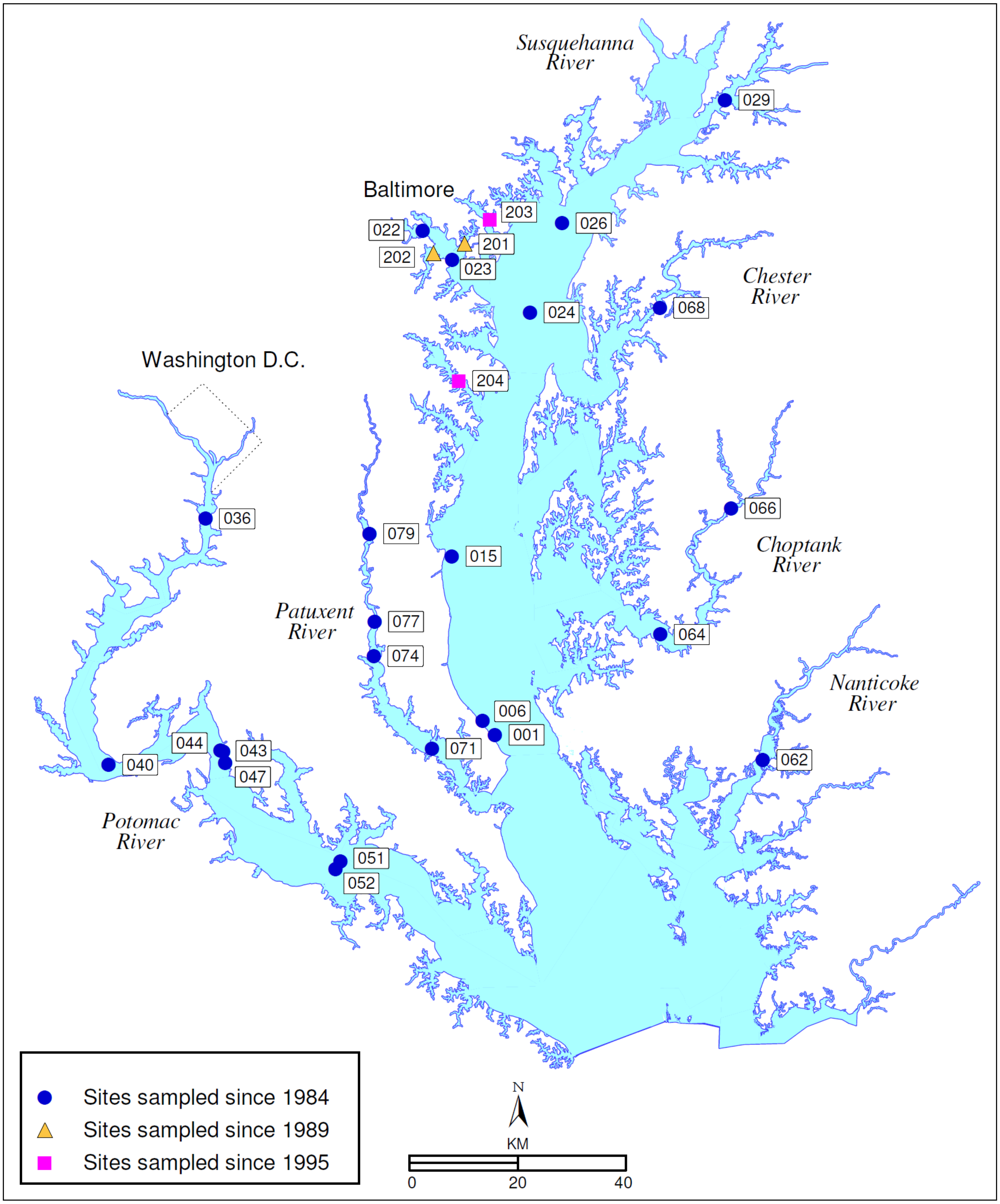

Figure 2-1. Fixed sites sampled in 2024

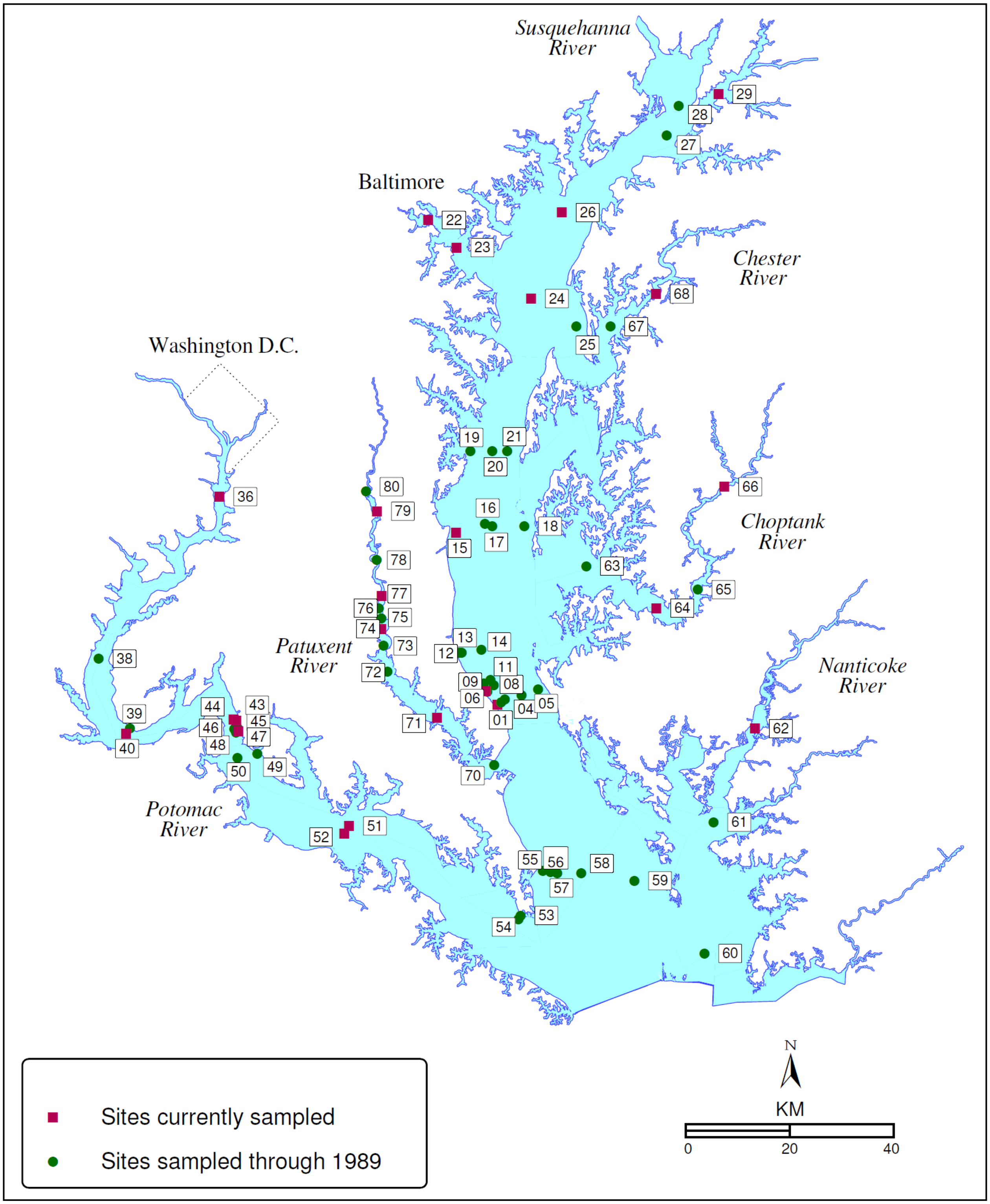

Figure 2-2. Fixed sites sampled from 1984 to 1989; some of these sites are part of the current design

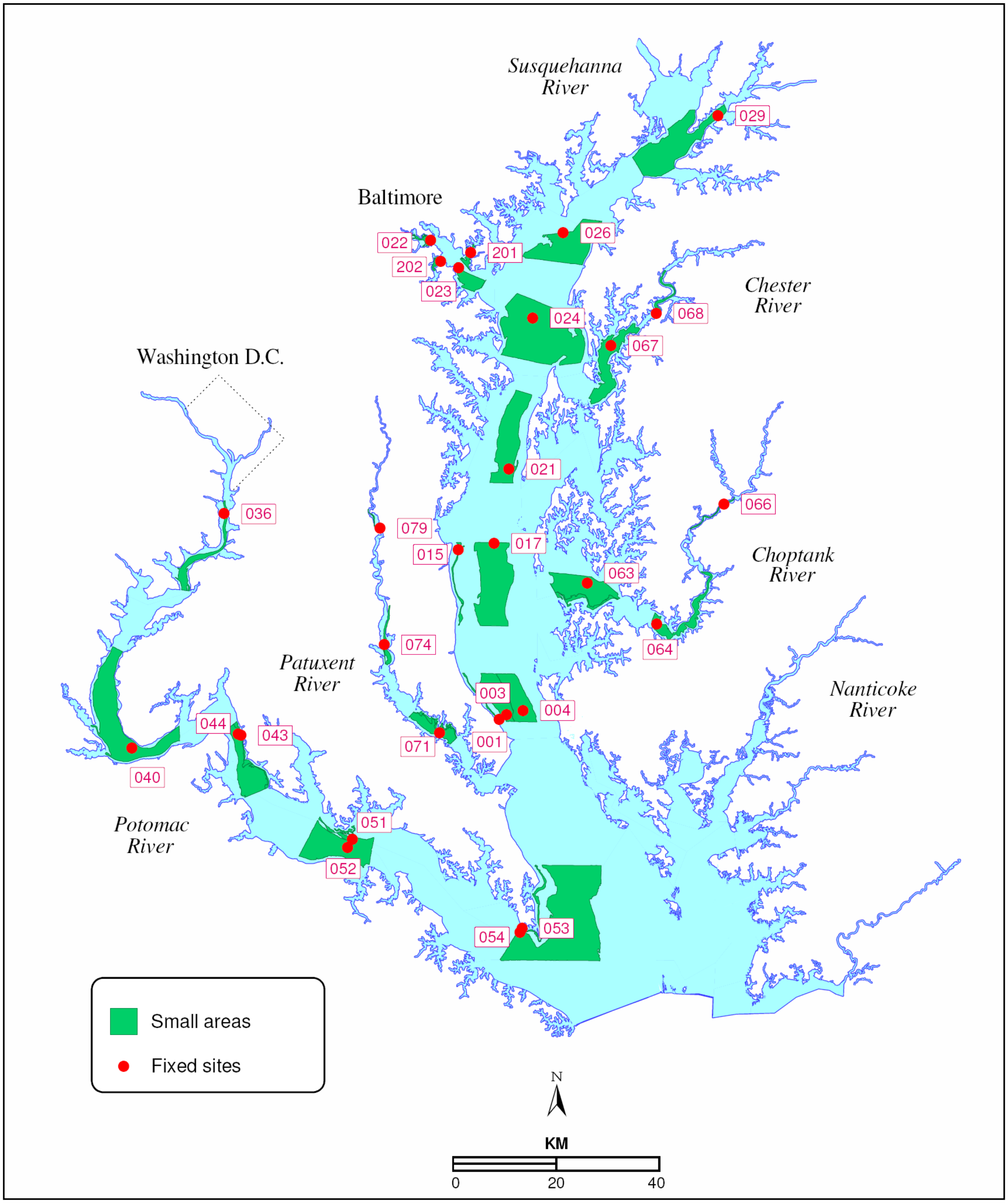

Figure 2-3. Small areas and fixed sites sampled from 1989 to 1994

Table 2-1. Location, habitat type (Table 5, Weisberg et al. 1997), sampling gear, and habitat criteria for fixed sites. [a]Station 047 temporally relocated to 38.37654, -76.98519 from 2020 to 2024 due to construction in the Potomac River Route 301 Bridge. [b]Station 022 permanently relocated across the channel during the 2010 field season because of construction at the old site. [c]Sampled in 2024 with a Young grab.

| Stratum | Sub-Estuary | Habitat | Station | Latitude (WGS84) | Longitude (WGS84) | Sampling Gear | Habitat Criteria | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Depth (m) | Silt-clay (%) | Distance (km) |
| Potomac River | Potomac River | Tidal Freshwater | 036 | 38.769788 | -77.037534 | WildCo Box Corer | <=5 | >=40 | 1.0 |
| | | Oligohaline | 040 | 38.357466 | -77.230537 | WildCo Box Corer | 6.5-10 | >=80 | 1.0 |
| | | Low Mesohaline | 043 | 38.384479 | -76.988329 | Modified Box Corer | <=5 | <=30 | 1.0 |
| | | Low Mesohaline | 047[a] | 38.363825 | -76.983737 | Modified Box Corer | <=5 | <=30 | 0.5 |
| | | Low Mesohaline | 044 | 38.385633 | -76.995698 | WildCo Box Corer | 11-17 | >=75 | 1.0 |
| | | High Mesohaline Sand | 051 | 38.205355 | -76.738622 | Modified Box Corer | <=5 | <=20 | 1.0 |
| | | High Mesohaline Mud | 052 | 38.192304 | -76.747689 | WildCo Box Corer | 9-13 | >=60 | 1.0 |
| Patuxent River | Patuxent River | Tidal Freshwater | 079 | 38.750457 | -76.689023 | WildCo Box Corer | <=6 | >=50 | 1.0 |
| | | Low Mesohaline | 077 | 38.604461 | -76.675020 | WildCo Box Corer | <=5 | >=50 | 1.0 |
| | | Low Mesohaline | 074 | 38.548962 | -76.676186 | WildCo Box Corer | <=5 | >=50 | 0.5 |
| | | High Mesohaline Mud | 071 | 38.395132 | -76.548847 | WildCo Box Corer | 12-18 | >=70 | 1.0 |

Table 2-1. (Continued)

| Stratum | Sub-Estuary | Habitat | Station | Latitude (WGS84) | Longitude (WGS84) | Sampling Gear | Habitat Criteria | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Depth (m) | Silt-clay (%) | Distance (km) |
| Upper Western Tributaries | Patapsco River | Low Mesohaline | 023 | 39.208283 | -76.523354 | WildCo Box Corer | 4-7 | >=50 | 1.0 |
| | Middle Branch | Low Mesohaline | 022[(b)] | 39.258082 | -76.59512 | WildCo Box Corer | 2-6 | >=40 | 1.0 |
| | Bear Creek | Low Mesohaline | 201 | 39.234167 | -76.497501 | WildCo Box Corer | 2-4.5 | >=70 | 1.0 |
| | Curtis Bay | Low Mesohaline | 202 | 39.217839 | -76.564171 | WildCo Box Corer | 5-8 | >=60 | 1.0 |
| | Back River | Oligohaline | 203 | 39.275005 | -76.444508 | Young-Grab | 1.5-2.5 | >=80 | 1.0 |
| | Severn River | High Mesohaline Mud | 204 | 39.006954 | -76.504955 | Young-Grab | 5-7.5 | >=50 | 1.0 |
| Eastern Tributaries | Chester River | Low Mesohaline | 068[(c)] | 39.132509 | -76.078780 | WildCo Box Corer | 4-8 | >=70 | 1.0 |
| | Choptank River | Oligohaline | 066 | 38.801455 | -75.921827 | WildCo Box Corer | <=5 | >=60 | 1.0 |
| | | High Mesohaline Mud | 064 | 38.590459 | -76.069331 | WildCo Box Corer | 7-11 | >=70 | 1.0 |
| | Nanticoke River | Low Mesohaline | 062 | 38.383960 | -75.849990 | Petite Ponar Grab | 5-8 | >=75 | 1.0 |

Table 2-1. (Continued)

| Stratum | Sub-Estuary | Habitat | Station | Latitude (WGS84) | Longitude (WGS84) | Sampling Gear | Habitat Criteria | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Depth (m) | Silt-clay (%) | Distance (km) |
| Upper Bay | Elk River | Oligohaline | 029(c) | 39.479505 | -75.944836 | WildCo Box Corer | 3-7 | >=40 | 1.0 |
| | Mainstem | Low Mesohaline | 026 | 39.271450 | -76.290013 | WildCo Box Corer | 2-5 | >=70 | 1.0 |
| | | High Mesohaline Mud | 024 | 39.122004 | -76.355673 | WildCo Box Corer | 5-8 | >=80 | 1.0 |
| Mid Bay | Mainstem | High Mesohaline Sand | 015(c) | 38.715126 | -76.513679 | Modified Box Corer | <=5 | <=10 | 1.0 |
| | | High Mesohaline Sand | 001 | 38.419001 | -76.418385 | Modified Box Corer | <=5 | <=20 | 1.0 |
| | | High Mesohaline Sand | 006 | 38.442000 | -76.444261 | Modified Box Corer | <=5 | <=20 | 0.5 |

### 2.1.2 Probability-based Sampling

The second sampling element, which was instituted in 1994, was probability-based summer sampling designed to estimate the area of the Maryland Chesapeake Bay and its tributaries that meet the Chesapeake Bay benthic community restoration goals (Ranasinghe et al. 1994, updated by Weisberg et al. 1997; Alden et al. 2002). Different probability sample allocation strategies were used in 1994 than in later years. In 1994, the design was intended to estimate impaired area for the Maryland Bay and one sub-region, while in later years the design targeted five additional sub-regions as well.

The 1994 sample allocation scheme was designed to produce estimates for the Maryland Bay and the Potomac River. The Maryland Bay was divided into three strata with samples allocated unequally among them (Table 2-2); sampling intensity in the Potomac was increased to permit estimation of degraded area with adequate confidence, while mainstem and other tributary and embayment samples were allocated in proportion to their area.

Table 2-2. Allocation of probability-based baywide samples, 1994

| Stratum | Area | | Number of Samples |
|---|---|---|---|
| | $km^2$ | % | |
| Maryland Mainstem (including Tangier and Pocomoke Sounds) | 3,611 | 55.5 | 27 |
| Potomac River | 1,850 | 28.4 | 28 |
| Other tributaries and embayments | 1,050 | 16.1 | 11 |

In subsequent years, the stratification scheme was designed to produce an annual estimate for the Maryland Bay and six subdivisions. Samples were allocated equally among strata (Figure 2-4, Table 2-3). According to this allocation, a fresh new set of sampling sites were selected each year. Figure 2-5 shows the locations of the probability-based Maryland sampling sites for 2024. Regions of the Maryland mainstem deeper than 12 m were not included in sampling strata because these areas are subjected to summer anoxia and have consistently been found to be azoic.

A similar stratification scheme has been used by the Commonwealth of Virginia since 1996, permitting annual estimates for the extent of area meeting the benthic community restoration goals for the entire Chesapeake Bay (Table 2-3, Figure 2-6). These samples were collected and processed, and the data analyzed by the Virginia Chesapeake Bay Benthic Monitoring Program.

Note: The random sites were not selected using the same process in 2021. See cautionary note in page 3-40 of this report.

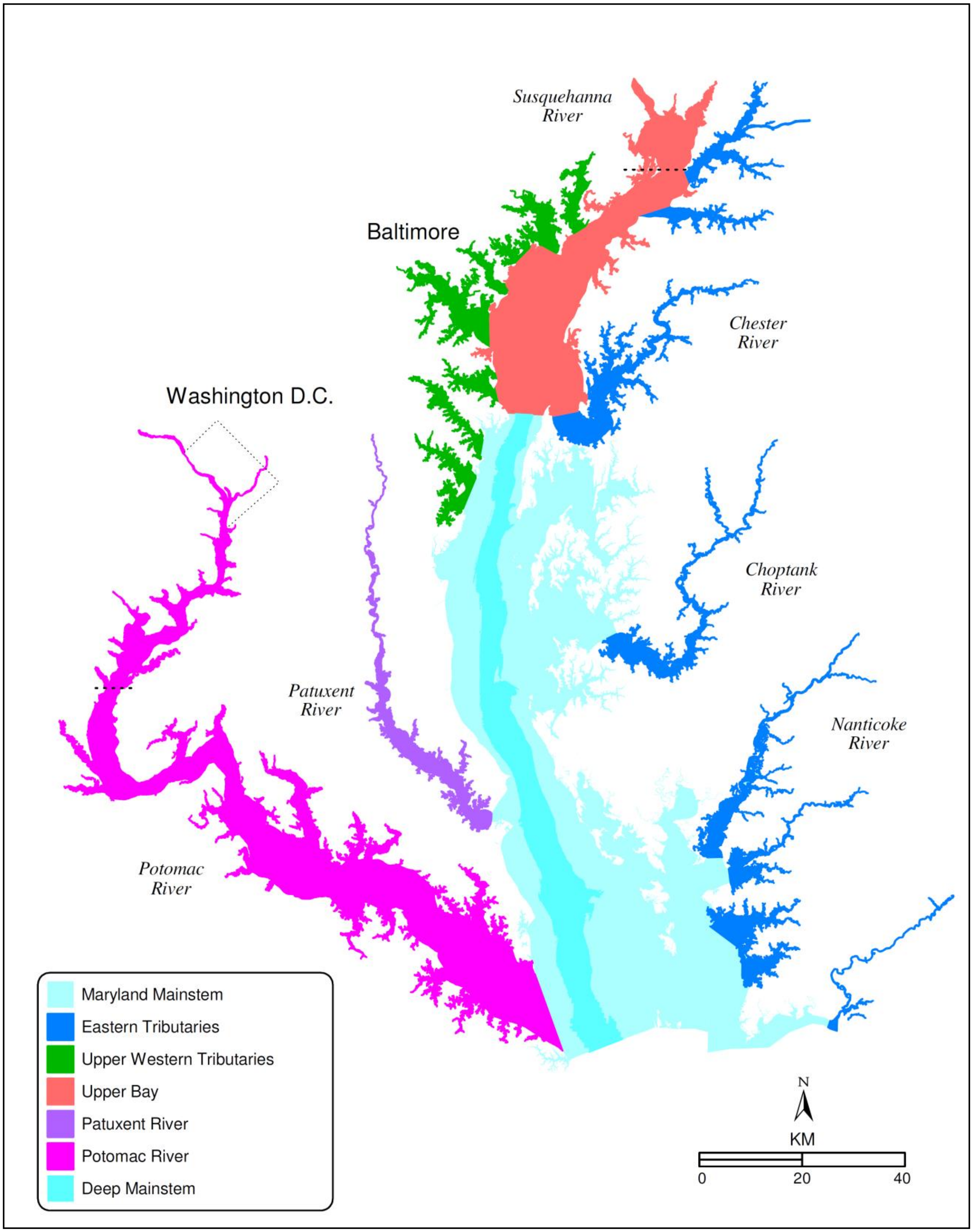

Figure 2-4. Maryland baywide sampling strata in and after 1995

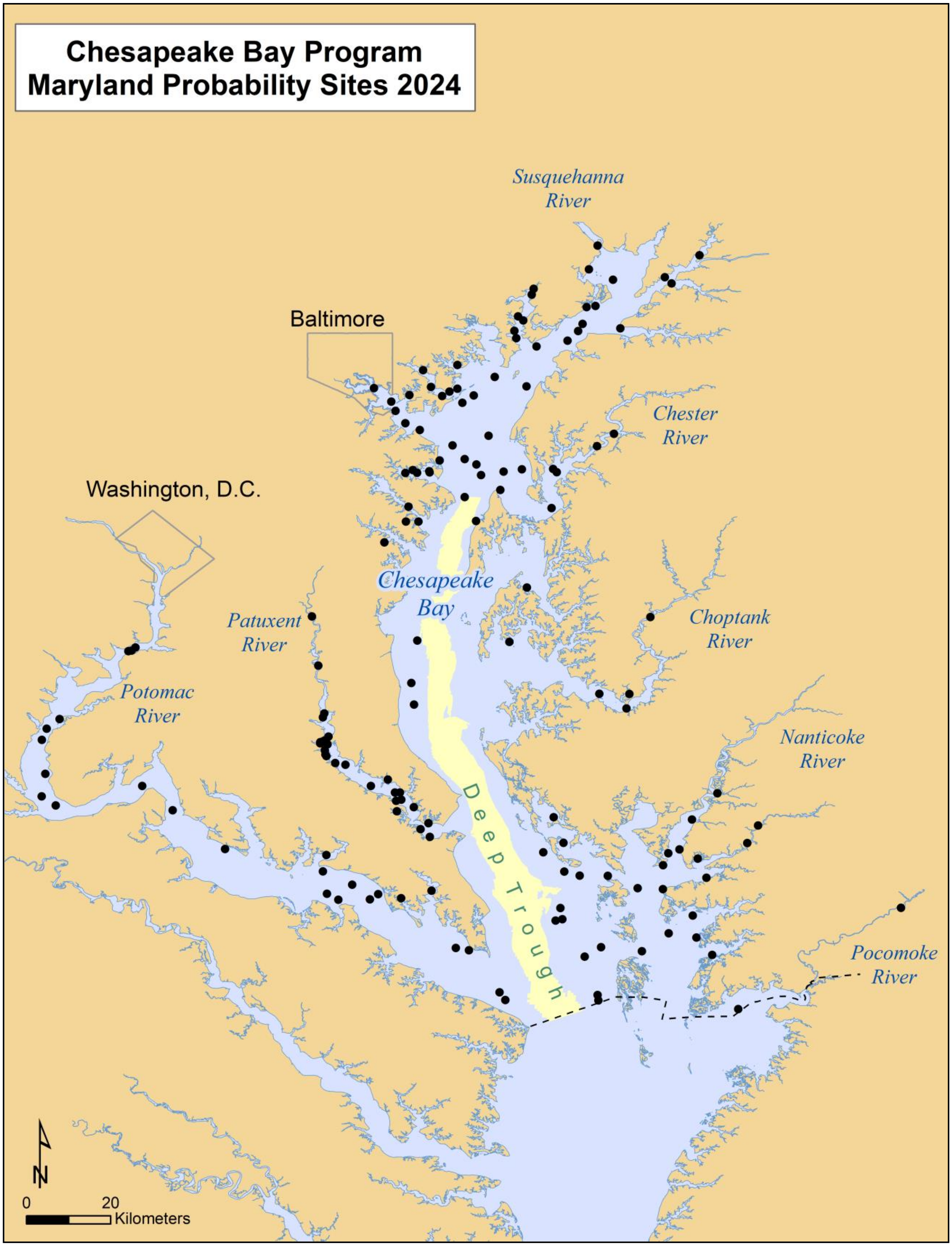

Figure 2-5. Maryland probability-based sampling sites for 2024

Table 2-3. Allocation of probability-based baywide samples, in and after 1995. Maryland areas exclude 676 km$^2$ of mainstem habitat deeper than 12 m. Virginia strata were sampled by the Virginia Chesapeake Bay Benthic Monitoring Program commencing in 1996.

| State | Stratum | Area | | | Number of Samples |
|---|---|---|---|---|---|
| | | km$^2$ | State % | Bay % | |
| Maryland | Deep Mainstem | 676 | 10.8 | 5.8 | 0 |
| | Mid Bay Mainstem | 2,552 | 40.9 | 22.0 | 25 |
| | Eastern Tributaries | 534 | 8.6 | 4.6 | 25 |
| | Western Tributaries | 292 | 4.7 | 2.5 | 25 |
| | Upper Bay Mainstem | 785 | 12.6 | 6.8 | 25 |
| | Patuxent River | 128 | 2.0 | 1.1 | 25 |
| | Potomac River* | 1,276 | 20.4 | 11.0 | 25 |
| | TOTAL | 6,243 | 100.0 | 53.8 | 150 |
| Virginia | Mainstem | 4,120 | 76.8 | 35.5 | 25 |
| | Rappahannock River | 372 | 6.9 | 3.2 | 25 |
| | York River | 187 | 3.5 | 1.6 | 25 |
| | James River | 684 | 12.8 | 5.9 | 25 |
| | TOTAL | 5,363 | 100.0 | 46.2 | 100 |

*Excludes Virginia tidal creeks and district of Columbia waters

## 2.2 SAMPLE COLLECTION

### 2.2.1 Station Location

From July 1984 to June 1996, stations were located using Loran-C. After June 1996 stations were located using a differential Global Positioning System. The WGS84 coordinate system (undistinguishable in practice from NAD83) is currently used.

### 2.2.2 Water Column Measurements

Water column vertical profiles of temperature, conductivity, salinity, dissolved oxygen concentration (DO), and pH were measured at each site. Oxidation reduction potential (ORP) was measured prior to 1996. For fixed sites, profiles consisted of water quality measurements at 1 m intervals from surface to bottom at sites 7 m deep or less, and at 3 m intervals, with additional measurements at 1.5 m intervals in the vicinity of the pycnocline, at sites deeper than 7 m. Surface and bottom measurements were made at all other sampling sites. In 2016, a modification to the fixed-site water quality profiles was introduced, whereby measurements were taken at 1 m intervals at sites 10 m deep or less, and at 2 m intervals, with additional measurements in the vicinity of the pycnocline,

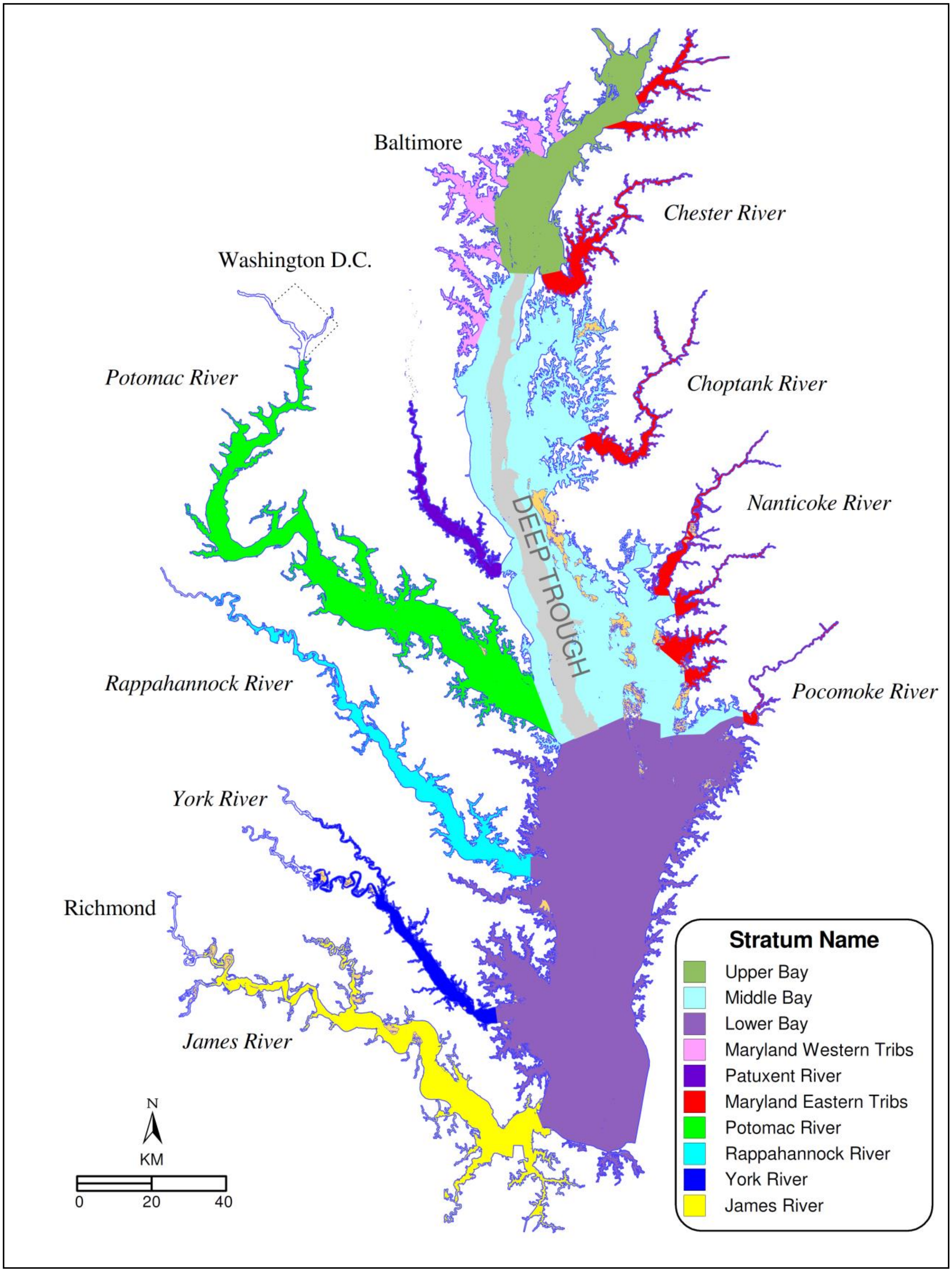

Figure 2-6. Chesapeake Bay stratification scheme

Table 2-4. Methods used to measure water quality parameters.

| Parameter | Period | Method |
|---|---|---|
| Temperature | July 1984 to November 1984 | Thermistor attached to Beckman Model RS5-3 salinometer |
| | December 1984 to December 1995 | Thermistor attached to Hydrolab Surveyor II |
| | January 1996 to present | Thermistor attached to Hydrolab DataSonde 4a, YSI 6600, or YSI EXO2 sonde |
| Salinity and Conductivity | July to November 1984 | Beckman Model RS5-3 salinometer toroidal conductivity cell with thermistor temperature compensation |
| | December 1984 to December 1995 | Hydrolab Surveyor II nickel six-pin electrode-salt water cell block combination with automatic temperature compensation |
| | January 1996 to present | Hydrolab DataSonde 4a four graphite electrode cell (open-cell design), YSI 6600, or YSI EXO2 four nickel electrode cell, with automatic temperature compensation |
| Dissolved Oxygen | July to November 1984 | YSI Model 57 or Model 58 Oxygen Meter with automatic temperature and manual salinity compensation |
| | December 1984 to December 1995 | Hydrolab Surveyor II membrane design probe with automatic temperature and salinity compensation |
| | January 1996 to present | Hydrolab DataSonde 4a membrane-design or optical DO sensor, YSI 6600 Rapid Pulse, or YSI EXO2 optical sensor, with automatic temperature and salinity compensation |
| pH | July to November 1984 | Orion analog pH meter with Ross glass combination electrode manually compensated for temperature |
| | December 1984 to December 1995 | Hydrolab Surveyor II glass pH electrode and Lazaran reference electrode automatically compensated for temperature |
| | January 1996 to present | Hydrolab DataSonde 4a, YSI 6600, or YSI EXO2 combined glass pH and reference sensor, automatically compensated for temperature |
| Oxidation Reduction Potential | December 1984 to December 1995 | Hydrolab Surveyor II platinum banded glass ORP electrode |

at sites deeper than 10 m. Table 2-4 lists the measurement methods used.

### 2.2.3 Benthic Samples

Samples were collected using four kinds of gear depending on the program element and habitat type. For the fixed site element (Table 2-1), a hand-operated box corer ("modified box corer"), which samples a 250 $cm^2$ area to a depth of 25 cm, was used in the nearshore shallow sandy habitats of the mainstem bay and tributaries. A Wildco box corer, which samples an area of 220 $cm^2$ to a depth of 23 cm, was used in shallow muddy or deep-water (> 5 m) habitats in the mainstem bay and tributaries. A Petite Ponar Grab, which samples 250 $cm^2$ to a depth of 7 cm, was used at the fixed site in the Nanticoke River to be consistent with previous sampling in the 1980s. At the two fixed sites first sampled in 1995 and at all probability-based sampling sites, a Young Grab, which samples an area of 440 $cm^2$ to a depth of 10 cm, was used.

Sample volume and penetration depth were measured for all samples; Wildco and hand-operated box cores penetrating less than 15 cm, and Young and Petite Ponar grabs penetrating less than 7 cm into the sediment were rejected and the site was re-sampled.

In the field, samples were sieved through a 0.5-mm screen using an elutriative process. Organisms and detritus retained on the screen were transferred into labeled jars and preserved in a 10% formaldehyde solution stained with Rose Bengal (a vital stain that aids in separating organisms from sediments and detritus).

One surface-sediment sub-sample of approximately 120 ml is collected for grain-size, carbon, and nitrogen analysis from an additional grab sample at each site. This sub-sample is maintained in the dark on wet ice while on board, and frozen until processed in the laboratory. In addition, starting in summer 2021 three surface sediment replicate samples (2.5 cm diameter x 1 cm sediment cores, 4.91 $cm^3$) were collected from a separate grab sample at each fixed site for benthic chlorophyll-*a* analysis. These samples were stored frozen in the dark until processed.

## 2.3 LABORATORY PROCESSING

Organisms were sorted from detritus under dissecting microscopes, identified to the lowest practical taxonomic level (most often species), and counted. Oligochaetes and chironomids were mounted on slides and examined under a compound microscope for genus and species identification.

Ash-free dry weight biomass was determined by three comparable techniques during the sampling period. For samples collected from July 1984 to June 1985, biomass was directly measured using an analytical balance for major organism groups (e.g., polychaetes, molluscs, and crustaceans). Ash-free dry weight biomass was determined by drying the organisms to a constant weight at 60 °C and ashing in a muffle furnace at 500 °C for four hours. For samples collected between July 1985 and August 1993, a regression relationship between ash-free dry weight biomass and size of morphometric characters was defined for 22 species (Ranasinghe et al. 1993). The biomass of the 22 selected species was estimated from these regression relationships. These taxa (Table 2-5) were selected because they accounted for more than 85% of the abundance (Holland et al. 1988). After August 1993, ash-free dry weight biomass was measured directly for each species by drying the organisms to a constant weight at 60 °C and ashing in a muffle furnace at 500 °C for four hours and re-weighing (ash weight). The difference between the dry weight and the ash weight is the ash-free dry weight. Bivalves were crushed to open the shells and expose the animal to drying and ashing (shells included).

Table 2-5. Taxa for which biomass was estimated in samples collected between 1985 and 1993

| **Polychaeta** | **Mollusca** |
|---|---|
| *Eteone heteropoda*<br>*Glycinde solitaria*<br>*Heteromastus filiformis*<br>*Marenzelleria viridis*<br>*Neanthes succinea*<br>*Paraprionospio pinnata*<br>*Streblospio benedicti* | *Acteocina canaliculata*<br>*Corbicula fluminea*<br>*Gemma gemma*<br>*Haminoea solitaria*<br>*Macoma balthica*<br>*Macoma mitchelli*<br>*Mulinia lateralis*<br>*Mya arenaria*<br>*Rangia cuneata*<br>*Tagelus plebeius* |
| **Crustacea** | |
| *Cyathura polita*<br>*Gammarus* spp.<br>*Leptocheirus plumulosus* | |
| **Nemertina** | |
| *Carinoma tremaphoros*<br>*Micrura leidyi* | |

Silt-clay composition was determined by wet-sieving through a 63-μm stainless steel sieve followed by pipetting of the silt and clay fraction using procedures described in the Versar, Inc., Laboratory Standard Operating Procedures (Versar 1999), and Folk (1974). Carbon and nitrogen content of dried sediments was determined using an elemental analyzer, following procedures in EPA's Method 440. Sediment carbon content was measured with a Perkin-Elmer Model 240B analyzer from 1984 to 1988, and an Exeter Analytical Inc., Model CE-440 analyzer in and after 1995. The results from both instruments are comparable. Samples were combusted at high temperature (975 °C) and the carbon dioxide and nitrogen produced were measured by thermal conductivity detection. Prior to combustion, each sample was homogenized and oven-dried. No acid was applied. Remaining sediment was archived for quality assurance purposes (Scott et al. 1988). Chlorophyll-*a* concentrations were determined by fluorometry following procedures in EPA's Method 445.0.

## 2.4 DATA ANALYSIS

Analyses for the fixed site and probability-based elements of LTB were both performed in the context of the Chesapeake Bay Program's benthic community restoration goals and the Benthic Index of Biotic Integrity (B-IBI) by which goal attainment is measured. The B-IBI, the Chesapeake Bay benthic community restoration goals, and statistical analysis methods for the two LTB elements are described below.

### 2.4.1 The B-IBI and the Chesapeake Bay Benthic Community Restoration Goals

The B-IBI is a multiple-attribute index developed to identify the degree to which a benthic assemblage meets the Chesapeake Bay Program's benthic community restoration goals (Ranasinghe et al. 1994, updated by Weisberg et al. 1997; Alden et al. 2002). The B-IBI provides a means for comparing relative condition of benthic invertebrate assemblages across habitat types. It also provides a validated mechanism for integrating several benthic community attributes indicative of habitat "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 values found at the best reference sites in similar habitats, and then averaging these scores across attributes. The criteria for assigning these scores are numeric and depend on habitat. Data from seasons for which the B-IBI has not been developed were not used for B-IBI based assessment.

Benthic community condition was classified into four levels based on the B-IBI. Values less than or equal to 2.0 were classified as severely degraded; values from 2.0 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 goals. 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.

### 2.4.2 Fixed Site Trend Analysis

Trends in condition at the fixed sites were identified using the nonparametric technique of van Belle and Hughes (1984) and run in SAS. This procedure is based on the

Mann-Kendall statistic and consists of a sign test comparing each value with all values measured in subsequent periods. The ratio of the Mann-Kendall statistic to its variance provides a normal deviate that is tested for significance. Alpha was set to 0.1 for these tests because of the low power for trend detection for biological data. An estimate of the magnitude of each significant trend was obtained using Sen's (1968) procedure which is closely related to the Mann-Kendall test. Sen's procedure identifies the median slope among all slopes between each value and all values measured in subsequent periods.

In addition to the Mann-Kendall test, and to explore non-linear relationships in the B-IBI, a Generalized Additive Model (GAM) analysis was employed using two separate models with year as the predictor. The first model is a simple linear model (the equivalent of a linear regression), and the second is a nonlinear smooth; both models use year as the predictor. Both models were run using B-IBI (mean of 3 replicate samples) as a response variable. Significance of each model was determined based on an F test with a minimum statistical test criterion of $p \leq 0.10$. All models were run with a default k value of 10 using GCV smoothness selection criteria (Wood 2006; Murphy et al. 2019). In many cases, both linear and nonlinear models were statistically significant. The k-index and its associated p value and effective degrees of freedom (edf) were used to determine whether interpreting the linear or nonlinear relationship was more appropriate. If the k-index was less than 1 and the p value for the index was significant ($p \leq 0.10$) then this indicates that the default k value for the model did not provide adequate complexity to the smoother and that a higher k value should be applied (Wood 2006; Pedersen, et al. 2019). This did not occur for any of the analyses conducted. For the remaining results with a k-index >1.0 and p>0.10, the edf were interpreted to determine if the results are nonlinear. The edf for smooth terms helps assess the complexity of the fitted model, with higher edf indicating capture of more complex patterns in the data. If the edf ≤1.00 then the linear results were interpreted. If the edf was >1.00 and ≤2.00 then the result was classified as a weak nonlinear relationship. If the edf was >2.00 then the result was classified as a strong nonlinear relationship. GAM analyses were conducted using the mgcv package in the R statistical programming language with specific statistics were generated using the gamcheck and gamout functions.

### 2.4.3 Probability-based Estimation

The Maryland Bay was divided into three strata (Bay Mainstem, Potomac River, other tributaries and embayments) in 1994 (Table 2-2). It was divided into six strata in and after 1995 (Figure 2-4, Table 2-3). The Virginia Bay was divided into four strata, beginning in 1996 (Figure 2-6, Table 2-3).

To estimate the amount of area in the entire Bay that failed to meet the Chesapeake Bay benthic community restoration goals (P), we defined for every site *i* in stratum *h* a variable $y_{hi}$ that had a value of 1 if the benthic community met the goals, and 0 otherwise. For each stratum, the estimated proportion of area meeting the goals, $p_h$, and its variance were calculated as the mean of the $y_{hi}$'s and its variance, as follows:

$$p_h = \bar{y}_h = \sum_{i=1}^{n_h} \frac{y_{hi}}{n_h} \tag{1}$$

and

$$\mathrm{var}\left(p_h\right) = s_h^2 = \sum_{i=1}^{n_h} \frac{\left(y_{hi} - \bar{y}_h\right)^2}{n_h - 1} \tag{2}$$

Estimates for strata were combined to achieve a statewide estimate as:

$$\hat{P}_{ps} = \bar{y}_{ps} = \sum_{h=1}^{6} W_h \bar{y}_h \tag{3}$$

where the weighting factor $W_h = A_h/A$; $A_h$ is the total area of the *h*th stratum, and A is the combined area of all strata. The variance of (3) was estimated as:

$$\mathrm{var}\left(\hat{P}_{ps}\right) = \mathrm{var}\left(\bar{y}_{ps}\right) = \sum_{h=1}^{6} W_h^2 s_h^2 / n_h \tag{4}$$

The standard error for individual strata is estimated as the square root of (2), and for the combined strata, as the square root of (4). Trends over time were tested by ANOVA using SAS software (v 9.4).

### 2.4.4 B-IBI Salinity Habitat Class Correction in 2018

Because of high precipitation in the Chesapeake Bay region, salinities were very low in summer 2018. Areas in the upper Chesapeake Bay that are in the low mesohaline range, had tidal freshwater bottom salinities at the time of sampling. The species composition of the 2018 probability-based sites was compared with the species composition of nearby sites sampled in 2017. The species composition was similar in both years. However, because of habitat salinity class differences, the B-IBI was quite different when calculated on the lower salinity classes of 2018; it tended to over-estimate benthic community condition. Therefore, a salinity habitat class correction was necessary for making the B-IBI more comparable to previous years. Box plots of bottom salinity were constructed for all sites, 1995-2017. Six years for which the salinity was clearly too high or too low (1995, 1996, 1999, 2002, 2004, and 2011) were removed. Using GIS, the bottom salinity values of the remaining years were mapped and the 2018 sites were superimposed on the map. The salinity class of the 2018 sites was then re-assigned to reflect the predominant salinity class of the average year. Some of the 2018 sites did not need re-assignment because their salinity, although low (e.g., 6) was still within the salinity class of the average year (e.g., 5-12). Affected sites included sites in each of the sampling strata in Maryland and Virginia (Table 2-6). Habitat class corrections were also made in 2011 because of very low salinity in Maryland after Hurricane Irene and Tropical Storm Lee (see the Methods Section of the 2012 through 2018 Level-I reports).

Table 2-6. Salinity class correction for 2018.

| Stratum | Site | Original | Corrected |
|---|---|---|---|
| Maryland Mid Bay Mainstem | MMS-25507 | Low Mesohaline | High Mesohaline |
| | MMS-25509 | Low Mesohaline | High Mesohaline |
| | MMS-25510 | Low Mesohaline | High Mesohaline |
| | MMS-25512 | Low Mesohaline | High Mesohaline |
| | MMS-25514 | Low Mesohaline | High Mesohaline |
| | MMS-25515 | Low Mesohaline | High Mesohaline |
| | MMS-25517 | Oligohaline | Low Mesohaline |
| | MMS-25520 | Low Mesohaline | High Mesohaline |
| | MMS-25523 | Low Mesohaline | High Mesohaline |
| Maryland Eastern Tributaries | MET-25413 | Oligohaline | Low Mesohaline |
| | MET-25415 | Oligohaline | Low Mesohaline |
| | MET-25416 | Oligohaline | Low Mesohaline |
| | MET-25422 | Tidal Fresh | Oligohaline |
| | MET-25423 | Tidal Fresh | Oligohaline |
| | MET-25425 | Tidal Fresh | Oligohaline |
| Maryland Western Tributaries | MWT-25303 | Oligohaline | Low Mesohaline |
| | MWT-25304 | Oligohaline | Low Mesohaline |
| | MWT-25305 | Oligohaline | Low Mesohaline |
| | MWT-25306 | Oligohaline | Low Mesohaline |
| | MWT-25307 | Oligohaline | Low Mesohaline |
| | MWT-25308 | Oligohaline | Low Mesohaline |
| | MWT-25309 | Oligohaline | Low Mesohaline |
| | MWT-25310 | Oligohaline | Low Mesohaline |
| | MWT-25311 | Oligohaline | Low Mesohaline |
| | MWT-25312 | Oligohaline | Low Mesohaline |
| | MWT-25313 | Oligohaline | Low Mesohaline |
| | MWT-25317 | Oligohaline | Low Mesohaline |
| | MWT-25318 | Tidal Fresh | Oligohaline |
| | MWT-25319 | Tidal Fresh | Oligohaline |
| | MWT-25320 | Tidal Fresh | Low Mesohaline |
| | MWT-25321 | Tidal Fresh | Oligohaline |
| | MWT-25322 | Tidal Fresh | Oligohaline |
| | MWT-25324 | Tidal Fresh | Oligohaline |
| | MWT-25325 | Tidal Fresh | Oligohaline |
| | MWT-25326 | Oligohaline | Low Mesohaline |

Table 2-6. (Continued)

| Stratum | Site | Original | Corrected |
|---|---|---|---|
| Maryland Upper Bay Mainstem | UPB-25604 | Oligohaline | Low Mesohaline |
| | UPB-25605 | Oligohaline | Low Mesohaline |
| | UPB-25607 | Oligohaline | Low Mesohaline |
| | UPB-25608 | Oligohaline | Low Mesohaline |
| | UPB-25609 | Oligohaline | Low Mesohaline |
| | UPB-25610 | Oligohaline | Low Mesohaline |
| | UPB-25611 | Oligohaline | Low Mesohaline |
| | UPB-25612 | Oligohaline | Low Mesohaline |
| | UPB-25613 | Oligohaline | Low Mesohaline |
| | UPB-25614 | Oligohaline | Low Mesohaline |
| | UPB-25615 | Oligohaline | Low Mesohaline |
| | UPB-25616 | Oligohaline | Low Mesohaline |
| | UPB-25617 | Tidal Fresh | Low Mesohaline |
| | UPB-25621 | Tidal Fresh | Oligohaline |
| | UPB-25622 | Tidal Fresh | Oligohaline |
| | UPB-25623 | Tidal Fresh | Oligohaline |
| Patuxent River | PXR-25201 | Low Mesohaline | High Mesohaline |
| | PXR-25202 | Low Mesohaline | High Mesohaline |
| | PXR-25203 | Low Mesohaline | High Mesohaline |
| | PXR-25204 | Low Mesohaline | High Mesohaline |
| | PXR-25205 | Low Mesohaline | High Mesohaline |
| | PXR-25206 | Low Mesohaline | High Mesohaline |
| | PXR-25207 | Low Mesohaline | High Mesohaline |
| | PXR-25208 | Low Mesohaline | High Mesohaline |
| | PXR-25209 | Low Mesohaline | High Mesohaline |
| | PXR-25210 | Low Mesohaline | High Mesohaline |
| | PXR-25221 | Oligohaline | Low Mesohaline |
| | PXR-25222 | Oligohaline | Low Mesohaline |
| | PXR-25223 | Oligohaline | Low Mesohaline |
| Potomac River | PMR-25104 | Low Mesohaline | High Mesohaline |
| | PMR-25105 | Low Mesohaline | High Mesohaline |
| | PMR-25106 | Low Mesohaline | High Mesohaline |
| | PMR-25108 | Low Mesohaline | High Mesohaline |
| | PMR-25109 | Oligohaline | Low Mesohaline |
| | PMR-25110 | Low Mesohaline | High Mesohaline |

Table 2-6. (Continued)

| Stratum | Site | Original | Corrected |
|---|---|---|---|
| Potomac River (continued) | PMR-25112 | Oligohaline | Low Mesohaline |
| | PMR-25114 | Oligohaline | Low Mesohaline |
| | PMR-25115 | Oligohaline | Low Mesohaline |
| | PMR-25116 | Oligohaline | Low Mesohaline |
| | PMR-25117 | Tidal Fresh | Low Mesohaline |
| | PMR-25118 | Tidal Fresh | Low Mesohaline |
| | PMR-25119 | Oligohaline | Low Mesohaline |
| | PMR-25120 | Tidal Fresh | Oligohaline |
| | PMR-25121 | Oligohaline | Low Mesohaline |
| | PMR-25122 | Tidal Fresh | Oligohaline |
| Virginia Mainstem | VBY-25M04 | High Mesohaline | Polyhaline |
| | VBY-25M09 | High Mesohaline | Polyhaline |
| | VBY-25M11 | High Mesohaline | Polyhaline |
| | VBY-25M22 | Low Mesohaline | High Mesohaline |
| Rappahannock River | RAP-25R01 | Low Mesohaline | High Mesohaline |
| | RAP-25R02 | Low Mesohaline | High Mesohaline |
| | RAP-25R04 | Low Mesohaline | High Mesohaline |
| | RAP-25R06 | Low Mesohaline | High Mesohaline |
| | RAP-25R07 | Low Mesohaline | High Mesohaline |
| | RAP-25R09 | Low Mesohaline | High Mesohaline |
| | RAP-25R11 | Low Mesohaline | High Mesohaline |
| | RAP-25R14 | Low Mesohaline | High Mesohaline |
| | RAP-25R15 | Low Mesohaline | High Mesohaline |
| | RAP-25R18 | Tidal Fresh | Oligohaline |
| | RAP-25R19 | Tidal Fresh | Oligohaline |
| | RAP-25R20 | Tidal Fresh | Oligohaline |
| | RAP-25R26 | Tidal Fresh | Low Mesohaline |
| York River | YRK-25Y01 | High Mesohaline | Polyhaline |
| | YRK-25Y03 | High Mesohaline | Polyhaline |
| | YRK-25Y05 | High Mesohaline | Polyhaline |
| | YRK-25Y23 | Tidal Fresh | Oligohaline |

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# 3.0 RESULTS

## 3.1 TRENDS IN FIXED SITE BENTHIC CONDITION

Trend analysis is conducted on 27 fixed sites located throughout the Bay and its tributaries to assess whether benthic community condition is changing. Through 2008 the sites were sampled yearly in the spring and summer. Since 2009, sites are sampled in the summer only. Trend analysis is performed on the summer data only in order to apply the B-IBI (Weisberg et al. 1997; Alden et al. 2002). B-IBI calculations and trend analysis methods are described in Section 2.4.

The B-IBI is the primary measure used in trend analysis because it integrates several benthic community attributes into a measure of overall condition. It provides context for interpretation of observed trends because status has been calibrated to reference conditions. Significant trends that result in a change of status (sites that previously met the Chesapeake Bay benthic community restoration goals which now fail, or vice versa) are of greater management interest than trends which do not result in a change. As a first step in identifying causes of changes in condition, trends on individual attributes are identified and examined.

Table 3-1 presents trends in benthic community condition from 1985 to the present. Although the Maryland benthic monitoring component began sampling in 1984, data collected in the first year of our program were excluded from analysis to facilitate comparison of results with other components of the monitoring program. Several components of the Maryland program as well as the Virginia Benthic Monitoring Program did not start sampling until 1985. Forty-year (1985-2024) trends are presented for 23 of the 27 trend sites, 36-year trends are presented for two sites in Baltimore Harbor (Stations 201 and 202) first sampled in 1989, and 30-year trends are presented for two western shore tributaries (Back River Station 203, and Severn River Station 204) first sampled in 1995. Maps of the trend site locations and results are shown in Figures 3-1 and 3-2. These maps include additional results for 21 trend sites monitored by the Virginia Benthic Monitoring Program to provide current conditions for the entire Chesapeake Bay.

Statistically significant B-IBI trends (10% significance level) were detected at 18 of the 27 fixed sites in Maryland (Table 3-1). If a 5% significance level is chosen, the number of statistically significant B-IBI trends is 16. The 10% level is kept for consistency with previous results. One trend (declining) appeared with the addition of the 2024 data. Trends in benthic community condition declined at 13 sites (significantly decreasing B-IBI score) and improved at 5 sites (significantly increasing B-IBI score). The directions of the trends did not change over those reported for 2023.

Sites with improving condition (Table 3-1, Figure 3-2) were located in the upper Bay mainstem (Station 026), Elk River (Station 029), mesohaline Choptank River (Station

064), Bear Creek (Station 201), and Back River (Station 203). Sites with declining condition (Table 3-1, Figure 3-2) were located in the mid-Bay mainstem at Calvert Cliffs (Stations 001 and 006), Baltimore Harbor (Station 022), tidal freshwater Potomac River (Station 036), mesohaline Potomac River at Morgantown (Stations 043 and 047), deep mesohaline Potomac River at St. Clements Island (Station 052), Nanticoke River (Station 062), oligohaline Choptank River (Station 066), Patuxent River at Broomes Island (Station 071), Patuxent River at Holland Cliff (Station 077), Curtis Bay (Station 202), and Severn River (Station 204). The only change in 2024 from the 2023 results was the appearance of a declining B-IBI trend in the mid-Bay mainstem (Station 006).

Using the last three years of data (2022-2024), the average B-IBI score remained within the same condition category at all of the fixed sites (Table 3-1). Currently, 7 sites meet the benthic community restoration goals and 20 sites fail the goals. Six of the failing sites were severely degraded (Table 1, Figure 3-1).

Trends in community attributes that are components of the B-IBI are presented in Table 3-2 (mesohaline stations), Table 3-3 (oligohaline and tidal freshwater stations), and Appendix A. Sites with decreasing B-IBI trends had decreasing trends (below restorative thresholds) in abundance, biomass, or both, and usually in several other components of the B-IBI such as Shannon diversity and the abundance or biomass of pollution sensitive species (Tables 3-2 and 3-3). The Nanticoke River (Station 062) and the oligohaline Choptank River (Station 066) had increasing trends in abundance but these trends indicated degrading conditions due to excess abundance relative to thresholds. The mesohaline Potomac River at Morgantown (Stations 043 and 047) had decreasing trends in abundance that indicated improving conditions from excess abundance.

Several sites without B-IBI trends also exhibited statistically significant, degrading trends in abundance, biomass, or Shannon diversity (Table 3-2). Using the Mann-Kendall test, 14 sites had significant degrading trends in abundance, 14 sites had significant degrading trends in biomass, and 15 sites had significant degrading trends in Shannon diversity. These sites tended to be in the mesohaline region of the estuary. Patterns in this region of the estuary also revealed overall lower abundance during the 1998-2024 period than during the 1984-1997 period.

Independently of the B-IBI, when the data are examined in relation to the metric thresholds, some of the decreases in abundance over time were from values above the upper threshold for abundance (indicating benthic community degradation) to values within the good range for abundance. These changes reflected improvements in benthic condition. Declining trends in abundance below the upper threshold were statistically significant in the shallow mesohaline region of the Potomac River (Stations 043 and 047, Table 3-2) and in the Elk River (Station 029, Table 3-3). Conversely, three sites had significant increasing trends in abundance in the direction of excess abundance (degrading). These sites were located in the oligohaline region of the Potomac River

(Station 040), the oligohaline region of the Choptank River (Station 066), and the mesohaline Nanticoke River (Station 062) (Tables 3-2 and 3-3).

Looking at the 2024 year alone, a majority of the B-IBI scores remained about the same, with eight sites showing increases in B-IBI scores and five sites showing decreases (Figures 3-3 through 3-29). Increases in B-IBI scores were most pronounced in the mid-Bay mainstem Station 001, Patapsco River estuary Station 023, and Back River Station 203, suggesting better water quality in 2024 than in 2023 in these regions of the Chesapeake Bay. Decreases in B-IBI scores were most pronounced in the mesohaline Potomac River Station 051.

The Maryland mainstem at Calvert Cliffs (Station 001) showed an increase in abundance, biomass, and Shannon diversity above restorative thresholds in 2024, and an increase in the B-IBI score from 1.9 to 2.9. Station 006 at Calvert Cliffs also exhibited an increase in biomass and Shannon diversity in 2024 but more modestly, and the B-IBI score remained the same at 2.2. It should be noted that Station 001 was sampled closer to shore by 58 m in 2024 due to coastal flooding and an inability to collect a valid sample at the station location. Benthic community composition at Station 001 looked different in 2024. Therefore, the results for this site in 2024 should be viewed with caution.

Although detection of monotonic (consistently increasing or decreasing) trends in time series analysis is best achieved with robust, distribution-free tests such as the Mann-Kendall, Generalized Additive Model (GAM) analysis permits the examination of nonlinear relationships in the data. GAM was employed using two separate models. The first model is a simple linear model (the equivalent of a linear regression), and the second is a nonlinear smooth; both models use year as the predictor. Both models were run using B-IBI (mean of 3 replicate samples) as a response variable. The significance of each model was determined by an F test. The strength of the nonlinear relationship was determined using the effective degrees of freedom (edf) as described in the Methods Section of this report. To lessen the sensitive of 5-6 years of missing data on the results of the GAM, the period of analysis for Stations 006, 047, 062, and 077 was reduced to 1995-2024.

Figures 3-3 through 3-29 present the observed mean B-IBI data for each of the fixed sites, the predicted trend using GAM, and whether this trend is statistically significant (10% level). GAM model output variables are provided in Appendix B-1. GAM results revealed nonlinear relationships in the mid-Bay mainstem (Stations 001 and 006), Baltimore Harbor (Station 022), upper oligohaline Choptank River (Station 066), tidal fresh Potomac River (Station 036), shallow mesohaline Potomac River (Stations 043 and 047), and Patuxent River at Broomes Island (Station 071). A comparison of results between the Mann-Kendall (M-K) test and the GAM is provided in Appendix B-2. All of the trends identified as statistically significant by GAM were also identified as statistically significant by the M-K test. M-K identified additional trends that were not significant by GAM; however, except for a strong improving trend at Station 064, the latter M-K trends were incipient or moderately weak, with probability values between 1% and 5% (Appendix B-2). Thus GAM was less sensitive at identifying linear relationships in the data but was useful in identifying cycles in the data. Some trends that were strongly linear by M-K had strong nonlinear components identified in GAM, including Stations 001, 022, 036, 043, 047, and 071. The strong nonlinear cycles in the B-IBI at Stations 001 and 006 near Calvert Cliffs are probably related to shifts in summer hypoxia. This region of the Chesapeake Bay is often affected by the seiching (lifting) of deep hypoxic water onto the shallow flanks of the mainstem, an event that can impact benthic communities in shallow water and modulate their recovery over time.

The mesohaline Potomac River (Stations 043, 044, 047, 051, and 052) continued to exhibit depauperate conditions in 2024. There was a small increase in abundance at these sites in 2024, but biomass and B-IBI scores were low, below restorative thresholds. The low abundance, biomass and B-IBI scores at these sites reflected recent changes in benthic community structure, including the appearance of the non-indigenous polychaete *Hermundura americana* and the disappearance of long-term dominant species in the community.

The benthos of the Potomac River in 2024 was numerically dominated by *H. americana*. This species was first reported in Chesapeake Bay in the Elizabeth River in 2009, and by 2012 it spread into the James River (Figure 3-30). In 2018, *H. americana* was found in the Potomac River near Morgantown and in the Wicomico and Nanticoke rivers. Later it became invasive and expanded its range into other Maryland and Virginia estuaries. By 2024 *H. americana* had colonized a wide range of salinity, depth, and sediment types in Maryland estuaries and the James and Rappahannock rivers, and was first recorded in the York River (Figure 3-30). In the Potomac River, *H. americana* has spread to the mouth of the river and possibly displaced long-term dominant members of the benthic community in shallow mesohaline water (Figure 3-31). Two numerically dominant benthic species in the Potomac River, the polychaetes *Heteromastus filiformis* and *Marenzelleria viridis*, disappeared in 2019 with the irruption of *H. americana* (Figure 3-31). Interestingly, a similar pattern to that of Figure 3-31 is observed in the James River at Station LE5.1, but the appearance of *H. americana* and disappearance of *Marenzelleria viridis* in the James River occurred in 2013. *Hermundura americana* is fully part of the B-IBI.

Table 3-1. Summer trends in benthic community condition, 1985-2024. Trends were identified using the van Belle and Hughes (1984) procedure. Current mean B-IBI and condition are based on 2022-2024 values. Initial mean B-IBI and condition are based on 1985-1987 values, except where noted. NS: not significant; (a): 1989-1991 initial condition; (b): 1995-1997 initial condition. Shaded areas highlight changes in trend direction or condition category over those reported for 2023 (light gray = better; deep gray = worse).

| Station | Trend Significance | Median Slope (B-IBI units/yr) | Current Condition (2022-2024) | Initial Condition (1985-1987 unless otherwise noted) |
|---|---|---|---|---|
| **Potomac River** | | | | |
| 036 | $p < 0.05$ | –0.00 | 4.00 (Meets Goal) | 3.14 (Meets Goal) |
| 040 | NS | 0.00 | 3.0 (Meets Goal) | 2.80 (Marginal) |
| 043 | $p < 0.001$ | –0.03 | 2.47 (Degraded) | 3.76 (Meets Goal) |
| 044 | NS | 0.00 | 2.38 (Degraded) | 2.80 (Marginal) |
| 047 | $p < 0.001$ | –0.02 | 2.51 (Degraded) | 3.89 (Meets Goal) |
| 051 | NS | 0.00 | 2.33 (Degraded) | 2.43 (Degraded) |
| 052 | $p < 0.05$ | –0.00 | 1.15 (Severely Degraded) | 1.37 (Severely Degraded) |
| **Patuxent River** | | | | |
| 071 | $p < 0.001$ | –0.03 | 1.44 (Severely Degraded) | 2.52 (Degraded) |
| 074 | NS | 0.00 | 3.58 (Meets Goal) | 3.78 (Meets Goal) |
| 077 | $p < 0.05$ | –0.01 | 2.91 (Marginal) | 3.76 (Meets Goal) |
| 079 | NS | 0.00 | 2.94 (Marginal) | 2.75 (Marginal) |
| **Choptank River** | | | | |
| 064 | $p < 0.01$ | +0.02 | 3.93 (Meets Goal) | 2.78 (Marginal) |
| 066 | $p < 0.001$ | –0.02 | 1.98 (Severely Degraded) | 2.60 (Degraded) |
| **Maryland Mainstem** | | | | |
| 001 | $p < 0.01$ | –0.01 | 2.26 (Degraded) | 2.93 (Marginal) |
| 006 | $p < 0.10$ | –0.00 | 2.19 (Degraded) | 2.56 (Degraded) |
| 015 | NS | 0.00 | 2.41 (Degraded) | 2.22 (Degraded) |
| 024 | NS | 0.00 | 3.70 (Meets Goal) | 3.04 (Meets Goal) |
| 026 | $p < 0.05$ | +0.00 | 3.49 (Meets Goal) | 3.16 (Meets Goal) |
| **Maryland Western Shore Tributaries** | | | | |
| 022 | $p < 0.001$ | –0.02 | 1.44 (Severely Degraded) | 2.08 (Degraded) |
| 023 | NS | 0.00 | 2.24 (Degraded) | 2.49 (Degraded) |
| 201 | $p < 0.05$ | +0.00 | 1.84 (Severely Degraded) | 1.10 (Severely Degraded) (a) |
| 202 | $p < 0.10$ | –0.00 | 1.22 (Severely Degraded) | 1.40 (Severely Degraded) (a) |
| 203 | $p < 0.01$ | +0.02 | 2.30 (Degraded) | 2.08 (Degraded) (b) |
| 204 | $p < 0.05$ | –0.02 | 2.78 (Marginal) | 3.67 (Meets Goal) (b) |
| **Maryland Eastern Shore Tributaries** | | | | |
| 029 | $p < 0.01$ | +0.01 | 2.89 (Marginal) | 2.38 (Degraded) |
| 062 | $p < 0.001$ | –0.05 | 2.24 (Degraded) | 3.42 (Meets Goal) |
| 068 | NS | 0.00 | 3.67 (Meets Goal) | 3.51 (Meets Goal) |

Table 3-2. Summer trends in benthic community attributes at mesohaline stations 1985-2024. Monotonic trends were identified using the van Belle and Hughes (1984) procedure. ⇑: Increasing trend; ⇓: Decreasing trend. *: $p<0.1$; **: $p<0.05$; ***: $p<0.01$; shaded trend cells indicate increasing degradation; unshaded trend cells indicate unchanging or improving conditions; (a): trends based on 1989-2024 data; (b): trends based on 1995-2024 data; (c): attribute trend based on 1990-2024 data; (d): attributes are used in B-IBI calculations when species specific biomass is unavailable; NA: attribute is not part of the reported B-IBI. Blanks indicate no trend (not significant). See Appendix A for further detail.

| Station | B-IBI | Abundance | Biomass | Shannon Diversity | Indicative Abundance | Sensitive Abundance | Indicative Biomass (c) | Sensitive Biomass (c) | Abundance Carnivore/ Omnivores |
|---|---|---|---|---|---|---|---|---|---|
| **Potomac River** | | | | | | | | | |
| 043 | ⇓ *** | ⇓ *** | ⇓ *** | ⇓ *** | ⇑ ** | ⇓ *** (d) | NA | ⇓ *** | NA |
| 044 | | | ⇓ ** | ⇓ * | ⇓ *** | (d) | NA | | NA |
| 047 | ⇓ *** | ⇓ *** | ⇓ *** | ⇓ *** | | ⇓ *** (d) | NA | ⇓ *** | NA |
| 051 | | ⇓ *** | ⇓ *** | ⇓ * | ⇓ *** | | NA | ⇓ *** | ⇑ *** |
| 052 | ⇓ ** | ⇓ *** | ⇓ *** | ⇓ *** | ⇑ * (d) | ⇓ ** (d) | | | |
| **Patuxent River** | | | | | | | | | |
| 071 | ⇓ *** | ⇓ *** | ⇓ *** | ⇓ *** | (d) | ⇓ ** (d) | ⇑ ** | | ⇓ * |
| 074 | | | ⇓ *** | | | ⇓ * (d) | NA | ⇓ *** | NA |
| 077 | ⇓ ** | ⇓ ** | ⇓ ** | | ⇑ * | (d) | NA | ⇑ ** | NA |
| **Choptank River** | | | | | | | | | |
| 064 | ⇑ *** | | ⇑ *** | ⇑ *** | ⇓ ** (d) | ⇑ *** (d) | | | |
| **Maryland Mainstem** | | | | | | | | | |
| 001 | ⇓ *** | ⇓ *** | | | ⇓ ** | ⇓ ** | NA | NA | ⇓ *** |
| 006 | ⇓ * | | | ⇓ * | ⇓ ** | ⇓ *** | NA | NA | ⇓ *** |
| 015 | | | ⇓ * | ⇓ *** | ⇓ *** | | NA | NA | |
| 024 | | | ⇑ *** | ⇓ *** | ⇓ *** (d) | ⇑ *** (d) | ⇓ * | ⇑ *** | |
| 026 | ⇑ ** | | | ⇑ * | | (d) | NA | ⇓ *** | NA |
| **Maryland Western Shore Tributaries** | | | | | | | | | |
| 022 | ⇓ *** | ⇓ *** | ⇓ ** | ⇓ *** | | (d) | NA | | NA |
| 023 | | ⇓ *** | | ⇓ *** | | ⇑ *** (d) | NA | | NA |
| 201(a) | ⇑ ** | ⇓ ** | ⇑ * | | ⇓ ** | ⇑ *** (d) | NA | ⇑ ** | NA |
| 202(a) | ⇓ * | ⇓ *** | | ⇓ *** | ⇑ * | (d) | NA | | NA |
| 204(b) | ⇓ ** | ⇓ *** | | ⇓ ** | (d) | ⇑ ** (d) | | | ⇓ *** |
| **Maryland Eastern Shore Tributaries** | | | | | | | | | |
| 062 | ⇓ *** | ⇑ *** | ⇓ *** | ⇓ ** | ⇑ *** | ⇓ *** (d) | NA | ⇓ *** | NA |
| 068 | | | ⇑ *** | ⇓ ** | | ⇑ * (d) | NA | | NA |

Table 3-3. Summer trends in benthic community attributes at oligohaline and tidal freshwater stations 1985-2024. Monotonic trends were identified using the van Belle and Hughes (1984) procedure. ⇑: Increasing trend; ⇓: Decreasing trend. *: $p<0.1$; **: $p<0.05$; ***: $p<0.01$; shaded trend cells indicate increasing degradation; unshaded trend cells indicate unchanging or improving conditions; (a): trends based on 1995-2024 data; NA: attribute not calculated. Blanks indicate no trend (not significant). See Appendix A for further detail.

| Station | B-IBI | Abundance | Tolerance Score | Freshwater Indicative Abundance | Oligohaline Indicative Abundance | Oligohaline Sensitive Abundance | Tanypodinae to Chironomidae Ratio | Abundance Deep Deposit Feeders | Abundance Carnivore/ Omnivores |
|---|---|---|---|---|---|---|---|---|---|
| **Potomac River** | | | | | | | | | |
| **036** | ⇓ ** | | ⇑ ** | ⇑ ** | NA | NA | NA | ⇑ * | NA |
| **040** | | ⇑ ** | | NA | | | | NA | |
| **Patuxent River** | | | | | | | | | |
| **079** | | | | | NA | NA | NA | | NA |
| **Choptank River** | | | | | | | | | |
| **066** | ⇓ *** | ⇑ *** | ⇑ *** | NA | ⇑ *** | ⇓ ** | ⇑ ** | NA | |
| **Maryland Western Shore Tributaries** | | | | | | | | | |
| **203(a)** | ⇑ *** | ⇓ * | | NA | ⇑ ** | | | NA | ⇑ *** |
| **Maryland Eastern Shore Tributaries** | | | | | | | | | |
| **029** | ⇑ *** | ⇓ *** | | NA | | ⇑ ** | | NA | ⇑ *** |

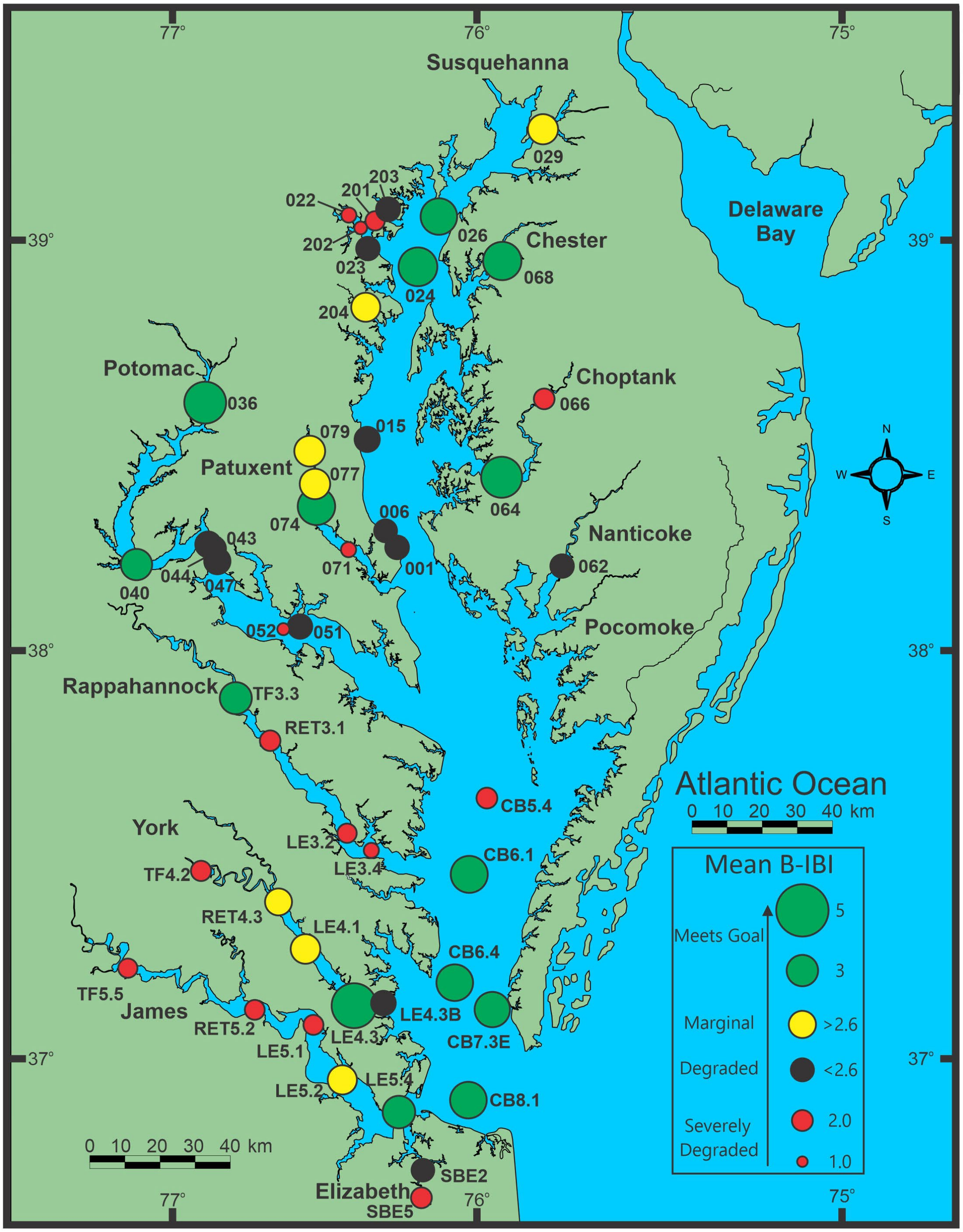


Figure 3-1. Summer status in benthic community condition at fixed sites. Status based on 2022-2024 mean B-IBI values. The size of the bubbles is proportional to the ratio of the mean value to the maximum possible value (5) of the B-IBI.

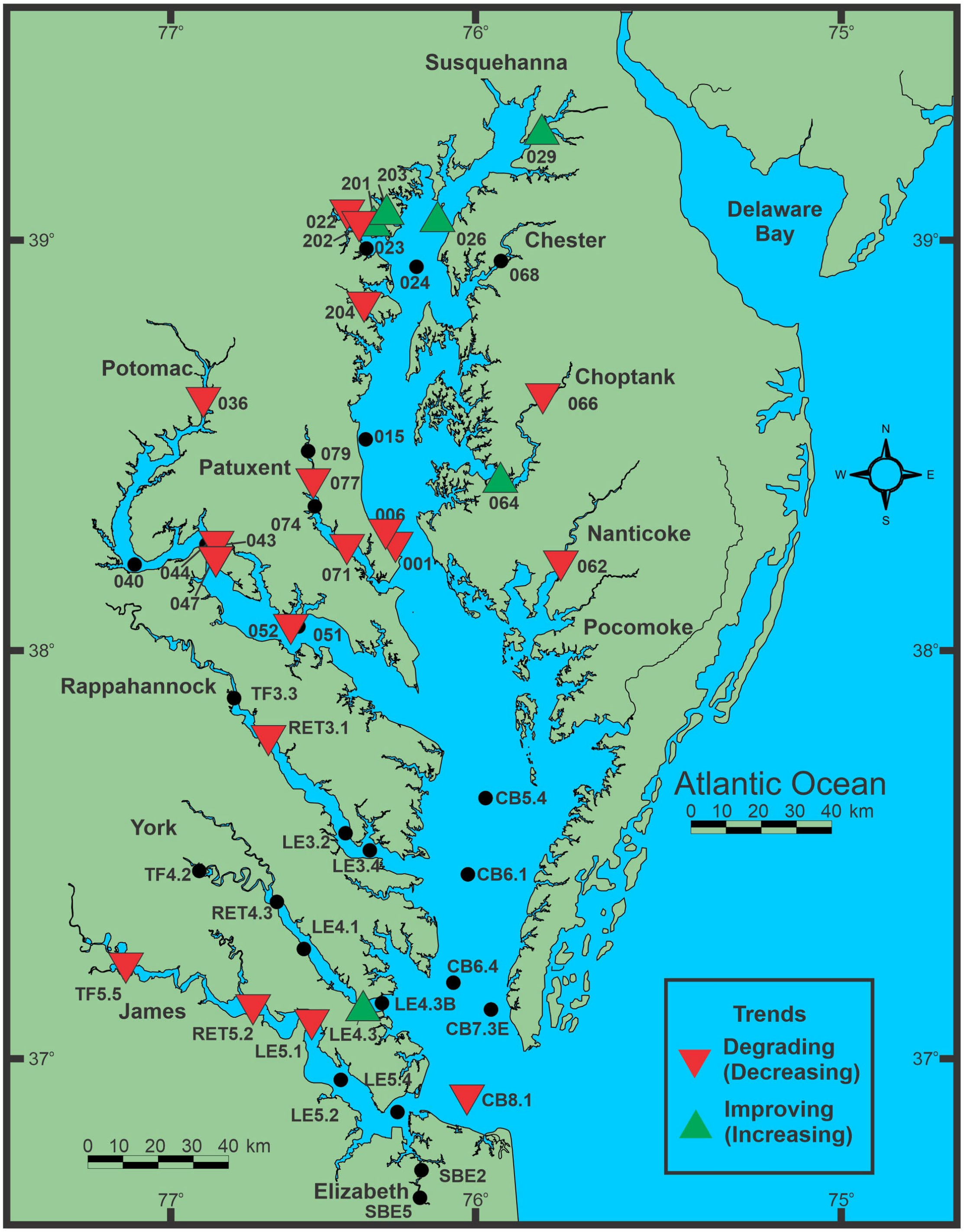


Figure 3-2. Summer trends in benthic community condition at fixed sites, 1985-2024. B-IBI trends were identified using the van Belle and Hughes procedure.

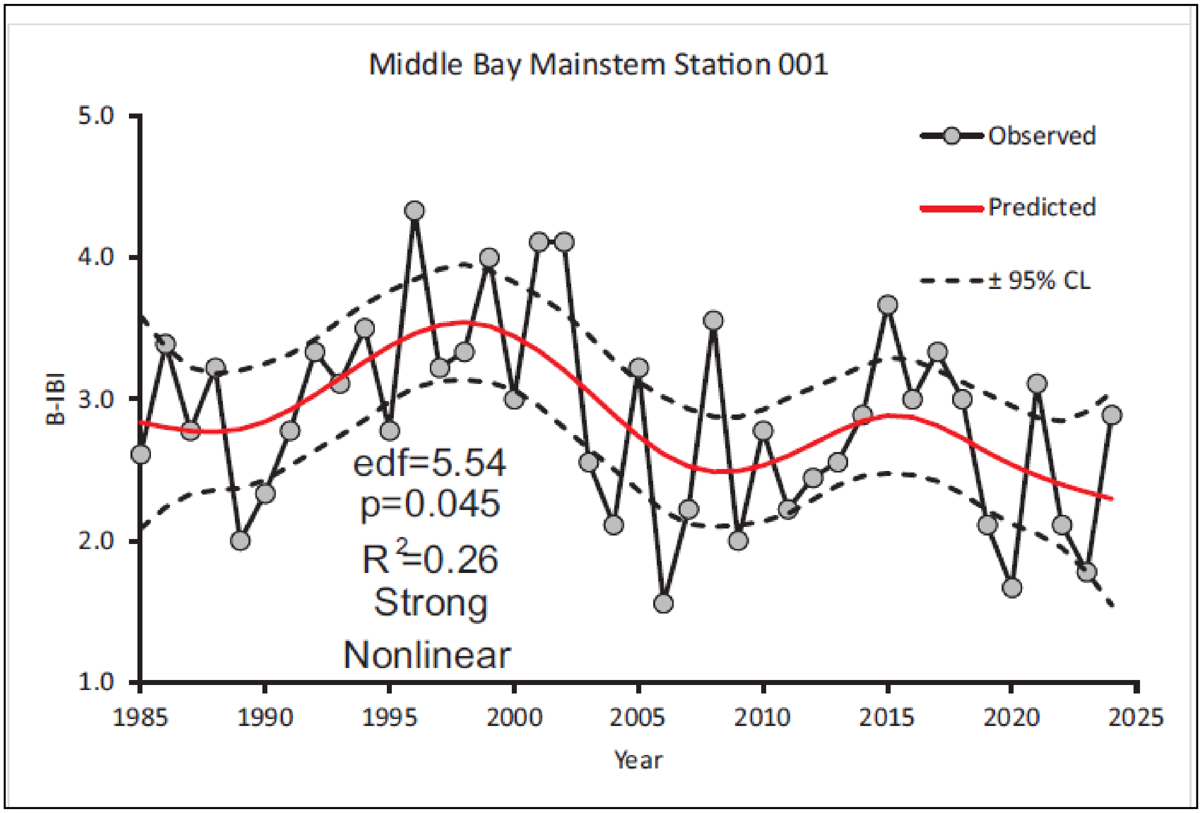


Figure 3-3. Trends in mean B-IBI at fixed sites. Station 001 = high mesohaline sand mid Bay mainstem (≤5 m) at Calvert Cliffs. The B-IBI for 2024 may not be representative of Station 001, see cautionary note in page 3-3 of this report

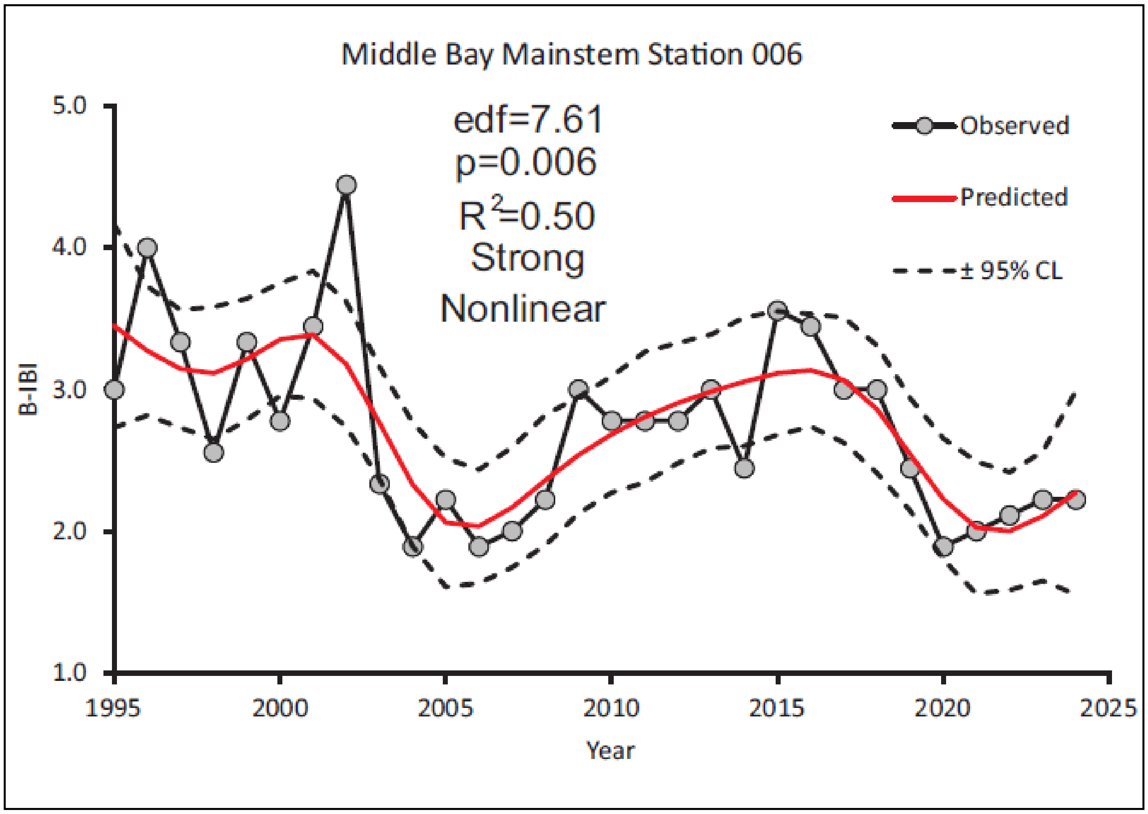


Figure 3-4. Trends in mean B-IBI at fixed sites. Station 006 = high mesohaline sand mid Bay mainstem (≤ 5 m) at Calvert Cliffs. Period of analysis reduced to 1995-2024 because of a 5-year data gap (1990-1994) where sampling was suspended because of program design changes

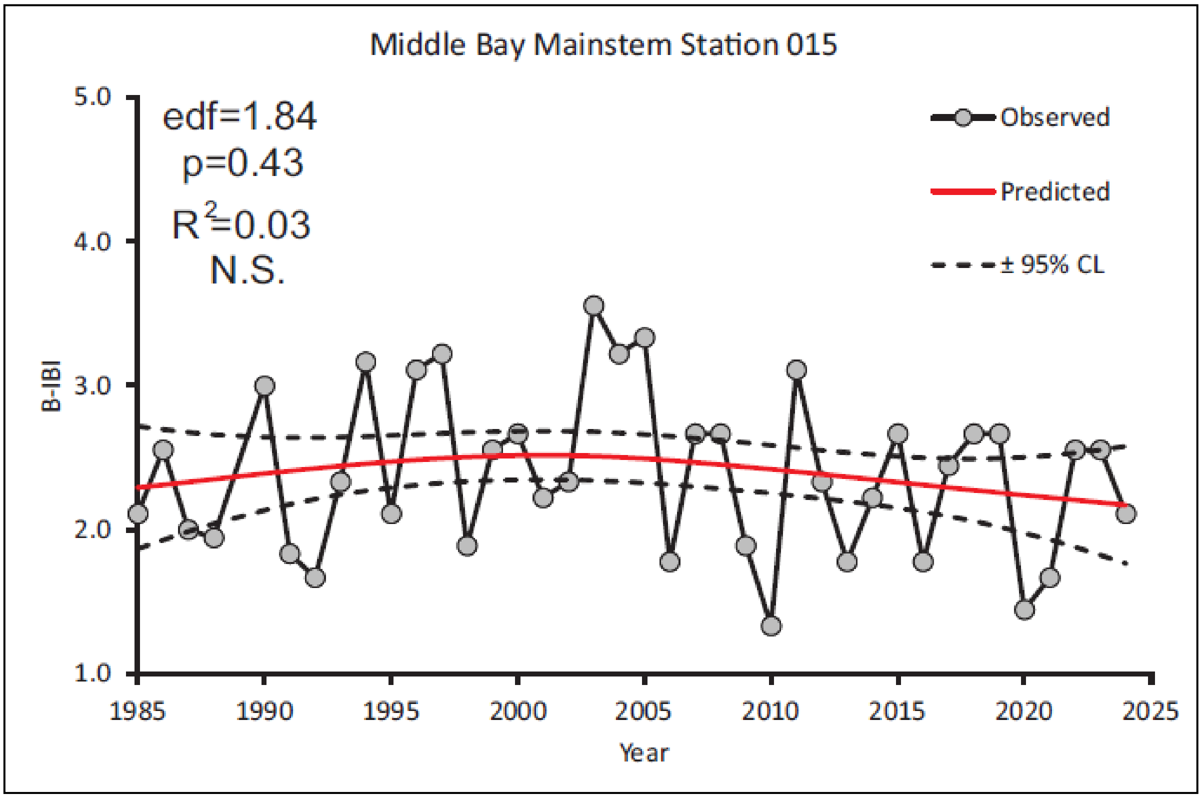


Figure 3-5. Trends in mean B-IBI at fixed sites. Station 015 = high mesohaline sand mid Bay mainstem (≤ 5 m) at North Beach. Data gap (1989) indicates period where sampling was suspended because of program design changes

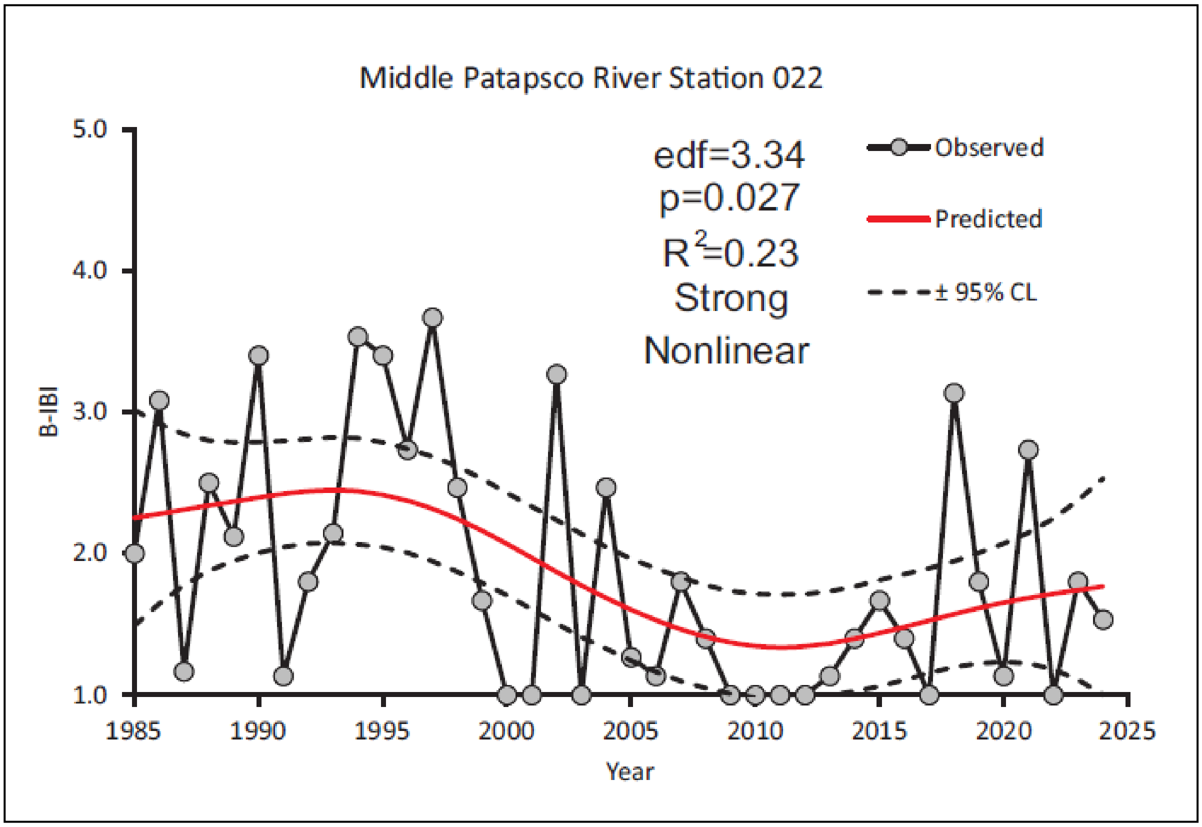


Figure 3-6. Trends in mean B-IBI at fixed sites. Station 022 = low mesohaline Patapsco River (2-6 m), Middle Branch.

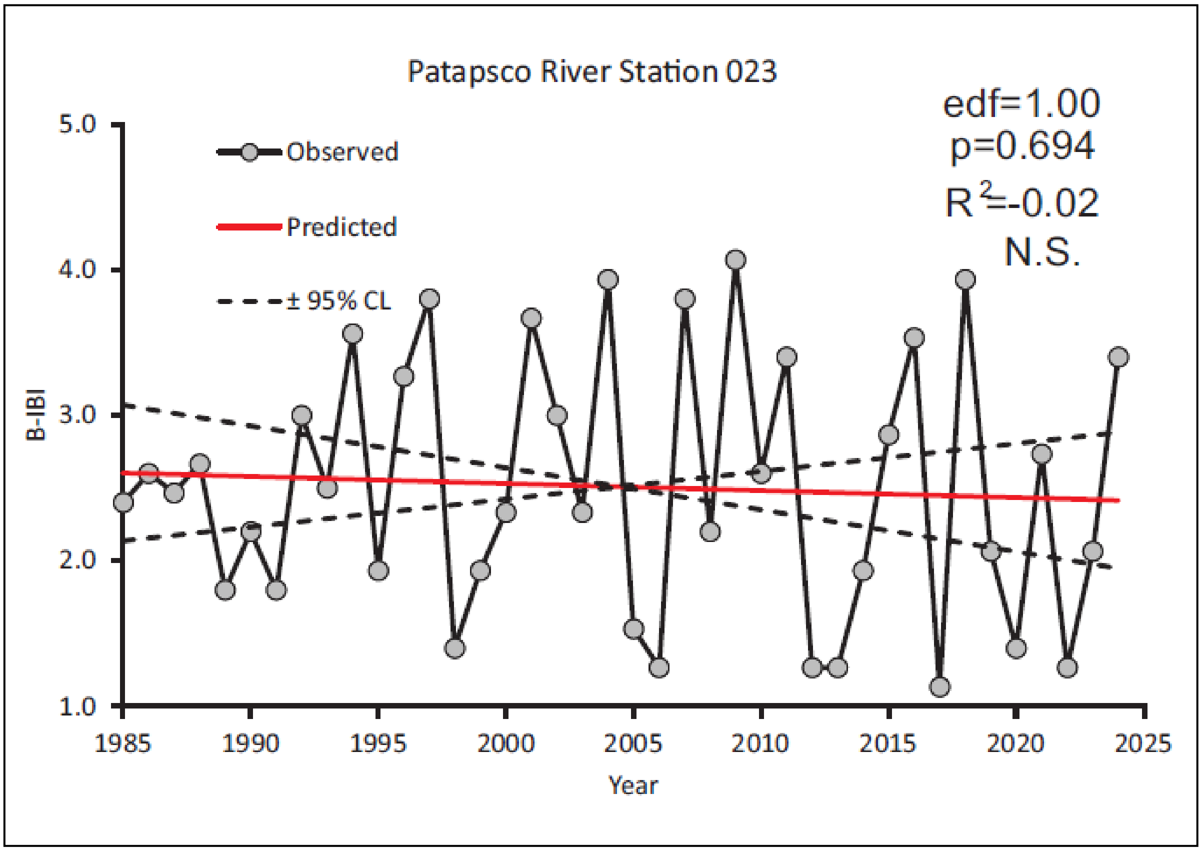


Figure 3-7. Trends in mean B-IBI at fixed sites. Station 023 = low mesohaline Patapsco River (4-7 m), lower mainstem.

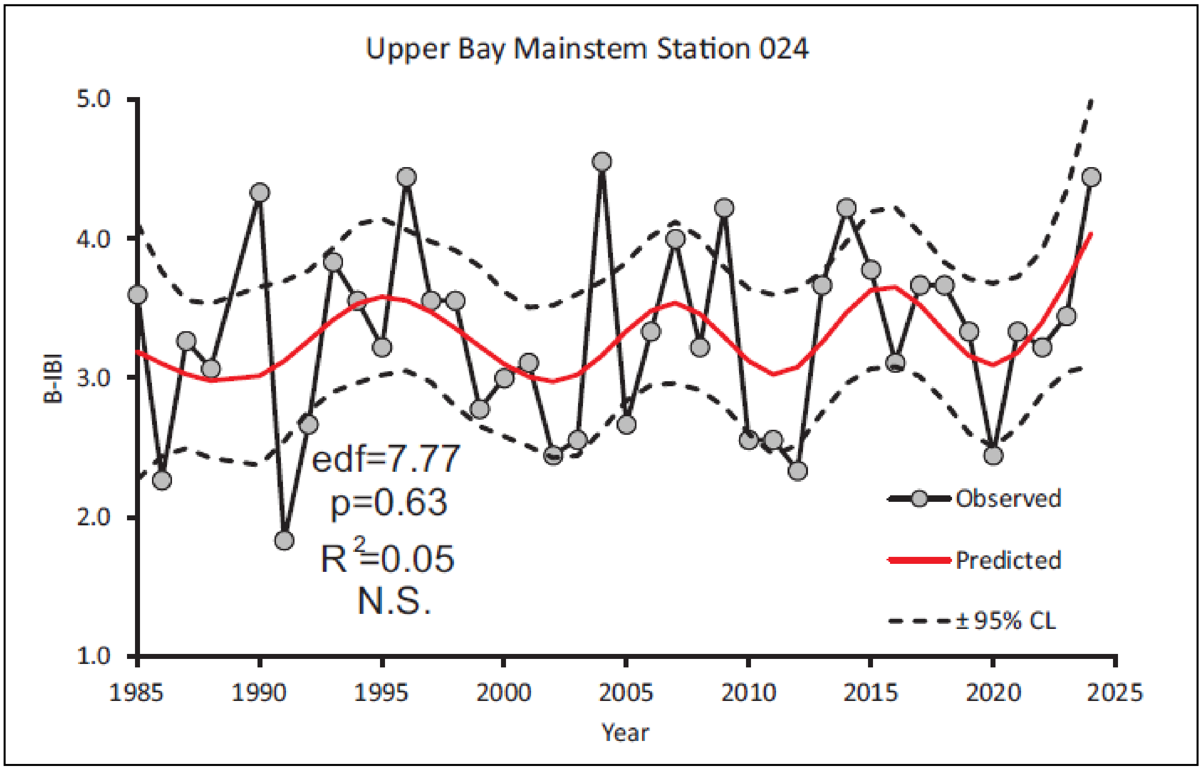


Figure 3-8. Trends in mean B-IBI at fixed sites. Station 024 = high mesohaline mud Upper Bay mainstem (5-8 m), near the mouth of the Patapsco River. Data gap (1989) indicates period where sampling was suspended because of program design changes

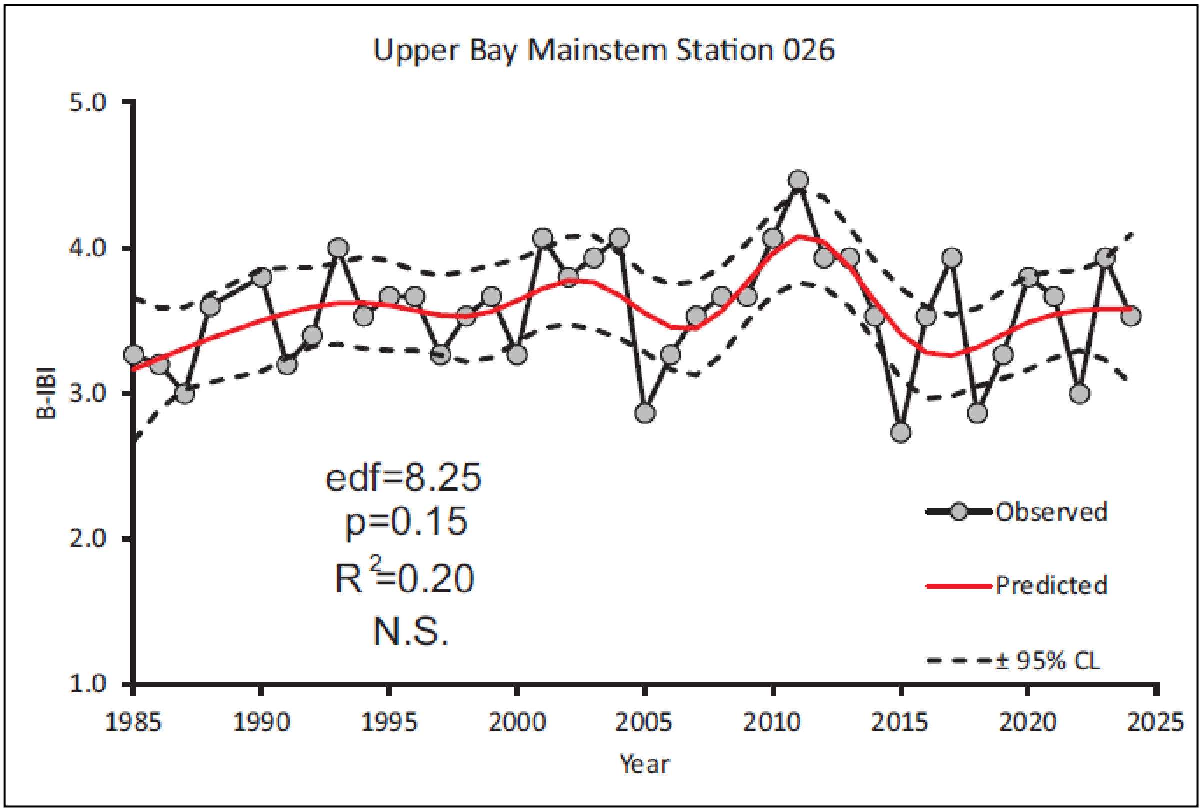


Figure 3-9. Trends in mean B-IBI at fixed sites. Station 026 = low mesohaline Upper Bay mainstem (2-5 m) at Pooles Island. Data gap (1989) indicates period where sampling was suspended because of program design changes

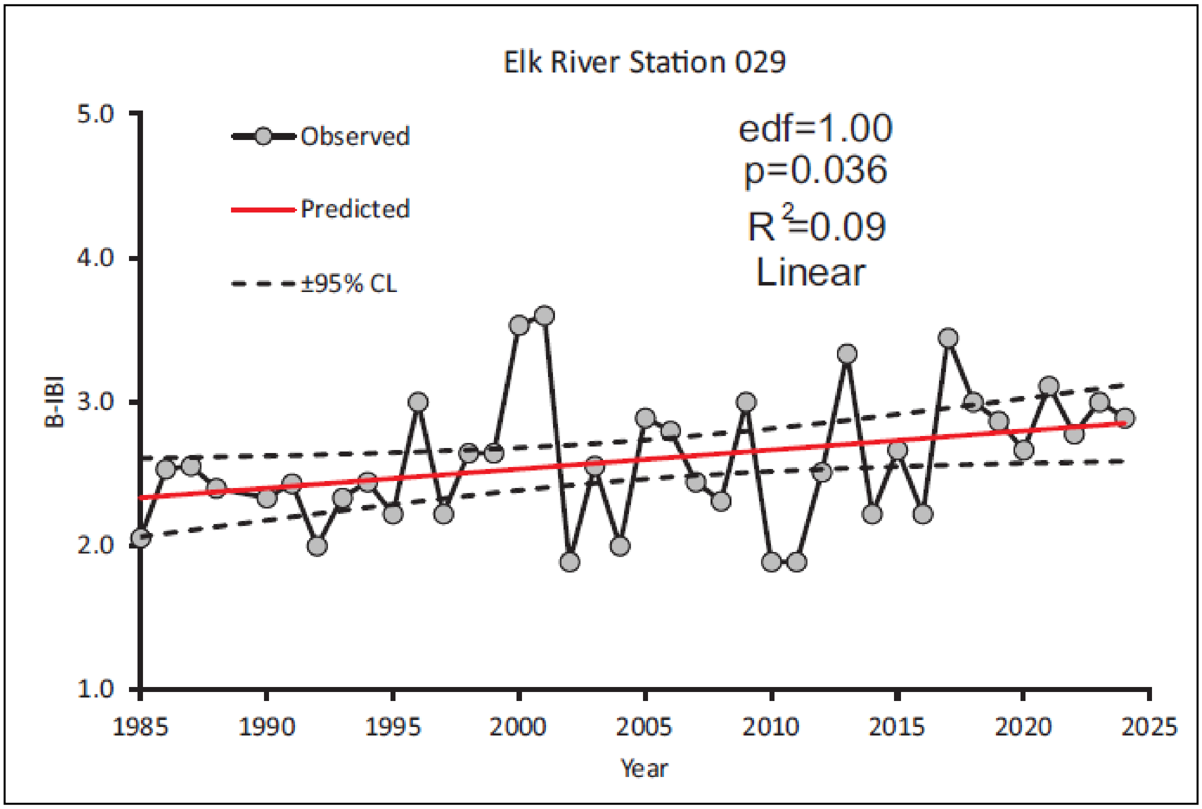


Figure 3-10. Trends in mean B-IBI at fixed sites. Station 029 = oligohaline Elk River. Data gap (1989) indicates period where sampling was suspended because of program design changes

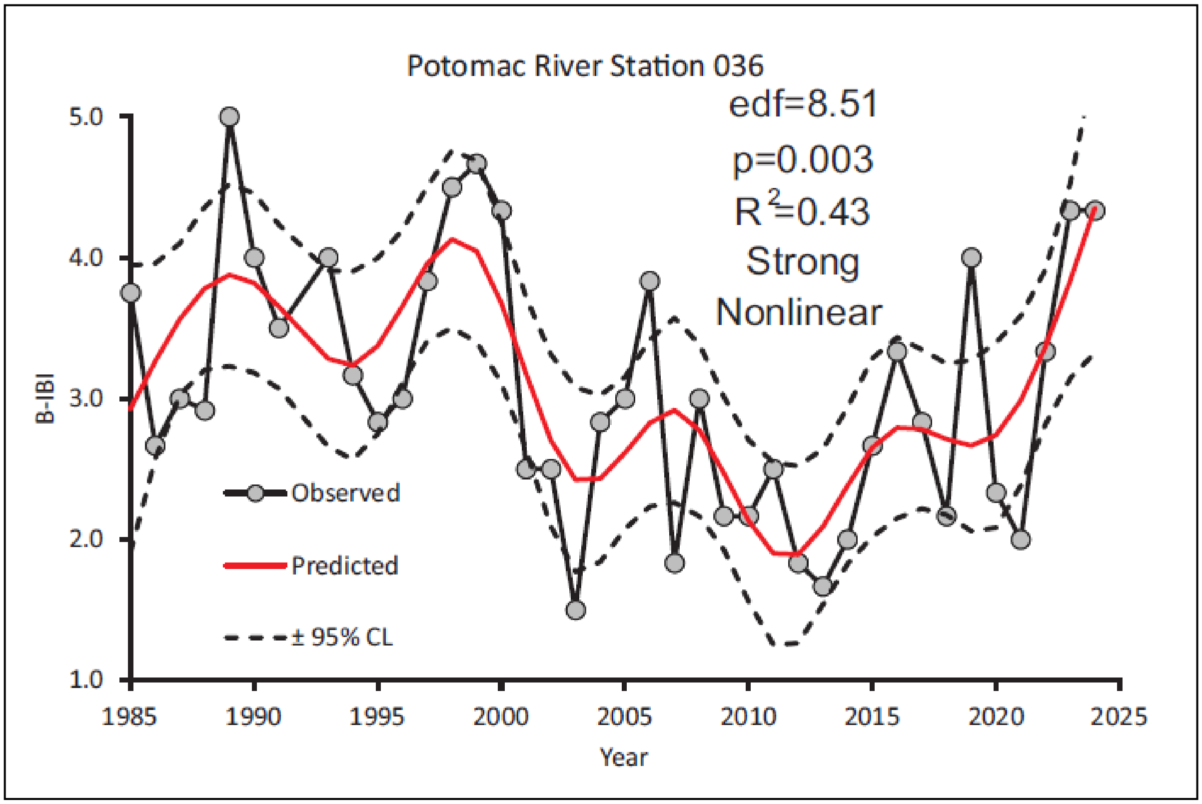


Figure 3-11. Trends in mean B-IBI at fixed sites. Station 036 = tidal fresh Potomac River (≤5 m) at Rosier Bluff. Data gap (1992) indicates period where sampling was suspended because of program design changes

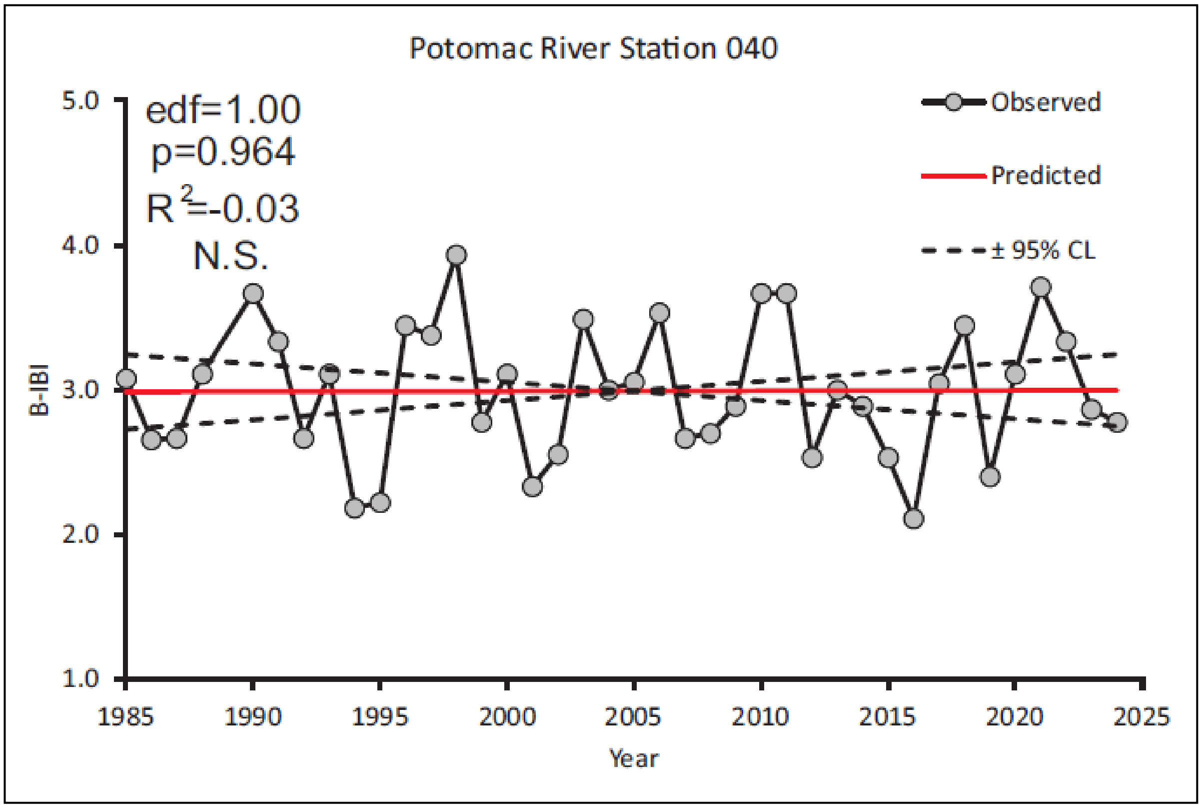


Figure 3-12. Trends in mean B-IBI at fixed sites. Station 040 = oligohaline Potomac River (6-10 m) at Maryland Point. Data gap (1989) indicates period where sampling was suspended because of program design changes

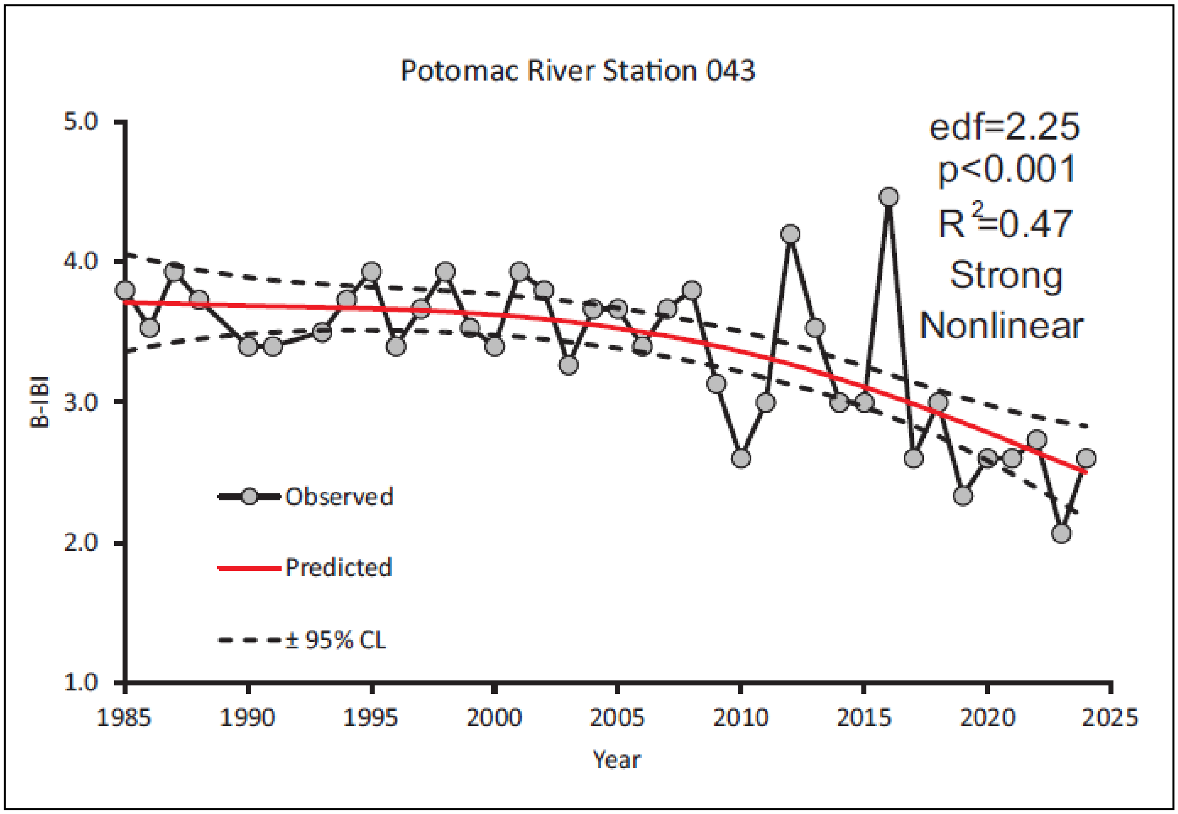


Figure 3-13. Trends in mean B-IBI at fixed sites. Station 043 = shallow (≤ 5 m), low mesohaline Potomac River at Morgantown. Data gap (1989) indicates period where sampling was suspended because of program design changes

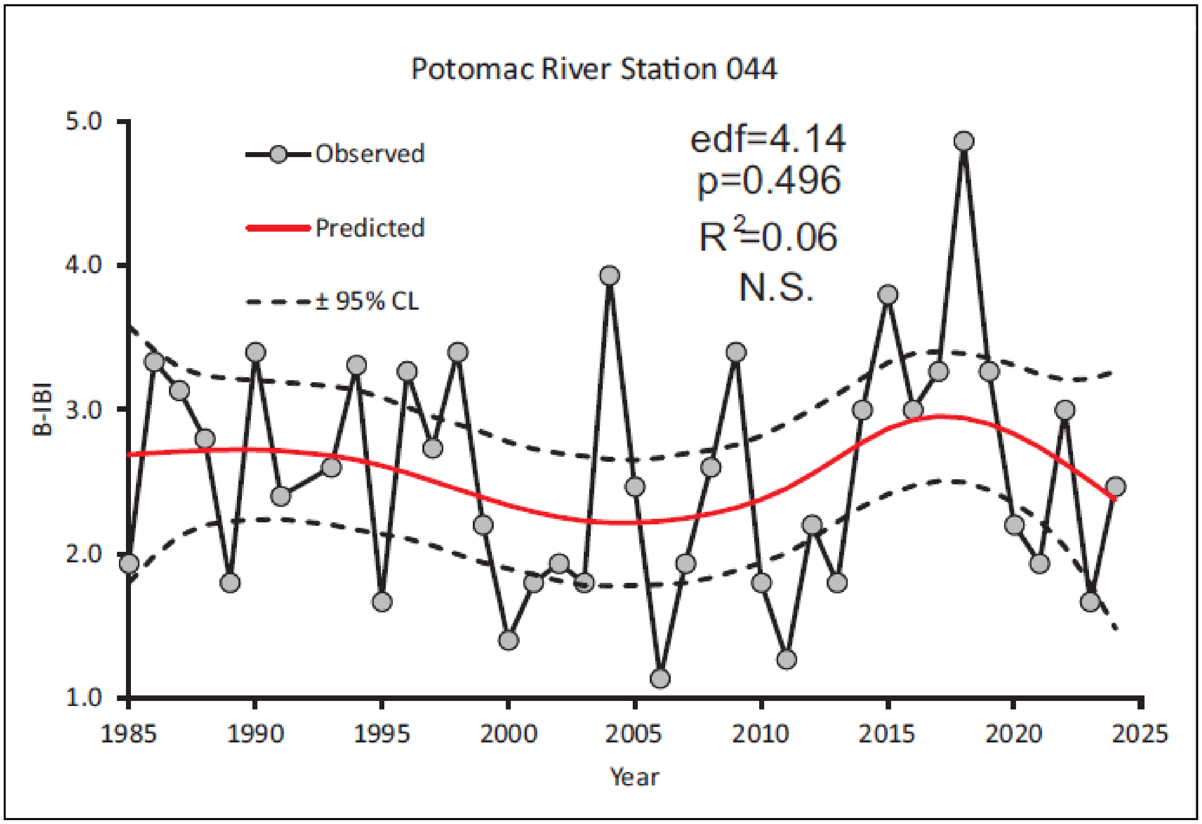


Figure 3-14. Trends in mean B-IBI at fixed sites. Station 044 = deep (11-17 m), low mesohaline Potomac River at Morgantown. Data gap (1992) indicates period where sampling was suspended because of program design changes

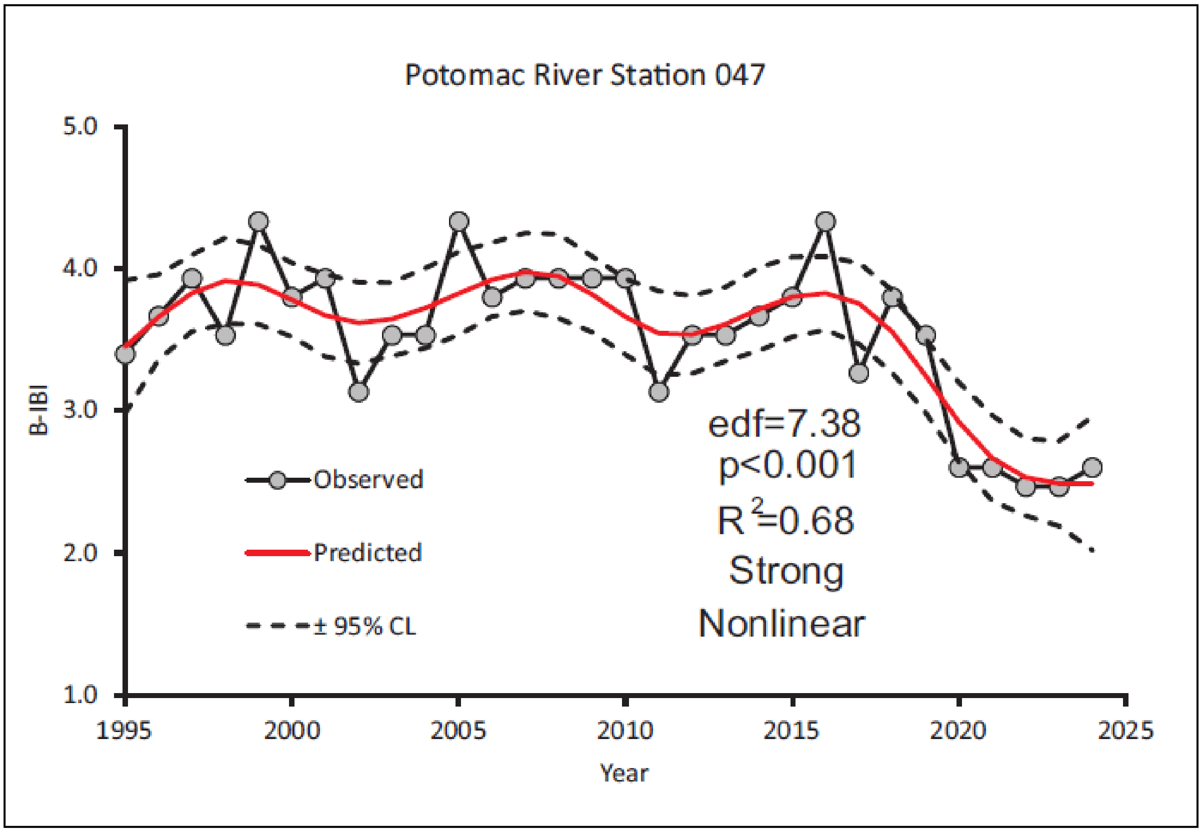


Figure 3-15. Trends in mean B-IBI at fixed sites. Station 047 = shallow (≤ 5 m), low mesohaline Potomac River at Morgantown. Period of analysis reduced to 1995-2024 because of a 6-year data gap (1989-1994) where sampling was suspended because of program design changes

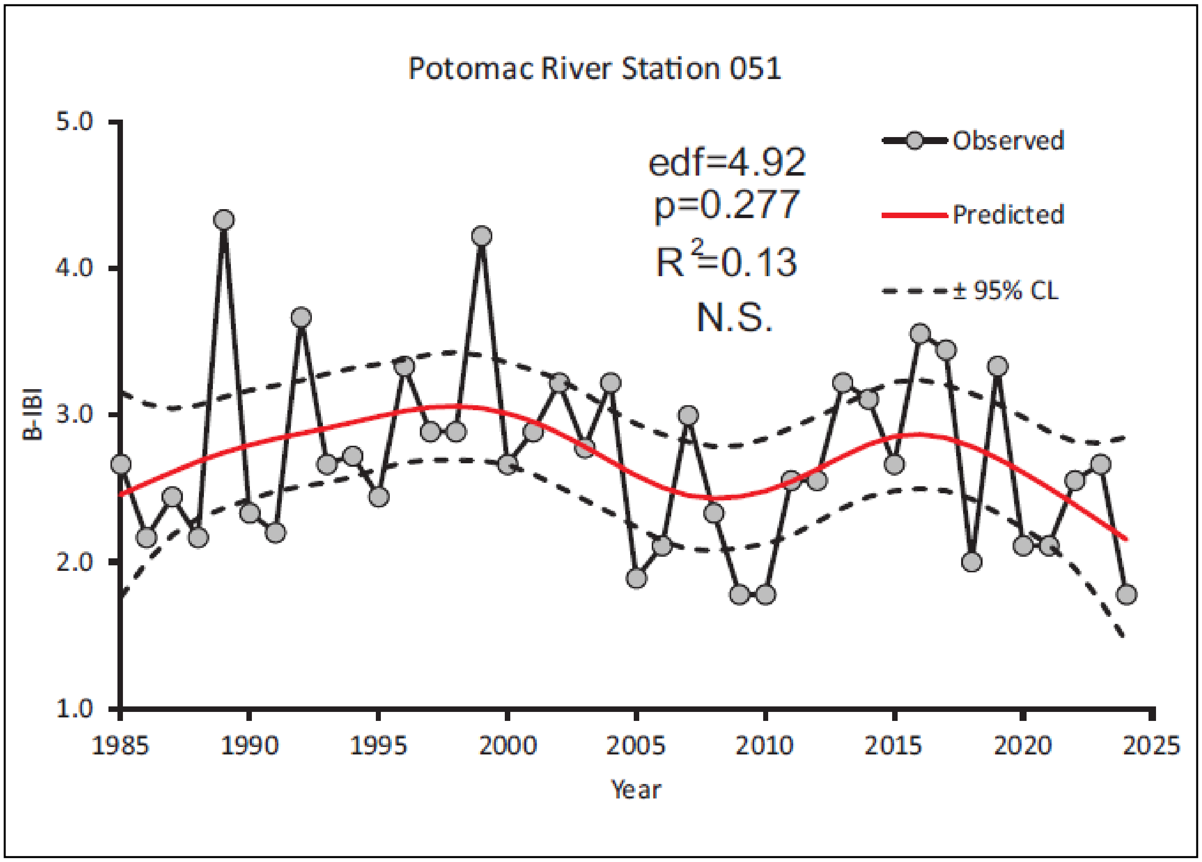


Figure 3-16. Trends in mean B-IBI at fixed sites. Station 051 = shallow (≤ 5 m), high mesohaline sand Potomac River (≤ 5 m) at St. Clements Island

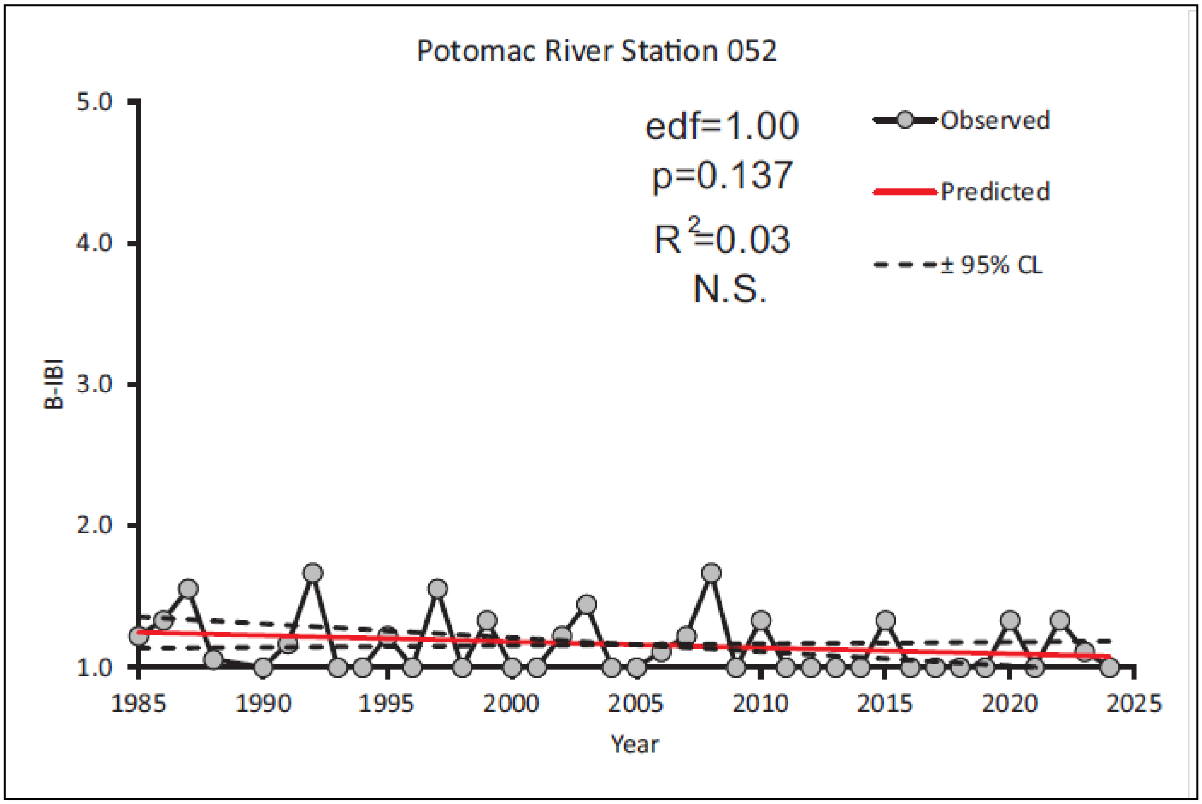


Figure 3-17. Trends in mean B-IBI at fixed sites. Station 052 = deep (9-13 m), high mesohaline mud Potomac River at St. Clements Island. Data gap (1989) indicates period where sampling was suspended because of program design changes

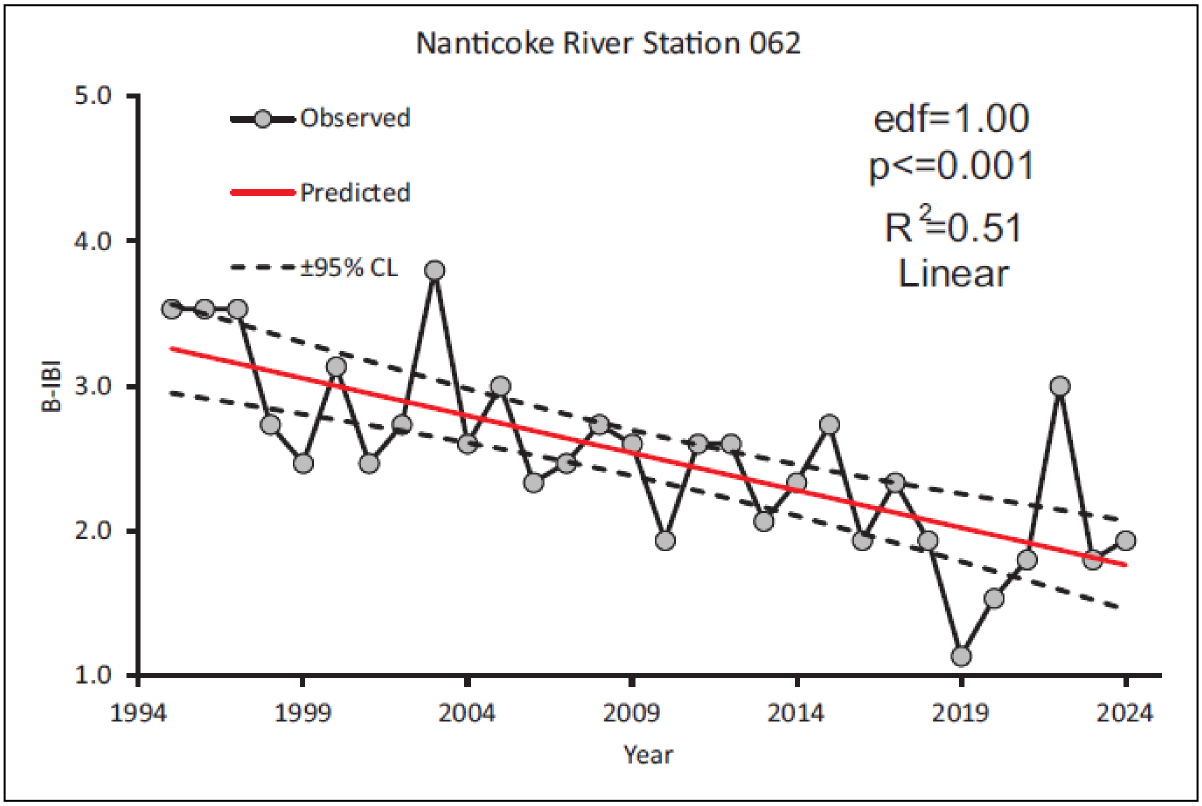


Figure 3-18. Trends in mean B-IBI at fixed sites. Station 062 = low mesohaline Nanticoke River. Period of analysis reduced to 1995-2024 because of a 6-year data gap (1989-1994) where sampling was suspended because of program design changes

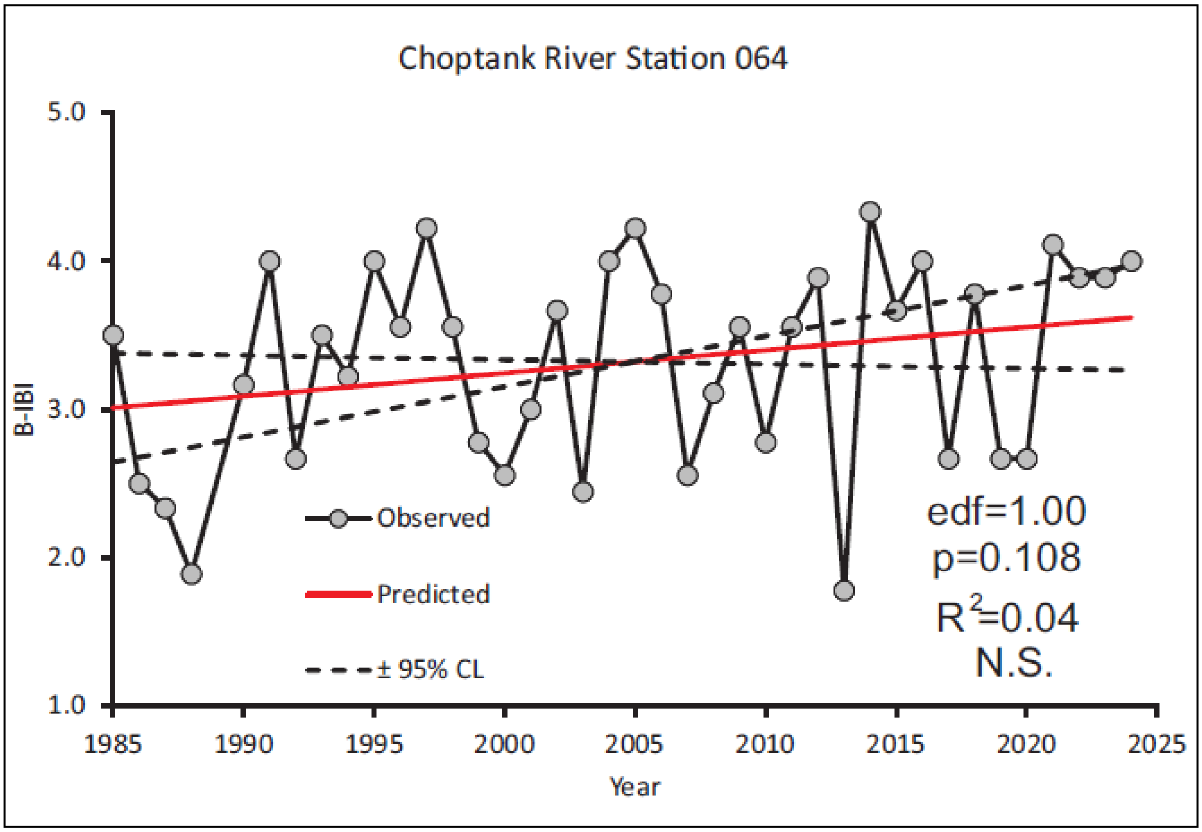


Figure 3-19. Trends in mean B-IBI at fixed sites. Station 064 = high mesohaline mud Choptank River. Data gap (1989) indicates period where sampling was suspended because of program design changes

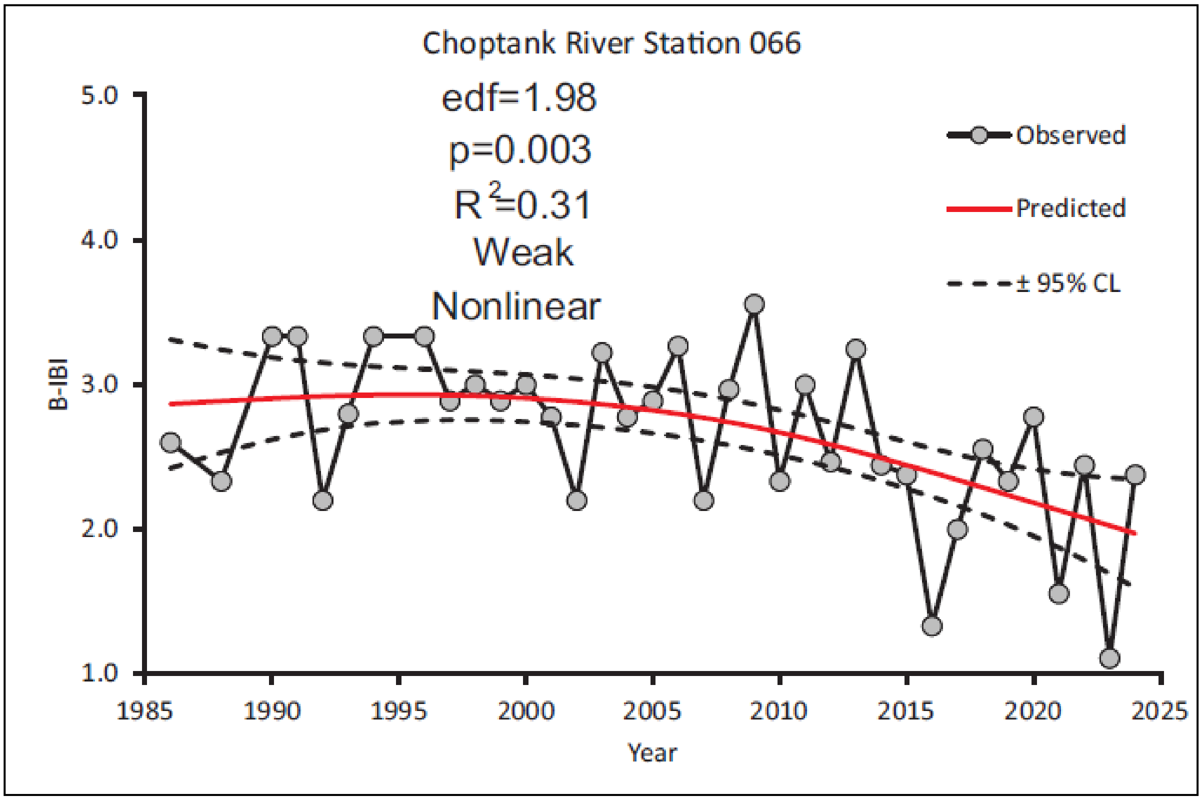


Figure 3-20. Trends in mean B-IBI at fixed sites. Station 066 = oligohaline Choptank River. Data gaps (1985, 1987, 1989) indicate periods where sampling was suspended because of program design changes

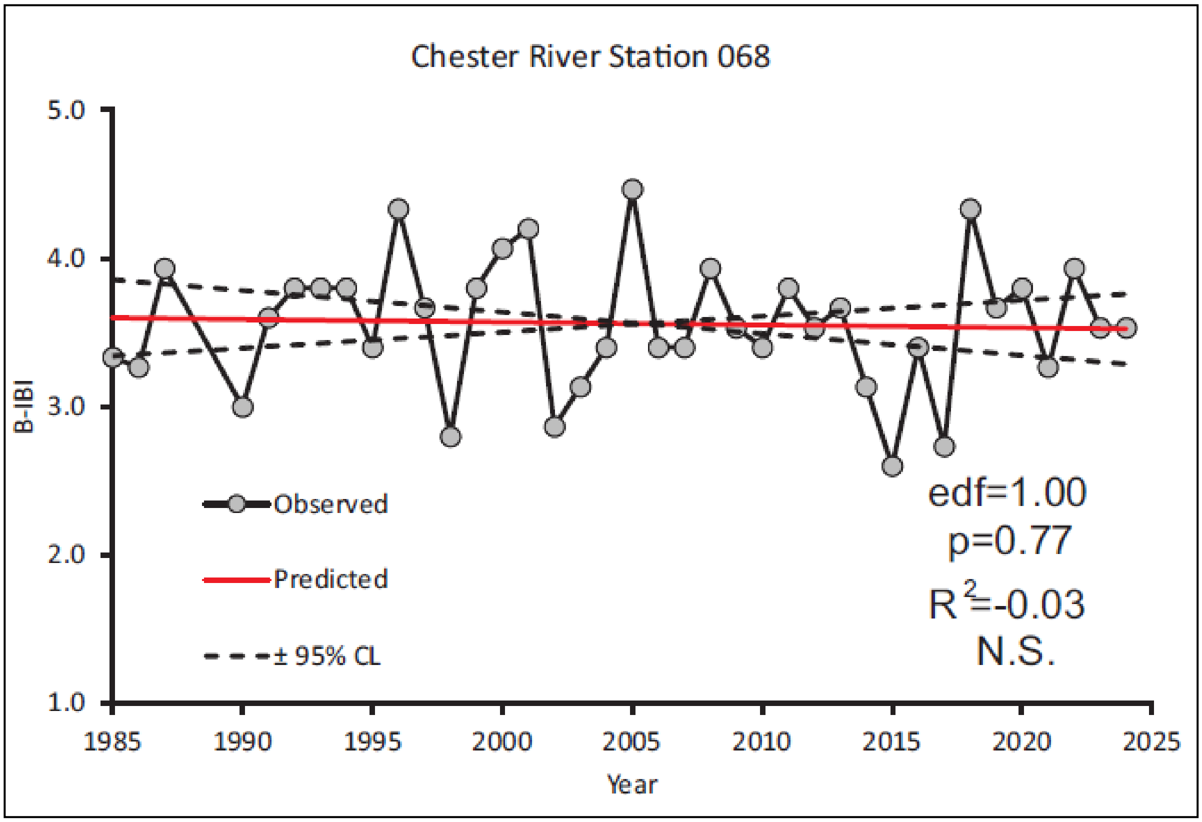


Figure 3-21. Trends in mean B-IBI at fixed sites. Station 068 = low mesohaline Chester River. Data gap (1988-1989) indicates period where sampling was suspended because of program design changes

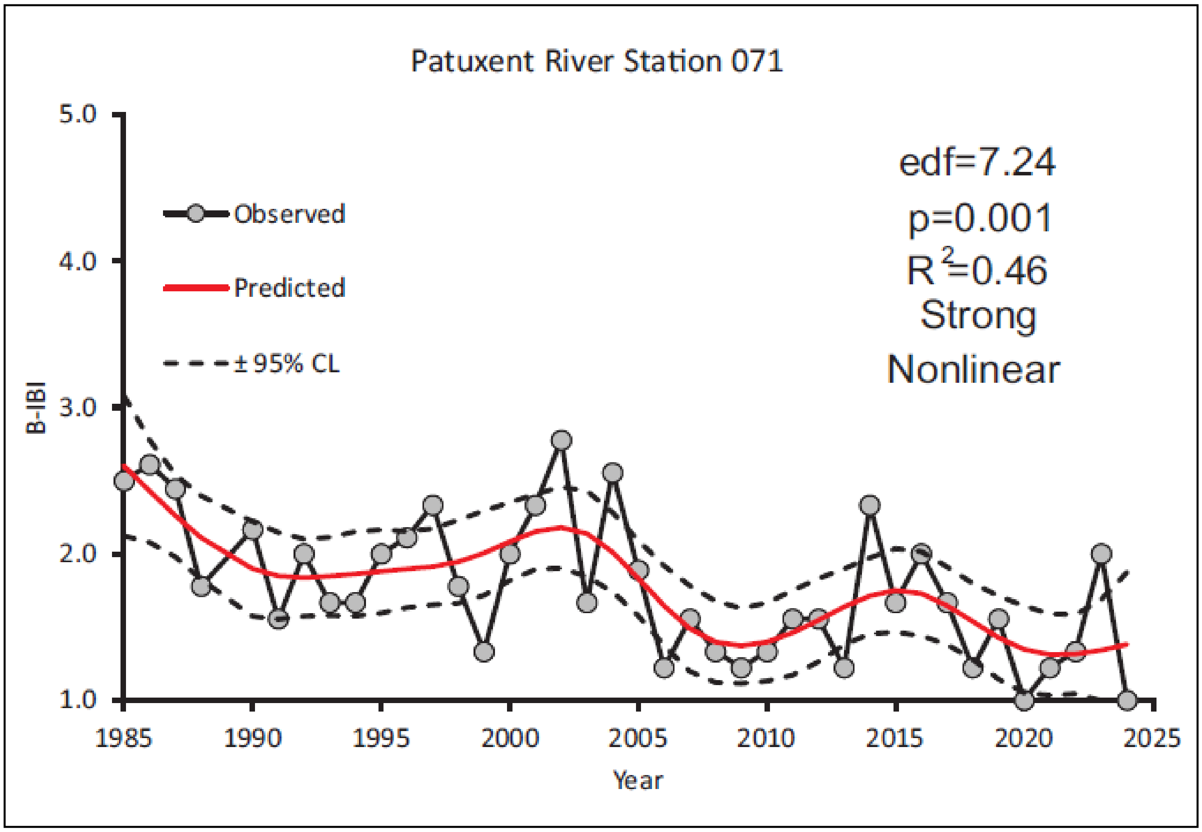


Figure 3-22. Trends in mean B-IBI at fixed sites. Station 071 = high mesohaline mud Patuxent River (12-18 m) at Broomes Island. Data gap (1989) indicates period where sampling was suspended because of program design changes

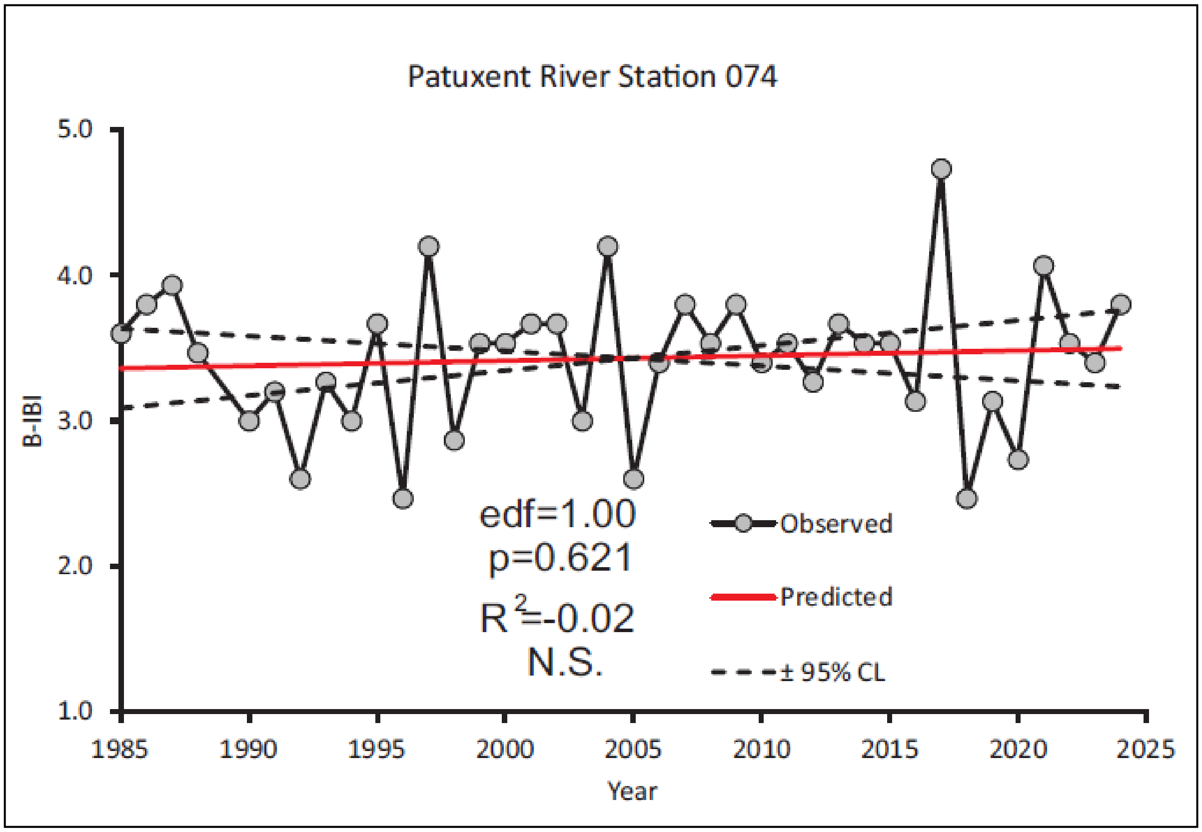


Figure 3-23. Trends in mean B-IBI at fixed sites. Station 074 = low mesohaline Patuxent River (≤ 5 m) at Chalk Point. Data gap (1989) indicates period where sampling was suspended because of program design changes

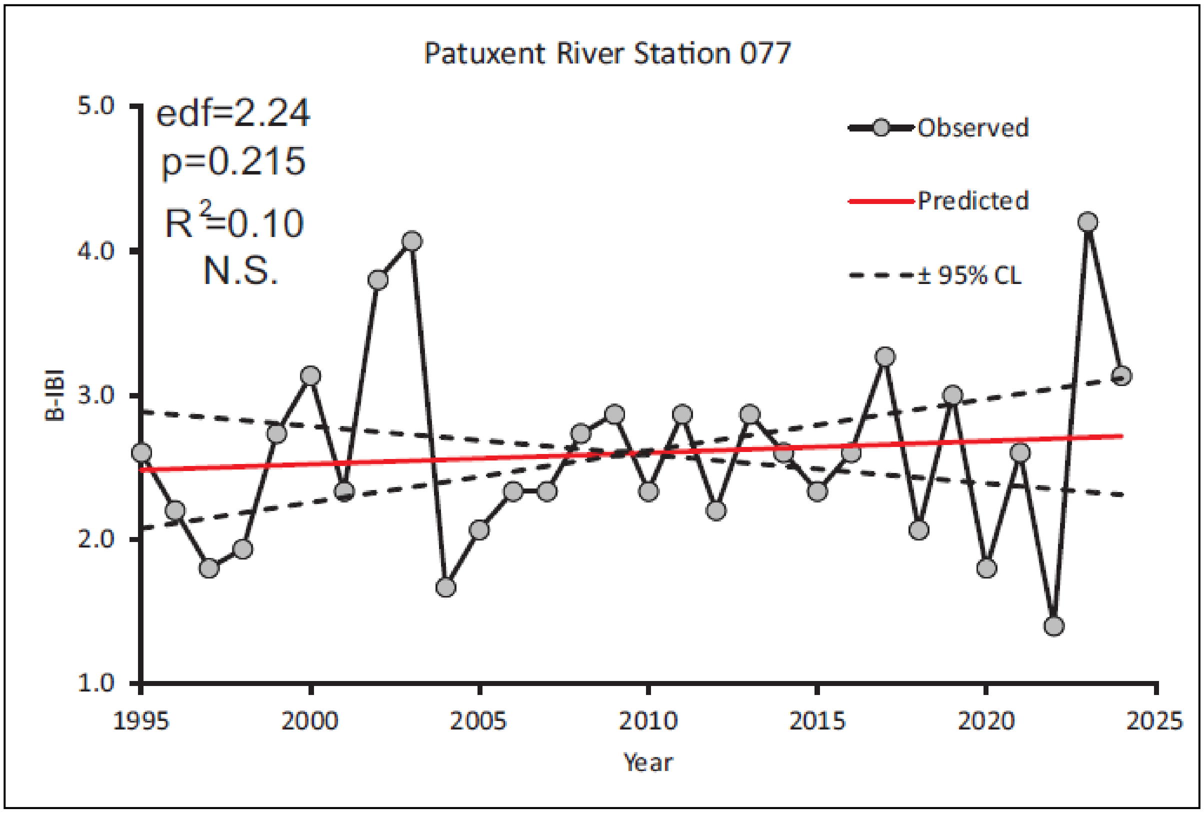


Figure 3-24. Trends in mean B-IBI at fixed sites. Station 077 = low mesohaline Patuxent River (≤ 5 m) at Holland Cliff. Period of analysis reduced to 1995-2024 because of a 5-year data gap (1990-1994) where sampling was suspended because of program design changes

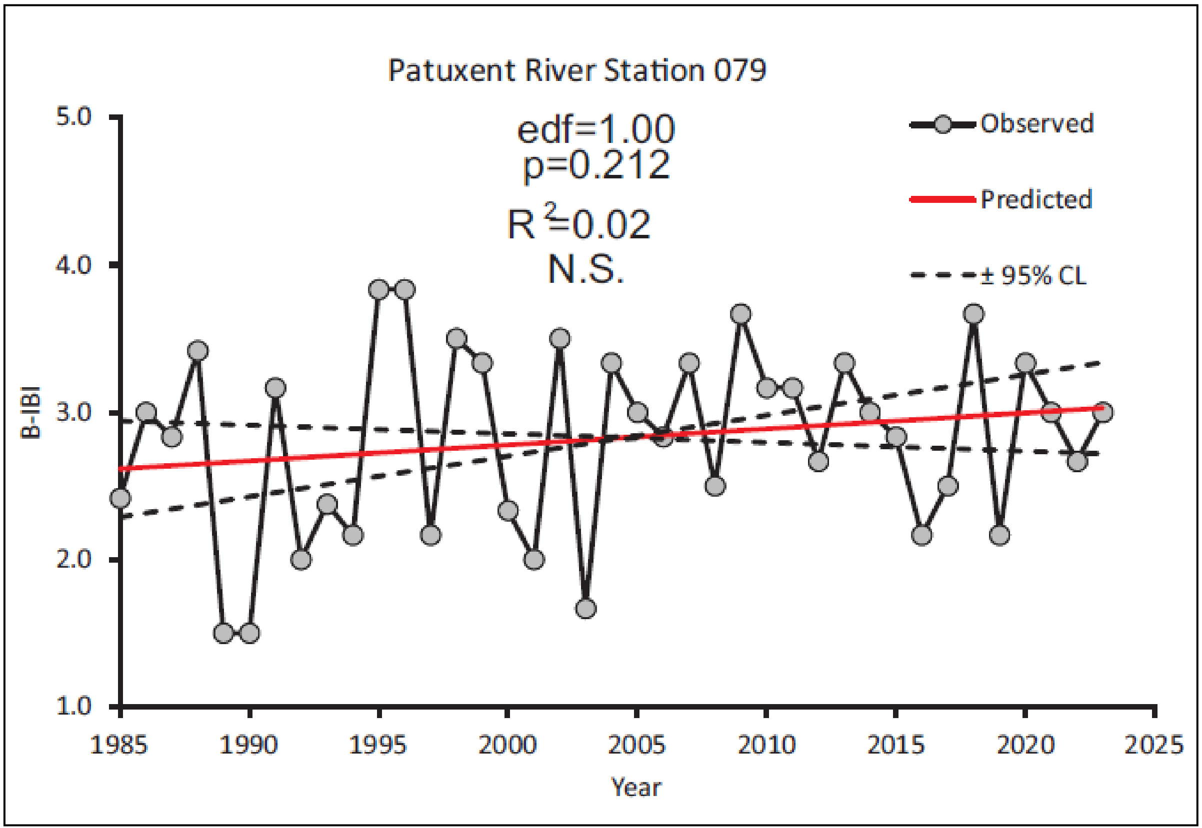


Figure 3-25. Trends in mean B-IBI at fixed sites. Station 079 = tidal fresh Patuxent River (≤ 6 m) at Lyons Creek.

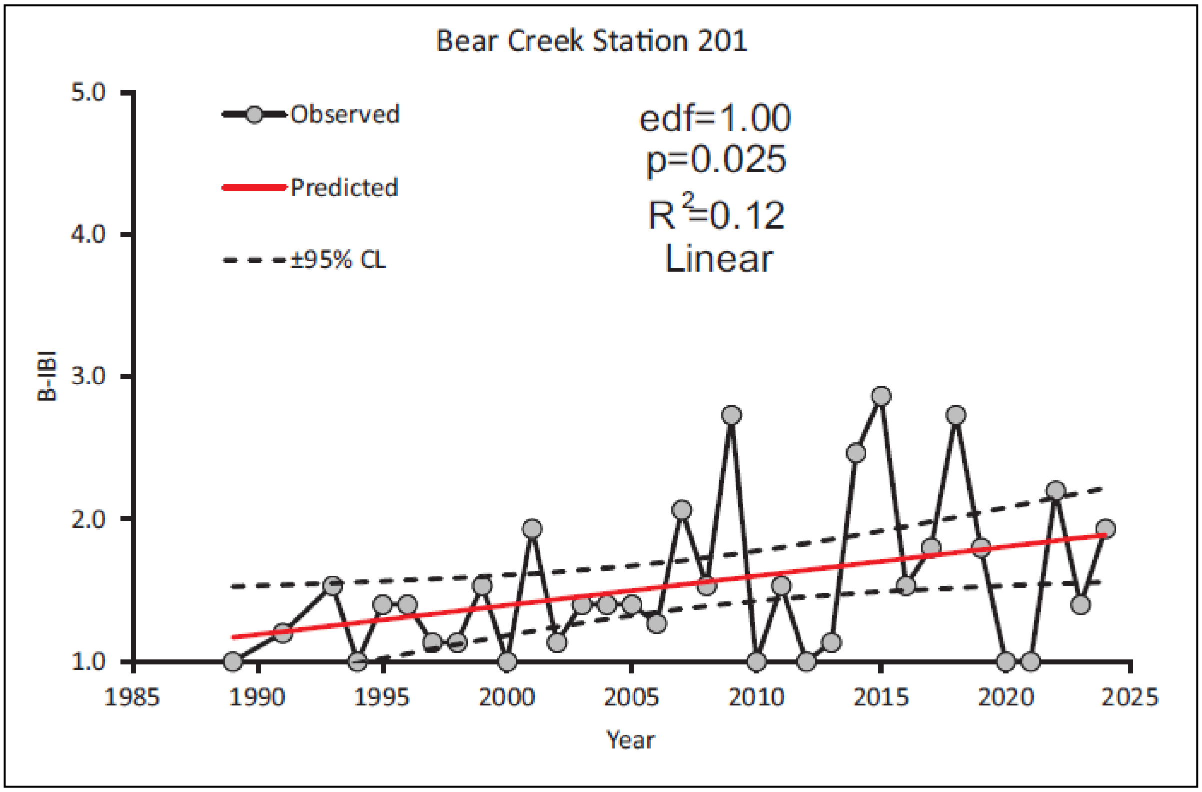


Figure 3-26. Trends in mean B-IBI at fixed sites. Station 201 = low mesohaline Patapsco River at Bear Creek. Data gaps (1990, 1992) indicate periods where sampling was suspended because of program design changes. Station first sampled in 1989

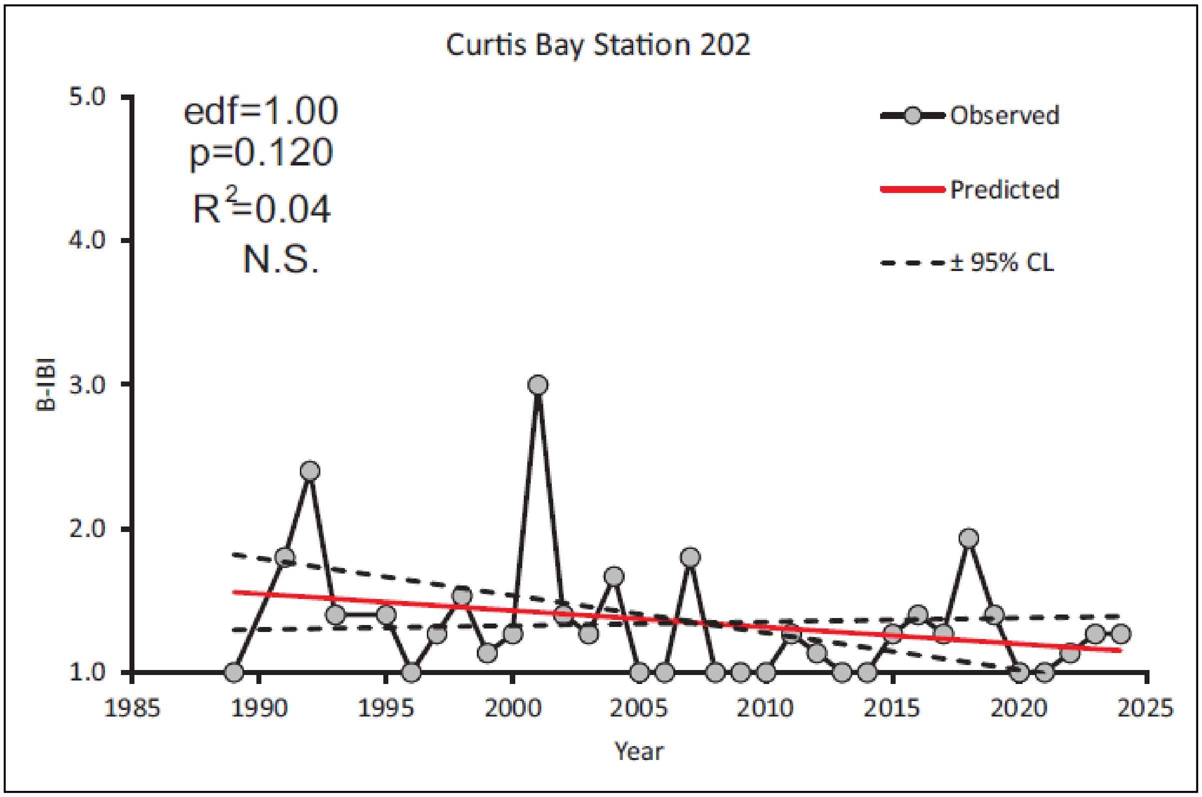


Figure 3-27. Trends in mean B-IBI at fixed sites. Station 202 = low mesohaline Patapsco River at Curtis Bay. Data gaps (1990, 1994) indicate periods where sampling was suspended because of program design changes. Station first sampled in 1989

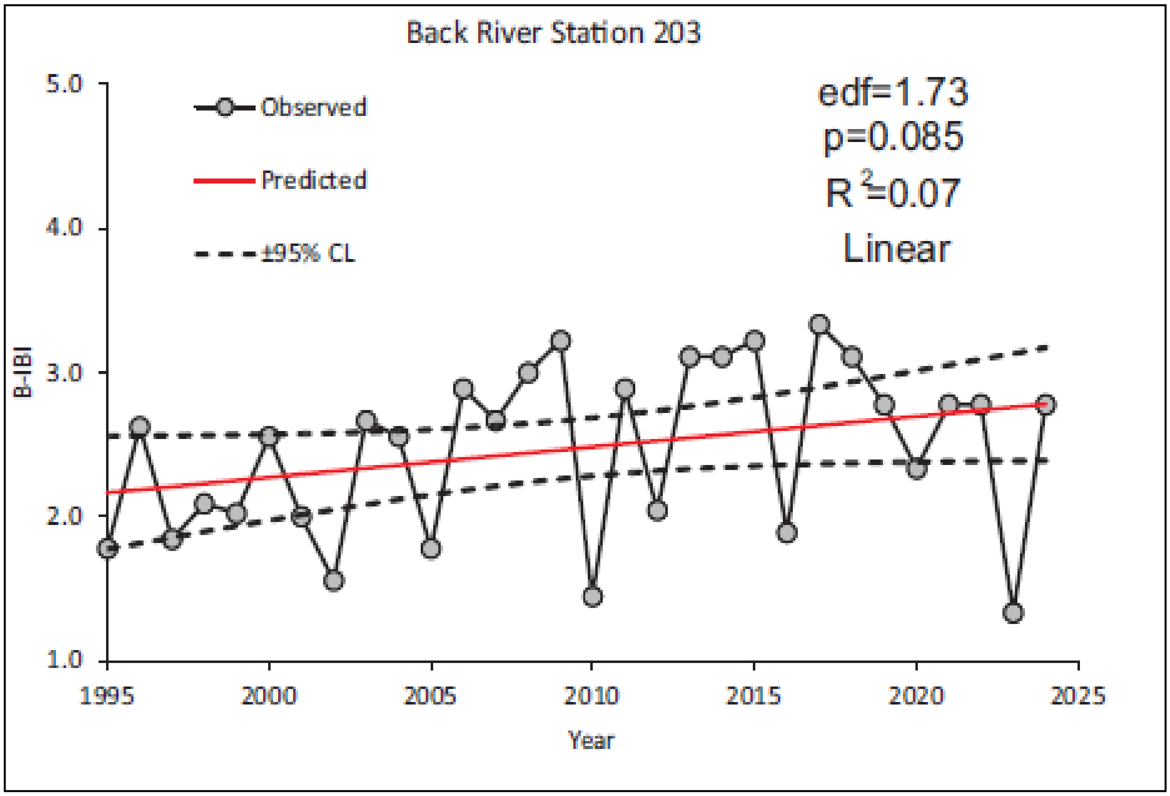


Figure 3-28. Trends in mean B-IBI at fixed sites. Station 203 = oligohaline Back River. Station first sampled in 1995

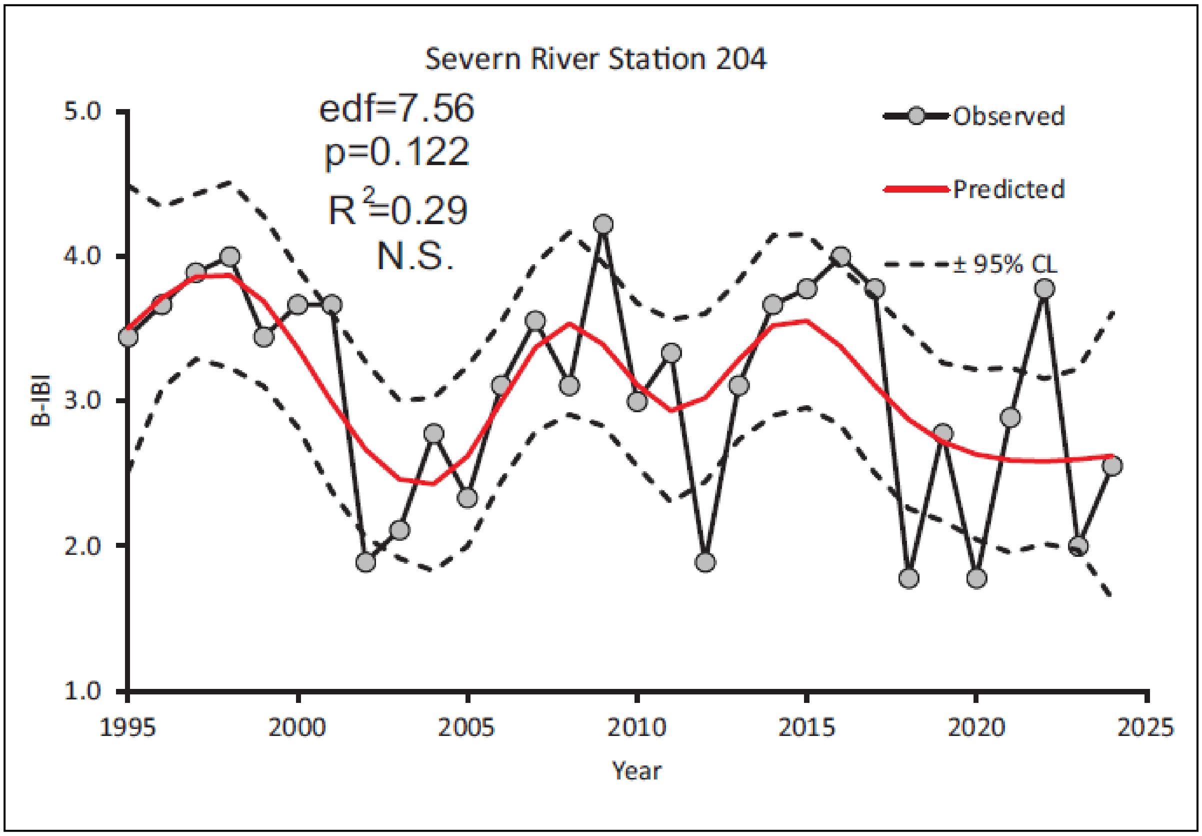


Figure 3-29. Trends in mean B-IBI at fixed sites. Station 204 = high mesohaline mud Severn River. Station first sampled in 1995

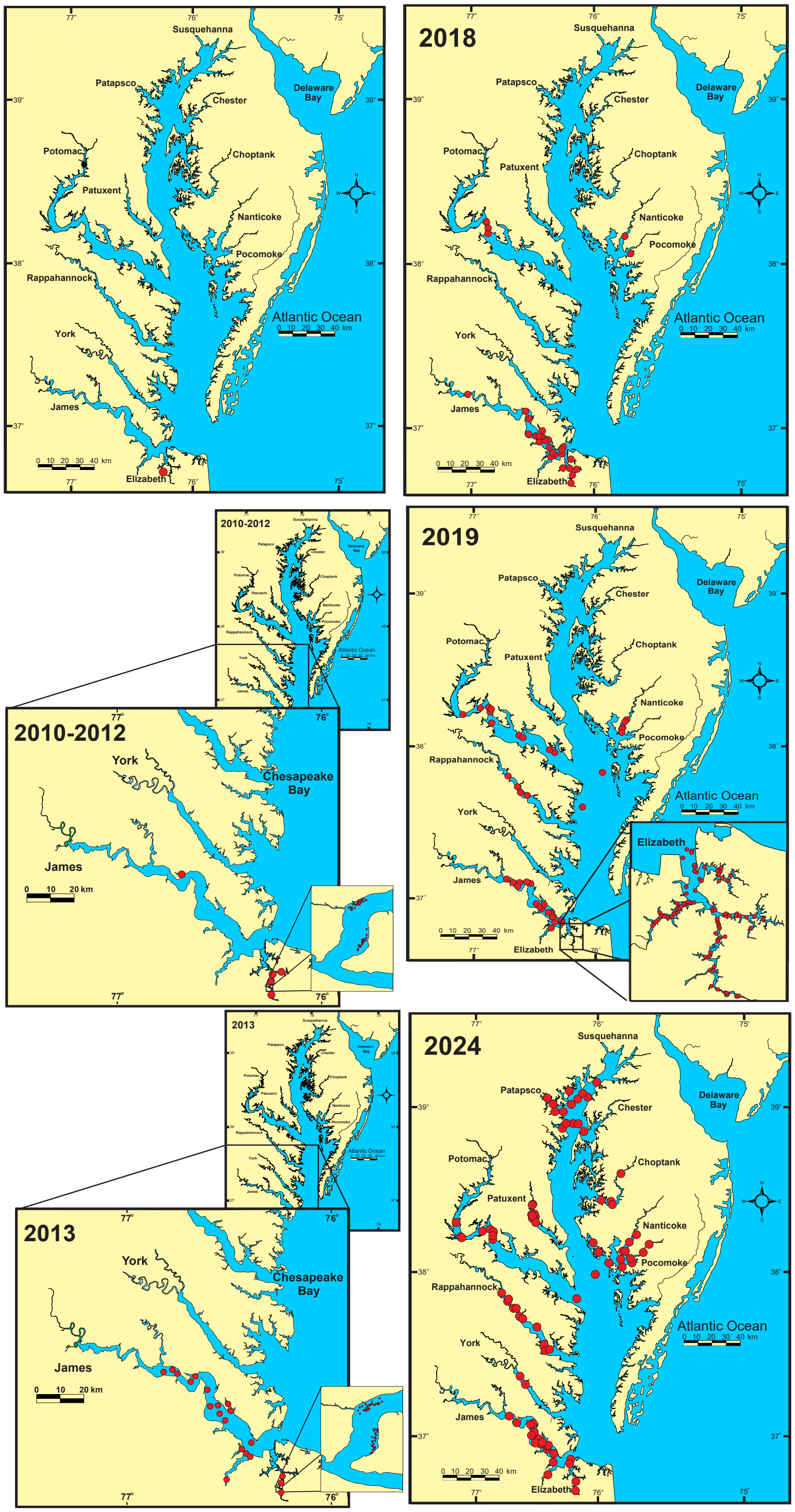


Figure 3-30. Spread of *H. americana* in Chesapeake Bay from a single location in the Elizabeth River in 2009 to multiple locations throughout the Bay in 2024

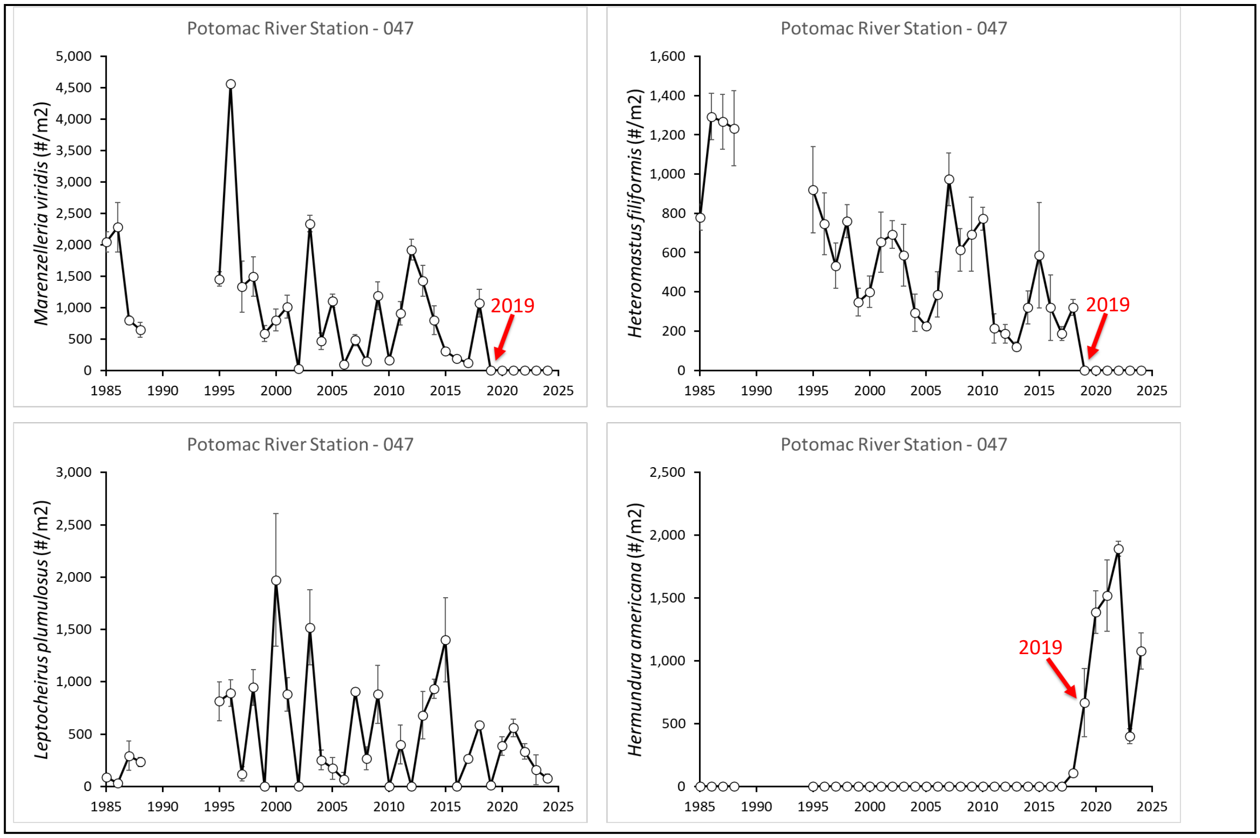


Figure 3-31. Trends in abundance (mean ± 1 SE, n=3) of top dominant species in the shallow mesohaline Potomac River Station 047, 1985-2024. Upper panels: the polychaete worms *Marenzelleria viridis* and *Heteromastus filiformis*. Lower panels: the amphipod *Leptocheirus plumulosus* and the non-indigenous polychaete *Hermundura americana*. Arrow marks the disappearance of long-term members of the community with the appearance of *H. americana*

## 3.2 BAYWIDE BOTTOM COMMUNITY CONDITION

The fixed site monitoring provides useful information about trends in the benthic community condition at 27 locations in the Maryland Chesapeake Bay but it does not provide an integrated assessment of the Bay's overall condition. The fixed sites were selected for trend monitoring because they are located in areas subject to management action and, therefore, are likely to undergo change. Because these sites were selected subjectively, there is no objective way of weighting them to obtain an unbiased estimate of Maryland baywide status.

An alternative approach for quantifying status of the bay, which was first adopted in the 1994 sampling program, is to use probability-based sampling to estimate the bottom area populated by benthos meeting the Chesapeake Bay benthic community restoration goals. Where the fixed site approach quantifies change at selected locations, the probability sampling approach quantifies the spatial extent of problems. While both approaches are valuable, developing and assessing the effectiveness of a Chesapeake Bay management strategy requires understanding the extent and distribution of problems throughout the Bay, instead of only assessing site-specific problems. Our probability-based sampling element is intended to provide that information, as well as a more widespread baseline data set for assessing the effects of unanticipated future contamination (e.g., oil or hazardous waste spills). Probability-based sampling information is used annually in the Bay Report Card and for Chesapeake Bay Aquatic Life Use Support decisions under the Clean Water Act (Llansó et al. 2005, 2009a).

Probability-based sampling was employed prior to 1994 by LTB, but the sampled area included only 16% of the Maryland Chesapeake Bay (Ranasinghe et al. 1994) which was insufficient to characterize the entire Bay. Probability-based sampling was also used in the Maryland Bay by the U.S. EPA Environmental Monitoring and Assessment Program (EMAP) and by the U.S. EPA National Coastal Condition Assessment, but at a sampling density too low to develop precise condition estimates for the Maryland Bay. The 2024 sampling continues with efforts initiated in 1994 to develop area-based bottom condition statements for the Maryland Bay.

Estimates of tidal bottom area meeting the benthic community restoration goals are included for the entire Chesapeake Bay. The estimates were enabled by including a probability-based sampling element in the Virginia Benthic Monitoring Program starting in 1996. The Virginia sampling is compatible and complementary to the Maryland effort and is part of a joint effort by the two programs to assess the extent of "healthy" tidal bottom baywide.

This section presents the results of the 2024 Maryland and Virginia probability-based sampling and provides thirty-one years (1994-2024) of benthic community monitoring in tidal waters of the Maryland Chesapeake Bay. The analytical methods for estimating the areal extent of bay bottom meeting the restoration goals were presented in Section 2.0. The physical data associated with the benthic samples (bottom water salinity, temperature, dissolved oxygen, and sediment silt-clay and organic carbon content) can be found in the Appendices Section of this report (Volume 2). Only summer data (July 15-September 30) are used for the probability-based assessments.

The results presented here are aimed to help managers better understand the general level of impact on benthic communities. However, the following cautionary note should be kept in mind when comparing this year to the 2021 data:

*"Due to an inadvertent misapplication of the random-site selection process, the Maryland 2021 data results cannot be assessed with confidence. Individual site data (species abundance and biomass; benthic index metrics and scores) are correct but summaries and interpretations of these data such as areal estimates of degradation and trends should be viewed with caution. Virginia data are unaffected."*

Of the 150 Maryland samples collected with the probability-based design in 2024, 59 met and 91 failed the Chesapeake Bay benthic community restoration goals (Figure 3-32). Of the 250 probability samples collected in the entire Chesapeake Bay in 2024, 91 met and 159 failed the restoration goals. The Virginia sampling results are presented in Figure 3-33. In terms of number of sites meeting the goals in Chesapeake Bay (Maryland plus Virginia), fewer sites met the goals in 2024 (36%) than in 2023 (43%).

The area with degraded benthos in the Maryland Bay increased in 2024 relative to 2023 (Maryland Tidal Waters, Figure 3-34 left panel), and the magnitude of the severely degraded condition also increased (Maryland Tidal Waters, Figure 3-34 right panel) albeit within the uncertainty margin of the estimate. Results from the individual sites were weighted based on the area of the stratum represented by the site in the stratified sampling design to estimate the tidal Maryland area failing the restoration goals. In 2024, 65% (±4.7% SE) of the Maryland Bay was estimated to fail the restoration goals (Figure 3-34). Expressed as area, 4,082±293 km$^2$ of the Maryland tidal waters in Chesapeake Bay remained to be restored in 2024 (Table 3-4). There was no statistically significant trend in percent area degraded over the 1995-2024 time period (ANOVA: $F = 2.21$, $p = 0.1484$).

The Potomac and Patuxent rivers were the Maryland strata in poorest condition, with 84% and 68% area degraded in 2024, respectively (Figures 3-35 and 3-37). The Upper Bay Mainstem was in best condition. The Maryland Mid-Bay Mainstem had 65% of its area degraded in 2024. The estimate for the Mid-Bay Mainstem includes the mid-bay deep trough, which is perennially hypoxic and accounts for 21% of the area of the stratum. In 2024 degradation increased in all of the Maryland strata except the Western Tributaries (Figure 3-35). The Patuxent River and the Maryland Eastern Tributaries had the largest increase in degradation.

Over the 1995-2024 time period, more than half of the Maryland Mid-Bay Mainstem (1,697-2,821 km$^2$) and the tidal Potomac River (714-1,173 km$^2$) (Table 3-4) failed the restoration goals each year, and a large portion of that area, ranging from 52% to 85% in the mainstem and 46% to 93% in the Potomac River, was severely degraded. The Patuxent River exhibited increasing trends in both the percent degraded and percent severely degraded condition over the 1995-2024 time series (ANOVA: Percent degraded, F = 8.07, *p* = 0.0083; percent severely degraded, F = 5.23, *p* = 0.0300). Over the same time series, the Maryland Eastern Tributaries exhibited for the first time an increasing trend in percent degraded condition (ANOVA: F = 6.00, *p* = 0.0208).

For the Chesapeake Bay, degradation in 2024 increased relative to 2023 (Chesapeake Bay, Figure 3-34 left panel), and the magnitude of the severely degraded condition also increased (Chesapeake Bay, Figure 3-34 right panel). Weighting results from the 250 probability sites in Maryland and Virginia, 54% (±4.2% SE) or 6,247±482 $km^2$ of the tidal Chesapeake Bay was estimated to fail the restoration goals in 2024, and 56% of that area (3,517 $km^2$) was severely degraded (Table 3-4).

In Virginia, degradation remained high in all strata, and increased in 2024 relative to 2023 (Table 3-4, Figure 3-36). Weighting results from the 100 probability sites, 40% (±7.1% SE) or 2,165±383 $km^2$ of the state's tidal waters remained to be restored in 2024 (Virginia Tidal Waters, Figure 3-34 left panel). However, over the 1996-2024 time period there was a statistically significant decreasing trend in percent area degraded in Virginia tidal waters (ANOVA: F = 5.90, *p* = 0.0220).

Stream flow into Chesapeake Bay in 2024 was high early in the year, and very high March through May, with peak flows exceeding 250,000 cfs (Figure 3-38). June and July flow was low, but high again in mid-August following the remnants of Hurricane Debby. This pattern contrasts with the much lower Susquehanna River flow in the spring and summer of 2023 (Figure 3-38).

Hypoxic volume in 2024 was above the long-term average in early June (Figure 3-39). In May, hypoxic volume was more than double the May average. After June, hypoxic volume remained smaller than average through the end of the summer (Figure 3-39). However, hypoxia may have been higher than reported in July and early August because several mainstem stations could not be sampled during this period due to mechanical issues with the research vessel. The minimum water temperature recorded during the benthic sampling period was higher in 2024 (21.9 °C) than in 2023 (19.7 °C) and 2022 (15.3 °C).

On average, Maryland tidal waters had lower abundance, lower number of species, lower biomass, and lower B-IBI score in 2024 than in 2023 (Figure 3-40). Over the time series, there were statistically significant declining trends in mean abundance, mean number of species, and mean B-IBI score (ANOVA: abundance, F = 9.34, *p* = 0.0049; number of species, F = 14.61, *p* = 0.0007; B-IBI score, F = 5.53, *p* = 0.0260). Particularly strong was the decline in number of species.

A similar pattern was observed baywide (Figure 3-41). Statistically significant declining trends over time were observed in mean abundance and mean number of species, but not mean B-IBI score (ANOVA: abundance, F = 4.73, $p = 0.0385$; number of species, F = 5.94, $p = 0.0217$; B-IBI score, F = 2.14, $p = 0.1550$).

In Maryland, the percentage of sites scoring 1 for excess abundance continued to decline (Figure 3-40, ANOVA: F = 22.10, $p < 0.0001$), indicating improvements in benthic community condition from excess abundance (eutrophic condition).

In addition to percent area degraded, results can be summarized by the type of stress experienced by the benthic communities. Low abundance, low biomass, and the level of widespread failure in most metrics necessary to classify a site as severely degraded is usually expected on exposure to catastrophic events such as prolonged dissolved oxygen stress. Conversely, excess abundance and excess biomass are phenomena usually associated with eutrophic conditions and organic enrichment of the sediment in the absence of low dissolved oxygen stress. For the period 1996-2024, four strata (Potomac River, Patuxent River, Mid Bay Mainstem, and Maryland Western Tributaries) had a large percentage (≥70%) of sites failing the goals because of insufficient abundance or biomass of organisms relative to reference conditions (Table 3-5). These regions were the most dissolved-oxygen stressed. These strata also had a high percentage (>60%) of failing sites classified as severely degraded (Table 3-5). These results contrast with those of the James, York, and Rappahannock rivers, which had fewer depauperate sites but excess abundance, excess biomass, or both in >20% of the failing sites (Table 3-6).

Table 3-4. Estimated tidal area (km$^2$) failing to meet the Chesapeake Bay benthic community restoration goals. In this table, the area of the mainstem deep trough is included in the estimates for the severely degraded condition. The Potomac River area sampled in 1994 differs (See Table 2-2). See cautionary note about the 2021data (where shaded below) in page 3-40.

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Chesapeake Bay | 1996 | 3,080 | 1,388 | 1,056 | 5,524 | 48 |
| | 1997 | 2,941 | 2,093 | 856 | 5,890 | 51 |
| | 1998 | 3,771 | 1,689 | 1,271 | 6,731 | 58 |
| | 1999 | 3,164 | 1,660 | 1,020 | 5,844 | 50 |
| | 2000 | 2,704 | 1,538 | 1,474 | 5,715 | 49 |
| | 2001 | 3,123 | 1,187 | 1,749 | 6,060 | 52 |
| | 2002 | 3,424 | 1,584 | 1,170 | 6,178 | 53 |
| | 2003 | 3,351 | 2,537 | 964 | 6,852 | 59 |
| | 2004 | 2,902 | 1,940 | 650 | 5,492 | 47 |
| | 2005 | 4,664 | 1,550 | 614 | 6,829 | 59 |
| | 2006 | 4,336 | 1,779 | 756 | 6,871 | 59 |
| | 2007 | 4,120 | 1,529 | 1,064 | 6,713 | 58 |
| | 2008 | 3,459 | 1,570 | 1,759 | 6,788 | 58 |
| | 2009 | 3,164 | 898 | 1,032 | 5,094 | 44 |
| | 2010 | 3,199 | 1,492 | 1,485 | 6,177 | 53 |
| | 2011 | 3,686 | 1,534 | 1,132 | 6,353 | 55 |
| | 2012 | 3,125 | 2,039 | 1,173 | 6,337 | 54.6 |
| | 2013 | 3,650 | 1,760 | 800 | 6,210 | 53.5 |
| | 2014 | 2,601 | 1,660 | 505 | 4,767 | 41.1 |
| | 2015 | 2,595 | 1,485 | 349 | 4,428 | 38.2 |
| | 2016 | 3,071 | 1,031 | 1,169 | 5,271 | 45.4 |
| | 2017 | 3,073 | 1,116 | 563 | 4,752 | 41 |
| | 2018 | 2,769 | 1,377 | 689 | 4,835 | 41.7 |
| | 2019 | 3,749 | 1,642 | 1,503 | 6,894 | 59.4 |
| | 2020 | 4,463 | 1,610 | 1,059 | 7,131 | 61.4 |
| | 2021 | 3,642 | 1,157 | 755 | 5,554 | 47.8 |
| | 2022 | 3,954 | 1,796 | 542 | 6,292 | 54.2 |
| | 2023 | 3,071 | 1,797 | 432 | 5,300 | 45.7 |
| | 2024 | 3,517 | 1,267 | 1,463 | 6,247 | 53.8 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Maryland Tidal Waters | 1994 | 2,684 | 1,152 | 497 | 4,332 | 67 |
| | 1995 | 2,872 | 605 | 182 | 3,659 | 59 |
| | 1996 | 2,614 | 700 | 155 | 3,469 | 56 |
| | 1997 | 2,349 | 719 | 462 | 3,529 | 57 |
| | 1998 | 2,663 | 1,016 | 623 | 4,302 | 69 |
| | 1999 | 2,423 | 1,137 | 374 | 3,935 | 63 |
| | 2000 | 2,455 | 1,137 | 236 | 3,828 | 61 |
| | 2001 | 2,313 | 582 | 644 | 3,538 | 57 |
| | 2002 | 2,444 | 713 | 928 | 4,086 | 65 |
| | 2003 | 2,571 | 1,288 | 228 | 4,086 | 65 |
| | 2004 | 2,037 | 985 | 226 | 3,248 | 52 |
| | 2005 | 2,771 | 1,014 | 295 | 4,080 | 65 |
| | 2006 | 3,077 | 1,013 | 504 | 4,595 | 74 |
| | 2007 | 3,088 | 851 | 513 | 4,452 | 71 |
| | 2008 | 2,727 | 767 | 854 | 4,348 | 70 |
| | 2009 | 2,484 | 580 | 540 | 3,605 | 58 |
| | 2010 | 2,656 | 1,171 | 355 | 4,182 | 67 |
| | 2011 | 2,320 | 1,027 | 703 | 4,050 | 65 |
| | 2012 | 2,620 | 1,161 | 785 | 4,565 | 73.1 |
| | 2013 | 2,549 | 1,269 | 184 | 4,001 | 64.1 |
| | 2014 | 2,110 | 1,402 | 241 | 3,753 | 60.1 |
| | 2015 | 1,997 | 1,071 | 254 | 3,322 | 53.2 |
| | 2016 | 2,813 | 650 | 685 | 4,148 | 66.4 |
| | 2017 | 2,223 | 832 | 278 | 3,333 | 53 |
| | 2018 | 2,416 | 1,163 | 215 | 3,794 | 60.8 |
| | 2019 | 2,860 | 1,052 | 328 | 4,240 | 67.9 |
| | 2020 | 3,255 | 845 | 425 | 4,525 | 72.5 |
| | 2021 | 2,940 | 978 | 309 | 4,227 | 67.7 |
| | 2022 | 3,274 | 1,014 | 468 | 4,756 | 76.2 |
| | 2023 | 2,241 | 1,237 | 246 | 3,724 | 59.6 |
| | 2024 | 2,808 | 906 | 368 | 4,082 | 65.4 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Virginia Tidal Waters | 1996 | 466 | 688 | 901 | 2,055 | 38.3 |
| | 1997 | 592 | 1,375 | 394 | 2,361 | 44.0 |
| | 1998 | 1,107 | 673 | 648 | 2,429 | 45.3 |
| | 1999 | 741 | 523 | 646 | 1,909 | 35.6 |
| | 2000 | 249 | 401 | 1,238 | 1,888 | 35.2 |
| | 2001 | 810 | 606 | 1,106 | 2,522 | 47.0 |
| | 2002 | 980 | 871 | 242 | 2,092 | 39.0 |
| | 2003 | 780 | 1,249 | 736 | 2,766 | 51.6 |
| | 2004 | 866 | 955 | 424 | 2,245 | 41.9 |
| | 2005 | 1,893 | 536 | 319 | 2,748 | 51.2 |
| | 2006 | 1,259 | 765 | 252 | 2,276 | 42.4 |
| | 2007 | 1,031 | 678 | 552 | 2,261 | 42.2 |
| | 2008 | 732 | 803 | 905 | 2,440 | 45.5 |
| | 2009 | 680 | 318 | 491 | 1,489 | 27.8 |
| | 2010 | 543 | 321 | 1,130 | 1,994 | 37.2 |
| | 2011 | 1,366 | 508 | 429 | 2,303 | 42.9 |
| | 2012 | 505 | 878 | 389 | 1,772 | 33.0 |
| | 2013 | 1,101 | 491 | 616 | 2,208 | 41.2 |
| | 2014 | 490 | 259 | 264 | 1,013 | 18.9 |
| | 2015 | 598 | 413 | 95 | 1,106 | 20.6 |
| | 2016 | 258 | 380 | 484 | 1,123 | 20.9 |
| | 2017 | 850 | 284 | 286 | 1,419 | 26.5 |
| | 2018 | 353 | 214 | 474 | 1,041 | 19.4 |
| | 2019 | 889 | 591 | 1,175 | 2,655 | 49.5 |
| | 2020 | 1,208 | 765 | 634 | 2,606 | 48.6 |
| | 2021 | 702 | 179 | 446 | 1,327 | 24.7 |
| | 2022 | 680 | 782 | 75 | 1,537 | 28.7 |
| | 2023 | 830 | 560 | 187 | 1,577 | 29.4 |
| | 2024 | 709 | 360 | 1,096 | 2,165 | 40.4 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Maryland Eastern Tributaries | 1995 | 107 | 128 | 0 | 235 | 44 |
| | 1996 | 21 | 150 | 21 | 192 | 36 |
| | 1997 | 43 | 86 | 0 | 128 | 24 |
| | 1998 | 21 | 64 | 64 | 150 | 28 |
| | 1999 | 43 | 150 | 86 | 278 | 52 |
| | 2000 | 64 | 150 | 21 | 235 | 44 |
| | 2001 | 128 | 64 | 86 | 278 | 52 |
| | 2002 | 64 | 107 | 64 | 235 | 44 |
| | 2003 | 128 | 214 | 0 | 342 | 64 |
| | 2004 | 86 | 107 | 21 | 214 | 40 |
| | 2005 | 86 | 64 | 86 | 235 | 44 |
| | 2006 | 86 | 128 | 43 | 257 | 48 |
| | 2007 | 150 | 86 | 128 | 363 | 68 |
| | 2008 | 86 | 86 | 64 | 235 | 44 |
| | 2009 | 192 | 64 | 64 | 321 | 60 |
| | 2010 | 150 | 171 | 43 | 363 | 68 |
| | 2011 | 86 | 86 | 86 | 257 | 48 |
| | 2012 | 128 | 128 | 0 | 257 | 48.0 |
| | 2013 | 64 | 150 | 43 | 257 | 48.0 |
| | 2014 | 86 | 64 | 21 | 171 | 32.0 |
| | 2015 | 64 | 86 | 21 | 171 | 32.0 |
| | 2016 | 86 | 150 | 107 | 342 | 64.0 |
| | 2017 | 64 | 192 | 21 | 278 | 52 |
| | 2018 | 43 | 128 | 21 | 192 | 36.0 |
| | 2019 | 107 | 43 | 107 | 257 | 48.0 |
| | 2020 | 128 | 107 | 64 | 299 | 56.0 |
| | 2021 | 86 | 192 | 64 | 342 | 64.0 |
| | 2022 | 107 | 150 | 43 | 300 | 56.0 |
| | 2023 | 64 | 128 | 107 | 299 | 56.0 |
| | 2024 | 64 | 235 | 64 | 363 | 68.0 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Maryland Mid-Bay Mainstem | 1995 | 1,799 | 204 | 102 | 2,106 | 65.2 |
| | 1996 | 1,595 | 306 | 102 | 2,004 | 62.1 |
| | 1997 | 1,493 | 306 | 306 | 2,106 | 65.2 |
| | 1998 | 1,799 | 204 | 408 | 2,412 | 74.7 |
| | 1999 | 1,391 | 715 | 102 | 2,208 | 68.4 |
| | 2000 | 1,493 | 510 | 204 | 2,208 | 68.4 |
| | 2001 | 1,289 | 102 | 408 | 1,799 | 55.7 |
| | 2002 | 1,595 | 204 | 613 | 2,412 | 74.7 |
| | 2003 | 1,289 | 613 | 204 | 2,106 | 65.2 |
| | 2004 | 983 | 510 | 204 | 1,697 | 52.6 |
| | 2005 | 1,595 | 613 | 204 | 2,412 | 74.7 |
| | 2006 | 1,697 | 613 | 306 | 2,616 | 81.0 |
| | 2007 | 1,799 | 510 | 306 | 2,616 | 81.0 |
| | 2008 | 1,799 | 306 | 613 | 2,718 | 84.2 |
| | 2009 | 1,595 | 204 | 408 | 2,208 | 68.4 |
| | 2010 | 1,697 | 510 | 204 | 2,412 | 74.7 |
| | 2011 | 1,391 | 408 | 510 | 2,310 | 71.5 |
| | 2012 | 1,595 | 408 | 510 | 2,514 | 77.9 |
| | 2013 | 1,697 | 613 | 102 | 2,412 | 74.7 |
| | 2014 | 1,085 | 919 | 102 | 2,106 | 65.2 |
| | 2015 | 1,187 | 408 | 102 | 1,697 | 52.6 |
| | 2016 | 1,493 | 102 | 510 | 2,106 | 65.2 |
| | 2017 | 1,493 | 204 | 102 | 1,799 | 55.7 |
| | 2018 | 1,391 | 715 | 102 | 2,208 | 68.4 |
| | 2019 | 1,493 | 715 | 204 | 2,412 | 74.7 |
| | 2020 | 2,208 | 408 | 204 | 2,820 | 87.4 |
| | 2021 | 1,799 | 204 | 204 | 2,208 | 68.4 |
| | 2022 | 2,106 | 613 | 102 | 2,821 | 87.4 |
| | 2023 | 1,187 | 613 | 102 | 1,902 | 58.9 |
| | 2024 | 1,595 | 306 | 204 | 2,105 | 65.2 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Maryland Upper Bay Mainstem | 1995 | 345 | 63 | 0 | 408 | 52 |
| | 1996 | 126 | 126 | 31 | 283 | 36 |
| | 1997 | 126 | 94 | 31 | 251 | 32 |
| | 1998 | 157 | 188 | 31 | 377 | 48 |
| | 1999 | 188 | 63 | 63 | 314 | 40 |
| | 2000 | 94 | 126 | 0 | 220 | 28 |
| | 2001 | 157 | 31 | 31 | 220 | 28 |
| | 2002 | 94 | 126 | 31 | 251 | 32 |
| | 2003 | 188 | 157 | 0 | 345 | 44 |
| | 2004 | 220 | 31 | 0 | 251 | 32 |
| | 2005 | 31 | 0 | 0 | 31 | 4 |
| | 2006 | 188 | 31 | 31 | 251 | 32 |
| | 2007 | 188 | 31 | 0 | 220 | 28 |
| | 2008 | 126 | 188 | 94 | 408 | 52 |
| | 2009 | 31 | 31 | 63 | 126 | 16 |
| | 2010 | 157 | 31 | 31 | 220 | 28 |
| | 2011 | 94 | 126 | 0 | 220 | 28 |
| | 2012 | 126 | 157 | 31 | 314 | 40 |
| | 2013 | 94 | 157 | 0 | 251 | 32 |
| | 2014 | 94 | 63 | 94 | 251 | 32 |
| | 2015 | 94 | 63 | 63 | 220 | 28 |
| | 2016 | 157 | 188 | 0 | 345 | 44 |
| | 2017 | 63 | 94 | 126 | 283 | 36 |
| | 2018 | 94 | 63 | 63 | 220 | 28 |
| | 2019 | 126 | 63 | 0 | 188 | 24 |
| | 2020 | 94 | 94 | 94 | 283 | 36 |
| | 2021 | 283 | 157 | 0 | 440 | 56 |
| | 2022 | 63 | 94 | 63 | 220 | 28 |
| | 2023 | 94 | 94 | 31 | 219 | 28 |
| | 2024 | 157 | 126 | 31 | 314 | 40 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Maryland Upper Western Tributaries | 1995 | 58 | 47 | 23 | 129 | 44 |
| | 1996 | 117 | 47 | 0 | 164 | 56 |
| | 1997 | 105 | 23 | 12 | 140 | 48 |
| | 1998 | 94 | 23 | 12 | 129 | 44 |
| | 1999 | 117 | 47 | 12 | 175 | 60 |
| | 2000 | 140 | 70 | 0 | 211 | 72 |
| | 2001 | 70 | 12 | 47 | 129 | 44 |
| | 2002 | 94 | 47 | 47 | 187 | 64 |
| | 2003 | 47 | 105 | 23 | 175 | 60 |
| | 2004 | 70 | 117 | 0 | 187 | 64 |
| | 2005 | 140 | 47 | 0 | 187 | 64 |
| | 2006 | 187 | 47 | 12 | 246 | 84 |
| | 2007 | 94 | 35 | 12 | 140 | 48 |
| | 2008 | 94 | 23 | 12 | 129 | 44 |
| | 2009 | 94 | 35 | 0 | 129 | 44 |
| | 2010 | 152 | 70 | 0 | 222 | 76 |
| | 2011 | 35 | 70 | 0 | 105 | 36 |
| | 2012 | 199 | 23 | 23 | 246 | 84 |
| | 2013 | 70 | 23 | 23 | 117 | 40 |
| | 2014 | 70 | 70 | 23 | 164 | 56 |
| | 2015 | 105 | 35 | 12 | 152 | 52 |
| | 2016 | 164 | 47 | 12 | 222 | 76 |
| | 2017 | 47 | 35 | 23 | 105 | 36 |
| | 2018 | 82 | 58 | 23 | 164 | 56 |
| | 2019 | 94 | 94 | 12 | 199 | 68 |
| | 2020 | 105 | 82 | 12 | 199 | 68 |
| | 2021 | 94 | 47 | 35 | 175 | 60 |
| | 2022 | 105 | 35 | 0 | 140 | 48 |
| | 2023 | 140 | 70 | 0 | 210 | 72 |
| | 2024 | 94 | 35 | 12 | 141 | 48 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Patuxent River | 1995 | 51 | 10 | 5 | 67 | 52 |
| | 1996 | 41 | 20 | 0 | 61 | 48 |
| | 1997 | 20 | 5 | 10 | 36 | 28 |
| | 1998 | 31 | 26 | 5 | 61 | 48 |
| | 1999 | 20 | 10 | 10 | 41 | 32 |
| | 2000 | 51 | 26 | 10 | 87 | 68 |
| | 2001 | 56 | 15 | 20 | 92 | 72 |
| | 2002 | 36 | 26 | 20 | 82 | 64 |
| | 2003 | 51 | 46 | 0 | 97 | 76 |
| | 2004 | 15 | 67 | 0 | 82 | 64 |
| | 2005 | 51 | 36 | 5 | 92 | 72 |
| | 2006 | 51 | 41 | 10 | 102 | 80 |
| | 2007 | 41 | 36 | 15 | 92 | 72 |
| | 2008 | 61 | 10 | 20 | 92 | 72 |
| | 2009 | 61 | 41 | 5 | 108 | 84 |
| | 2010 | 41 | 31 | 26 | 97 | 76 |
| | 2011 | 51 | 31 | 5 | 87 | 68 |
| | 2012 | 61 | 36 | 15 | 113 | 88 |
| | 2013 | 61 | 20 | 15 | 97 | 76 |
| | 2014 | 61 | 31 | 0 | 92 | 72 |
| | 2015 | 36 | 20 | 5 | 61 | 48 |
| | 2016 | 46 | 10 | 5 | 61 | 48 |
| | 2017 | 46 | 51 | 5 | 102 | 80 |
| | 2018 | 41 | 46 | 5 | 92 | 72 |
| | 2019 | 72 | 36 | 5 | 113 | 88 |
| | 2020 | 56 | 51 | 0 | 108 | 84 |
| | 2021 | 67 | 20 | 5 | 92 | 72 |
| | 2022 | 77 | 20 | 5 | 102 | 80 |
| | 2023 | 41 | 26 | 5 | 72 | 56 |
| | 2024 | 31 | 51 | 5 | 87 | 58 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Potomac River | 1994 | 793 | 330 | 0 | 1,123 | 61 |
| | 1995 | 510 | 153 | 51 | 714 | 56 |
| | 1996 | 714 | 51 | 0 | 765 | 60 |
| | 1997 | 561 | 204 | 102 | 867 | 68 |
| | 1998 | 561 | 510 | 102 | 1,173 | 92 |
| | 1999 | 663 | 153 | 102 | 918 | 72 |
| | 2000 | 612 | 255 | 0 | 867 | 68 |
| | 2001 | 612 | 357 | 51 | 1,020 | 80 |
| | 2002 | 561 | 204 | 153 | 918 | 72 |
| | 2003 | 867 | 153 | 0 | 1,020 | 80 |
| | 2004 | 663 | 153 | 0 | 816 | 64 |
| | 2005 | 867 | 255 | 0 | 1,122 | 88 |
| | 2006 | 867 | 153 | 102 | 1,122 | 88 |
| | 2007 | 816 | 153 | 51 | 1,020 | 80 |
| | 2008 | 561 | 153 | 51 | 765 | 60 |
| | 2009 | 510 | 204 | 0 | 714 | 56 |
| | 2010 | 459 | 357 | 51 | 867 | 68 |
| | 2011 | 663 | 306 | 102 | 1,071 | 84 |
| | 2012 | 510 | 408 | 204 | 1,122 | 88 |
| | 2013 | 561 | 306 | 0 | 867 | 68 |
| | 2014 | 714 | 255 | 0 | 969 | 76 |
| | 2015 | 510 | 459 | 51 | 1,020 | 80 |
| | 2016 | 867 | 153 | 51 | 1,071 | 84 |
| | 2017 | 510 | 255 | 0 | 765 | 60 |
| | 2018 | 765 | 153 | 0 | 918 | 72 |
| | 2019 | 969 | 102 | 0 | 1,071 | 84 |
| | 2020 | 663 | 102 | 51 | 816 | 64 |
| | 2021 | 612 | 357 | 0 | 969 | 76 |
| | 2022 | 816 | 102 | 255 | 1,173 | 92 |
| | 2023 | 714 | 306 | 0 | 1,020 | 80 |
| | 2024 | 867 | 153 | 51 | 1,071 | 84 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Rappahannock River | 1996 | 119 | 60 | 0 | 179 | 48 |
| | 1997 | 149 | 74 | 15 | 238 | 64 |
| | 1998 | 60 | 134 | 45 | 238 | 64 |
| | 1999 | 89 | 89 | 74 | 253 | 68 |
| | 2000 | 149 | 104 | 15 | 268 | 72 |
| | 2001 | 30 | 60 | 60 | 149 | 40 |
| | 2002 | 134 | 45 | 0 | 179 | 48 |
| | 2003 | 89 | 104 | 0 | 194 | 52 |
| | 2004 | 60 | 89 | 30 | 179 | 48 |
| | 2005 | 253 | 60 | 30 | 343 | 92 |
| | 2006 | 223 | 15 | 45 | 283 | 76 |
| | 2007 | 209 | 104 | 15 | 328 | 88 |
| | 2008 | 179 | 60 | 45 | 283 | 76 |
| | 2009 | 119 | 104 | 45 | 268 | 72 |
| | 2010 | 209 | 45 | 45 | 298 | 80 |
| | 2011 | 134 | 119 | 30 | 283 | 76 |
| | 2012 | 179 | 60 | 30 | 268 | 72 |
| | 2013 | 194 | 30 | 60 | 283 | 76 |
| | 2014 | 89 | 104 | 30 | 223 | 60 |
| | 2015 | 60 | 89 | 30 | 179 | 48 |
| | 2016 | 119 | 89 | 15 | 223 | 60 |
| | 2017 | 134 | 60 | 119 | 313 | 84 |
| | 2018 | 89 | 74 | 74 | 238 | 64 |
| | 2019 | 149 | 89 | 60 | 298 | 80 |
| | 2020 | 45 | 134 | 15 | 194 | 52 |
| | 2021 | 164 | 74 | 60 | 298 | 80 |
| | 2022 | 149 | 134 | 60 | 343 | 92 |
| | 2023 | 134 | 119 | 60 | 313 | 84 |
| | 2024 | 164 | 179 | 15 | 358 | 96 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| York River | 1996 | 45 | 52 | 22 | 120 | 64 |
| | 1997 | 60 | 37 | 22 | 120 | 64 |
| | 1998 | 60 | 45 | 0 | 105 | 56 |
| | 1999 | 75 | 22 | 22 | 120 | 64 |
| | 2000 | 45 | 22 | 15 | 82 | 44 |
| | 2001 | 67 | 52 | 30 | 150 | 80 |
| | 2002 | 22 | 30 | 22 | 75 | 40 |
| | 2003 | 60 | 75 | 22 | 157 | 84 |
| | 2004 | 37 | 15 | 37 | 90 | 48 |
| | 2005 | 75 | 37 | 15 | 127 | 68 |
| | 2006 | 75 | 37 | 15 | 127 | 68 |
| | 2007 | 82 | 52 | 15 | 150 | 80 |
| | 2008 | 60 | 30 | 37 | 127 | 68 |
| | 2009 | 67 | 22 | 7 | 97 | 52 |
| | 2010 | 60 | 30 | 15 | 105 | 56 |
| | 2011 | 52 | 60 | 15 | 127 | 68 |
| | 2012 | 52 | 22 | 30 | 105 | 56 |
| | 2013 | 112 | 22 | 7 | 142 | 76 |
| | 2014 | 45 | 45 | 15 | 105 | 56 |
| | 2015 | 45 | 22 | 37 | 105 | 56 |
| | 2016 | 30 | 45 | 30 | 105 | 56 |
| | 2017 | 30 | 60 | 30 | 120 | 64 |
| | 2018 | 45 | 30 | 15 | 90 | 48 |
| | 2019 | 0 | 7 | 45 | 52 | 28 |
| | 2020 | 37 | 0 | 15 | 52 | 28 |
| | 2021 | 45 | 22 | 30 | 97 | 52 |
| | 2022 | 37 | 45 | 15 | 97 | 52 |
| | 2023 | 37 | 30 | 45 | 112 | 60 |
| | 2024 | 52 | 45 | 37 | 134 | 72 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| James River | 1996 | 137 | 82 | 55 | 273 | 40 |
| | 1997 | 219 | 109 | 27 | 355 | 52 |
| | 1998 | 164 | 164 | 109 | 437 | 64 |
| | 1999 | 82 | 246 | 55 | 383 | 56 |
| | 2000 | 55 | 109 | 55 | 219 | 32 |
| | 2001 | 219 | 164 | 27 | 410 | 60 |
| | 2002 | 164 | 137 | 55 | 355 | 52 |
| | 2003 | 137 | 246 | 55 | 437 | 64 |
| | 2004 | 109 | 191 | 27 | 328 | 48 |
| | 2005 | 82 | 109 | 109 | 301 | 44 |
| | 2006 | 137 | 219 | 27 | 383 | 56 |
| | 2007 | 246 | 191 | 27 | 465 | 68 |
| | 2008 | 164 | 219 | 164 | 547 | 80 |
| | 2009 | 164 | 191 | 109 | 465 | 68 |
| | 2010 | 109 | 82 | 82 | 273 | 40 |
| | 2011 | 355 | 164 | 55 | 574 | 84 |
| | 2012 | 109 | 137 | 164 | 410 | 60 |
| | 2013 | 301 | 109 | 55 | 465 | 68 |
| | 2014 | 191 | 109 | 55 | 355 | 52 |
| | 2015 | 164 | 137 | 27 | 328 | 48 |
| | 2016 | 109 | 246 | 109 | 465 | 68 |
| | 2017 | 191 | 164 | 137 | 492 | 72 |
| | 2018 | 219 | 109 | 55 | 383 | 56 |
| | 2019 | 246 | 164 | 82 | 492 | 72 |
| | 2020 | 137 | 137 | 109 | 383 | 56 |
| | 2021 | 328 | 82 | 27 | 437 | 64 |
| | 2022 | 164 | 273 | 0 | 437 | 64 |
| | 2023 | 164 | 246 | 82 | 492 | 72 |
| | 2024 | 328 | 137 | 55 | 520 | 76 |

Table 3-4. (Continued)

| Region | Year | Severely Degraded | Degraded | Marginal | Total Failing | % Failing |
|---|---|---|---|---|---|---|
| Virginia Mainstem | 1996 | 165 | 494 | 824 | 1,483 | 36 |
| | 1997 | 165 | 1,154 | 330 | 1,648 | 40 |
| | 1998 | 824 | 330 | 494 | 1,648 | 40 |
| | 1999 | 494 | 165 | 494 | 1,154 | 28 |
| | 2000 | 0 | 165 | 1,154 | 1,318 | 32 |
| | 2001 | 494 | 330 | 989 | 1,813 | 44 |
| | 2002 | 659 | 659 | 165 | 1,483 | 36 |
| | 2003 | 494 | 824 | 659 | 1,977 | 48 |
| | 2004 | 659 | 659 | 330 | 1,648 | 40 |
| | 2005 | 1,483 | 330 | 165 | 1,977 | 48 |
| | 2006 | 824 | 494 | 165 | 1,483 | 36 |
| | 2007 | 494 | 330 | 494 | 1,318 | 32 |
| | 2008 | 330 | 494 | 659 | 1,483 | 36 |
| | 2009 | 330 | 0 | 330 | 659 | 16 |
| | 2010 | 165 | 165 | 989 | 1,318 | 32 |
| | 2011 | 824 | 165 | 330 | 1,318 | 32 |
| | 2012 | 165 | 659 | 165 | 989 | 24 |
| | 2013 | 494 | 330 | 494 | 1,318 | 32 |
| | 2014 | 165 | 0 | 165 | 330 | 8 |
| | 2015 | 330 | 165 | 0 | 494 | 12 |
| | 2016 | 0 | 0 | 330 | 330 | 8 |
| | 2017 | 494 | 0 | 0 | 494 | 12 |
| | 2018 | 0 | 0 | 330 | 330 | 8 |
| | 2019 | 494 | 330 | 989 | 1,813 | 44 |
| | 2020 | 989 | 494 | 494 | 1,977 | 48 |
| | 2021 | 165 | 0 | 330 | 495 | 12 |
| | 2022 | 330 | 330 | 0 | 660 | 16 |
| | 2023 | 494 | 165 | 0 | 659 | 16 |
| | 2024 | 165 | 0 | 989 | 1,154 | 28 |

Table 3-5. Sites severely degraded (B-IBI≤2) and failing the restoration goals (scored at 1) for insufficient abundance, insufficient biomass, or both as a percentage of sites failing the goals (B-IBI<3), 1996 to 2024. Strata are listed in decreasing percent order of sites with insufficient abundance/biomass.

| Stratum | Sites Severely Degraded | | Sites Failing the Goals Due to Insufficient Abundance, Biomass, or Both | |
|---|---|---|---|---|
| | Number of Sites | As Percentage of Sites Failing the Goals | Number of Sites | As Percentage of Sites Failing the Goals |
| Potomac River | 385 | 70.4 | 471 | 86.1 |
| Patuxent River | 269 | 55.0 | 408 | 83.4 |
| Mid Bay Mainstem | 247 | 55.1 | 353 | 78.8 |
| Western Tributaries | 258 | 61.7 | 300 | 71.8 |
| Upper Bay Mainstem | 118 | 49.2 | 163 | 67.9 |
| Rappahannock River | 260 | 51.7 | 301 | 59.8 |
| Virginia Mainstem | 77 | 36.5 | 125 | 59.2 |
| Eastern Tributaries | 118 | 33.1 | 203 | 57.0 |
| York River | 202 | 47.3 | 140 | 32.8 |
| James River | 190 | 43.8 | 115 | 26.5 |

Table 3-6. Sites failing the restoration goals (scored at 1) for excess abundance, excess biomass, or both as a percentage of sites failing the goals (B-IBI<3), 1996 to 2024. Strata are listed in decreasing percent order of sites with excess abundance/biomass.

| Stratum | Number of Sites | As Percentage of Sites Failing the Goals |
|---|---|---|
| James River | 151 | 34.8 |
| York River | 116 | 27.2 |
| Rappahannock River | 112 | 22.3 |
| Eastern Tributaries | 65 | 18.3 |
| Upper Bay Mainstem | 38 | 15.8 |
| Western Tributaries | 55 | 13.2 |
| Mid Bay Mainstem | 51 | 11.4 |
| Virginia Mainstem | 18 | 8.5 |
| Patuxent River | 38 | 7.8 |
| Potomac River | 38 | 6.9 |

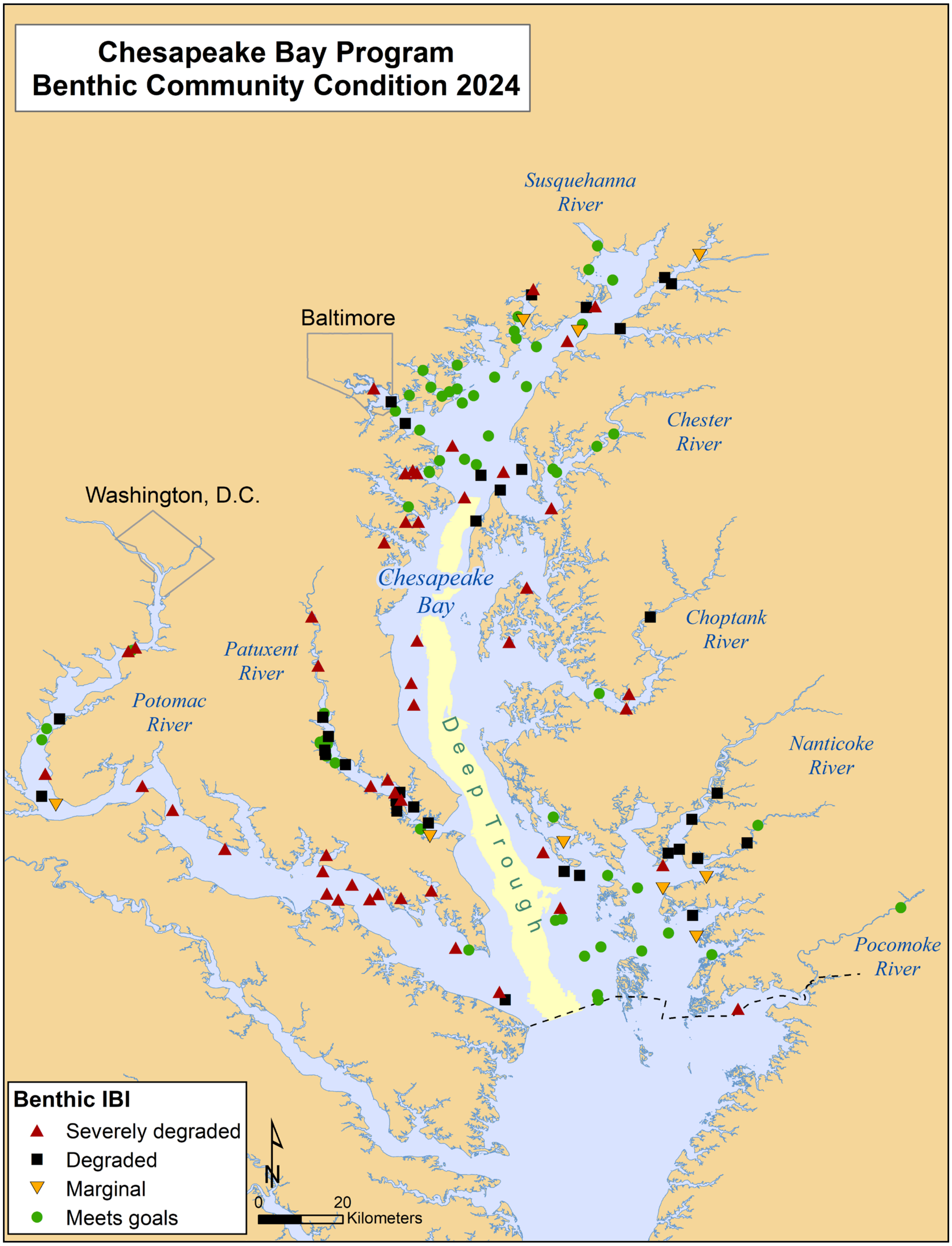


Figure 3-32. Results of probability-based benthic sampling of the Maryland Chesapeake Bay and its tidal tributaries in 2024. Each sample was evaluated in context of the Chesapeake Bay benthic community restoration goals

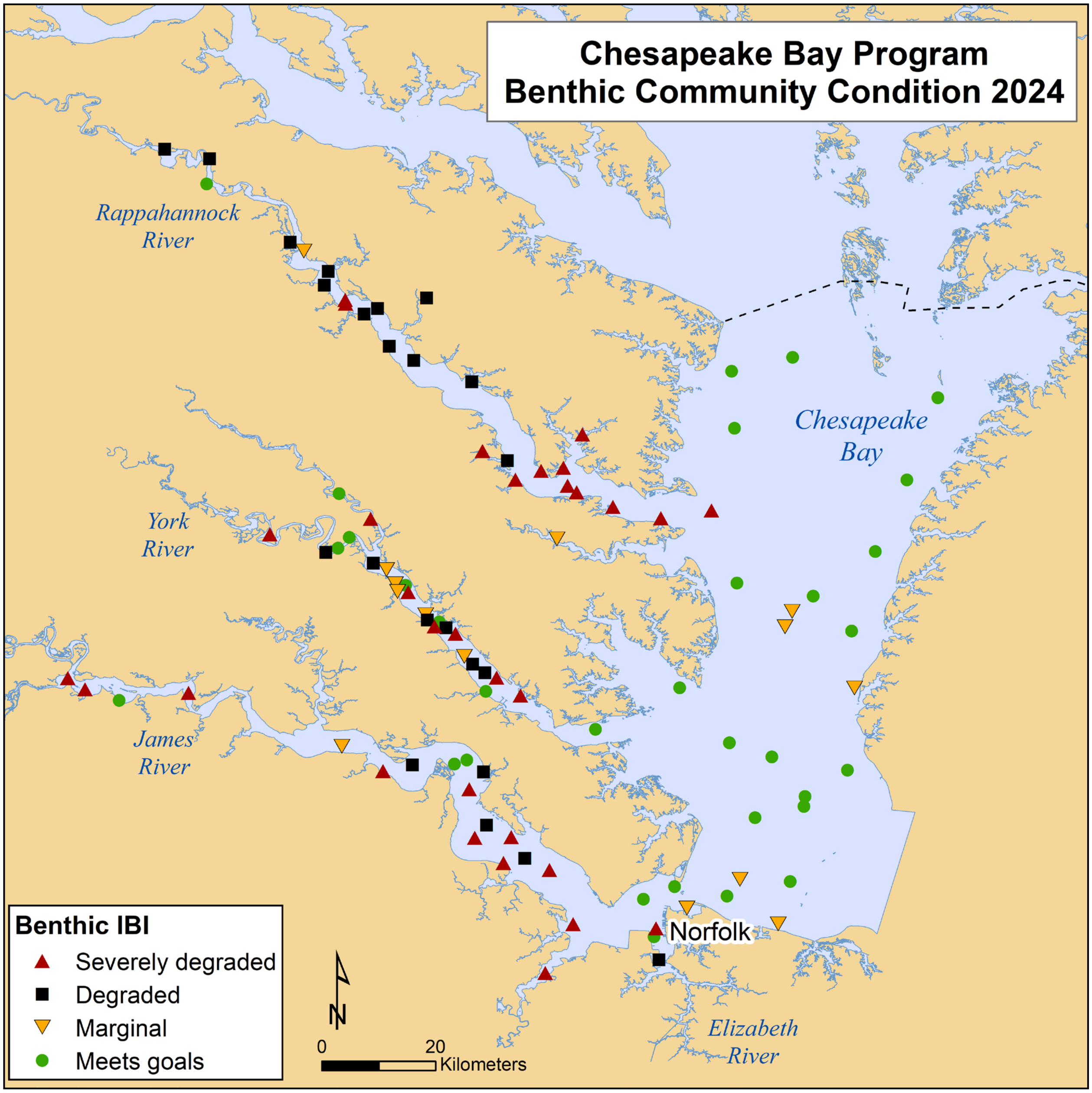


Figure 3-33. Results of probability-based benthic sampling of the Virginia Chesapeake Bay and its tidal tributaries in 2024. Each sample was evaluated in context of the Chesapeake Bay benthic community restoration goals

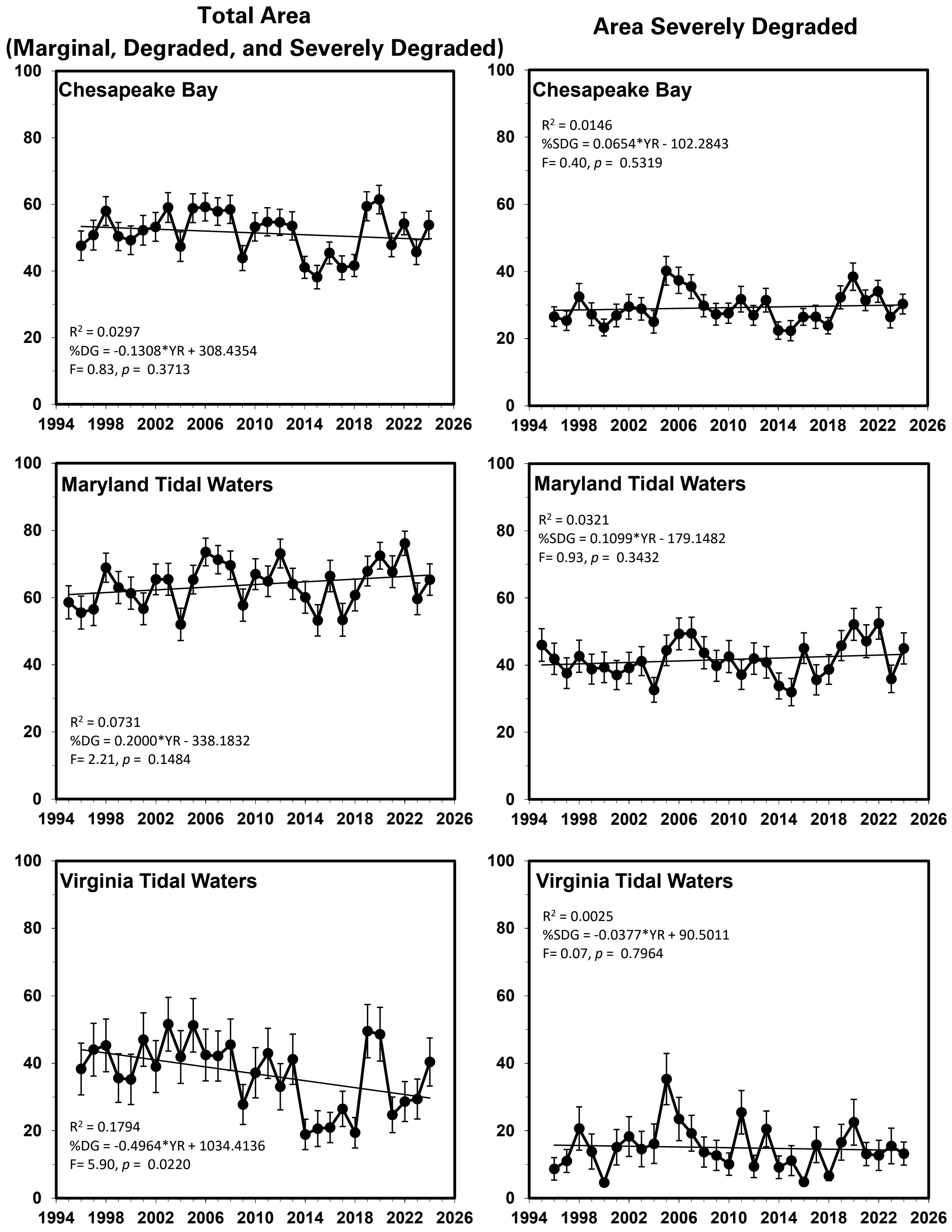


Figure 3-34. Proportion of the Chesapeake Bay, Maryland tidal waters, and Virginia tidal waters failing the Chesapeake Bay benthic community restoration goals, 1996 to 2024 (1995-2024 for Maryland). Panels on left show percent total area degraded (B-IBI<3); panels on right show percent area severely degraded (B-IBI≤2). Error bars indicate ± 1 standard error. The mainstem deep trough is included in the severely degraded condition estimates. See cautionary note in page 3-40. Significance of trend tested by ANOVA

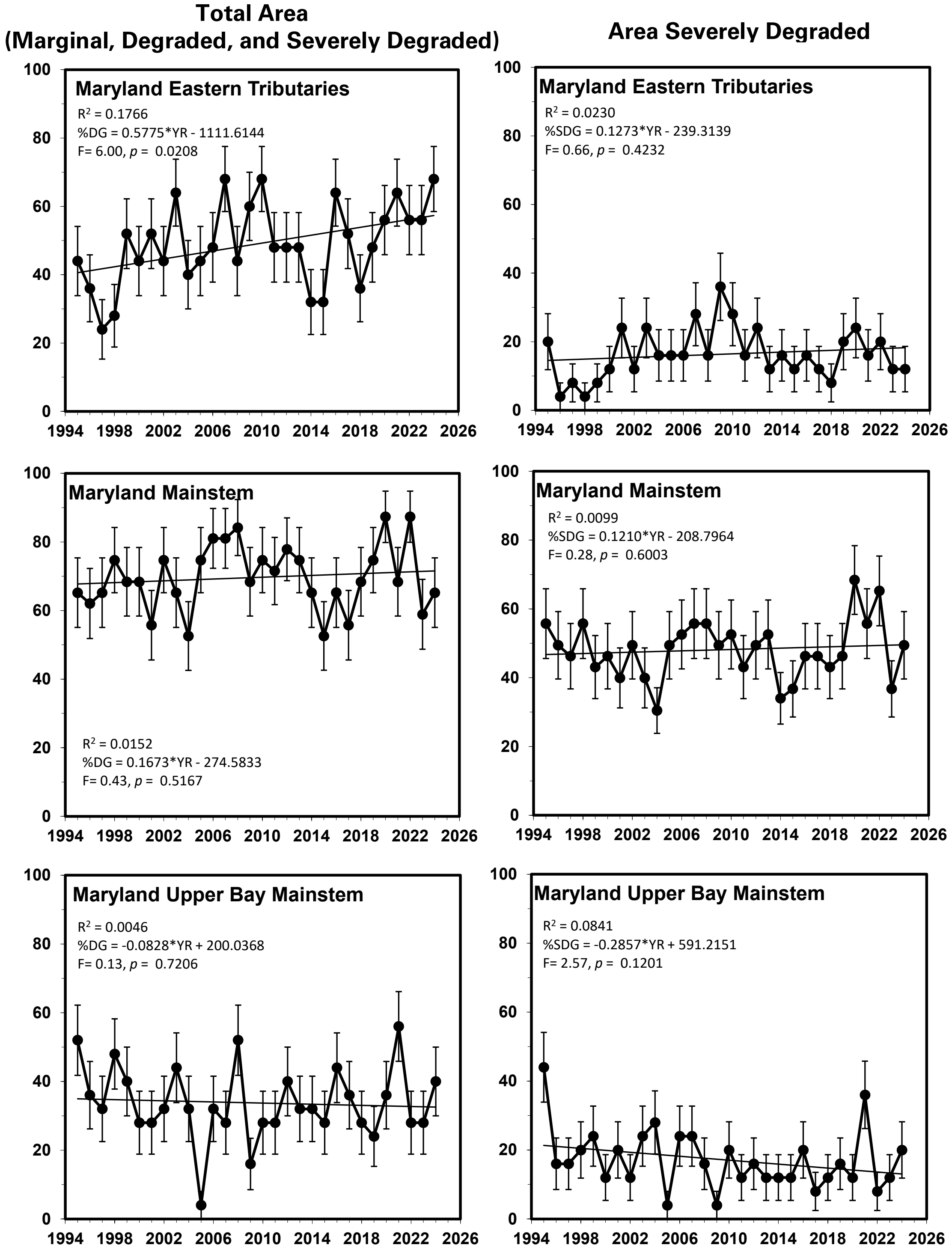
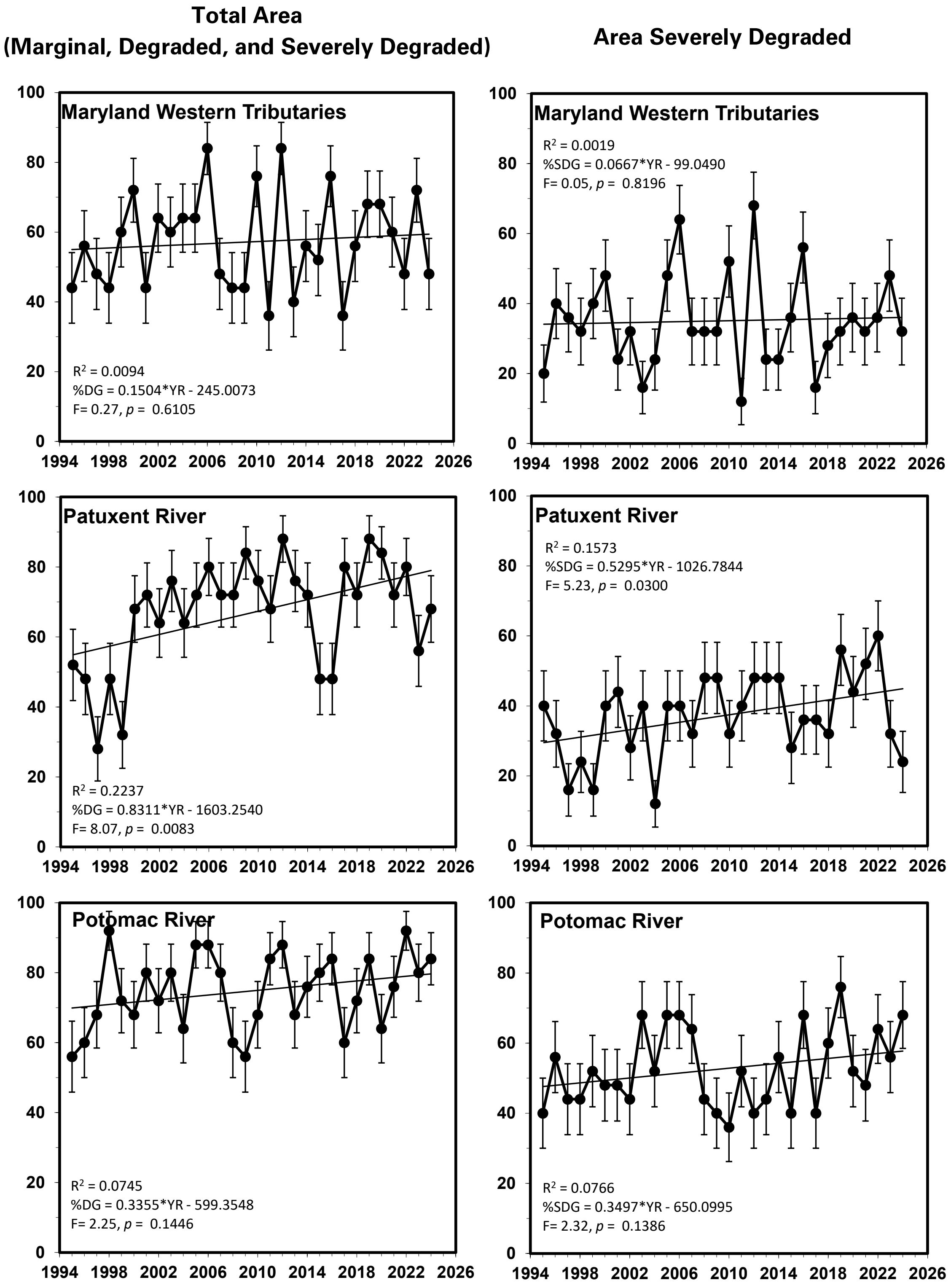


Figure 3-35. Proportion of the Maryland sampling strata failing the Chesapeake Bay benthic community restoration goals, 1995 to 2024. Panels on left show percent total area degraded (B-IBI<3); panels on right show percent area severely degraded (B-IBI≤2). Error bars indicate ± 1 standard error. The deep trough is included in the Maryland mainstem stratum estimates. See cautionary note in page 3-40. Significance of trend tested by ANOVA


Total Area
(Marginal, Degraded, and Severely Degraded)

Area Severely Degraded

Figure 3-35. (Continued)

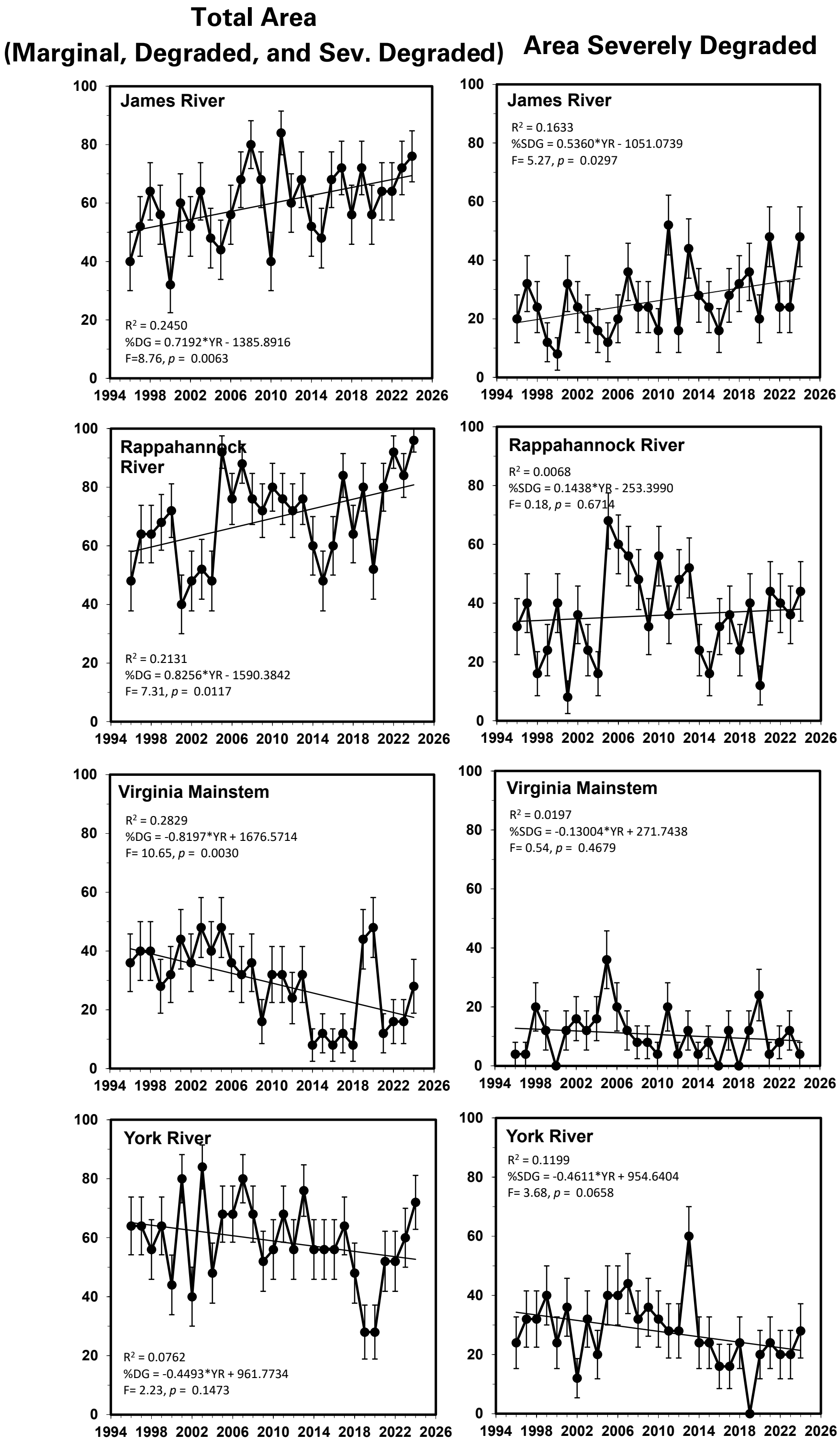


Figure 3-36. Proportion of the Virginia sampling strata failing the Chesapeake Bay benthic community restoration goals, 1996 to 2024. Panels on left show percent total area degraded (B-IBI<3); panels on right show percent area severely degraded (B-IBI≤2). Error bars indicate ± 1 standard error. Significance of trend tested by ANOVA

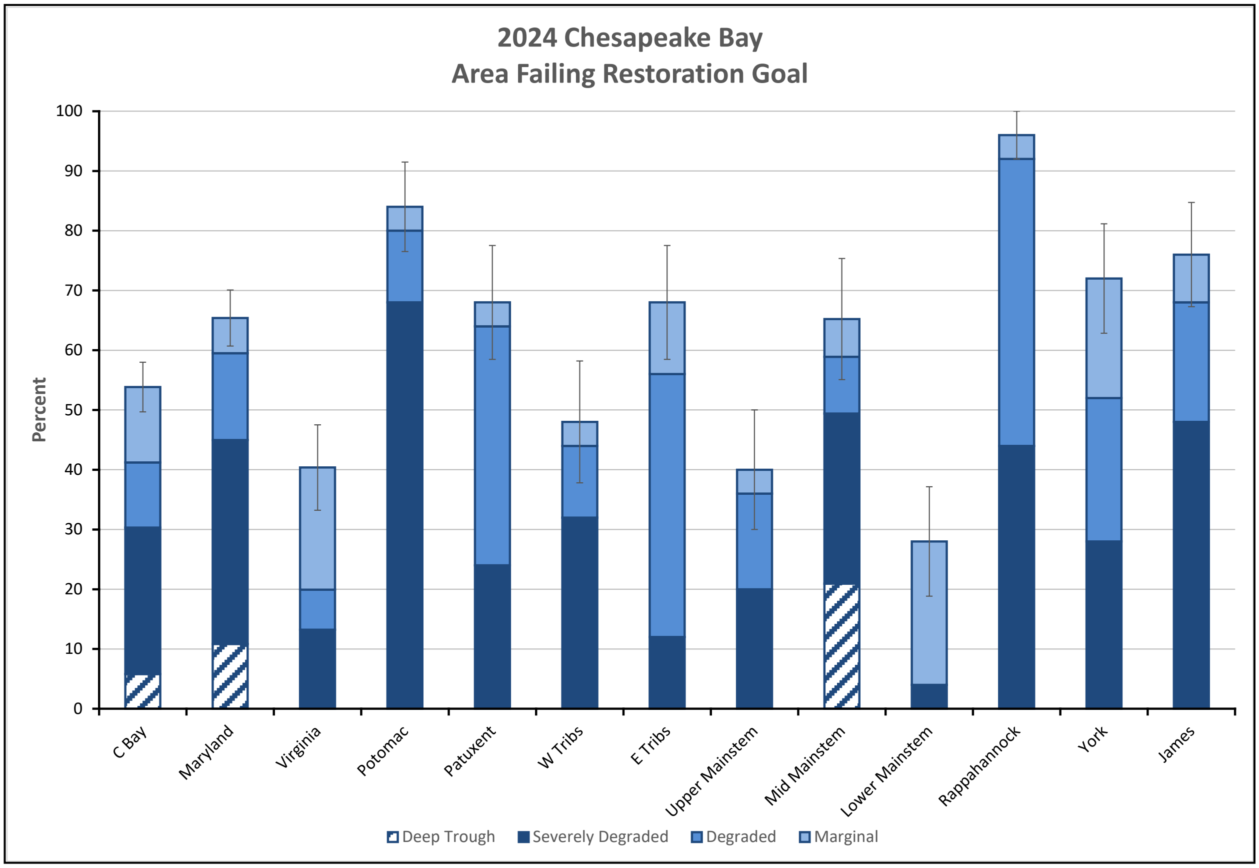


Figure 3-37. Proportion of the Chesapeake Bay, Maryland, Virginia, and the 10 sampling strata failing the Chesapeake Bay benthic community restorations goals in 2024. The deep trough is considered severely degraded. Error bars indicate ± 1 standard error

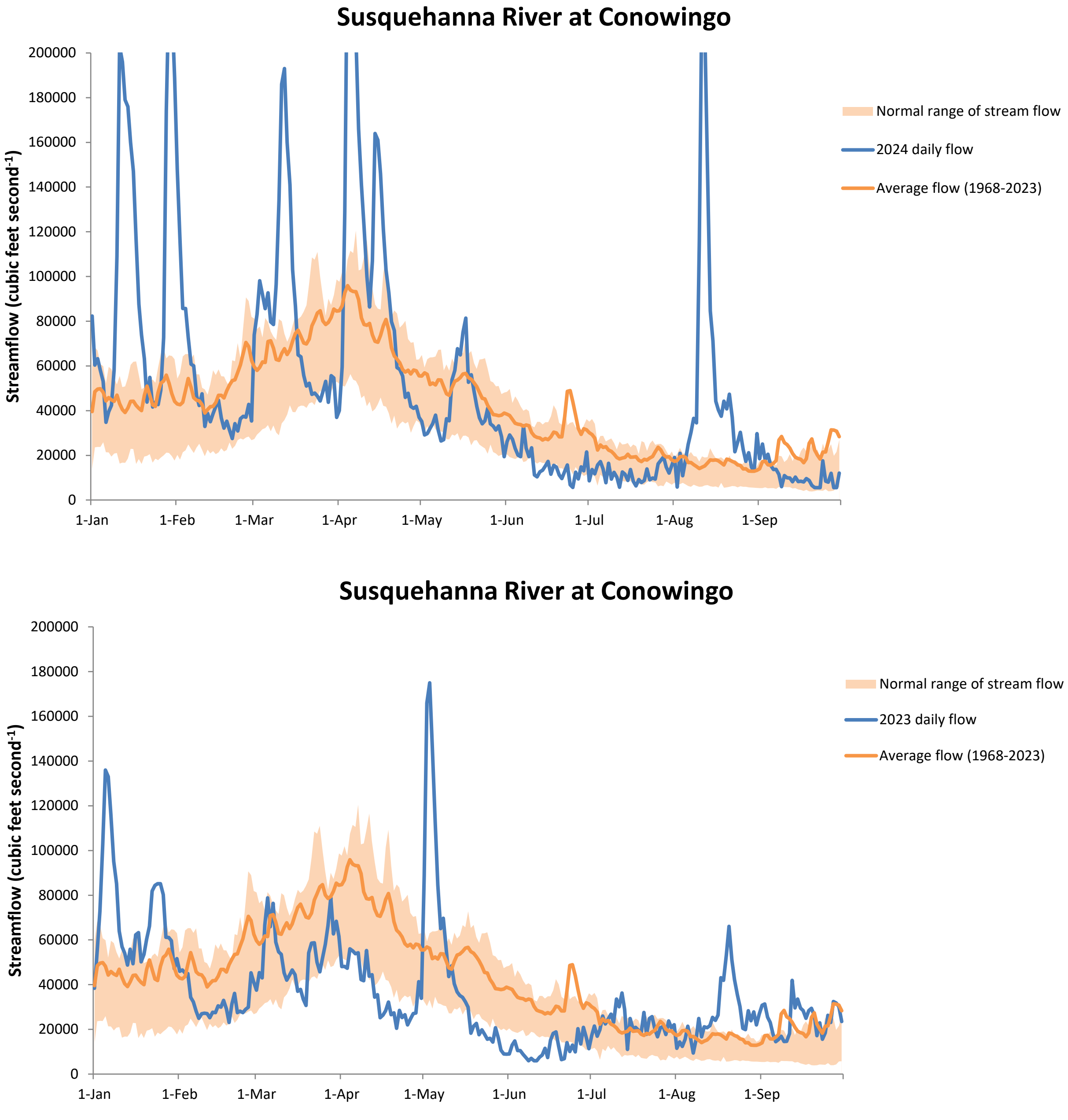


Figure 3-38. Daily flow entering Chesapeake Bay from the Susquehanna River at Conowingo in 2024 (top panel) and 2023 (bottom panel) compared to the long-term average, January through September. Normal range of stream flow: 25%-75%, 1968-2023. Data source: United States Geological Survey

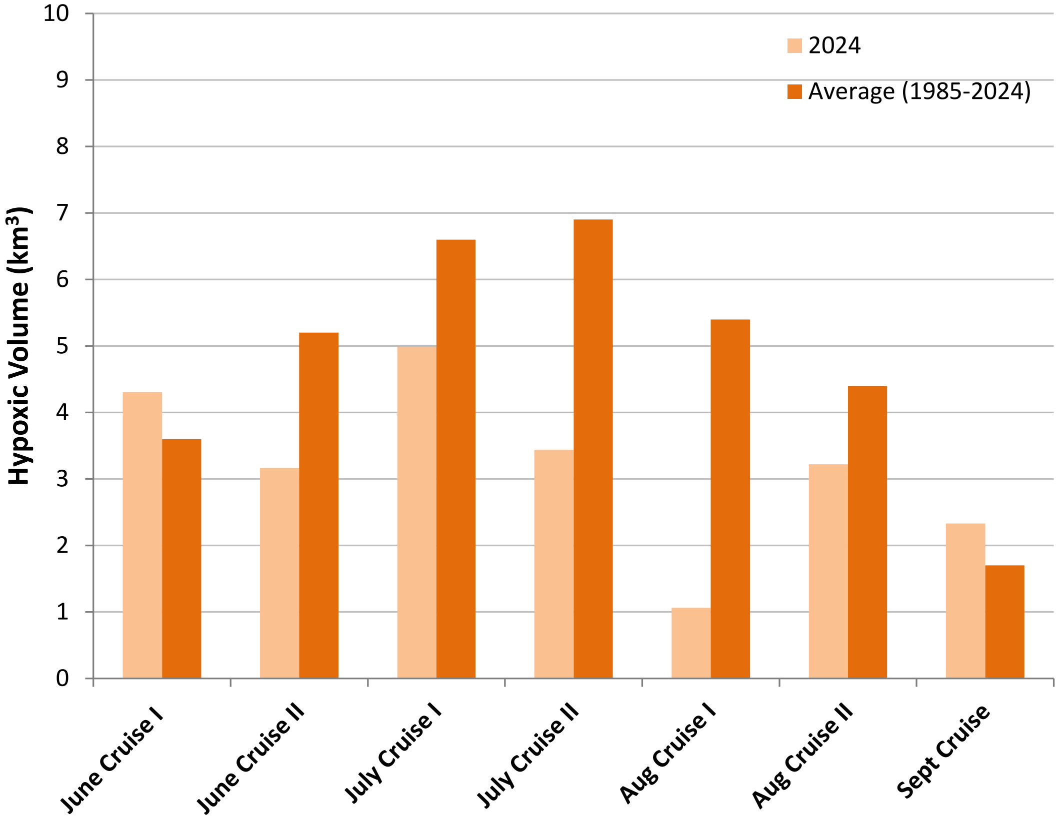


Figure 3-39. Hypoxic volume in Chesapeake Bay in 2024 compared to the long-term average. Data provided by the Maryland Department of Natural Resources (DNR). Cruises conducted by Maryland DNR and Virginia DEQ

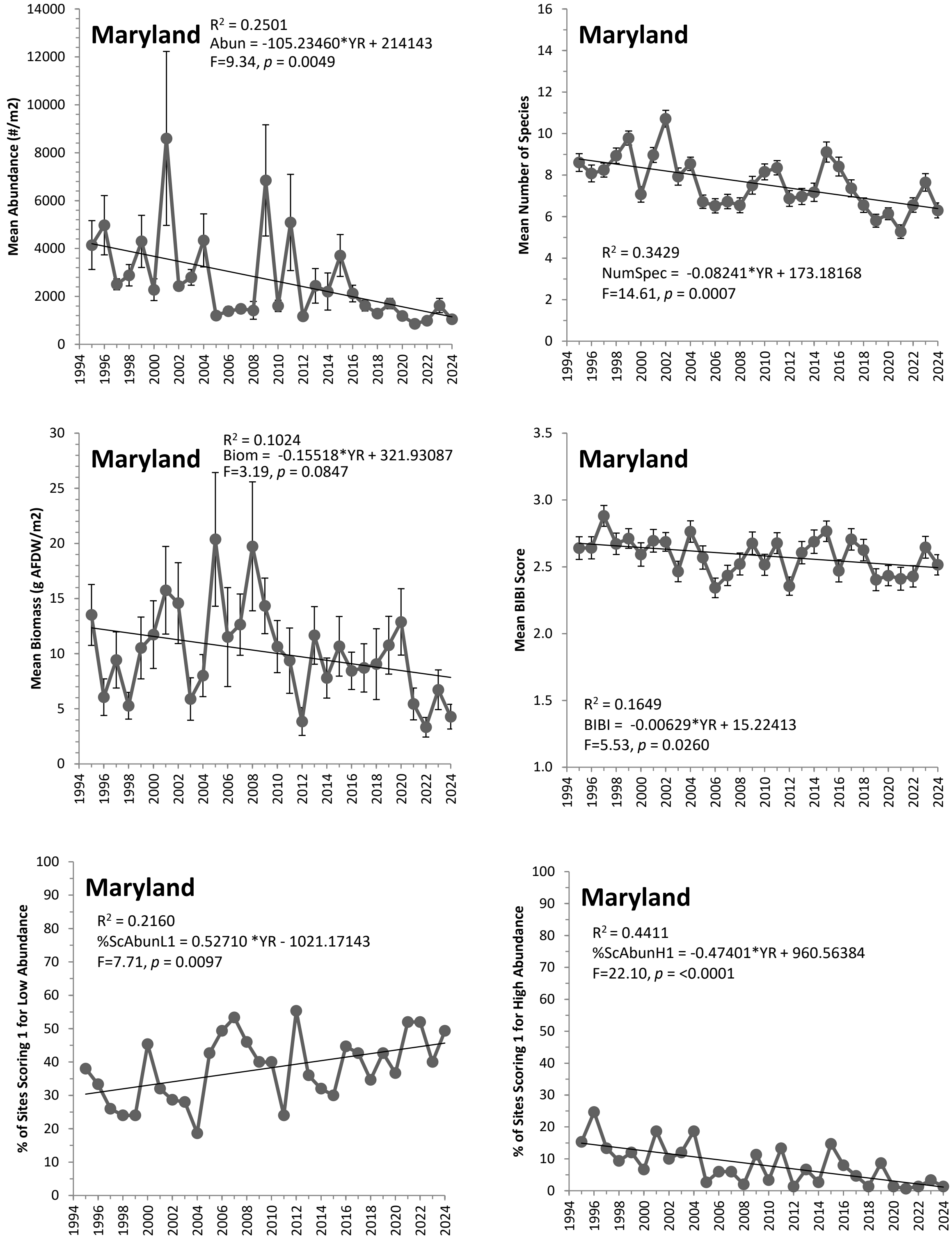


Figure 3-40. Trends in abundance, biomass, number of species, B-IBI score (mean ± 1 SE), and percent sites scoring "1" for low abundance and "1" for high abundance in Maryland tidal waters, 1995-2024 (N = 150 sites per year). Significance of trend tested by ANOVA

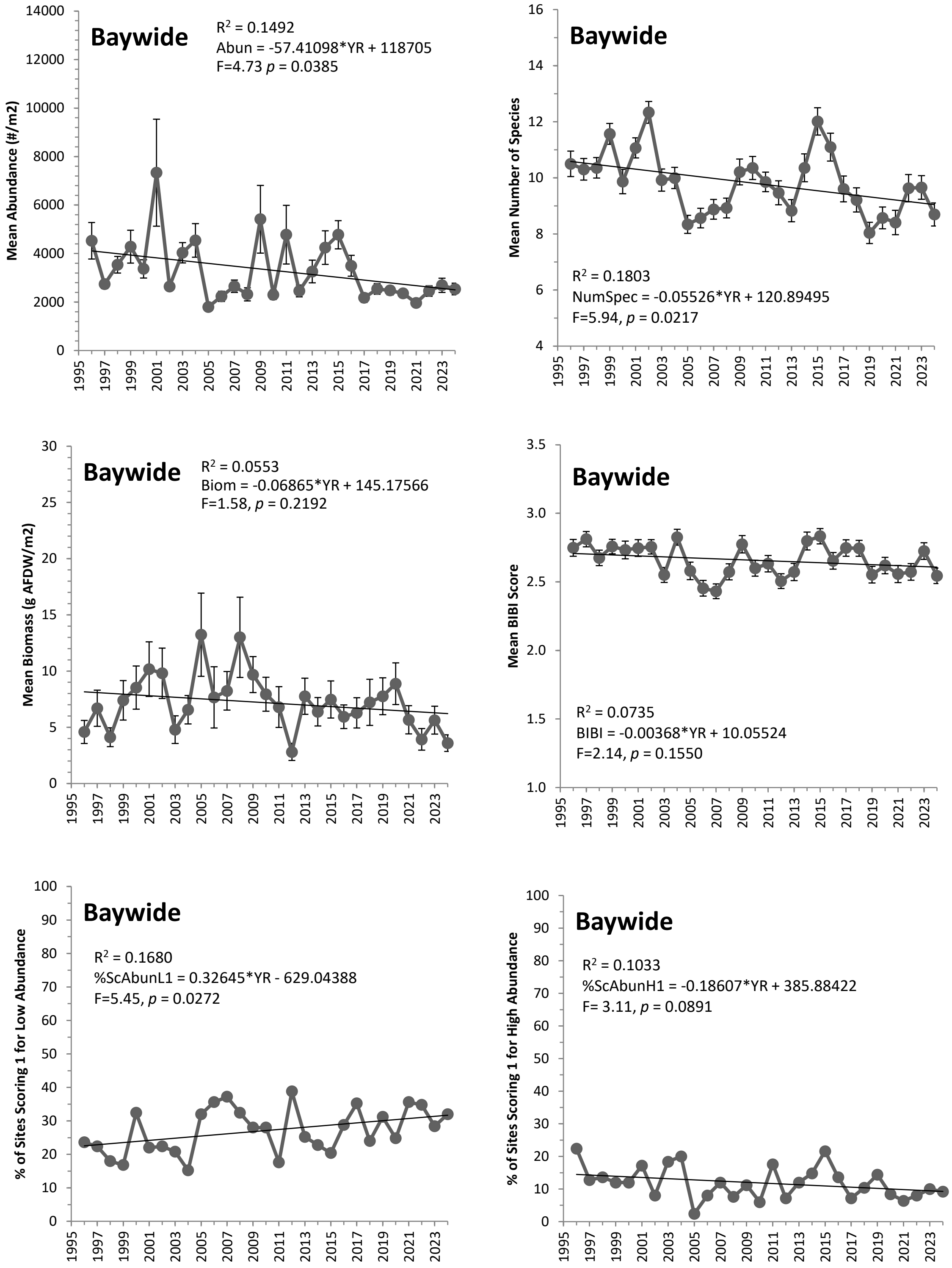


Figure 3-41. Trends in abundance, biomass, number of species, B-IBI score (mean ± 1 SE), and percent sites scoring "1" for low abundance and "1" for high abundance in Chesapeake Bay, 1996-2024 (N = 250 sites per year). Significance of trend tested by ANOVA

## 3.3 BASIN-LEVEL BOTTOM COMMUNITY CONDITION

Probability-based sampling can be used to produce areal estimates of degradation for regions of interest. The 2024 random sites were post-stratified into 15 reporting regions used by the Chesapeake Bay Program to assess the health of the Bay's ecosystem (Figure 3-42). The Bay Program conducts an annual integrated assessment for the Bay and its tidal tributaries using indicators of water quality conditions (chlorophyll-*a*, dissolved oxygen, water clarity, total nitrogen, total phosphorus), living resources (plankton and benthos), and habitat (bay grasses) combined into a Bay Health Index (BHI, Williams et al. 2009). The BHI is a spatially explicit management tool that was developed to evaluate the status of water quality, habitat quality, and biotic condition in Chesapeake Bay. This information is linked to nutrient and sediment pollution sources and is intended to assist in setting restoration goals at the level of tributary basins.

Probability-based estimates for each region followed the methods described in Section 2.4.3 for single Benthic Monitoring Program strata (formulae 1 and 2), except for regions that overlapped strata (Maryland Upper Eastern Shore, Choptank River, Maryland Lower Eastern Shore, and Mid Bay regions). Regions that overlapped benthic program strata were partitioned into the portions corresponding to each stratum, and the estimates for each portion or sub-region were weighted by area and combined into region-wide estimates, as described in Section 2.4.3 (formulae 3 and 4). For example, the Choptank River reporting region consisted of two sub-regions: the Choptank River proper (Bay Program segments CHOTF, CHOOH, and CHOMH2) and the open waters of the Choptank and Little Choptank Rivers (Bay Program segments CHOMH1 and LCHMH). While the former sub-region is part of the Maryland Eastern Tributaries stratum, the latter is part of the Maryland Mid Bay Mainstem stratum. Thus, degradation estimates were produced for each of the Choptank River sub-regions, weighted by the proportion of area represented by each sub-region, and combined.

At the BHI reporting region level, degradation in 2024 was largest in all of the major tributaries of Chesapeake Bay: Patuxent, Potomac, Choptank, Rappahannock, York, and James rivers (Table 3-7). The percent area failing the restoration goals in each of these systems was higher in 2024 than in 2023 by 3% to 17%. The Upper Bay, the Patapsco/Back rivers and the Lower Bay had the lowest degradation. The Patapsco/Back rivers saw a decrease in degradation of 50% relative to 2023, and the Maryland Lower Western Shore tributaries saw a decrease of 25% relative to 2023. The standard error of estimates for regions is typically large because of small sample size or poor data coverage. Thus, at the BHI reporting region level, large changes in benthic condition are likely to be observed from year to year, and these changes should be viewed with caution.

Table 3-7. Estimated tidal area failing to meet the Chesapeake Bay benthic community restoration goals in 2024 by Bay Health Index (BHI) Reporting Region and Tributary Basin. See Figure 3-42 for reporting regions. *The lower Choptank River; Northeast River and Eastern Bay (part of the Maryland Upper Eastern Shore); and Pocomoke Sound (part of the Maryland Lower Eastern Shore) are not included in the estimates because of insufficient data.

| Region/Basin | Percent Failing | Km$^2$ Failing | SE | N |
|---|---|---|---|---|
| Rappahannock River | 96 | 357.5 | 4.0 | 25 |
| Potomac River | 84 | 1077.3 | 7.1 | 25 |
| James River | 78 | 500.7 | 8.8 | 23 |
| Choptank River* | 75 | 73.6 | 25.0 | 5 |
| York River | 72 | 134.8 | 9.2 | 25 |
| Patuxent River | 68 | 87.0 | 9.5 | 25 |
| Maryland Lower Western Shore | 67 | 66.9 | 16.7 | 9 |
| Mid Bay | 62 | 1487.6 | 7.4 | 13 |
| Maryland Upper Eastern Shore* | 56 | 124.5 | 17.6 | 10 |
| Elizabeth River | 50 | 23.5 | 50.0 | 2 |
| Maryland Lower Eastern Shore* | 46 | 473.8 | 11.5 | 25 |
| Maryland Upper Western Shore | 43 | 38.0 | 20.2 | 7 |
| Upper Bay | 40 | 315.4 | 10.0 | 25 |
| Patapsco/Back Rivers | 33 | 36.6 | 16.7 | 9 |
| Lower Bay | 32 | 989.1 | 10.2 | 22 |

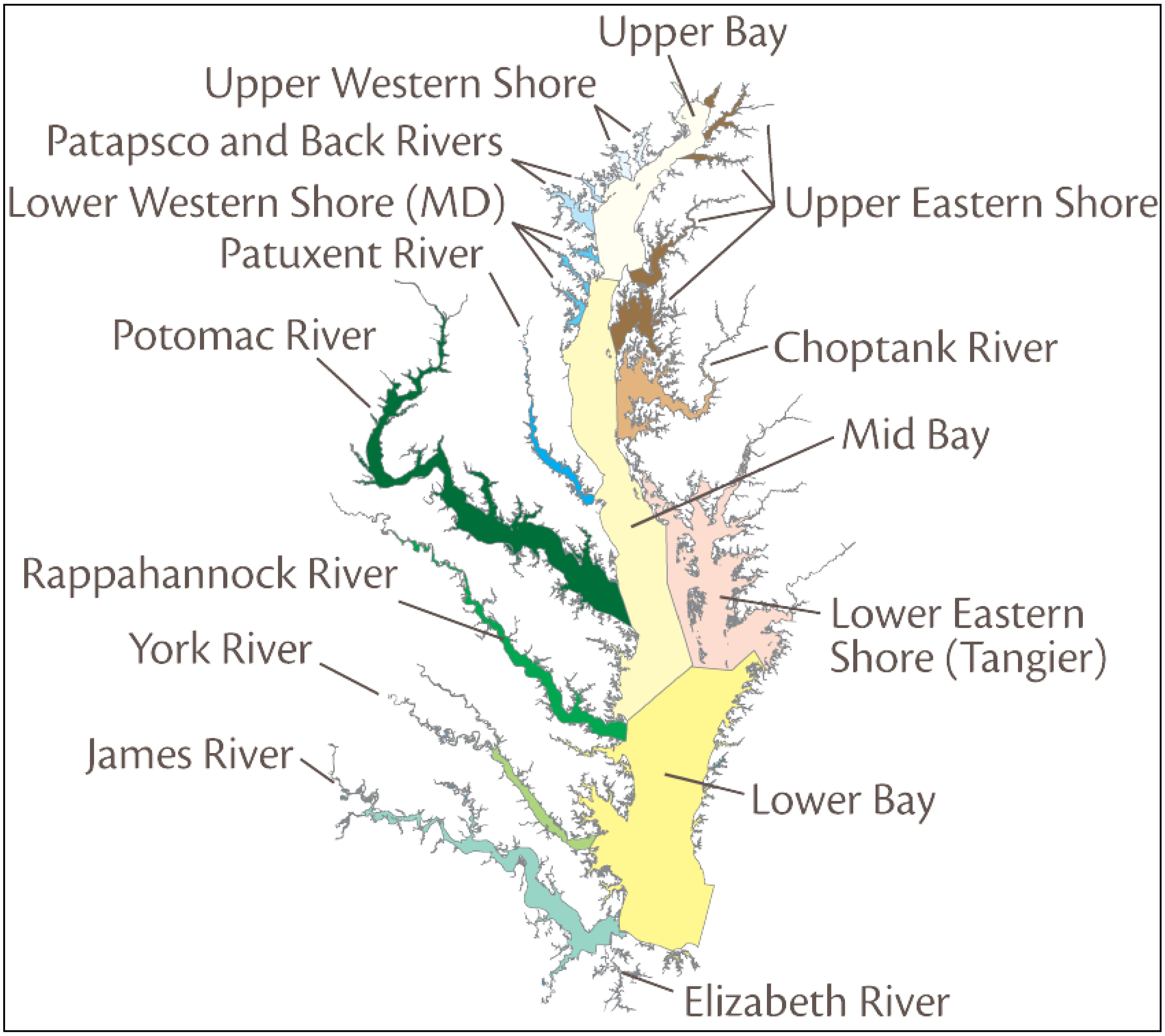


Figure 3-42. Bay Health Index Reporting Regions and Tributary Basins. Source: *EcoCheck*, University of Maryland Center for Environmental Science

## 3.4 BENTHIC CHLOROPHYLL-A AND PHAEOPHYTIN

The monitoring of microphytobenthos was initiated in 2021 with samples collected in summer to determine surface chlorophyll-*a* concentrations as an index of algal biomass. Biomass of microphytobenthos varies with irradiance, temperature, and nutrient availability (Jacobs et al. 2021). Microphytobenthos help regulate the flux of nutrients and oxygen at the sediment-water interface (Sundback et al. 2000) and may be useful in tracking eutrophication (Kemp et al. 2005). Benthic chlorophyll-*a* concentrations at the fixed sites (mg/m$^2$) were determined from three surface sediment replicate samples (2.5 cm diameter x 1 cm sediment cores, 4.91 cm$^3$).

Chlorophyll-*a* is corrected for the presence of its degradation product phaeophytin, and the results are presented separately for chlorophyll-*a* and phaeophytin in Figures 3-43 and 3-44. Individual replicate sample concentrations are presented in Appendix E. Mean chlorophyll-*a* concentrations in 2024 ranged between 9 and 62 mg/m$^2$ at 23 sites, and a mean concentration of 694 mg/m$^2$ was measured at Station 051 (Figure 3-43). Mid-Bay mainstem stations 001, 006, and 015 had elevated chlorophyll-*a* concentrations between 78 and 295 mg/m$^2$, indicating bloom conditions. These are sandy, shallow sites with low silt-clay content. Mean phaeophytin concentrations ranged between 35 and 292 mg/m$^2$ (Figure 3-44). Chlorophyll-*a* and phaeophytin concentrations were generally higher in 2024 than in 2023.

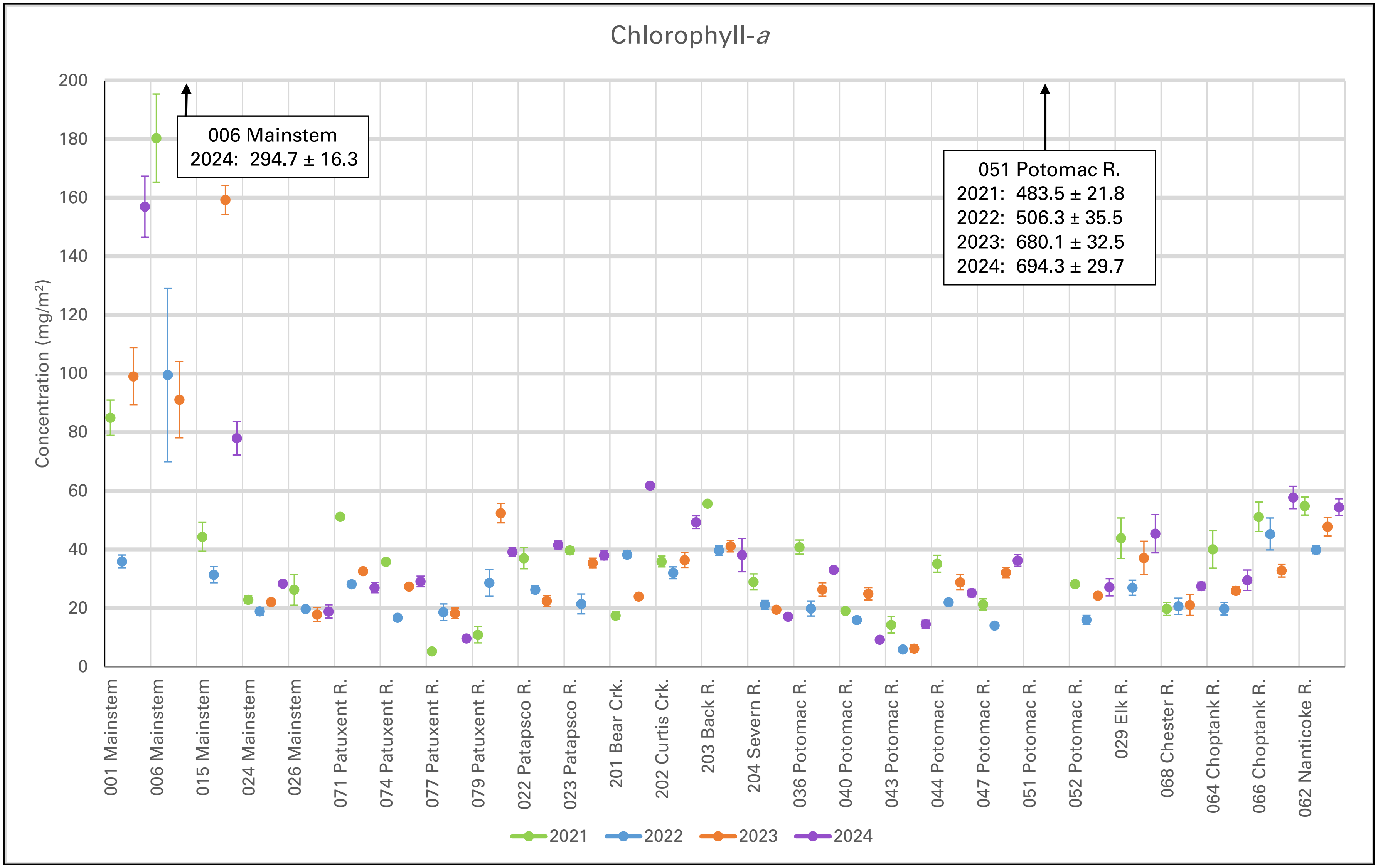


Figure 3-43. Benthic chlorophyll-*a* concentrations at fixed sites for 2021-2024. Error bars indicate ± 1 standard error (n=3)

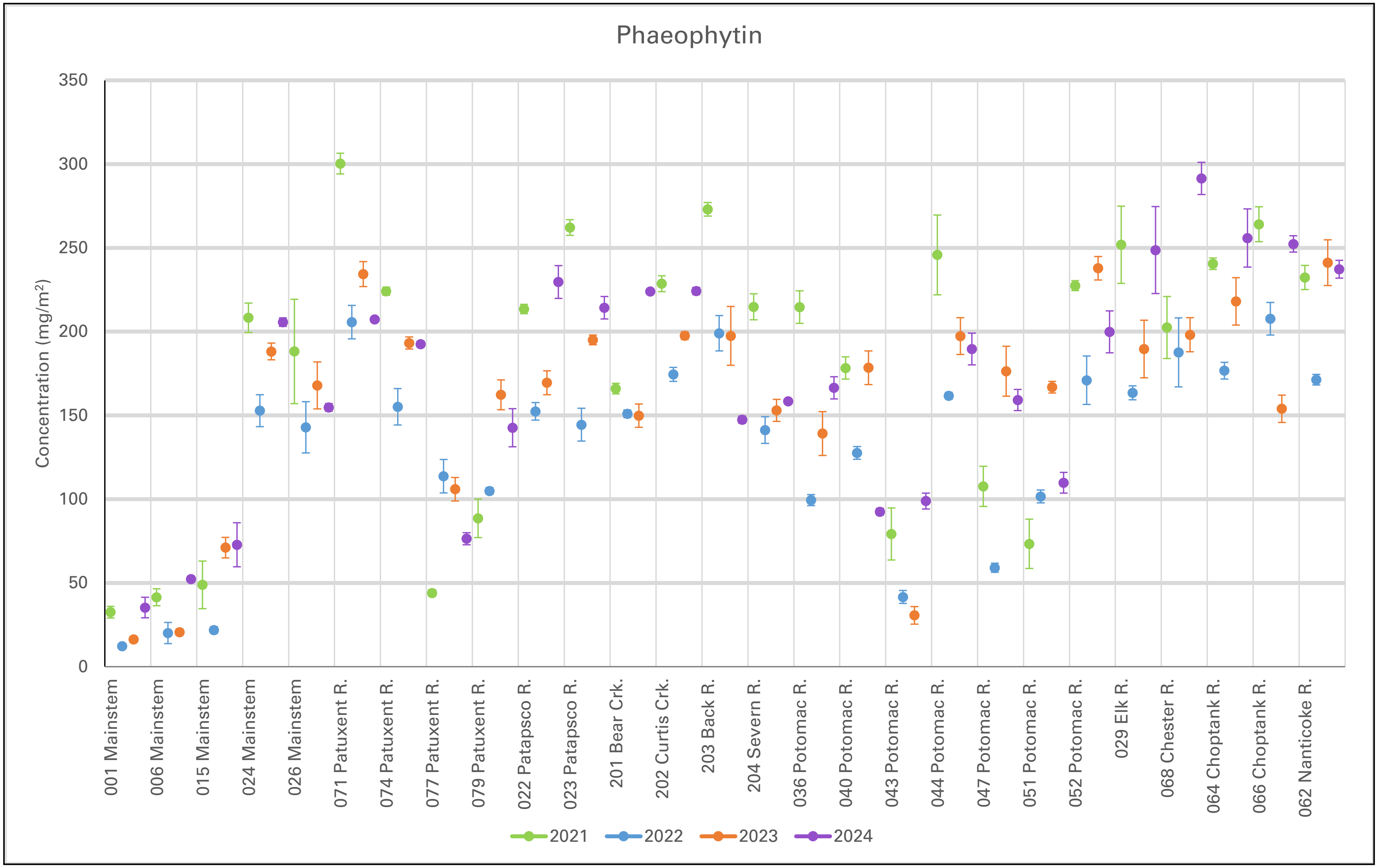


Figure 3-44. Benthic phaeophytin concentration at fixed sites for 2021-2024. Error bars indicate ± 1 standard error (n=3)

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# 4.0 DISCUSSION

The highlights for 2024 can be summarized as follows:

Random-site Results

(1) The tidal area with degraded benthos in Chesapeake Bay increased from 46% in 2023 to 54% in 2024. There was no statistically significant trend in percent area degraded over the 1996-2024 time period.

(2) In Maryland the tidal area with degraded benthos increased from 60% in 2023 to 65% in 2024. The percent severely degraded condition also increased from 36% in 2023 to 45% in 2024. There was no statistically significant trend in percent area degraded over the 1995-2024 time period.

(3) In 2024 degradation increased in all of the Maryland strata except the Maryland Western Tributaries. The Patuxent River and the Maryland Eastern Tributaries had the largest increase in degradation. The Potomac and the Patuxent rivers were in poorest condition. The Upper Bay Mainstem was in best condition.

Fixed-site Results

(4) Benthic community condition (B-IBI scores averaged over the last 3 years of monitoring) remained within the same condition category at all of the fixed sites. As in the previous year, 7 sites met the benthic community restoration goals and 20 sites failed the goals.

(5) Statistically significant B-IBI trends were detected at 18 of the 27 fixed sites in Maryland. Trends declined at 13 sites (significantly decreasing B-IBI score) and improved at 5 sites (significantly increasing B-IBI score). Changes in B-IBI trends between 2023 and 2024 were limited to the appearance of a declining B-IBI trend at the mid-Bay mainstem Station 006.

Discussion

Benthic community degradation in Chesapeake Bay and the Maryland portion of the Chesapeake Bay increased in 2024. The increase, as estimated by the benthic index of biotic integrity, affected all of the sampling strata in Maryland except the Maryland Western Tributaries, and all of the sampling strata in Virginia. The increase was not very large, within the uncertainty of the estimate in both Maryland and Virginia. Degradation in Chesapeake Bay in 2024 was within the same level as in 2022, with 54% of the Bay’s tidal area failing the benthic community restoration goals.

The change observed between 2023 and 2024 was consistent with larger than average hypoxic volume (bottom waters with dissolved oxygen below 2 mg/L) in Chesapeake Bay in May and early June 2024, when the effect of hypoxia on the developing benthic communities is greatest. As in previous years, there was a correlation between benthic community degradation, hypoxia, and river flow. Flow entering the Chesapeake Bay was high in winter 2024, and spring river flow was very high compared to 2023. River flow was again high in mid-August following the remnants of Hurricane Debby. Spring river flow in general, and pulse events in particular (frequent, intense rain events), play a major role in determining benthic community condition in Chesapeake Bay. In 2021 and 2023 spring river flow was low and benthic condition improved, whereas in 2022 and 2024 spring river flow was high and benthic condition declined. Excess nutrient runoff after heavy rains changes the balance of biological and chemical processes, and the alteration of these processes frequently leads to hypoxia and loss of benthic biomass and productivity. Winds and water temperature also play a significant role modulating hypoxia in Chesapeake Bay (Scully 2010, Lee et al. 2013, Zhou et al. 2014). The bottom water temperature record in the last three years of the benthic monitoring has shown an increase in minimum temperature from 15.3 ℃ in 2022 to 21.9 ℃ in 2024 over the same sampling period. The higher the temperature, the smaller the amount of oxygen the water can hold.

Nutrient inputs typically fuel benthic and phytoplankton growth in the spring as waters warm up, leading to oxygen consumption and development of summer-time hypoxia (Tuttle et al. 1987, Kemp et al. 2005). In years with pulses in spring river flow effects on benthic communities are manifested through low B-IBI scores as revealed by general linear model analyses of flow and benthic data (Versar, Inc. 2023). According to the results of these analyses, intensity and periodicity of spring river flow appear to be factors affecting benthic condition, particularly in the Chesapeake Bay mainstem (no effect was noted in the Patuxent and Choptank rivers). In 2024, Susquehanna river flow was high with several pulse events between January and May. However, the response of the benthic communities to high spring river flow in 2024 was attenuated compared to other years with similar high river flow. We propose that better than expected benthic conditions in 2024 were likely related to the ongoing efforts to reduce nutrient pollution in Chesapeake Bay. Even though spring river flow was high in 2024, the amount of nitrogen measured at river input monitoring stations (131 million pounds) was about the same as the average taken between 1985 and 2023 (Chesapeake Bay Program 2024, Soroka and Blomquist 2024). The USGS computes total nitrogen loads each year to support an annual forecast of dissolved oxygen conditions in Chesapeake Bay. Thus efforts to keep nutrient pollution from entering the Chesapeake Bay appeared to be working and the net result may be attenuated hypoxia and attenuated effects on benthic communities.

The fixed monitoring sites showed conditions similar to 2023. The average B-IBI score remained within the same condition category at all of the fixed sites, and the same trends observed in 2023 were present in 2024, with the exception of an incipient, declining B-IBI trend at the mid-Bay mainstem Station 006.

With benthic community health in any one year improving or declining depending on whether it was a dry or wet year, the question of most interest is how is benthic community condition changing over the long term. Is the Chesapeake Bay on track to recovery? The answer is that, overall, we cannot statistically detect a trend in percent area degraded either for the Chesapeake Bay or in Maryland tidal waters, although we do see a decreasing trend in percent area failing the B-IBI (improving benthic condition) in Virginia tidal waters. However, when we look at the average abundance of species and the average number of species in Chesapeake Bay or in Maryland tidal waters, we see strong, statistically significant declining trends over time. We also see significant declining trends in mean B-IBI and biomass in Maryland.

For the fixed monitoring sites, a shift in summer hypoxia from midsummer to early summer was revealed in Llansó et al. (2011). This shift appeared in 1998 and coincided with decreases in abundance and species numbers at many of the fixed sites in the Maryland tributaries and the mainstem. Independently of this research, Murphy et al. (2011) also observed increasing hypoxia in June over time. The implications of such a shift is an increase in the likelihood of cumulative impacts on the benthic communities, through suppression of recruitment processes taking place in the spring and an inability of the community to recover from previous years hypoxic events.

Declining trends in abundance were manifested at many of the fixed sites; however, some Maryland regions showed improvements in benthic community health. Overall, the percentage of the random sites in Maryland tidal waters scoring 1 for excess abundance (eutrophic condition due to nutrient pollution) continued to decline significantly through 2024. This trend is important because it may be evidence of favorable conditions in recent years associated with restoration efforts to reduce nutrient pollution. Likewise, among the fixed sites, the mesohaline Potomac River (Stations 043 and 047) and the Elk River (Station 029) showed declining trends in abundance from excess abundance (scored at 1) to abundance in the good range (scored at 5). We also see improving trends in the B-IBI in the upper bay mainstem (Station 026), Elk River (Station 029), Choptank River (Station 064), Bear Creek (Station 201), and Back River (Station 203).

The Choptank River is an example of diverging patterns in benthic condition. The upper region of the estuary monitored at Station 066 showed a degrading trend in the B-IBI suggesting influences from land based, agricultural sources of pollution. On the other hand, the lower region of the Choptank River monitored at Station 064 showed an improving trend in the B-IBI and a mature benthic community most likely influenced by the Bay's open waters.

With regard to the shallow mesohaline Potomac River (Stations 043 and 047), while we see a declining trend in abundance from excess abundance to abundance in the good range, we also see significant degrading trends in biomass, number of species, and the B-IBI. Moreover, the shallow mesohaline Potomac River emerges as an area of rapid degradation. Several long-term dominant species of large biomass have declined or disappeared from the community. The disappearance of community dominant species coincided with the arrival of the non-indigenous polychaete *Hermundura americana* in the Potomac River in 2018.

*H. americana* is a warm-water species of the Gulf of Mexico and Central America, first reported in Chesapeake Bay in the Elizabeth River in 2009. In 2012, this species spread into the James River and is now found throughout the tidal James River in salinities between 0.7 and 20.4, depths of 1 m to 12 m, and a wide range of sediment types from sand (5% silt-clay) to mud (95% silt-clay). The highest abundance of *Hermundura* occurs in mesohaline water.

In 2018, *H. americana* was found in the Potomac River near Morgantown and the Wicomico and Nanticoke rivers. Later it became invasive and expanded its range to other Maryland estuaries. By 2024, *H. americana* had colonized a wide range of salinity, depth, and sediment types in the James, Rappahannock, and Potomac rivers, and was recorded in the York River. In 2024, *H. americana* spread to many new locations in Maryland, where it was previously unrecorded. We hypothesize that low salinity and warm temperatures facilitate the spread of *H. americana* larvae. Large freshwater inputs (low salinity) in 2024 may have facilitated the spread of *H. americana* into new regions.

The ecological effects of *H. americana* as it expands throughout the Chesapeake Bay are unknown. In the Potomac River, *H. americana* has spread to the mouth of the river and possibly displaced long-term dominant members of the benthic community in shallow mesohaline water. *H. americana* is now density dominant in those habitats. Interestingly, a similar pattern is observed in the James River at the LE5.1 fixed site. This station is predominantly mesohaline, with an average salinity of 6.75 and a depth of 7.4 m. At this station *H. americana* was first recorded in 2013, and in that year the polychaete *Marenzelleria viridis*, a dominant species in the James River mesohaline benthos, disappeared from the community. No other warm water, non-indigenous benthic species has recently been found in Chesapeake Bay. However, the widespread intrusion of *H. americana* in Chesapeake Bay and its ability to rapidly colonize a wide range of habitat types is serious cause of concern and should be closely monitored during the next few years.

In terms of interactions of *H. americana* with fisheries, an index of trophic transfer potential based on functional diversity traits and productivity was developed (Llansó, unpublished) and applied to the Potomac River data. The index suggests that trophic transfer potential increases in areas dominated by *H. americana*. However, the hypothesis of greater predation in habitats with higher trophic transfer potential remains to be evaluated. In addition to this index of trophic transfer potential, the benthic index of biotic integrity used in the monitoring of the Chesapeake Bay fully includes *H. americana* in its assessments.

Since benthic monitoring in Chesapeake Bay begun in 1985, biomass-dominant species have declined over the years (Llansó et al. 2013, Seitz et al. 2009) and low rates of benthic secondary production are observed in areas impacted by hypoxia (Sturdivant et al. 2014), most pronounced in the mid-Bay mainstem, and the Patuxent and Potomac rivers (Dauer et al. 2011, Llansó et al. 2012). This background suggests that the recovery of the benthic communities, on which many fisheries and avian species depend, may be tied to factors in which not only management plays a role but increasingly important aspects of climate change (sensu Lee et al. 2013) interact with species populations to provide patterns of benthic community change that mask the restoration efforts. However, inter-annual variability in benthic condition and improvements in recent years suggest that benthic communities are resilient and respond quickly to improvements in water quality.

The results presented in this report were enabled by the combination of probability-based sampling and fixed point monitoring. Probability-based sampling allows determination of levels of benthic community degradation at multiple spatial scales, from strata and Bay Health Index reporting regions (this report) to tidal creeks (Dauer and Llansó 2003) and Chesapeake Bay Program segments (Llansó et al. 2003). Probability-based data are also useful for reporting overall condition and identification of impaired waters (305b report) under the Clean Water Act (Llansó et al. 2005, 2009a). These assessments are dependent on fully validated thresholds for assessing benthic community condition at sampling sites. The thresholds were established and validated by Ranasinghe et al. (1994) and updated by Weisberg et al. (1997). The thresholds and the B-IBI and its component metrics allow for a validated, unambiguous approach to characterizing conditions in the Chesapeake Bay. The B-IBI has been shown by Alden et al. (2002) to be sensitive, stable, robust, and statistically sound. Its performance was verified by Llansó et al. (2009b) using data independent of those used in the initial index development effort. This last study revealed good classification performance of the B-IBI, balanced Type I and Type II errors, and the influence of a variety of metrics in the final B-IBI score, characteristics that made assessments in Chesapeake Bay more reliable with the B-IBI than with any of the alternative benthic indicators.

The use of probability-based sampling and fixed point monitoring allows us to provide an overall picture of benthic condition in Chesapeake Bay that helps track the success of efforts to clean up the bay. This picture would not have emerged if only water quality were monitored, and points to the value of long-term biological monitoring in the face of natural variability and climate change.

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# APPENDIX A

# FIXED SITE COMMUNITY ATTRIBUTE 1985-2024 TREND ANALYSIS RESULTS

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Appendix Table A-1. Summer trends in benthic community attributes at mesohaline stations 1985-2024. Shown is the median slope of the trend. Monotonic trends were identified using the van Belle and Hughes (1984) procedure. Shaded cells indicate statistically significant trend results ($p<0.1$). (a) trends based on 1989-2024 data; (b) trends based on 1995-2024 data; (c) attribute trend based on 1990-2024 data; (d): attributes are used in B-IBI calculations when species specific biomass is unavailable; (e): attribute and trend are not part of the reported B-IBI. Probability values shown in Table A-3.

| Station | B-IBI | Abundance | Biomass | Shannon Diversity | Indicative Abundance | Sensitive Abundance | Indicative Biomass (c) | Sensitive Biomass (c) | Abundance Carnivore/ Omnivores |
|---|---|---|---|---|---|---|---|---|---|
| **Potomac River** | | | | | | | | | |
| **43** | -0.0286 | -56.8421 | -0.4806 | -0.0146 | 0.0897 | -0.9472 (d) | 0.0161 (e) | -2.2517 | 0.2970 (e) |
| **44** | 0.0000 | -1.2013 | -0.0233 | -0.0084 | -0.3445 | 0.0000 (d) | 0.0000 (e) | 0.0000 | 0.3428 (e) |
| **47** | -0.0200 | -61.1765 | -0.7126 | -0.0154 | 0.0640 | -0.9354 (d) | 0.0334 (e) | -2.3748 | 0.3416 (e) |
| **51** | 0.0000 | -30.7692 | -0.0575 | -0.0060 | -0.4592 | 0.0000 | 0.0000 (e) | -0.5805 (e) | 0.3590 |
| **52** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 (d) | 0.0000 (d) | 0.0000 | 0.0000 | 0.0000 |
| **Patuxent River** | | | | | | | | | |
| **71** | -0.0247 | -26.8597 | -0.0137 | -0.0366 | 0.2179 (d) | 0.0000 (d) | 0.5572 | 0.0000 | -0.0210 |
| **74** | 0.0000 | 18.9281 | -0.5219 | -0.0004 | 0.0566 | -0.2587 (d) | 0.0003 (e) | -0.2550 | -0.1225 (e) |
| **77** | -0.0143 | -20.4459 | -0.0211 | -0.0009 | 0.2976 | 0.0508 (d) | -0.2401 (e) | 0.8928 | 0.0656 (e) |
| **Choptank River** | | | | | | | | | |
| **64** | 0.0185 | -9.0820 | 0.1473 | 0.0114 | -0.3210 (d) | 0.9169 (d) | -0.0015 | 0.1113 | 0.1234 |
| **Maryland Mainstem** | | | | | | | | | |
| **01** | -0.0139 | -26.0621 | -0.0106 | -0.0035 | -0.1217 | -0.2101 | 0.0000 (e) | -0.1509 (e) | -0.5912 |
| **06** | 0.0000 | -4.0000 | 0.0034 | -0.0089 | -0.0892 | -0.4282 | 0.0000 (e) | -0.2435 (e) | -0.5561 |
| **15** | 0.0000 | -9.0909 | -0.0189 | -0.0091 | -0.3225 | -0.0496 | 0.0129 (e) | -0.4616 (e) | 0.0376 |
| **24** | 0.0042 | -9.0000 | 0.2189 | -0.0167 | -0.3030 (d) | 0.7762 (d) | -0.0011 | 0.7728 | 0.1264 |
| **26** | 0.0000 | 0.4077 | -0.3654 | 0.0076 | 0.0000 | -0.2430 (d) | 0.0000 (e) | -0.0267 | 0.0686 (e) |
| **Maryland Western Shore Tributaries** | | | | | | | | | |
| **22** | -0.0174 | -28.0750 | -0.0030 | -0.0373 | 0.2318 | 0.0000 (d) | 0.0000 (e) | 0.0000 | -0.1916 (e) |
| **23** | 0.0000 | -45.4553 | -0.0060 | -0.0178 | 0.0000 | 0.4546 (d) | 0.0000 (e) | 0.0000 | 0.0874 (e) |
| **201(a)** | 0.0000 | -8.0273 | 0.0013 | 0.0000 | -0.4386 | 0.0000 (d) | -0.0167 (e) | 0.0000 | 0.0000 (e) |
| **202(a)** | 0.0000 | -9.0909 | -0.0002 | 0.0000 | 0.0000 | 0.0000 (d) | 0.0000 (e) | 0.0000 | 0.0000 (e) |
| **204(b)** | -0.0222 | -58.0900 | -0.0194 | -0.0125 | 0.1087 (d) | 0.3759 (d) | 0.0000 | 0.2188 | -0.3810 |
| **Maryland Eastern Shore Tributaries** | | | | | | | | | |
| **62** | -0.0462 | 120.0000 | -0.0231 | -0.0120 | 0.3989 | -0.2483 (d) | 0.2369 (e) | -2.2690 | -0.1681 (e) |
| **68** | 0.0000 | 18.9563 | 0.3373 | -0.0087 | 0.0632 | 0.2624 (d) | 0.0017 (e) | -0.0145 | -0.1103 (e) |

Appendix Table A-2. Summer trends in benthic community attributes at oligohaline and tidal freshwater stations 1985-2024. Shown is the median slope of the trend. Monotonic trends were identified using the van Belle and Hughes (1984) procedure. Shaded cells indicate statistically significant trend results (p<0.1). (a): trends based on 1989-2024 data; NA: attribute not calculated. Probability values shown in Table A-4.

| Station | B-IBI | Abundance | Tolerance Score | Freshwater Indicative Abundance | Oligohaline Indicative Abundance | Oligohaline Sensitive Abundance | Tanypodinae to Chironomidae Ratio | Abundance Deep Deposit Feeders | Abundance Carnivore/ Omnivores |
|---|---|---|---|---|---|---|---|---|---|
| **Potomac River** | | | | | | | | | |
| **36** | 0.0000 | 30.2083 | 0.0075 | 0.3347 | NA | NA | NA | 0.1878 | NA |
| **40** | 0.0000 | 16.4686 | -0.0005 | NA | 0.0000 | 0.0000 | 0.0000 | NA | 0.1839 |
| **Patuxent River** | | | | | | | | | |
| **79** | 0.0000 | -14.4737 | -0.0048 | 0.1149 | NA | NA | NA | 0.0278 | NA |
| **Choptank River** | | | | | | | | | |
| **66** | -0.0222 | 67.2652 | 0.0563 | NA | 0.8210 | 0.0000 | 0.0000 | NA | 0.0000 |
| **Maryland Western Shore Tributaries** | | | | | | | | | |
| **203(a)** | 0.0230 | -17.0400 | -0.0029 | NA | 0.0000 | 0.0000 | 0.0000 | NA | 1.2077 |
| **Maryland Eastern Shore Tributaries** | | | | | | | | | |
| **29** | 0.0111 | -49.3478 | 0.0109 | NA | -0.1346 | 0.1020 | 0.0000 | NA | 0.2996 |

Appendix Table A-3. Summer trends in benthic community attributes at mesohaline stations 1985-2024. Shown is the probability for each trend. Shaded cells indicate statistically significant trend results ($p<0.1$). See Table A-1 for attribute information.

| Station | B-IBI | Abundance | Biomass | Shannon Diversity | Indicative Abundance | Sensitive Abundance | Indicative Biomass (c) | Sensitive Biomass (c) | Abundance Carnivore/ Omnivores |
|---|---|---|---|---|---|---|---|---|---|
| **Potomac River** | | | | | | | | | |
| **43** | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0421 | 0.0000 | 0.0083 | 0.0000 | 0.0025 |
| **44** | 0.4727 | 0.7666 | 0.0107 | 0.0529 | 0.0010 | 0.7366 | 0.6051 | 0.3974 | 0.0005 |
| **47** | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.1549 | 0.0000 | 0.0000 | 0.0000 | 0.0032 |
| **51** | 0.8157 | 0.0000 | 0.0000 | 0.0718 | 0.0000 | 0.9220 | 0.8102 | 0.0000 | 0.0017 |
| **52** | 0.0409 | 0.0001 | 0.0006 | 0.0034 | 0.0879 | 0.0442 | 0.7129 | 0.5736 | 0.1194 |
| **Patuxent River** | | | | | | | | | |
| **71** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1250 | 0.0135 | 0.0133 | 0.5042 | 0.0793 |
| **74** | 0.9856 | 0.2038 | 0.0000 | 0.9365 | 0.2029 | 0.0776 | 0.6787 | 0.0000 | 0.0708 |
| **77** | 0.0217 | 0.0164 | 0.0107 | 0.8150 | 0.0833 | 0.6451 | 0.0064 | 0.0290 | 0.5885 |
| **Choptank River** | | | | | | | | | |
| **64** | 0.0014 | 0.1906 | 0.0003 | 0.0040 | 0.0106 | 0.0000 | 0.7025 | 0.2825 | 0.2276 |
| **Maryland Mainstem** | | | | | | | | | |
| **01** | 0.0056 | 0.0003 | 0.1583 | 0.3009 | 0.0363 | 0.0397 | 0.7666 | 0.0636 | 0.0000 |
| **06** | 0.0915 | 0.4307 | 0.4953 | 0.0552 | 0.0401 | 0.0014 | 0.7382 | 0.0027 | 0.0006 |
| **15** | 0.6666 | 0.1475 | 0.0870 | 0.0053 | 0.0039 | 0.3550 | 0.5502 | 0.0030 | 0.5645 |
| **24** | 0.1120 | 0.1850 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0951 | 0.0000 | 0.3196 |
| **26** | 0.0418 | 0.8966 | 0.1366 | 0.0606 | 0.7420 | 0.2270 | 0.7658 | 0.0022 | 0.3687 |
| **Maryland Western Shore Tributaries** | | | | | | | | | |
| **22** | 0.0001 | 0.0000 | 0.0488 | 0.0000 | 0.1826 | 0.2386 | 0.6449 | 0.2967 | 0.0001 |
| **23** | 0.3237 | 0.0000 | 0.5168 | 0.0004 | 0.8690 | 0.0000 | 0.8479 | 0.9673 | 0.3475 |
| **201(a)** | 0.0142 | 0.0129 | 0.0963 | 0.4352 | 0.0130 | 0.0073 | 0.0477 | 0.0265 | 0.2327 |
| **202(a)** | 0.0661 | 0.0002 | 0.1411 | 0.0033 | 0.0840 | 0.6480 | 0.0807 | 0.8859 | 0.5170 |
| **204(b)** | 0.0171 | 0.0000 | 0.2827 | 0.0258 | 0.4041 | 0.0187 | 0.9277 | 0.4673 | 0.0058 |
| **Maryland Eastern Shore Tributaries** | | | | | | | | | |
| **62** | 0.0000 | 0.0000 | 0.0002 | 0.0104 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **68** | 0.5571 | 0.2639 | 0.0014 | 0.0289 | 0.3655 | 0.0626 | 0.1928 | 0.6021 | 0.0718 |

Appendix Table A-4. Summer trends in benthic community attributes at oligohaline and tidal freshwater stations 1985-2024. Shown is the probability for each trend. Shaded cells indicate statistically significant trend results ($p<0.1$). See Table A-2 for attribute information. NA: attribute not calculated.

| Station | B-IBI | Abundance | Tolerance Score | Freshwater Indicative Abundance | Oligohaline Indicative Abundance | Oligohaline Sensitive Abundance | Tanypodinae to Chironomidae Ratio | Abundance Deep Deposit Feeders | Abundance Carnivore/ Omnivores |
|---|---|---|---|---|---|---|---|---|---|
| **Potomac River** | | | | | | | | | |
| **36** | 0.0460 | 0.1097 | 0.0271 | 0.0154 | NA | NA | NA | 0.0743 | NA |
| **40** | 0.7715 | 0.0483 | 0.2406 | NA | 0.9934 | 0.1844 | 0.2114 | NA | 0.1635 |
| **Patuxent River** | | | | | | | | | |
| **79** | 0.5697 | 0.3322 | 0.1489 | 0.4358 | NA | NA | NA | 0.6595 | NA |
| **Choptank River** | | | | | | | | | |
| **66** | 0.0000 | 0.0000 | 0.0000 | NA | 0.0000 | 0.0474 | 0.0142 | NA | 0.8623 |
| **Maryland Western Shore Tributaries** | | | | | | | | | |
| **203(a)** | 0.0022 | 0.0836 | 0.1361 | NA | 0.0492 | 0.1114 | 0.2922 | NA | 0.0000 |
| **Maryland Eastern Shore Tributaries** | | | | | | | | | |
| **29** | 0.0014 | 0.0011 | 0.1604 | NA | 0.5051 | 0.0308 | 0.9117 | NA | 0.0000 |

# APPENDIX B

# FIXED SITE GAM ANALYSIS RESULTS

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Appendix Table B-1. Summary of linear and non-linear GAM model results for the Benthic Index of Biotic Integrity (B-IBI) for fixed sites from the start of monitoring through 2024. Provided are summary statistics (F value, p value, and Intercept) and a summary of statistical significance (Sign.) which indicates the p-value level at which a given model is statistically significant. NS indicates the model was not statistically significant (p> 0.10). Additional statistics for the Non-linear model include the k-index and its associated p-value along with the effective degrees of freedom (edf). See the Methods Section of this report for details. Also included are estimates of accuracy (the $R^2$ and Akaike information criterion AIC) for both models, a comparison between models indicating the difference in $R^2$ and AIC between each model, and an assessment of the shape (Linear, Weak Non-linear, or Strong Non-linear) of the trend over time (Year). A negative $R^2$ indicates the model prediction is less reliable than a horizontal line.

Chesapeake Bay Mainstem - B-IBI

| Station | Linear Model | | | | | | | Non-linear Model | | | | | | | | | Model Comparison/Assessement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | F | p | Sign. | Int. | AIC | $R^2$ | F | p | Sign. | Int. | AIC | $R^2$ | k index p value | k index | edf | Diff. in AIC | Diff. in R2 | Assessment |
| 029 | 39 | 4.76 | 0.036 | p<=0.05 | 2.3 | 49 | 0.09 | 4.76 | 0.0355 | p<=0.05 | 2.60 | 49 | 0.09 | 0.5650 | 1.03 | 1.00 | 0.00 | 0.00 | Linear |
| 026 | 39 | 0.35 | 0.557 | NS | 3.5 | 41 | -0.02 | 1.51 | 0.1497 | NS | 3.57 | 38 | 0.20 | 0.9400 | 1.28 | 8.25 | -3.35 | 0.22 | NS |
| 024 | 39 | 0.73 | 0.397 | NS | 3.1 | 84 | -0.01 | 0.58 | 0.6344 | NS | 3.30 | 88 | 0.05 | 0.9650 | 1.30 | 7.77 | 3.52 | 0.05 | NS |
| 015 | 39 | 0.37 | 0.547 | NS | 2.5 | 70 | -0.02 | 0.73 | 0.4298 | NS | 2.39 | 69 | 0.03 | 0.6075 | 1.07 | 1.84 | -1.18 | 0.05 | NS |
| 006 | 30 | 5.22 | 0.030 | p<=0.05 | 3.2 | 59 | 0.13 | 4.01 | 0.0055 | p<=0.01 | 2.74 | 48 | 0.50 | 0.8525 | 1.23 | 7.61 | -11.28 | 0.37 | Strong Nonlinear |
| 001 | 40 | 3.27 | 0.079 | p<=0.10 | 3.2 | 86 | 0.05 | 2.34 | 0.0454 | p<=0.05 | 2.87 | 80 | 0.26 | 0.9000 | 1.24 | 5.54 | -5.63 | 0.20 | Strong Nonlinear |

Eastern Tributaries - B-IBI

| Station | Linear Model | | | | | | | Non-linear Model | | | | | | | | | Model Comparison/Assessement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | F | p | Sign. | Int. | AIC | $R^2$ | F | p | Sign. | Int. | AIC | $R^2$ | k index p value | k index | edf | Diff. in AIC | Diff. in R2 | Assessment |
| 068 | 38 | 0.09 | 0.768 | NS | 3.6 | 51 | -0.03 | 0.09 | 0.7676 | NS | 3.56 | 51 | -0.03 | 0.6850 | 1.11 | 1.00 | 0.00 | 0.00 | NS |
| 066 | 36 | 10.73 | 0.002 | p<=0.01 | 3.2 | 57 | 0.22 | 6.38 | 0.0028 | p<=0.01 | 2.65 | 53 | 0.31 | 0.9025 | 1.26 | 1.98 | -3.38 | 0.09 | Weak Nonlinear |
| 064 | 39 | 2.72 | 0.107 | NS | 3.0 | 84 | 0.04 | 2.72 | 0.1075 | NS | 3.32 | 84 | 0.04 | 0.5800 | 1.06 | 1.00 | 0.00 | 0.00 | NS |
| 062 | 30 | 30.88 | 0.000 | p<=0.001 | 3.3 | 40 | 0.51 | 30.88 | 0.0000 | p<=0.001 | 2.51 | 40 | 0.51 | 0.5225 | 1.05 | 1.00 | 0.00 | 0.00 | Linear |

Western Tributaries - B-IBI

| Station | Linear Model | | | | | | | Non-linear Model | | | | | | | | | Model Comparison/Assessement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | F | p | Sign. | Int. | AIC | $R^2$ | F | p | Sign. | Int. | AIC | $R^2$ | k index p value | k index | edf | Diff. in AIC | Diff. in R2 | Assessment |
| 022 | 40 | 6.43 | 0.015 | p<=0.05 | 2.4 | 101 | 0.12 | 3.06 | 0.0265 | p<=0.05 | 1.87 | 98 | 0.23 | 0.8525 | 1.19 | 3.34 | -2.98 | 0.11 | Strong Nonlinear |
| 023 | 40 | 0.16 | 0.694 | NS | 2.6 | 108 | -0.02 | 0.16 | 0.6940 | NS | 2.51 | 108 | -0.02 | 0.8950 | 1.21 | 1.00 | 0.00 | 0.00 | NS |
| 201 | 34 | 5.57 | 0.025 | p<=0.05 | 1.1 | 54 | 0.12 | 5.57 | 0.0246 | p<=0.05 | 1.55 | 54 | 0.12 | 0.6100 | 1.08 | 1.00 | 0.00 | 0.00 | Linear |
| 202 | 34 | 2.55 | 0.120 | NS | 1.6 | 42 | 0.04 | 2.55 | 0.1204 | NS | 1.34 | 42 | 0.04 | 0.3925 | 0.99 | 1.00 | 0.00 | 0.00 | NS |
| 203 | 30 | 3.19 | 0.085 | p<=0.10 | 2.1 | 55 | 0.07 | 2.10 | 0.1253 | NS | 2.47 | 54 | 0.12 | 0.9525 | 1.34 | 1.73 | -0.99 | 0.05 | Linear |
| 204 | 30 | 2.81 | 0.105 | NS | 3.5 | 70 | 0.06 | 1.78 | 0.1220 | NS | 3.10 | 67 | 0.29 | 0.9000 | 1.28 | 7.56 | -3.16 | 0.23 | NS |

Patuxent River - B-IBI

| Station | Linear Model | | | | | | | Non-linear Model | | | | | | | | | Model Comparison/Assessement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | F | p | Sign. | Int. | AIC | $R^2$ | F | p | Sign. | Int. | AIC | $R^2$ | k index p value | k index | edf | Diff. in AIC | Diff. in R2 | Assessment |
| 079 | 40 | 1.62 | 0.211 | NS | 2.6 | 80 | 0.02 | 1.62 | 0.2115 | NS | 2.83 | 80 | 0.02 | 0.9050 | 1.21 | 1.00 | 0.00 | 0.00 | NS |
| 077 | 35 | 1.53 | 0.225 | NS | 3.0 | 78 | 0.02 | 1.54 | 0.2147 | NS | 2.70 | 76 | 0.10 | 0.5625 | 1.07 | 2.42 | -1.73 | 0.08 | NS |
| 074 | 39 | 0.25 | 0.621 | NS | 3.4 | 60 | -0.02 | 0.25 | 0.6205 | NS | 3.43 | 60 | -0.02 | 0.9875 | 1.39 | 1.00 | 0.00 | 0.00 | NS |
| 071 | 39 | 17.21 | 0.000 | p<=0.001 | 2.3 | 43 | 0.30 | 4.43 | 0.0012 | p<=0.01 | 1.77 | 38 | 0.46 | 0.9600 | 1.32 | 7.24 | -4.63 | 0.16 | Strong Nonlinear |

Potomac River - B-IBI

| Station | Linear Model | | | | | | | Non-linear Model | | | | | | | | | Model Comparison/Assessement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | F | p | Sign. | Int. | AIC | $R^2$ | F | p | Sign. | Int. | AIC | $R^2$ | k index p value | k index | edf | Diff. in AIC | Diff. in R2 | Assessment |
| 036 | 39 | 2.89 | 0.097 | p<=0.10 | 3.5 | 106 | 0.05 | 3.98 | 0.0026 | p<=0.01 | 3.07 | 92 | 0.43 | 0.7300 | 1.12 | 8.51 | -14.03 | 0.39 | Strong Nonlinear |
| 040 | 39 | 0.00 | 0.964 | NS | 3.0 | 56 | -0.03 | 0.00 | 0.9640 | NS | 2.99 | 56 | -0.03 | 0.1750 | 0.88 | 1.00 | 0.00 | 0.00 | NS |
| 043 | 38 | 22.62 | 0.000 | p<=0.001 | 4.0 | 49 | 0.37 | 12.33 | 0.0000 | p<=0.001 | 3.36 | 43 | 0.47 | 0.7175 | 1.12 | 2.25 | -5.75 | 0.10 | Strong Nonlinear |
| 044 | 39 | 0.02 | 0.879 | NS | 2.5 | 101 | -0.03 | 0.87 | 0.4958 | NS | 2.56 | 100 | 0.06 | 0.4250 | 0.99 | 4.14 | -0.76 | 0.09 | NS |
| 047 | 30 | 12.70 | 0.001 | p<=0.001 | 4.1 | 42 | 0.29 | 7.95 | 0.0000 | p<=0.001 | 3.53 | 23 | 0.68 | 0.9925 | 1.47 | 7.38 | -19.24 | 0.39 | Strong Nonlinear |
| 051 | 40 | 0.92 | 0.344 | NS | 2.9 | 80 | 0.00 | 1.31 | 0.2769 | NS | 2.71 | 78 | 0.13 | 0.9525 | 1.31 | 4.92 | -2.18 | 0.13 | NS |
| 052 | 39 | 2.31 | 0.137 | NS | 1.3 | -9 | 0.03 | 2.31 | 0.1368 | NS | 1.16 | -9 | 0.03 | 0.9525 | 1.26 | 1.00 | 0.00 | 0.00 | NS |

Appendix Table B-2. Comparison of trend analysis results for the Mann-Kendall (MK) test and the linear and non-linear generalized additive models (GAM) for the Benthic Index of Biotic Integrity (B-IBI) for fixed sites from the start of monitoring through 2024. Provided are the p values for each trend analysis and the resultant analytical trend determination. Further detail is provided in Table 3-1 and Appendix Table B-1.

| Chesapeake Bay Mainstem - B-IBI | | | | | | |
|---|---|---|---|---|---|---|
| Station | MK p value | MK Trend Direction | Linear GAM Significance | Linear GAM Direction | Non-linear GAM Significance | Linear/Nonlinear GAM Comparison |
| 029 | p < 0.01 | Increasing | p<=0.05 | Increasing | p<=0.05 | Linear |
| 026 | p < 0.05 | Increasing | NS | NS | NS | NS |
| 024 | NS | Not Significant | NS | NS | NS | NS |
| 015 | NS | Not Significant | NS | NS | NS | NS |
| 006 | p<0.10 | Decreasing | p<=0.05 | Decreasing | p<=0.01 | Strong Nonlinear |
| 001 | p<0.01 | Decreasing | p<=0.10 | Decreasing | p<=0.05 | Strong Nonlinear |
| Eastern Tributaries - B-IBI | | | | | | |
| Station | MK p value | MK Trend Direction | Linear GAM Significance | Linear GAM Direction | Non-linear GAM Significance | Linear/Nonlinear GAM Comparison |
| 068 | NS | Not Significant | NS | NS | NS | NS |
| 066 | p < 0.001 | Decreasing | p<=0.01 | Decreasing | p<=0.01 | Weak Nonlinear |
| 064 | p < 0.01 | Increasing | NS | NS | NS | NS |
| 062 | p < 0.001 | Decreasing | p<=0.001 | Decreasing | p<=0.001 | Linear |
| Western Tributaries - B-IBI | | | | | | |
| Station | MK p value | MK Trend Direction | Linear GAM Significance | Linear GAM Direction | Non-linear GAM Significance | Linear/Nonlinear GAM Comparison |
| 022 | p < 0.001 | Decreasing | p<=0.05 | Decreasing | p<=0.05 | Strong Nonlinear |
| 023 | NS | Not Significant | NS | NS | NS | NS |
| 201 | p < 0.05 | Increasing | p<=0.05 | Increasing | p<=0.05 | Linear |
| 202 | p<0.10 | Decreasing | NS | NS | NS | NS |
| 203 | p < 0.01 | Increasing | p<=0.10 | Increasing | NS | Linear |
| 204 | p<0.05 | Decreasing | NS | NS | NS | NS |
| Patuxent River - B-IBI | | | | | | |
| Station | MK p value | MK Trend Direction | Linear GAM Significance | Linear GAM Direction | Non-linear GAM Significance | Linear/Nonlinear GAM Comparison |
| 079 | NS | Not Significant | NS | NS | NS | NS |
| 077 | p<0.05 | Decreasing | NS | NS | NS | NS |
| 074 | NS | Not Significant | NS | NS | NS | NS |
| 071 | p < 0.001 | Decreasing | p<=0.001 | Decreasing | p<=0.01 | Strong Nonlinear |
| Potomac River - B-IBI | | | | | | |
| Station | MK p value | MK Trend Direction | Linear GAM Significance | Direction | Non-linear GAM Significance | Linear/Nonlinear GAM Comparison |
| 036 | p<0.05 | Decreasing | p<=0.10 | Decreasing | p<=0.01 | Strong Nonlinear |
| 040 | NS | Not Significant | NS | NS | NS | NS |
| 043 | p < 0.001 | Decreasing | p<=0.001 | Decreasing | p<=0.001 | Strong Nonlinear |
| 044 | NS | Not Significant | NS | NS | NS | NS |
| 047 | p < 0.001 | Decreasing | p<=0.001 | Decreasing | p<=0.001 | Strong Nonlinear |
| 051 | NS | Not Significant | NS | NS | NS | NS |
| 052 | p<0.05 | Decreasing | NS | NS | NS | NS |

# APPENDIX C

## FIXED SITE B-IBI VALUES, SUMMER 2024

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Appendix Table C-1. Fixed site B-IBI values, Summer 2024.

| Station | Sampling Date | Latitude (WGS84 Decimal Degrees) | Longitude (WGS84 Decimal Degrees) | Mean B-IBI | Status |
|---|---|---|---|---|---|
| 001 | 9/21/2024 | 38.41887580 | -76.41892257 | 2.89 | Marginal |
| 006 | 9/21/2024 | 38.44178774 | -76.44438101 | 2.22 | Degraded |
| 015 | 9/21/2024 | 38.71484122 | -76.51512293 | 2.11 | Degraded |
| 022 | 8/13/2024 | 39.25826850 | -76.59511462 | 1.53 | Severely Degraded |
| 023 | 8/13/2024 | 39.20814355 | -76.52341942 | 3.40 | Meets Goal |
| 024 | 8/15/2024 | 39.12205302 | -76.35581581 | 4.44 | Meets Goal |
| 026 | 8/22/2024 | 39.27149230 | -76.28995945 | 3.53 | Meets Goal |
| 029 | 9/5/2024 | 39.47936643 | -75.94495604 | 2.89 | Marginal |
| 036 | 9/3/2024 | 38.76979591 | -77.03741650 | 4.33 | Meets Goal |
| 040 | 9/20/2024 | 38.35741751 | -77.23048434 | 2.78 | Marginal |
| 043 | 9/20/2024 | 38.38454193 | -76.98826100 | 2.60 | Degraded |
| 044 | 9/20/2024 | 38.38563158 | -76.99573782 | 2.47 | Degraded |
| 047 | 9/20/2024 | 38.37659949 | -76.98509716 | 2.60 | Degraded |
| 051 | 9/19/2024 | 38.20565871 | -76.73893567 | 1.78 | Severely Degraded |
| 052 | 9/19/2024 | 38.19245311 | -76.74796608 | 1.00 | Severely Degraded |
| 062 | 9/10/2024 | 38.38399166 | -75.84983971 | 1.93 | Severely Degraded |
| 064 | 9/9/2024 | 38.59046954 | -76.06935077 | 4.00 | Meets Goal |
| 066 | 9/9/2024 | 38.80142628 | -75.92193187 | 2.38 | Degraded |
| 068 | 9/4/2024 | 39.13250249 | -76.07883305 | 3.53 | Meets Goal |
| 071 | 8/27/2024 | 38.39502334 | -76.54874057 | 1.00 | Severely Degraded |
| 074 | 8/26/2024 | 38.54891751 | -76.67604868 | 3.80 | Meets Goal |
| 077 | 8/26/2024 | 38.60450001 | -76.67500002 | 3.13 | Meets Goal |
| 079 | 8/28/2024 | 38.75025250 | -76.68931321 | 3.17 | Meets Goal |
| 201 | 8/13/2024 | 39.23420104 | -76.49758623 | 1.93 | Severely Degraded |
| 202 | 8/13/2024 | 39.21780772 | -76.56419118 | 1.27 | Severely Degraded |
| 203 | 8/22/2024 | 39.27497297 | -76.44446625 | 2.78 | Marginal |
| 204 | 8/19/2024 | 39.00694963 | -76.50490305 | 2.56 | Degraded |

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# APPENDIX D

## RANDOM SITE B-IBI VALUES, SUMMER 2024

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Appendix Table D-1.  Random site B-IBI values, Summer 2024

| Station | Sampling Date | Latitude (WGS84 Decimal Degrees) | Longitude (WGS84 Decimal Degrees) | B-IBI | Status |
|---|---|---|---|---|---|
| MET-31401 | 9/11/2024 | 38.043583 | -75.845309 | 3.00 | Meets Goal |
| MET-31402 | 9/11/2024 | 38.080756 | -75.878771 | 2.67 | Marginal |
| MET-31403 | 9/11/2024 | 38.127657 | -75.886805 | 2.33 | Degraded |
| MET-31404 | 9/10/2024 | 38.208601 | -75.857527 | 2.67 | Marginal |
| MET-31405 | 9/10/2024 | 38.249328 | -75.875911 | 2.33 | Degraded |
| MET-31406 | 9/10/2024 | 38.260649 | -75.939201 | 2.33 | Degraded |
| MET-31407 | 9/10/2024 | 38.269066 | -75.915116 | 2.33 | Degraded |
| MET-31408 | 9/10/2024 | 38.282550 | -75.770075 | 2.60 | Degraded |
| MET-31409 | 9/10/2024 | 38.320137 | -75.747099 | 3.40 | Meets Goal |
| MET-31410 | 9/10/2024 | 38.333047 | -75.888226 | 2.60 | Degraded |
| MET-31411 | 9/10/2024 | 38.389006 | -75.834121 | 2.20 | Degraded |
| MET-31412 | 9/9/2024 | 38.570304 | -76.028318 | 1.80 | Severely Degraded |
| MET-31413 | 9/9/2024 | 38.601024 | -76.022526 | 1.40 | Severely Degraded |
| MET-31414 | 9/9/2024 | 38.601787 | -76.086640 | 3.80 | Meets Goal |
| MET-31415 | 9/9/2024 | 38.765683 | -75.977526 | 2.60 | Degraded |
| MET-31416 | 9/4/2024 | 38.998525 | -76.188622 | 1.67 | Severely Degraded |
| MET-31418 | 9/4/2024 | 39.075267 | -76.177860 | 3.40 | Meets Goal |
| MET-31419 | 9/4/2024 | 39.082295 | -76.185553 | 3.80 | Meets Goal |
| MET-31420 | 9/4/2024 | 39.130568 | -76.091707 | 4.20 | Meets Goal |
| MET-31421 | 9/4/2024 | 39.156959 | -76.055210 | 3.00 | Meets Goal |
| MET-31422 | 9/5/2024 | 39.382672 | -76.041769 | 2.33 | Degraded |
| MET-31423 | 9/5/2024 | 39.478656 | -75.932095 | 2.20 | Degraded |
| MET-31424 | 9/5/2024 | 39.491875 | -75.946626 | 2.20 | Degraded |
| MET-31425 | 9/5/2024 | 39.538812 | -75.872419 | 2.67 | Marginal |
| MET-31426 | 9/10/2024 | 38.144249 | -75.441279 | 5.00 | Meets Goal |
| MMS-31501 | 9/12/2024 | 37.927703 | -75.789476 | 2.00 | Severely Degraded |
| MMS-31502 | 9/11/2024 | 37.946385 | -76.088653 | 4.00 | Meets Goal |
| MMS-31503 | 9/11/2024 | 37.957838 | -76.090328 | 3.33 | Meets Goal |
| MMS-31504 | 9/11/2024 | 38.040078 | -76.118017 | 3.67 | Meets Goal |
| MMS-31505 | 9/11/2024 | 38.051423 | -75.995445 | 3.33 | Meets Goal |
| MMS-31506 | 9/11/2024 | 38.059926 | -76.083013 | 3.33 | Meets Goal |
| MMS-31507 | 9/11/2024 | 38.089844 | -75.938101 | 3.67 | Meets Goal |
| MMS-31508 | 9/11/2024 | 38.116797 | -76.180152 | 3.00 | Meets Goal |
| MMS-31509 | 9/11/2024 | 38.120006 | -76.165579 | 3.33 | Meets Goal |
| MMS-31510 | 9/11/2024 | 38.143723 | -76.170005 | 1.33 | Severely Degraded |
| MMS-31512 | 9/11/2024 | 38.184078 | -75.950503 | 2.67 | Marginal |
| MMS-31513 | 9/11/2024 | 38.186205 | -76.004752 | 3.00 | Meets Goal |
| MMS-31514 | 9/11/2024 | 38.212755 | -76.068483 | 3.67 | Meets Goal |

Appendix Table D-1. (Continued)

| Station | Sampling Date | Latitude (WGS84 Decimal Degrees) | Longitude (WGS84 Decimal Degrees) | B-IBI | Status |
|---|---|---|---|---|---|
| MMS-31515 | 9/11/2024 | 38.213066 | -76.128708 | 2.33 | Degraded |
| MMS-31516 | 9/11/2024 | 38.221698 | -76.161690 | 2.33 | Degraded |
| MMS-31517 | 9/10/2024 | 38.235092 | -75.950106 | 2.00 | Severely Degraded |
| MMS-31518 | 9/11/2024 | 38.262686 | -76.206546 | 2.00 | Severely Degraded |
| MMS-31519 | 9/11/2024 | 38.337887 | -76.184478 | 3.33 | Meets Goal |
| MMS-31520 | 9/21/2024 | 38.578385 | -76.482883 | 1.00 | Severely Degraded |
| MMS-31521 | 9/21/2024 | 38.624706 | -76.488883 | 1.00 | Severely Degraded |
| MMS-31522 | 9/9/2024 | 38.712374 | -76.279166 | 1.40 | Severely Degraded |
| MMS-31523 | 9/21/2024 | 38.715406 | -76.475913 | 1.33 | Severely Degraded |
| MMS-31524 | 9/12/2024 | 38.828604 | -76.241384 | 1.00 | Severely Degraded |
| MMS-31525 | 8/15/2024 | 38.970716 | -76.350470 | 2.60 | Degraded |
| MMS-31526 | 9/11/2024 | 38.283095 | -76.163343 | 2.67 | Marginal |
| MWT-31301 | 8/19/2024 | 38.925158 | -76.546639 | 1.00 | Severely Degraded |
| MWT-31302 | 8/19/2024 | 38.969579 | -76.500515 | 1.40 | Severely Degraded |
| MWT-31303 | 8/19/2024 | 38.969682 | -76.473482 | 1.80 | Severely Degraded |
| MWT-31304 | 8/19/2024 | 39.001338 | -76.494865 | 3.40 | Meets Goal |
| MWT-31305 | 8/14/2024 | 39.073550 | -76.501686 | 1.40 | Severely Degraded |
| MWT-31306 | 8/14/2024 | 39.073923 | -76.476352 | 1.00 | Severely Degraded |
| MWT-31307 | 8/14/2024 | 39.074831 | -76.449764 | 3.00 | Meets Goal |
| MWT-31308 | 8/14/2024 | 39.077025 | -76.450657 | 3.00 | Meets Goal |
| MWT-31309 | 8/14/2024 | 39.079645 | -76.485486 | 1.00 | Severely Degraded |
| MWT-31310 | 8/13/2024 | 39.165410 | -76.470610 | 3.80 | Meets Goal |
| MWT-31311 | 8/13/2024 | 39.179735 | -76.501630 | 2.60 | Degraded |
| MWT-31312 | 8/13/2024 | 39.206100 | -76.522513 | 3.80 | Meets Goal |
| MWT-31313 | 8/13/2024 | 39.225968 | -76.531653 | 2.60 | Degraded |
| MWT-31314 | 8/22/2024 | 39.237939 | -76.422741 | 3.33 | Meets Goal |
| MWT-31315 | 8/13/2024 | 39.240113 | -76.492755 | 3.00 | Meets Goal |
| MWT-31316 | 8/13/2024 | 39.254875 | -76.568917 | 1.40 | Severely Degraded |
| MWT-31317 | 8/22/2024 | 39.257175 | -76.446851 | 3.00 | Meets Goal |
| MWT-31318 | 8/22/2024 | 39.293225 | -76.463769 | 3.33 | Meets Goal |
| MWT-31319 | 8/22/2024 | 39.304417 | -76.390496 | 3.33 | Meets Goal |
| MWT-31320 | 9/6/2024 | 39.361488 | -76.264149 | 4.00 | Meets Goal |
| MWT-31321 | 9/6/2024 | 39.377071 | -76.268360 | 3.00 | Meets Goal |
| MWT-31322 | 9/6/2024 | 39.399614 | -76.249322 | 2.67 | Marginal |
| MWT-31323 | 9/6/2024 | 39.407908 | -76.260456 | 3.00 | Meets Goal |
| MWT-31324 | 8/23/2024 | 39.454619 | -76.231357 | 2.50 | Degraded |
| MWT-31325 | 8/23/2024 | 39.466886 | -76.227338 | 1.50 | Severely Degraded |

Appendix Table D-1. (Continued)

| Station | Sampling Date | Latitude (WGS84 Decimal Degrees) | Longitude (WGS84 Decimal Degrees) | B-IBI | Status |
|---|---|---|---|---|---|
| PMR-31101 | 9/19/2024 | 37.947139 | -76.287699 | 2.33 | Degraded |
| PMR-31102 | 9/19/2024 | 37.963855 | -76.300168 | 1.00 | Severely Degraded |
| PMR-31103 | 9/19/2024 | 38.053561 | -76.365659 | 3.00 | Meets Goal |
| PMR-31104 | 9/19/2024 | 38.058536 | -76.393444 | 1.00 | Severely Degraded |
| PMR-31105 | 9/19/2024 | 38.161570 | -76.644882 | 2.00 | Severely Degraded |
| PMR-31106 | 9/19/2024 | 38.162427 | -76.577367 | 1.00 | Severely Degraded |
| PMR-31107 | 9/19/2024 | 38.164617 | -76.510663 | 2.00 | Severely Degraded |
| PMR-31108 | 9/19/2024 | 38.173587 | -76.559855 | 1.67 | Severely Degraded |
| PMR-31109 | 9/19/2024 | 38.174406 | -76.669256 | 1.00 | Severely Degraded |
| PMR-31110 | 9/19/2024 | 38.180920 | -76.445350 | 1.00 | Severely Degraded |
| PMR-31111 | 9/19/2024 | 38.193468 | -76.615360 | 1.33 | Severely Degraded |
| PMR-31112 | 9/19/2024 | 38.221923 | -76.677923 | 1.00 | Severely Degraded |
| PMR-31113 | 9/19/2024 | 38.256979 | -76.670399 | 1.00 | Severely Degraded |
| PMR-31114 | 9/20/2024 | 38.270012 | -76.887170 | 1.00 | Severely Degraded |
| PMR-31115 | 9/20/2024 | 38.352880 | -76.999475 | 1.80 | Severely Degraded |
| PMR-31116 | 9/20/2024 | 38.362779 | -77.249611 | 2.67 | Marginal |
| PMR-31117 | 9/20/2024 | 38.382221 | -77.279510 | 2.33 | Degraded |
| PMR-31118 | 9/20/2024 | 38.404549 | -77.064340 | 1.80 | Severely Degraded |
| PMR-31119 | 9/20/2024 | 38.430660 | -77.271680 | 2.00 | Severely Degraded |
| PMR-31120 | 9/20/2024 | 38.503057 | -77.279421 | 3.00 | Meets Goal |
| PMR-31121 | 9/20/2024 | 38.527096 | -77.269074 | 3.40 | Meets Goal |
| PMR-31122 | 9/20/2024 | 38.547747 | -77.241463 | 2.33 | Degraded |
| PMR-31123 | 9/3/2024 | 38.692585 | -77.094050 | 2.00 | Severely Degraded |
| PMR-31124 | 9/3/2024 | 38.694073 | -77.087229 | 3.00 | Meets Goal |
| PMR-31125 | 9/3/2024 | 38.700305 | -77.078949 | 2.00 | Severely Degraded |
| PXR-31201 | 8/27/2024 | 38.295731 | -76.449242 | 2.67 | Marginal |
| PXR-31202 | 8/27/2024 | 38.312106 | -76.469183 | 3.00 | Meets Goal |
| PXR-31203 | 8/27/2024 | 38.325013 | -76.452204 | 2.20 | Degraded |
| PXR-31205 | 8/27/2024 | 38.350537 | -76.519898 | 2.20 | Degraded |
| PXR-31206 | 8/27/2024 | 38.359118 | -76.483642 | 2.60 | Degraded |
| PXR-31207 | 8/27/2024 | 38.372669 | -76.521302 | 2.20 | Degraded |
| PXR-31208 | 8/27/2024 | 38.375393 | -76.510292 | 1.00 | Severely Degraded |
| PXR-31209 | 8/27/2024 | 38.390403 | -76.523781 | 1.80 | Severely Degraded |
| PXR-31210 | 8/27/2024 | 38.390703 | -76.513029 | 2.20 | Degraded |
| PXR-31211 | 8/27/2024 | 38.404675 | -76.575167 | 1.00 | Severely Degraded |
| PXR-31212 | 8/27/2024 | 38.418095 | -76.538955 | 1.00 | Severely Degraded |
| PXR-31213 | 8/27/2024 | 38.450115 | -76.629869 | 2.20 | Degraded |
| PXR-31214 | 8/27/2024 | 38.453597 | -76.651705 | 3.00 | Meets Goal |
| PXR-31215 | 8/26/2024 | 38.468495 | -76.670742 | 3.00 | Meets Goal |

Appendix Table D-1. (Continued)

| Station | Sampling Date | Latitude (WGS84 Decimal Degrees) | Longitude (WGS84 Decimal Degrees) | B-IBI | Status |
|---|---|---|---|---|---|
| PXR-31216 | 8/26/2024 | 38.471885 | -76.672450 | 2.60 | Degraded |
| PXR-31217 | 8/26/2024 | 38.493561 | -76.668111 | 3.80 | Meets Goal |
| PXR-31218 | 8/26/2024 | 38.495658 | -76.683626 | 3.80 | Meets Goal |
| PXR-31219 | 8/26/2024 | 38.498334 | -76.683776 | 3.00 | Meets Goal |
| PXR-31220 | 8/26/2024 | 38.501411 | -76.674807 | 3.80 | Meets Goal |
| PXR-31221 | 8/26/2024 | 38.510058 | -76.665937 | 2.60 | Degraded |
| PXR-31222 | 8/26/2024 | 38.551234 | -76.678027 | 2.60 | Degraded |
| PXR-31223 | 8/26/2024 | 38.559618 | -76.674984 | 3.80 | Meets Goal |
| PXR-31224 | 8/26/2024 | 38.661754 | -76.687686 | 1.40 | Severely Degraded |
| PXR-31225 | 8/28/2024 | 38.766889 | -76.701279 | 1.50 | Severely Degraded |
| PXR-31226 | 8/26/2024 | 38.480853 | -76.673951 | 2.60 | Degraded |
| UPB-31601 | 8/15/2024 | 39.021883 | -76.374500 | 1.33 | Severely Degraded |
| UPB-31602 | 8/15/2024 | 39.037166 | -76.298571 | 2.20 | Degraded |
| UPB-31603 | 8/15/2024 | 39.069054 | -76.339822 | 2.33 | Degraded |
| UPB-31604 | 8/15/2024 | 39.076188 | -76.291361 | 2.00 | Severely Degraded |
| UPB-31605 | 8/15/2024 | 39.081356 | -76.252305 | 2.60 | Degraded |
| UPB-31606 | 8/15/2024 | 39.091585 | -76.349406 | 3.80 | Meets Goal |
| UPB-31607 | 8/14/2024 | 39.100122 | -76.428042 | 3.80 | Meets Goal |
| UPB-31608 | 8/15/2024 | 39.103211 | -76.374742 | 3.80 | Meets Goal |
| UPB-31609 | 8/15/2024 | 39.132246 | -76.400660 | 1.33 | Severely Degraded |
| UPB-31610 | 8/15/2024 | 39.152843 | -76.323668 | 3.40 | Meets Goal |
| UPB-31611 | 8/22/2024 | 39.223474 | -76.379604 | 3.50 | Meets Goal |
| UPB-31612 | 8/22/2024 | 39.239162 | -76.355332 | 3.00 | Meets Goal |
| UPB-31613 | 8/22/2024 | 39.247250 | -76.407222 | 3.33 | Meets Goal |
| UPB-31614 | 8/22/2024 | 39.253526 | -76.390164 | 3.00 | Meets Goal |
| UPB-31615 | 8/22/2024 | 39.258316 | -76.242422 | 5.00 | Meets Goal |
| UPB-31616 | 8/22/2024 | 39.278521 | -76.310522 | 3.80 | Meets Goal |
| UPB-31617 | 9/6/2024 | 39.343665 | -76.221034 | 3.00 | Meets Goal |
| UPB-31618 | 9/5/2024 | 39.356074 | -76.154688 | 1.40 | Severely Degraded |
| UPB-31619 | 9/5/2024 | 39.376553 | -76.131951 | 2.67 | Marginal |
| UPB-31620 | 9/5/2024 | 39.391983 | -76.122536 | 3.00 | Meets Goal |
| UPB-31621 | 9/6/2024 | 39.427966 | -76.114015 | 2.50 | Degraded |
| UPB-31622 | 9/6/2024 | 39.430375 | -76.094702 | 1.50 | Severely Degraded |
| UPB-31623 | 9/5/2024 | 39.486487 | -76.057541 | 4.00 | Meets Goal |
| UPB-31624 | 9/5/2024 | 39.508541 | -76.108693 | 4.00 | Meets Goal |
| UPB-31625 | 9/5/2024 | 39.559244 | -76.090502 | 3.00 | Meets Goal |

# APPENDIX E

# CHLOROPHYLL-A AND PHAEOPHYTIN LABORATORY RESULTS SUMMER 2024

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Appendix Table E-1. Benthic Chlorophyll-*a* and Phaeophytin laboratory analysis results. Three replicate samples were collected and analyzed for each parameter; the results are presented in replicate order (1, 2, 3) for each unique station-parameter combination.

| Station | Sampling Date | Parameter | Result (mg/m²) |
|---|---|---|---|
| 001 | 9/21/2024 | Active | 136.88 |
| 001 | 9/21/2024 | Active | 162.18 |
| 001 | 9/21/2024 | Active | 171.8 |
| 001 | 9/21/2024 | Phaeo | 24.53 |
| 001 | 9/21/2024 | Phaeo | 35.53 |
| 001 | 9/21/2024 | Phaeo | 45.86 |
| 001 | 9/21/2024 | Total | 150.07 |
| 001 | 9/21/2024 | Total | 181.37 |
| 001 | 9/21/2024 | Total | 196.66 |
| 006 | 9/21/2024 | Active | 268.54 |
| 006 | 9/21/2024 | Active | 291.09 |
| 006 | 9/21/2024 | Active | 324.51 |
| 006 | 9/21/2024 | Phaeo | 53.95 |
| 006 | 9/21/2024 | Phaeo | 53.83 |
| 006 | 9/21/2024 | Phaeo | 49.22 |
| 006 | 9/21/2024 | Total | 297.62 |
| 006 | 9/21/2024 | Total | 320.05 |
| 006 | 9/21/2024 | Total | 350.85 |
| 015 | 9/21/2024 | Active | 80.46 |
| 015 | 9/21/2024 | Active | 67.09 |
| 015 | 9/21/2024 | Active | 86.28 |
| 015 | 9/21/2024 | Phaeo | 64.61 |
| 015 | 9/21/2024 | Phaeo | 55.12 |
| 015 | 9/21/2024 | Phaeo | 98.57 |
| 015 | 9/21/2024 | Total | 115.88 |
| 015 | 9/21/2024 | Total | 97.3 |
| 015 | 9/21/2024 | Total | 140.4 |
| 022 | 8/13/2024 | Active | 39.95 |
| 022 | 8/13/2024 | Active | 44.24 |
| 022 | 8/13/2024 | Active | 40.42 |
| 022 | 8/13/2024 | Phaeo | 210.91 |
| 022 | 8/13/2024 | Phaeo | 243.91 |
| 022 | 8/13/2024 | Phaeo | 234.09 |
| 022 | 8/13/2024 | Total | 156.1 |
| 022 | 8/13/2024 | Total | 178.56 |
| 022 | 8/13/2024 | Total | 169.34 |
| 023 | 8/13/2024 | Active | 41.1 |
| 023 | 8/13/2024 | Active | 36.35 |
| 023 | 8/13/2024 | Active | 36.58 |
| 023 | 8/13/2024 | Phaeo | 217.53 |
| 023 | 8/13/2024 | Phaeo | 223.93 |
| 023 | 8/13/2024 | Phaeo | 201.41 |
| 023 | 8/13/2024 | Total | 160.89 |
| 023 | 8/13/2024 | Total | 159.69 |
| 023 | 8/13/2024 | Total | 147.49 |
| 024 | 8/15/2024 | Active | 27.29 |
| 024 | 8/15/2024 | Active | 28.85 |
| 024 | 8/15/2024 | Active | 29.04 |
| 024 | 8/15/2024 | Phaeo | 205.15 |
| 024 | 8/15/2024 | Phaeo | 201.69 |
| 024 | 8/15/2024 | Phaeo | 210.28 |
| 024 | 8/15/2024 | Total | 140.3 |
| 024 | 8/15/2024 | Total | 139.95 |
| 024 | 8/15/2024 | Total | 144.87 |
| 026 | 8/22/2024 | Active | 22.4 |
| 026 | 8/22/2024 | Active | 19.64 |
| 026 | 8/22/2024 | Active | 14.58 |
| 026 | 8/22/2024 | Phaeo | 154.09 |
| 026 | 8/22/2024 | Phaeo | 151.16 |
| 026 | 8/22/2024 | Phaeo | 158.99 |
| 026 | 8/22/2024 | Total | 107.27 |
| 026 | 8/22/2024 | Total | 102.9 |
| 026 | 8/22/2024 | Total | 102.18 |
| 029 | 9/5/2024 | Active | 58.45 |
| 029 | 9/5/2024 | Active | 38.95 |
| 029 | 9/5/2024 | Active | 38.76 |
| 029 | 9/5/2024 | Phaeo | 299.9 |
| 029 | 9/5/2024 | Phaeo | 216.08 |
| 029 | 9/5/2024 | Phaeo | 230.1 |
| 029 | 9/5/2024 | Total | 223.6 |
| 029 | 9/5/2024 | Total | 157.95 |
| 029 | 9/5/2024 | Total | 165.48 |

Appendix Table E-1. (Continued)

| Station | Sampling Date | Parameter | Result (mg/m$^2$) | Station | Sampling Date | Parameter | Result (mg/m$^2$) |
|---|---|---|---|---|---|---|---|
| 036 | 9/3/2024 | Active | 32.18 | 047 | 9/20/2024 | Active | 38.49 |
| 036 | 9/3/2024 | Active | 32.25 | 047 | 9/20/2024 | Active | 38 |
| 036 | 9/3/2024 | Active | 34.81 | 047 | 9/20/2024 | Active | 32.29 |
| 036 | 9/3/2024 | Phaeo | 165.57 | 047 | 9/20/2024 | Phaeo | 161.59 |
| 036 | 9/3/2024 | Phaeo | 155.48 | 047 | 9/20/2024 | Phaeo | 168.68 |
| 036 | 9/3/2024 | Phaeo | 178.34 | 047 | 9/20/2024 | Phaeo | 147.2 |
| 036 | 9/3/2024 | Total | 123.35 | 047 | 9/20/2024 | Total | 127.46 |
| 036 | 9/3/2024 | Total | 117.86 | 047 | 9/20/2024 | Total | 130.88 |
| 036 | 9/3/2024 | Total | 133.02 | 047 | 9/20/2024 | Total | 113.34 |
| 040 | 9/20/2024 | Active | 8.63 | 051 | 9/19/2024 | Active | 705.38 |
| 040 | 9/20/2024 | Active | 11.04 | 051 | 9/19/2024 | Active | 638.24 |
| 040 | 9/20/2024 | Active | 8.08 | 051 | 9/19/2024 | Active | 739.19 |
| 040 | 9/20/2024 | Phaeo | 95.93 | 051 | 9/19/2024 | Phaeo | 117.78 |
| 040 | 9/20/2024 | Phaeo | 92.38 | 051 | 9/19/2024 | Phaeo | 97.57 |
| 040 | 9/20/2024 | Phaeo | 89.28 | 051 | 9/19/2024 | Phaeo | 114.02 |
| 040 | 9/20/2024 | Total | 61.48 | 051 | 9/19/2024 | Total | 768.58 |
| 040 | 9/20/2024 | Total | 61.93 | 051 | 9/19/2024 | Total | 690.47 |
| 040 | 9/20/2024 | Total | 57.26 | 051 | 9/19/2024 | Total | 800.24 |
| 043 | 9/20/2024 | Active | 11.79 | 052 | 9/19/2024 | Active | 23.63 |
| 043 | 9/20/2024 | Active | 16.15 | 052 | 9/19/2024 | Active | 32.97 |
| 043 | 9/20/2024 | Active | 15.64 | 052 | 9/19/2024 | Active | 24.73 |
| 043 | 9/20/2024 | Phaeo | 96.07 | 052 | 9/19/2024 | Phaeo | 178.22 |
| 043 | 9/20/2024 | Phaeo | 108.15 | 052 | 9/19/2024 | Phaeo | 221.49 |
| 043 | 9/20/2024 | Phaeo | 92.47 | 052 | 9/19/2024 | Phaeo | 199.78 |
| 043 | 9/20/2024 | Total | 64.71 | 052 | 9/19/2024 | Total | 121.8 |
| 043 | 9/20/2024 | Total | 75.72 | 052 | 9/19/2024 | Total | 154.97 |
| 043 | 9/20/2024 | Total | 66.56 | 052 | 9/19/2024 | Total | 134.78 |
| 044 | 9/20/2024 | Active | 24.04 | 062 | 9/10/2024 | Active | 58.14 |
| 044 | 9/20/2024 | Active | 27.84 | 062 | 9/10/2024 | Active | 48.7 |
| 044 | 9/20/2024 | Active | 23.64 | 062 | 9/10/2024 | Active | 56.46 |
| 044 | 9/20/2024 | Phaeo | 203.24 | 062 | 9/10/2024 | Phaeo | 247.93 |
| 044 | 9/20/2024 | Phaeo | 194.21 | 062 | 9/10/2024 | Phaeo | 231.12 |
| 044 | 9/20/2024 | Phaeo | 171.43 | 062 | 9/10/2024 | Phaeo | 232.79 |
| 044 | 9/20/2024 | Total | 135.99 | 062 | 9/10/2024 | Total | 194.65 |
| 044 | 9/20/2024 | Total | 134.81 | 062 | 9/10/2024 | Total | 175.97 |
| 044 | 9/20/2024 | Total | 118.07 | 062 | 9/10/2024 | Total | 184.63 |

Appendix Table E-1. (Continued)

| Station | Sampling Date | Parameter | Result (mg/m²) | Station | Sampling Date | Parameter | Result (mg/m²) |
|---|---|---|---|---|---|---|---|
| 064 | 9/9/2024 | Active | 35.97 | 074 | 8/26/2024 | Active | 25.59 |
| 064 | 9/9/2024 | Active | 28.47 | 074 | 8/26/2024 | Active | 29.97 |
| 064 | 9/9/2024 | Active | 24.04 | 074 | 8/26/2024 | Active | 31.64 |
| 064 | 9/9/2024 | Phaeo | 267.24 | 074 | 8/26/2024 | Phaeo | 192.09 |
| 064 | 9/9/2024 | Phaeo | 278.6 | 074 | 8/26/2024 | Phaeo | 195.77 |
| 064 | 9/9/2024 | Phaeo | 221.82 | 074 | 8/26/2024 | Phaeo | 189.83 |
| 064 | 9/9/2024 | Total | 183.17 | 074 | 8/26/2024 | Total | 131.4 |
| 064 | 9/9/2024 | Total | 181.95 | 074 | 8/26/2024 | Total | 137.8 |
| 064 | 9/9/2024 | Total | 146.24 | 074 | 8/26/2024 | Total | 136.18 |
| 066 | 9/9/2024 | Active | 52.29 | 077 | 8/26/2024 | Active | 10.45 |
| 066 | 9/9/2024 | Active | 55.89 | 077 | 8/26/2024 | Active | 10.2 |
| 066 | 9/9/2024 | Active | 65.09 | 077 | 8/26/2024 | Active | 8.43 |
| 066 | 9/9/2024 | Phaeo | 255.34 | 077 | 8/26/2024 | Phaeo | 83.49 |
| 066 | 9/9/2024 | Phaeo | 242.85 | 077 | 8/26/2024 | Phaeo | 71.95 |
| 066 | 9/9/2024 | Phaeo | 258.87 | 077 | 8/26/2024 | Phaeo | 73.8 |
| 066 | 9/9/2024 | Total | 192.89 | 077 | 8/26/2024 | Total | 56.44 |
| 066 | 9/9/2024 | Total | 189.6 | 077 | 8/26/2024 | Total | 49.83 |
| 066 | 9/9/2024 | Total | 207.61 | 077 | 8/26/2024 | Total | 49.08 |
| 068 | 9/4/2024 | Active | 29.48 | 079 | 8/28/2024 | Active | 36.39 |
| 068 | 9/4/2024 | Active | 28.12 | 079 | 8/28/2024 | Active | 41.84 |
| 068 | 9/4/2024 | Active | 24.92 | 079 | 8/28/2024 | Active | 39.25 |
| 068 | 9/4/2024 | Phaeo | 273.17 | 079 | 8/28/2024 | Phaeo | 159.31 |
| 068 | 9/4/2024 | Phaeo | 305.49 | 079 | 8/28/2024 | Phaeo | 147.7 |
| 068 | 9/4/2024 | Phaeo | 295.77 | 079 | 8/28/2024 | Phaeo | 120.97 |
| 068 | 9/4/2024 | Total | 179.96 | 079 | 8/28/2024 | Total | 124.1 |
| 068 | 9/4/2024 | Total | 196.42 | 079 | 8/28/2024 | Total | 123.14 |
| 068 | 9/4/2024 | Total | 187.88 | 079 | 8/28/2024 | Total | 105.83 |
| 071 | 8/27/2024 | Active | 29.43 | 201 | 8/13/2024 | Active | 62.41 |
| 071 | 8/27/2024 | Active | 23.55 | 201 | 8/13/2024 | Active | 61.55 |
| 071 | 8/27/2024 | Active | 28.1 | 201 | 8/13/2024 | Active | 61.38 |
| 071 | 8/27/2024 | Phaeo | 205.03 | 201 | 8/13/2024 | Phaeo | 227.13 |
| 071 | 8/27/2024 | Phaeo | 209.28 | 201 | 8/13/2024 | Phaeo | 222.46 |
| 071 | 8/27/2024 | Phaeo | 207.48 | 201 | 8/13/2024 | Phaeo | 222.37 |
| 071 | 8/27/2024 | Total | 142.36 | 201 | 8/13/2024 | Total | 187.44 |
| 071 | 8/27/2024 | Total | 138.83 | 201 | 8/13/2024 | Total | 184.01 |
| 071 | 8/27/2024 | Total | 142.38 | 201 | 8/13/2024 | Total | 183.79 |

Appendix Table E-1. (Continued)

| **Station** | **Sampling Date** | **Parameter** | **Result ($mg/m^2$)** |
|---|---|---|---|
| 202 | 8/13/2024 | Active | 48.13 |
| 202 | 8/13/2024 | Active | 46.28 |
| 202 | 8/13/2024 | Active | 53.49 |
| 202 | 8/13/2024 | Phaeo | 228.5 |
| 202 | 8/13/2024 | Phaeo | 221.94 |
| 202 | 8/13/2024 | Phaeo | 222.38 |
| 202 | 8/13/2024 | Total | 173.95 |
| 202 | 8/13/2024 | Total | 168.49 |
| 202 | 8/13/2024 | Total | 175.93 |
| 203 | 8/22/2024 | Active | 36.88 |
| 203 | 8/22/2024 | Active | 48.48 |
| 203 | 8/22/2024 | Active | 28.97 |
| 203 | 8/22/2024 | Phaeo | 150.78 |
| 203 | 8/22/2024 | Phaeo | 143.42 |
| 203 | 8/22/2024 | Phaeo | 147.99 |
| 203 | 8/22/2024 | Total | 119.89 |
| 203 | 8/22/2024 | Total | 127.41 |
| 203 | 8/22/2024 | Total | 110.46 |
| 204 | 8/19/2024 | Active | 15.88 |
| 204 | 8/19/2024 | Active | 16.75 |
| 204 | 8/19/2024 | Active | 18.8 |
| 204 | 8/19/2024 | Phaeo | 156.97 |
| 204 | 8/19/2024 | Phaeo | 159.47 |
| 204 | 8/19/2024 | Phaeo | 158.67 |
| 204 | 8/19/2024 | Total | 102.36 |
| 204 | 8/19/2024 | Total | 104.6 |
| 204 | 8/19/2024 | Total | 106.2 |